RIPARIAN AREA MANAGEMENT

TR 1737-15 1998

A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas

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by

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A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas

I. Introduction

Riparian-wetland areas are some of the most productive resources found on public and private lands. They are highly prized for their recreation, fish and wildlife, water supply, cultural, and historic values, as well as for their economic values, which stem from their use for livestock production, timber harvest, and mineral extraction.

Proper functioning condition (PFC) is a qualitative method for assessing the condition of riparian-wetland areas. The term PFC is used to describe both the assessment process, and a defined, on the-ground condition of a riparian-wetland area.

The PFC **assessment** refers to **a consistent approach for considering hydrology, vegetation, and erosion/deposition (soils) attributes and processes** to assess the condition of riparian-wetland areas. A checklist is used for the PFC assessment (Appendix A), which synthesizes information that is foundational to determining the overall health of a riparian-wetland system.

The on-the-ground **condition** termed PFC refers to **how well the physical processes are functioning.** PFC is a state of resiliency that will allow a riparian-wetland area to hold together during high-flow events with a high degree of reliability. This resiliency allows an area to then produce desired values, such as fish habitat, neotropical bird habitat, or forage, over time. Riparian-wetland areas that are not functioning properly cannot sustain these values.

PFC is a qualitative assessment based on quantitative science. The PFC assessment is intended to be performed by an interdisciplinary (ID) team with local, on-the-ground experience in the kind of quantitative sampling techniques that support the PFC checklist. These quantitative techniques are encouraged in conjunction with the PFC assessment for individual calibration, where answers are uncertain, or where experience is limited. PFC is also an appropriate starting point for determining and prioritizing the type and location of quantitative inventory or monitoring necessary.

The PFC assessment has also proven to be an excellent communication tool for bringing a wide diversity of publics to agreement. This process forms a "common vocabulary" for identifying the building blocks for the development of desired condition (DC) and resulting values.

Again, the method developed for assessing PFC is qualitative and is based on using a checklist to make a relatively quick determination of condition. The purpose of this technical reference is to explain how this methodology was developed and to assist an ID team in answering checklist items by providing examples and methods for quantification where necessary.

II. Method Development

The Bureau of Land Management (BLM), the Fish and Wildlife Service (FWS), and the Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service, worked together to develop the PFC method. The methodology for assessing condition of running water (lotic) systems is presented in Technical Reference (TR) 1737-9, *Process for Assessing Proper Functioning Condition* (Prichard et al. 1993), and the method for standing water (lentic) systems is presented in TR 1737-11, *Process for Assessing Proper Functioning Condition for Lentic Riparian-Wetland Areas* (Prichard et al. 1994).

The PFC method for assessing condition of lotic riparian-wetland areas was developed over several years, beginning in February 1988. An ID team of soil, vegetation, hydrology, and biology specialists from the BLM, NRCS, and FWS was formed to: 1) summarize state-of-the-art procedures for describing and/or classifying riparian-wetland areas, and 2) determine the feasibility of describing riparian-wetland areas using BLM's standard ecological site description method, which was designed for uplands.

The ID team first conducted an intensive literature search of existing classification work on riparian-wetland areas. This 2-year effort resulted in publication of TR 1737-5, *Riparian and Wetland Classification Review* (Gebhardt et al. 1990). They then initiated inventories on a host of riparian-wetland sites. Over a 4-year period, numerous field sites were visited in each of the 12 Western States. First priority was given to inventorying lotic riparian-wetland sites, but lentic riparian-wetland sites were inventoried as well. The ID team made intensive soil, hydrology, and vegetation measurements at each field site. In each state, they were assisted by a number of resource specialists from Federal and State agencies and universities. This effort resulted in the development of Ecological Site Inventory (ESI) as a classification tool, and in publication of TR 1737-7, *Procedures for Ecological Site Inventory—with Special Reference to Riparian-Wetland Sites* (Leonard et al. 1992). Drafts of both TR 1737-5 and TR 1737-7 were reviewed by Federal agencies, State agencies in the Western States, and Western resource universities. Many review comments/ideas were incorporated into the final documents.

The ESI procedures in TR 1737-7 set forth a rigorous science base for classifying riparian-wetland sites. However, field offices needed a qualitative tool that would allow them to assess the condition of riparian-wetland areas. The ID team thus built a qualitative method (PFC) from the quantitative method (ESI).

To develop the PFC method, the ID team reviewed the rigorous science (ESI) and identified attributes and processes that are common and important, and that can be judged visually to assess the condition of a riparian-wetland area. These attributes and processes were then incorporated into standard checklists for lentic and lotic riparian-wetland areas. For example, item 1 on the lotic PFC checklist is asking whether the floodplain above bankfull is inundated in “relatively frequent” events.

For many riparian-wetland areas, the process of inundation has to take place if there is going to be any recruitment of vegetation. In addition, to dissipate energies, there has to be frequent access to a floodplain. Matting of vegetation and/or accumulation of debris/litter provide visual evidence of inundation. No detailed measurements have to be taken to judge whether this is happening. If for some reason this evidence needs to be quantified, ESI and other tools provide the rigorous science to do so. The same kind of scenario can be produced for each item on the checklist.

A draft of TR 1737-9, which described the qualitative methodology and incorporated a checklist for lotic systems, was produced by the ID team in 1992. The document was reviewed by BLM field offices and other Federal and State agencies. In May 1993, the ID team presented the review comments to 49 resource specialists, including hydrologists, vegetation specialists, soil scientists, and biologists, to resolve and produce a final checklist for TR 1737-9.

Because the PFC tool was being incorporated into the Department of the Interior's *Rangeland Reform* effort, TR 1737-9 was given an additional round of field tests during the summer of 1993, and the checklist was reviewed extensively. Field tests were conducted on riparian-wetland sites around Cody, WY, Richfield, UT, Farmington, NM, and Prineville, OR, by different ID teams. Based on the positive results from these field tests, TR 1737-9 was finalized and published in December 1993, and the checklist was incorporated into the *Rangeland Reform* draft Environmental Impact Statement. A document for lentic riparian-wetland areas was developed through a similar process, and TR 1737-11 was finalized 1 year later.

The PFC method has been implemented by BLM and adopted by several other agencies. In 1996, the BLM and the USDA Forest Service (FS) announced a cooperative riparian-wetland management strategy, which would include the NRCS as a principal partner. A National Riparian Service Team was formed to act as a catalyst for implementing this strategy.

This cooperative strategy recognizes that if riparian-wetland areas are to be productive, they have to be managed on a watershed basis, which means working together across ownership boundaries. To be successful, common terms and definitions and a minimum method for evaluating the condition of riparian-wetland areas was needed. The BLM and the FS identified the PFC method as the starting point—as the minimum level of assessment for riparian-wetland areas.

To implement use of the PFC method, ID teams, with members from Federal and State agencies and universities, were formed in 11 Western States. These teams are currently providing training in each of those states on this method.

III. Definitions

To assess the condition of a riparian-wetland area, there has to be a gauge to measure against. A riparian-wetland area is considered to be in proper functioning condition when adequate vegetation, landform, or large woody debris is present to:

- dissipate stream energy associated with high waterflow, 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;
- support greater biodiversity.

The components of this definition are in order relative to how processes work on the ground.

The reason that the definition includes "adequate vegetation, landform, *or* large woody debris" is that not all riparian-wetland areas are created equally. For example, in most western Oregon riparian-wetland areas, large wood must be present to dissipate energy, capture bedload, and aid floodplain development. However, most areas in the Great Basin do not have the potential or require large wood to dissipate stream energy associated with high streamflows. They can dissipate energy through the presence of vegetation such as willows, sedges, and rushes.

A good example where adequate landform is present to dissipate stream energy is in the Yellowstone River below the Lower Falls in Yellowstone National Park. The canyon's geology and bedrock channel are such that they dissipate stream energy associated with high waterflows. This reach of the Yellowstone River has no potential to produce vegetation, does not need vegetation to dissipate energy, and is functioning properly. Energy is being dissipated through hydraulic features produced by downcutting and erosion of the bed.

When adequate vegetation, landform, or large woody debris is present to dissipate energy associated with high flows, then a number of physical changes begin to occur, such as reduced erosion, sediment filtering, and improved flood-water retention. As the physical aspects of a system begin to function, they start the process of developing ponding and channel characteristics that provide habitat for fish, waterfowl, and other uses. *The physical aspects have to be in working order to sustain the channel characteristics that provide the habitat for these resource values.*

For areas that are not functioning properly, changes have to be made that allow them to recover (e.g., acquire adequate vegetation). A change such as acquiring vegetation leads to other physical changes, which allows the system to begin to function.

Recovery starts with acquiring the right element(s) to dissipate energy, which puts the physical process into working order and provides the foundation to sustain the desired condition.

When determining PFC, high-flow events are frequent events like 5-, 10-, and 20-year events. To sustain a given riparian-wetland area over time, those events that occur on a regular basis have to be accommodated. Experience has shown that riparian-wetland areas rated PFC generally withstand these events. Extreme events like 60-, 80-, and 100-year events occur infrequently and have such power that riparian-wetland areas in excellent condition can unravel, at least in places.

Each riparian-wetland area has to be judged against its capability and potential. The capability and potential of natural riparian-wetland areas are characterized by the interaction of three components: 1) hydrology, 2) vegetation, and 3) erosion/deposition (soils).

> **Potential** is defined as the highest ecological status a riparian-wetland area can attain given no political, social, or economical constraints, and is often referred to as the potential natural community (PNC).

Ecological status is defined as the degree of similarity between existing conditions (vegetation, or vegetation and soil) and the potential of a site; the higher the ecological status, the closer the site is to potential. Potential, for this assessment, encompasses all the resources defined by the interaction of hydrology, vegetation, and erosion/deposition (soils). As an example, the potential of the hydrologic component includes the concept of a stream channel's physical characteristics (dimension, pattern, profile) being within a "normal or usual" range (e.g., entrenchment, sinuosity, width, depth, and slope of the bankfull channel) as defined by landform and stream type.

Potential is applied to the PFC checklist by considering and answering *each item* relative to the attributes and processes of the system. When there is *no* possibility for a "yes" answer for an item, because a "yes" answer does not exist within the system's potential, the item is answered "NA." When the possibility does exist for a "yes" answer, a determination of whether the item should be answered "yes" or "no" based on current conditions has to be made. However, a site does *not* have to be *at* potential for an answer to be "yes"; it only has to be evaluated considering its potential and physical function.

For example, item 12 states, "Plant communities are an adequate source of coarse and/or large woody material." If the potential of a site is a sedge/grass community, then the answer to item 12 is "NA." If the site potential includes "coarse and/or large woody material" *and* the coarse and/or large woody material is also necessary for the physical functioning of the riparian-wetland area, the amount is evaluated to determine if it is an *adequate* source. The item can be answered "yes" if the supply is adequate, even if the site hasn't reached potential.

Capability is something less than potential, and is a result of human changes on the landscape.

> **Capability** is defined as the highest ecological status an area can attain given political, social, or economical constraints, which are often referred to as limiting factors.

It is important to note that these factors are different than natural limiting factors (e.g., badlands).

For example, the presence of a dam can greatly change a riparian-wetland area's flow regime, which can preclude the presence of vegetation like cottonwoods. This does not mean that this area does not need to have adequate vegetation to achieve PFC, it just means that it has to do it with another kind of riparian-wetland vegetation. Some of these alterations may affect an area so much that it may never achieve PFC.

Capability does not apply to uses such as grazing, farming, recreation, and timber practices, which can be changed. While these uses can affect the condition of a riparian-wetland area, they do not prevent it from achieving potential. Capability only applies to constraints that the land manager's cannot eliminate or change through a management action.

Examples of how both potential and capability apply to the checklist and rating can be found in Appendix B.

The above definitions are important aspects of the PFC methodology. The PFC tool is designed to assess if the physical elements (abiotic and biotic) are in working order relative to an area's capability and potential. When these physical elements are in working order, then channel characteristics develop that provide habitat for wildlife and other uses. Functionality comes first, then desired conditions are achieved.

Performing a PFC assessment requires an understanding of a number of additional terms. While "stream" is a general term for a body of flowing water, in hydrology, this 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 above the water table at all times.

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 most 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. Intermittent or seasonal streams usually have visible vegetation or physical characteristics reflective of permanent water influence, such as the presence of cottonwood.

Also, intermittent or seasonal streams need to be distinguished from interrupted streams.

> **Interrupted** - A stream with discontinuities in *space*.

If a riparian-wetland area is not in PFC, it is placed into one of three other categories:

> **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.

> **Unknown** - Riparian-wetland areas that managers lack sufficient information on to make any form of determination.

IV. PFC Assessment Procedure

The process for assessing PFC involves reviewing existing documents, analyzing the PFC definition, and assessing functionality using an ID team. Each step is important because it provides a foundation and a certain level of understanding necessary to complete the next step.

A. Review Existing Documents

To start this process, existing documents that provide a basis for assessing PFC should be reviewed. TR 1737-5 (Gebhardt et al. 1990) provides a helpful review of the more common procedures that are used to classify, inventory, and describe riparian-wetland areas.

TR 1737-10, *The Use of Aerial Photography to Manage Riparian-Wetland Areas* (Clemmer 1994), TR 1737-3, *Inventory and Monitoring of Riparian Areas* (Myers 1989), and TR 1737-7 (Leonard et al. 1992) provide additional thought processes that will be useful in assessing functional status of riparian-wetland areas. *Reviewing these documents helps an ID team develop an understanding of the concepts of the riparian-wetland area they are assessing.*

In addition to reviewing these references, existing files should be reviewed for pertinent information. For some riparian-wetland areas, enough information may exist to assess functionality 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 of PFC

Next, the definition of PFC must be analyzed. One way to do this is by breaking the definition down as follows:

> Riparian-wetland areas are functioning properly when adequate vegetation, land form, 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.

Riparian-wetland areas are functioning properly when there is adequate stability 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 woody vegetation, that criteria would not be used in the assessment.

Another way to analyze this definition is presented in Figure 1. With adequate vegetation, landform, or large wood, physical aspects fall into a working order and yield channel characteristics that can sustain important resource values.

C. Assess Functionality

1. Stratification

To perform a PFC assessment of a lotic riparian-wetland area, a starting point and an ending point have to be identified on the ground. Through stratification, which involves using aerial photographs and topographic maps, land areas and water segments can be delineated into units (lines and polygons) that share a common set of attributes and processes.

Stratification can be based on terrestrial ecological units (land) and aquatic ecological units (streams and lakes). These ecological units are described in *Ecological Subregions of the United States: Section Descriptions* (USDA Forest Service 1994), *Hierarchy of Ecological Units in Applications for Sustainable Forest and Wildlife Resources* (Cleland et al. 1997), and *Hierarchical Framework of Aquatic Ecological Units in North America (Nearctic Zone)* (Maxwell et al. 1995). These provide a scientific basis for regionalization of ecosystems into successively smaller, more homogeneous units using factors such as climate, physiography, water, soils, air, hydrology, and potential natural communities.

Since the integration of soil, water, and vegetation is important in riparian-wetland areas, both terrestrial and aquatic ecological units are used to define riparian-wetland

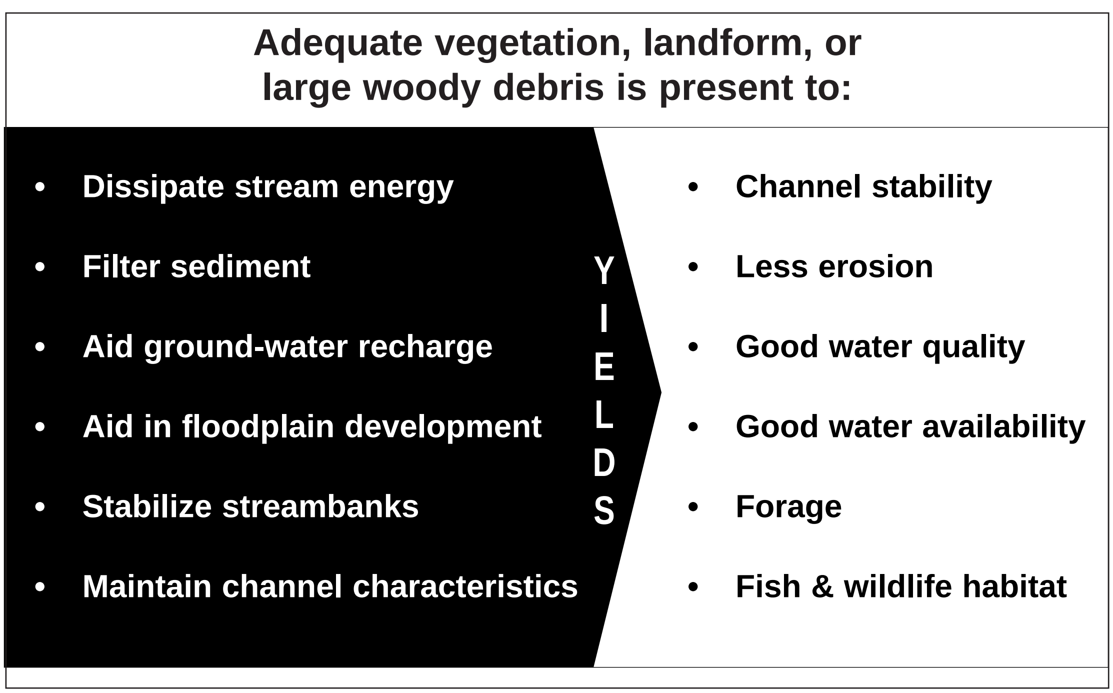

Figure 1. Proper functioning condition.

areas and/or riparian complexes. A riparian complex is an ecological unit that supports or may potentially support a specified pattern of riparian ecosystems, soils, landforms, and hydrologic characteristics (USDA Forest Service 1996). Land-type associations and land types on the terrestrial side, and valley segments and stream reaches on the aquatic side, are variables that help to delineate riparian complexes.

If ecological unit information is unavailable, riparian complex breaks should be based on observable differences in landform, geology, geomorphology, fluvial processes, major soil and/or vegetation changes, and hydrologic changes. Ecological units are further stratified based on nonecological factors, such as changes in management or ownership boundaries, to determine endpoints for conducting a PFC assessment. Information on how this is done can be found in TR 1737-3, TR 1737-7, and TR 1737-12, *Using Aerial Photographs to Assess Proper Functioning Condition of Riparian-Wetland Areas* (Prichard et al. 1996).

Aerial photos and topographic maps can be checked in the field, and endpoints can be adjusted or more reaches added if something was missed. It is important to remember that ecotones can exist between riparian complexes; these transitional areas should not be sampled and used to make interpretations for the whole riparian complex.

Stratified sampling involves a field assessment of representative parts of riparian-wetland areas to draw conclusions (extrapolate) about other similar areas. Stratified sampling is appropriate for lotic systems when you assess a representative area within one continuous stream reach of the same stream type to represent the entire riparian complex.

Stratified sampling may also be appropriate for lotic and lentic systems when you assess and extrapolate from one type of riparian-wetland area to another riparian-wetland area of the same type when environmental (climate, geology, geomorphology), management, and other factors relating to the assessment are *constant*. Even when these factors are constant, current aerial photos need to be checked to ensure conditions are the same (see TR 1737-12).

2. Attributes and Processes

The second aspect of assessing PFC involves understanding the attributes and processes occurring in a riparian-wetland area. *An ID team must determine the attributes and processes important to the riparian-wetland area that is being assessed. If they do not spend the time to develop an understanding of the processes affecting an area, their judgement about PFC will be incomplete and may be incorrect.* Table 1 provides a list of attributes and processes that may occur in any given riparian-wetland area.

To understand these processes, an example from the Great Basin of an alluvial/nongraded valley bottom type riparian-wetland area is provided in Figure 2 (Jensen 1992). Using the definition for PFC, **State A** represents a high degree of bank

Table 1. Attributes/processes list.*

Hydrogeomorphic	Vegetation	Soils
Ground-Water Discharge	Community Types	Soil Type
Accessible Floodplain	Community Type Distribution	Distribution of Aerobic/Anaerobic Soils
Ground-Water Recharge	Surface Density	Capillarity
Floodplain Storage and Release	Canopy	Annual Pattern of Soil Water States
Flood Modification	Community Dynamics and succession	
Bankfull Width	Recruitment/Reproduction	**Water Quality**
Width/Depth Ratio	Root Density	Temperature
Sinuosity	Survival	Salinity
Gradient	**Erosion/Deposition**	Nutrients
Stream Power	Bank Stability	Dissolved Oxygen
Hydraulic Controls	Bed Stability (Bedload Transport Rate)	Sediment
Bed Elevation	Depositional Features	

* This list provides examples of various attributes/ processes that may be present in a riparian-wetland area. By no means is it complete.

stability, floodplain, and plant community development, and would be classified as PFC. The important attributes and processes present for **State A** are:

> Hydrogeomorphic - Accessible floodplain, floodplain storage and release, flood modification, bankfull width, width/depth ratio, sinuosity, gradient, stream power, and hydraulic controls.
>
> Vegetation - Community type, 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 functioning at-risk. It would be classified as PFC 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 vary in their ability to stabilize streambanks and filter sediment.

State B would be classified as functional—at risk if bank-stabilizing vegetation is not dominant (even though it may be in an improving trend from prior conditions), undesirable 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, decrease in depth), floodplain frequency (decrease).

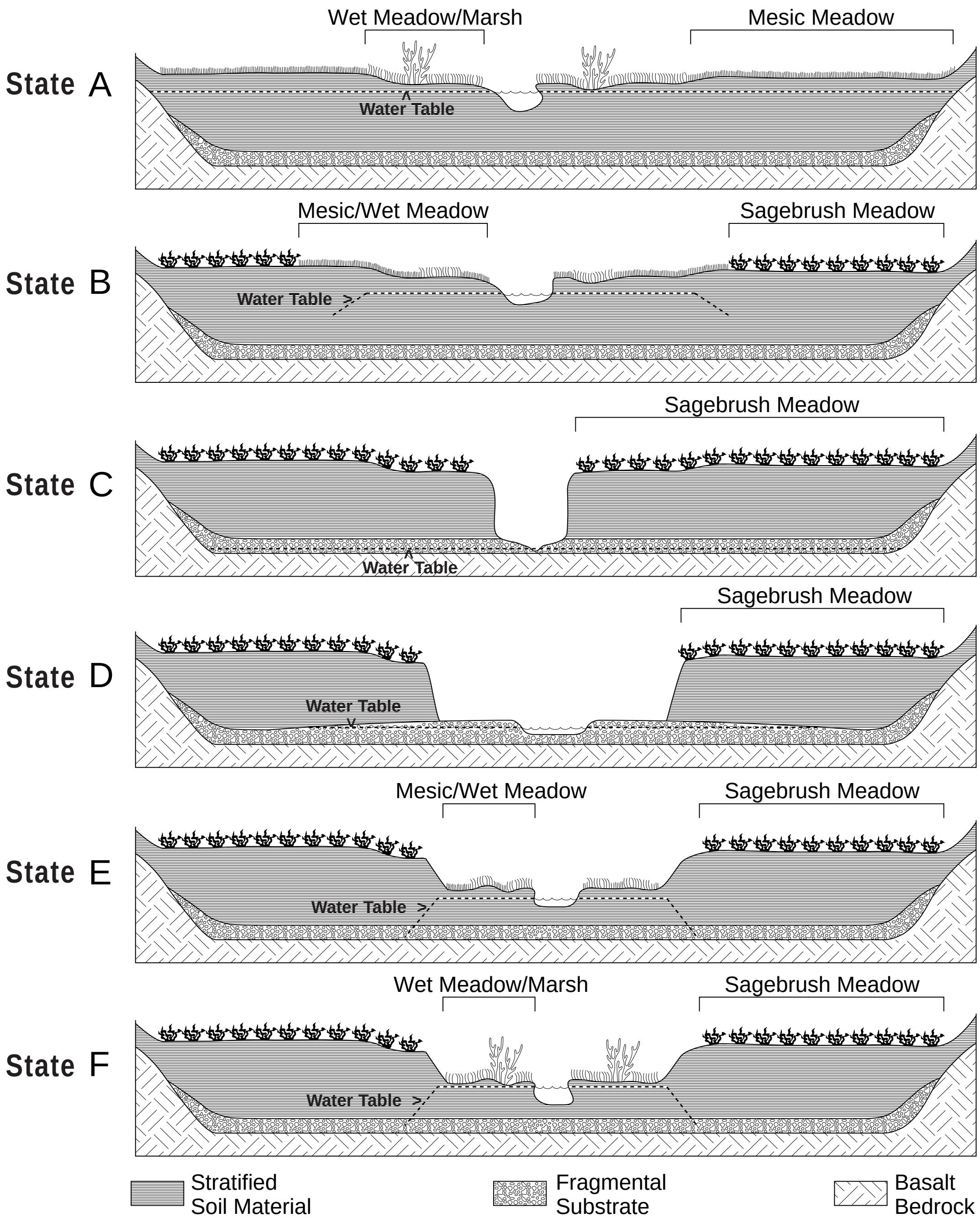

Figure 2. Succession of states for alluvial/nongraded valley-bottom type.

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.

States C and D would be classified as nonfunctional. **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/ decrease), floodplain access frequency (decrease).
>
> Vegetation - Riparian-wetland 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 PFC 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-wetland 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-wetland area.

This valley-bottom example represents only one of many types found. 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 components 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 lands in the West (Jensen 1992). The analogy used for Figure 2 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 TR 1737-5 (Gebhardt et al. 1990).

3. 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 and plants - historic and present).
- Determine species habitat needs (animals and plants) related to species that are/were present.
- Examine the soils. Were they saturated at one time and are they now well-drained?
- Examine the hydrology; establish cross sections if necessary to determine frequency and duration of flooding.
- Identify vegetation species that currently exist. 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.

4. 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 condition, the channel network adjusts in form and slope to handle increases in stormflow/snowmelt runoff with minimal disturbance of channel and associated riparian-wetland plant communities.

Riparian-wetland areas can function properly before they achieve their potential. 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, the PFC definition goes beyond the processes of channel evolution and includes vegetation and some biological attributes. The PFC definition does not mean potential or optimal conditions for a particular species have to be achieved for an area to be considered functioning properly.

Figures 3 and 4 provide an example of the relationship between PFC and vegetation community succession for one riparian-wetland area; the relationship may be different for other areas. In this example, assuming succession continues uninterrupted (Step 1 to Step 2 in Figure 3), the channel will evolve through some predictable changes from bare ground to potential *(although not necessarily as linearly as depicted)*. The riparian-wetland area will progress through phases of not functioning, functioning at-risk, and functioning properly along with plant succession. *In this example,* PFC occurs at the mid-seral stage (Step 3), though this is not always the case. Figure 4 shows a stream cross section of each condition (State A-E) displayed in Figure 3.

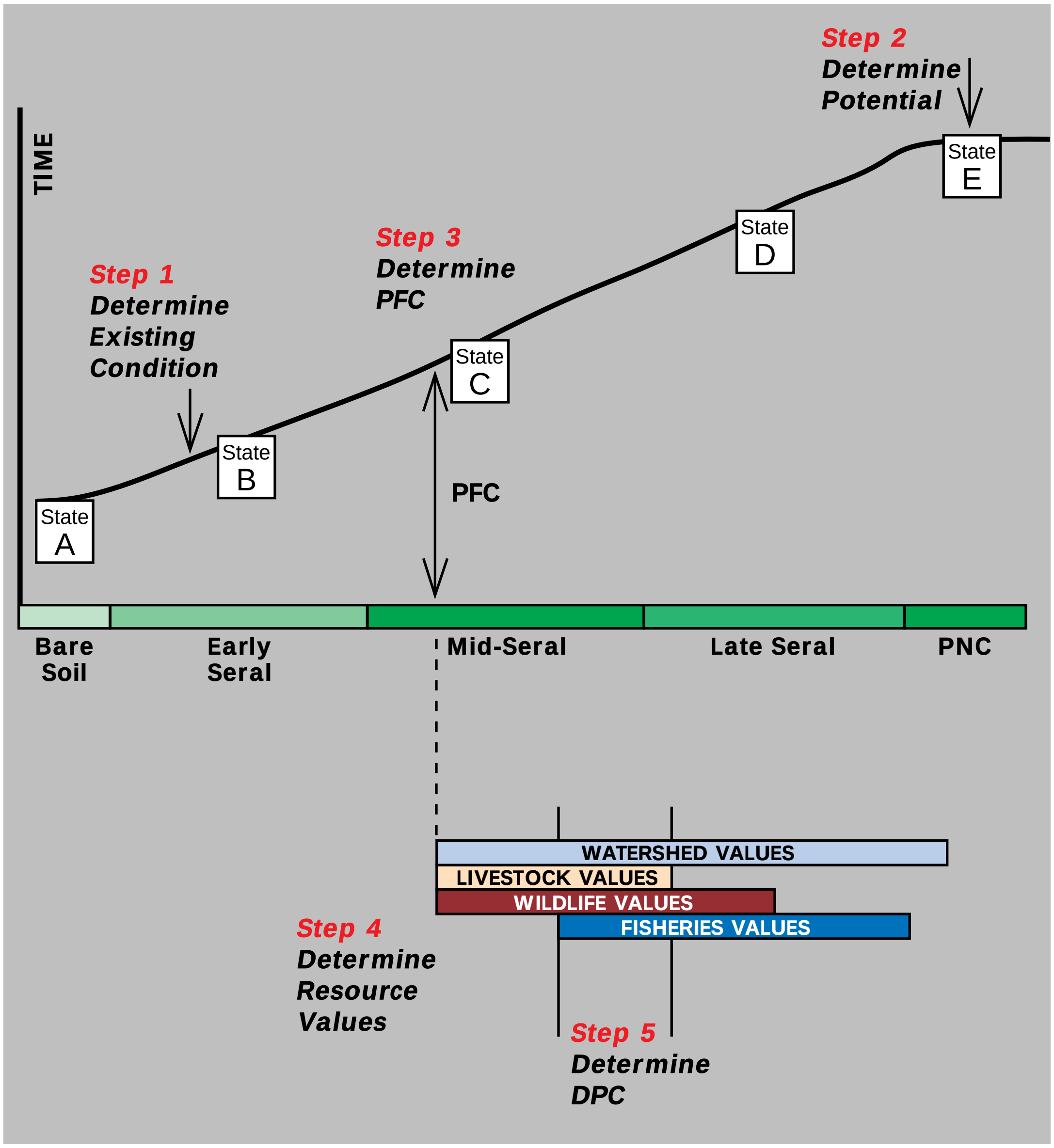

Figure 3. Succession for stream recovery.

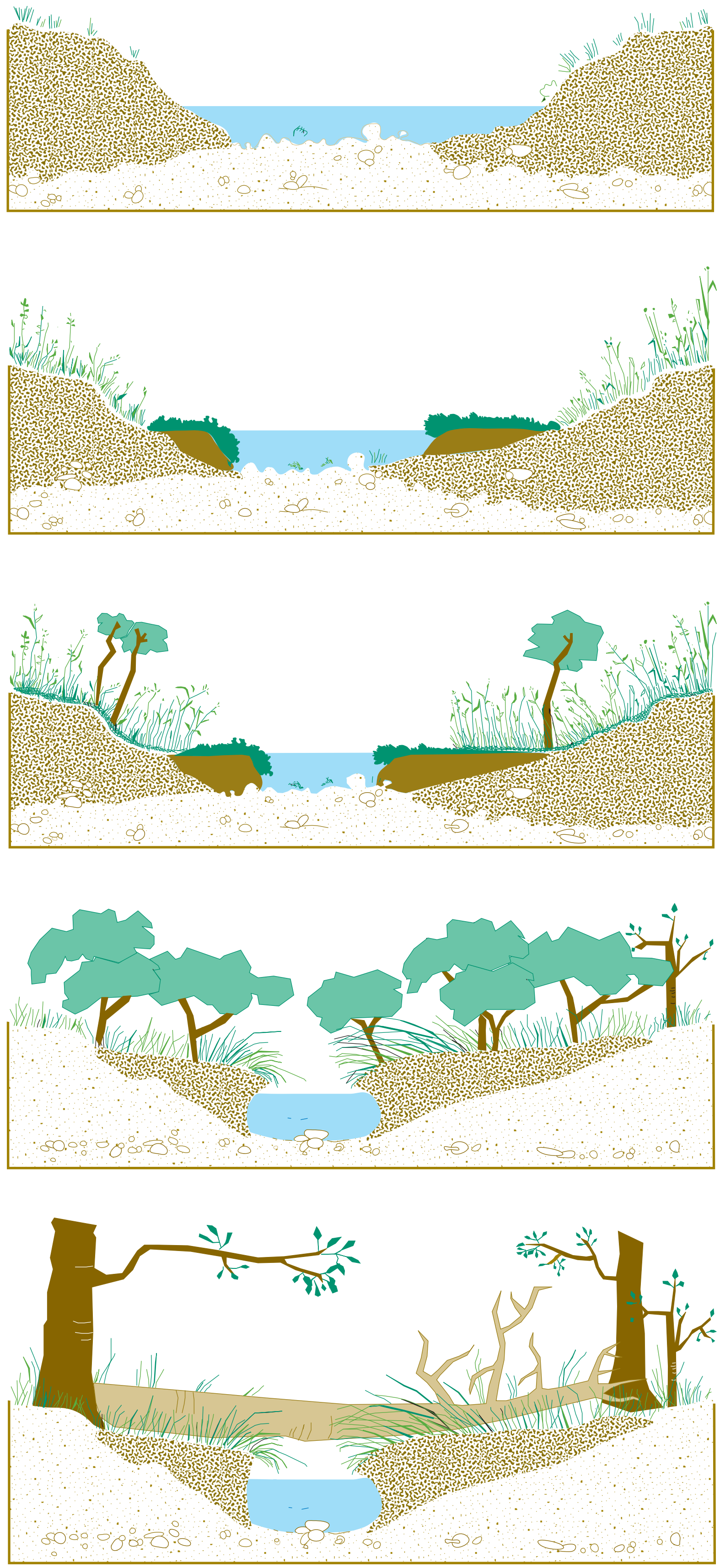

Figure 4. Stream cross sections.

At various stages within this successional process, the stream can provide a variety of values for different uses (Step 4). In Figure 3, 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 in Figure 3 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. Desired plant community (DPC) would be determined based on management objectives through an interdisciplinary approach (Step 5). *The threshold for any goal is at least PFC because any rating below this would not be sustainable. PFC is not a point in time, it may occur from early seral to late seral.*

Figure 5 illustrates this concept in another way. A riparian-wetland area goes through the recovery process from nonfunctioning, functioning at-risk, to PFC and DC. The red line in Figure 5 represents a general example of an area's recovery over time under ideal conditions. In actuality, an area may remain at one condition for an undetermined length of time because of coinciding circumstances of management and climate. Progress toward a higher condition may at times be impeded by greater natural stresses associated with high flows. Regression toward a lower condition may be dependent on exceeding a threshold of stability, progressing slowly at first, then rapidly declining as the threshold is crossed. Often during recovery, the progress will appear like a stock market graph with a series of peaks and lows with the average over time representing progress toward a higher condition. In any condition, from functioning at-risk to desired condition, an event, either human-induced or natural (fire, volcanic eruption, floods, dewatering, etc.), can cause the area to fall

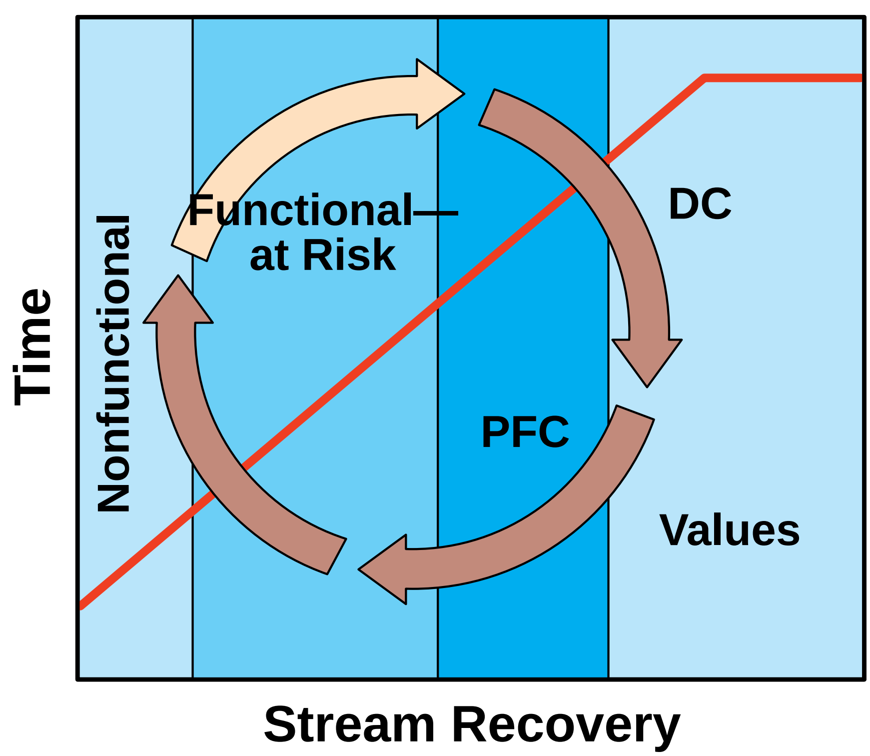

Figure 5. Stream recovery.

back to a lower condition. An important distinction is that a much greater event is necessary to cause degradation in areas that are in proper functioning condition than in those that are functioning at-risk.

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. Using the standard checklist (Appendix A) helps to ensure consistency in reporting PFC.

The 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 this standard checklist to address unique riparian-wetland attributes. To further assist users in assessing functionality, Appendix D provides examples of riparian-wetland areas and depicts the categories of PFC, functional—at risk, and nonfunctional.

As with any tool, the PFC method has it limits. Appendix E contains a summary of what PFC is and isn't, and what it can and can't do.

5. Functional Rating

Following completion of the checklist, a "functional rating" is determined based on an ID team's discussion. This ID team must review the "yes" and "no" answers on the checklist and their respective comments about the severity of the situation, then collectively agree on a rating of proper functioning condition, functional—at risk, or nonfunctional. If an ID team agrees on a functional—at risk rating, a determination of trend toward or away from proper functioning condition is then made if possible.

Because of the variability in kinds of lotic riparian-wetland areas (based on differences in climatic setting, geology, landform, and substrate) and the variability in the severity of individual factors relative to an area's ability to withstand relatively high flow events, there is no set number of "no" answers that dictate that an area is at-risk or nonfunctional. A **properly functioning** riparian wetland area will provide the elements contained in the definition:

- dissipate stream energy associated with high water flows, 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

in accordance with it's capability and potential.

If a riparian-wetland area possesses these elements, then it has a **high probability to withstand relatively high flow events.** If all the answers on the checklist are "yes," this area is undoubtedly meeting these criteria. However, if some answers on the checklist are "no," this area may still meet the definition of PFC. For example, following a recent change in management, a riparian wetland area has narrowed to within the normal range of variability for the width/depth ratio, but sinuosity is still too low, a profusion of young willows is present, and a few beaver have moved into the system, although their occasional dams are still unstable because of the small material. Items 2, 3, and 6 could all be answered "no." However, an ID team determines that sinuosity is not far enough out of balance to affect either lateral or vertical stability, the beaver dam failures are not contributing more sediment or flow than the system can handle, and the absence of older age classes are remnant of past management and recruitment is not a problem now. The ID team rates this area as PFC. However, the riparian-wetland area may still be a long way from desired condition for many uses and values.

A **functional—at risk** riparian-wetland area may possess some or even most of the elements in the definition, but at least one of its attributes/processes gives it a **high probability of degradation with a relatively high flow event(s).** Most of the time, several "no" answers will be evident because of the interrelationships between items. If these "no" answers, in the ID team's opinion, collectively provide the probability for degradation in relatively high-flow events, then the rating is functional—at risk. If there is disagreement between team members after all comments have been discussed, it is probably advisable to be conservative in the rating (i.e., if the discussion is between PFC and functional—at risk, then the rating should be functional—at risk). There is one situation where only one "no" answer can put a riparian-wetland area at-risk. *If an area is vertically unstable (item 16) because of a head-cut moving upstream, then the reach above the head-cut to a point where there is some geologic or structural control is functioning at-risk regardless of other factors.*

Trend must be determined, if possible, when a rating of functional—at risk is given. Preferably, trend is determined by comparing the present situation with previous photos, trend studies, inventories, and any other documentation or personal knowledge attained in a review of existing documents or interviews prior to the PFC assessment. In the absence of information prior to the assessment, indicators of "apparent trend" may be deduced during the assessment process. Recruitment and establishment of riparian-wetland species (or the absence thereof) that indicate an increase (or decline) in soil moisture characteristics can be especially useful. However, care must be taken to relate these indicators to recent climatic conditions as well as management. If there is insufficient evidence to make a determination that there is a trend toward PFC (upward) or away from PFC (downward), then the trend is not apparent.

Nonfunctional riparian-wetland areas **clearly lack the elements** listed in the PFC definition. Usually nonfunctional riparian-wetland areas translate to a preponderance of "no" answers on the checklist, but not necessarily all "no" answers. A laterally unstable stream may still retain a floodplain, the upland watershed conditions may be fine, and the stream may be vertically stable, but still clearly nonfunctional. There are also situations where only a few "no" answers could still result in a nonfunctional rating because of the extreme severity of the situation. Cases have been observed where the checklist items pertaining to vegetation were mostly "yes," except for a "no" for adequate vegetation to protect banks (item 11) and an "N/A" for coarse and/or large wood (item 12). However, extreme bedload (item 17) was so severe that channel characteristics (item 3) and lateral stream movement (item 15) were also so far out of balance to be essentially nonfunctioning.

It is imperative for management interpretation of the checklist to document *factors contributing to unacceptable conditions outside management's control* for functional—at risk and nonfunctional ratings where achievement of PFC may be impaired. It is desirable to document any of the factors listed if they occur, even if they don't appear to be affecting the achievement of PFC. Their presence may still affect achievement of desired condition for other values when compared to a natural system.

D. Institute the Process

1. Planning

A logical sequence for incorporating information collected from a checklist into a management plan is as follows (refer to Figure 3 in the Functioning Condition section):

Step 1 **Existing Condition** - Determine the existing riparian-wetland and watershed condition using the standard checklist.

Step 2 **Potential** - Each area is assessed relative to its potential. Determine potential 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** - Identify specific objectives to reach management goals for the watershed, PFC, DPC, or DC.

Step 6 **Planned Actions** - Design management actions to achieve PFC and then DC.

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.

2. Management

To be successful in managing riparian-wetland areas, 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.

A PFC assessment does provide strong clues as to the actual condition of habitat for plants and animals. Generally a riparian-wetland area in nonfunctioning condition will not provide quality habitat conditions. A riparian-wetland area that has recovered to proper functioning condition would either be providing all or some quality habitat conditions, or would be moving in that direction if recovery is allowed to progress. A riparian-wetland area that is functioning at-risk would likely be lacking habitat features that exist in areas that are in PFC.

The PFC assessment can be used for prioritizing restoration activities. PFC provides a sorting of project areas, which allows managers to establish priorities for treatment. By concentrating on the sensitive *at-risk* areas that may be near the threshold of rapidly degrading into nonfunctional condition, restoration activities can halt the decline and begin the recovery process at a much lower cost. Once an area is nonfunctional, the effort, cost, and time required for recovery is dramatically increased. Restoration of nonfunctional systems should be reserved for those situations where the riparian-wetland has reached a point where recovery *is possible*, when efforts are not at *the expense* of at-risk systems, or when unique opportunities exist. At the same time, areas that are functioning properly are usually not the highest priorities for restoration because they are more resilient than the at-risk areas. It is critical to manage these areas to retain their resilience and further recovery towards desired condition. Identifying systems in PFC also allows local managers to assess why these systems have fared well in the past and to possibly use them as models for recovery of similar systems.

The PFC assessment can also help determine the appropriate timing and design of riparian-wetland restoration projects (including structural and management changes). It can identify situations where instream structures are either entirely inappropriate or premature.

The results of the PFC assessment can be used in watershed analysis. While the methodology and resultant data is reach-based, the ratings can be aggregated and analyzed at the watershed scale. The PFC method is most useful when condition is determined based on local information, experience, and knowledge of functions and processes at the watershed scale. Information from the PFC assessment, along with other watershed and habitat condition information, helps provide a good picture of watershed health and the possible causal factors affecting watershed health. Using the PFC method will help to identify watershed-scale problems and suggest management remedies and priorities. *These management decisions are derived by concentrating on the "no" answers on the checklist.* Additional uses for this information can be found in Appendix E.

There are two other documents that can be helpful in assisting with this process: TR 1737-14, *Grazing Management for Riparian-Wetland Areas* (Leonard et al. 1997), 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, TR 1737-6, *Management*

Techniques in Riparian Areas (Smith and Prichard 1992), provides suggested 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.

3. Monitoring

Management effectiveness can be assessed and progress towards attaining 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. Quantification of Checklist Items

As long as the procedure is followed and the definitions are understood, the PFC assessment will work for most sites because it was founded from rigorous science (ESI) and is performed by an ID team. However, there will be times when items from the checklist need to be quantified.

There is a considerable body of literature addressing relationships between hydrologic and geomorphic processes, vegetation, and other riparian-wetland functions, as well as a growing number of "success stories" from which empirical comparisons can (and have) been made. The references presented here are selected as examples of supporting documentation for the PFC assessment. *By no means are these references all-encompassing, as there are many other ways to quantify these items.*

The checklist items are designed to address the common attributes and processes that have to be in working order for a riparian-wetland area to function properly. Each item on the checklist is answered with a "yes," meaning that the attribute or process is working, a "no," meaning that it is not working, or an "N/A," meaning the item is not applicable to that particular area. For any item marked "no," the severity of the condition must be explained in the "Remarks" section and must be discussed by the ID team in determining riparian-wetland functionality. Using the "Remarks" section to also explain items marked "yes" is encouraged but not required.

Outlined below is the intent of each item, examples of how each item might be answered, and ways to quantify each item. *These examples should not be misconstrued as a cookbook, as there are many riparian-wetland types.* Before assessing condition of any riparian-wetland area, its attributes and processes have to be defined to answer the checklist items correctly.

It is important to note that many of the checklist items are closely related. This provides a system of checks and balances for how any one item is answered. For example, if item 14 (point bars are revegetating) is answered "yes" for a recovering system, item 4 should be answered "yes" because the riparian-wetland area is widening. It is also important to note the items are numbered for the purpose of cataloging comments and that the numbers do not declare importance. The importance of any one item will vary relative to a riparian-wetland area's attributes and processes. However, there is an order to when some of the items are answered "yes." Any time item 11 is answered "yes," more than likely items 6, 7, 8, and 9 will be answered "yes." For a riparian-wetland area to recover, the right plants have to establish themselves and then produce the adequate amount of cover. The supporting science for some of the items is the same or overlapping. Explanations are with the most appropriate items, but some cross-referencing may be required.

A. Hydrology

Items 1-5 focus on hydrologic attributes and processes that need to be in working order for an area to function properly. Montgomery and Buffington (1993), Rosgen

(1996), and (Leonard et al. 1992) are excellent sources that explain these attributes and processes.

Item 1: Floodplain above bankfull is inundated in "relatively frequent" events

Purpose

Schmudde (1968) provides three definitions of floodplain. Topographically, it is flat and lies adjacent to a stream. Geomorphically, it is a landform composed primarily of unconsolidated depositional material (sediments) derived from the stream. Hydrologically, it is a landform subject to periodic flooding by the stream. Schmudde provides a good summary of the functional purpose of the floodplain: "Thus, the floodplain is seen as an integral part of the stream system and the adjustment mechanism needed to meet the requirements of discharge and load imposed by the basin it serves."

The purpose of item 1 is to determine whether frequent floodflows are capable of spreading out on a low-lying area adjacent to the stream and thus provide for energy dissipation, sediment deposition, and periodic flooding of vegetation. Stream systems that are not highly confined generally support a floodplain landform that is flat and adjacent to the stream. However, if the channel is downcut and floodflows can no longer access the floodplain, it no longer provides those important hydrologic functions.

The floodplain provides additional capacity for the stream system to transport and store water and sediment. The magnitude and significance of the additional capacity depends on the spatial extent of the floodplain along with basin and stream system characteristics. Vegetation often is an important player in the efficiency and longevity of floodplain function. Periodic flooding of the floodplain is often necessary to promote and sustain riparian vegetation, and therefore is a key factor in determining the functional condition of the riparian system.

Examples

Item 1 would be answered "NA" if a floodplain is not required for the riparian-wetland area to function. This would be characteristic of very confined "V" shaped canyons.

Item 1 would be answered "yes" if evidence of flooding is apparent, such as vegetation on the floodplain being bent downstream or the floodplain containing recent deposits of sediment and/or debris. These indicators will be more prevalent near the stream in the area that is flooded every year or two (the "active floodplain"). It should be evident that as discharge increases, the inundation of the topographic floodplain will also increase. For example, for State A in Figure 2, the answer would be "yes."

Item 1 would be answered "no" if frequent floods do not reach the floodplain. Indicators are generally an oversized channel, incised channel, or upstream reservoir.

Where these conditions are not obvious, quantitative techniques need to be used that estimate flood frequency and channel carrying capacity. Channels having large drainage areas may look like they have such indicators; however, they are likely to have annual floods that reach their floodplain every year or two. For example, for State C in Figure 2, the answer would be “no.”

Supporting Science/Quantitative Methodologies

The floodplain is functional if it is normally connected to the stream at the bankfull discharge point of the channel. Wolman and Leopold (1957) suggest there is an annual flood that normally reaches the floodplain every year or so. Gebhardt et al. (1989) call this area of inundation the active floodplain to distinguish floodplain activity from floodplain inactivity. Thus, an active floodplain would see some inundation every year or so, and the spatial extent of the inundation would increase over the floodplain as the magnitude of the flood increases. This implies that a hydraulic continuity between the topographic floodplain and the stream must exist if the floodplain is considered functional. As the hydraulic continuity becomes less apparent, the floodplain becomes functioning at-risk to nonfunctioning. The loss or reduction in potential for the floodplain to dissipate energy and transport water and sediment are key factors in contributing to loss of functionality.

Evaluation of bankfull discharge is key in determining if the topographic floodplain feature is or is not connected to the stream. Water enters the floodplain when flows begin to exceed bankfull discharge. Bankfull discharge is significant for riparian resource management in that it represents a measure of interaction between the stream and its adjacent valley bottom; thus, it strongly influences the geomorphic and biological characteristics of the riparian environment. Bankfull discharge on the majority of streams in the world has a recurrence interval between 1 and 3 years; 1.5 years is considered a reasonable average (Leopold 1994). Hence, the floodplain will be accessed in relatively frequent events.

Bankfull stage (elevation of water surface) can be identified in the field through several observable features:

1. Top of the point bar,
2. Changes in vegetation,
3. Topographic break in slope,
4. Change in size, staining, or color of substrate materials, and
5. Change in the nature and amount of debris deposits (Leopold 1994).

There should be more than one indicator, as just one (e.g., vegetation) can be indicative of more short-term events than the channel-forming flows.

Bankfull discharge for a channel may be determined through the use of one or more surveyed cross sections (Harrelson et al. 1994) and a number of hydraulic models. The hydraulic models use assumptions of normal depth and uniform flow (single transect models) or gradually varied flow (multiple-transect models) and the conservation of mass and energy to estimate mean cross-section velocity at bankfull conditions. Mean velocity and cross-sectional area of flow are multiplied to obtain bankfull discharge.

Bankfull discharge is compared with flood frequency estimates for the reach of interest to determine the frequency of overbank flows and inundation of the flood-plain. Flood frequency estimates for sites with streamflow data are determined using statistical procedures developed by the U.S. Water Resources Council (1982). Flood frequency for sites without streamgage data is usually estimated from empirical equations relating flood frequency to basin characteristics. Such empirical relationships are usually published for a state or major physiographic region by the Water Resources Division of the U.S. Geological Survey and are based on gaging stations with sufficiently long periods of record.

Item 2: Where beaver dams are present they are active and stable

Purpose

Beavers are key agents of riparian-wetland succession because the dams they build act as hydrologic modifiers. For some riparian-wetland areas, beavers have been largely responsible for the establishment of the floodplain (Gebhardt et al. 1989). The purpose of this item is to document whether beaver dams are present, and if so, whether they are being maintained. This item is important because beaver dams are blockages that change an area's site progression (see Figure 2 in TR 1737-5). A flowing stream can be changed overnight to an aquatic pond. If the dams are not maintained or captured by vegetation, over time, they breach and unleash tremendous energies that usually result in degradation.

Some beavers pack their dams with mud (mudders). This construction technique creates a better basis for vegetation to capture a dam, thus helping to stabilize it. Nonmudder dams are usually not very stable.

A sufficient amount of woody vegetation also has to be present for dam construction and maintenance.

Examples

If beaver dams are present, then stability has to be addressed. If the dams have been captured by riparian-wetland vegetation and are stable, the answer to item 2 would be "yes." If beaver dams are present but are broken, leaking, or lack vegetation, they would be considered unstable and the answer to item 2 would be "no."

If abondoned beaver dams are present, are vegetated with woody riparian-wetland species and are causing no impacts, the answer would be "yes."

If beavers dams are not present, item 2 would be answered "N/A."

Supporting Science/Quantitative Methodologies

Beaver modification can be positive or negative (see Figure 2 in TR 1737-5). Beavers naturally transform woody vegetation into physical structures (dams) that can aid floodplain development and riparian vegetation structure, diversity, and productivity. However, if dams fail, they can result in degradation and stream adjustments that include channel widening, lowering, and lateral migration.

Assessing this parameter requires professional judgement. Active dams are usually considered stable, but over time, vegetation needs to establish and provide stability to the dam. This vegetation has to be the right kind of vegetation and the right amount. Much of the science that has been applied to items 7, 9, and 11 can be applied here.

Additional information about beavers can be found in TR 1737-6 (Smith and Prichard 1992).

Item 3: Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region)

Purpose

Sinuosity, width/depth ratio, and gradient play important roles in how well a stream dissipates energy. A decrease in stream length relative to valley length (sinuosity) results in a higher stream gradient, which increases velocities. Increased velocities accelerate erosion, which alters sinuosity, gradient, and width/depth ratios. To be in balance, a stream has to be near the shape and size expected for its setting. Channel classification tools like Montgomery and Buffington (1993) or Rosgen (1996) describe a range of characteristics for a setting and make this item easier to answer.

Examples

If a riparian-wetland area is located in a very wide valley constructed from alluvial deposition and has a sinuosity >1.2, a gradient <2.0 percent, and a width/depth ratio >12, the answer to item 3 would be "yes" if overhanging banks are present where they are expected, as they are good indicators that the above elements are in balance with the setting.

If this same riparian-wetland area being assessed has a stream length that is equal to its valley length (sinuosity=1.0), the answer to item 3 would be "no." If sinuosity and gradient are in balance but width/depth ratio is not because the active channel is still very wide and shallow, the answer to item 3 would be "no."

Item 3 is one of the few items that will never be answered "N/A"; it will always have a "yes" or "no" answer. *All three elements have to be in balance with the landscape setting for this item to be answered "yes."*

Supporting Science/Quantitative Methodologies

The position of a stream in its landscape and watershed setting is a strong determinant of that stream's ability to develop and support significant riparian-wetland resources. Several stream classification systems have been proposed for describing both the landscape/watershed setting and the potential attributes of the stream corridor. Systems have been as simple as identifying straight or meandering streams with either single or multiple channels, or as detailed and complete as Rosgen's (1994) classification system, which recognizes nearly 100 stream types. Classification systems have been based on topographic position [e.g., the stream ordering systems of Horton (1945) and Strahler (1957)], sediment transport and channel adjustment processes [e.g., Schumm (1977) and Montgomery and Buffington (1993)], and channel morphological characteristics [e.g., Rosgen (1996)]. Regardless of the classification system used in a channel inventory, the purpose of stream classification is to describe the stream's position in the landscape and the expected range of variability for composition of bed and bank materials and for parameters related to channel size, shape, and pattern.

Classification of the stream reach under consideration (as well as adjacent reaches in both upstream and downstream directions), and evaluation of recent channel evolution with the qualitative relationships described under item 5 (i.e., equations 5 through 14), will provide a great deal of information for determining if the sinuosity, width/depth ratio, and gradient of a stream are in balance with the landscape setting. Additional analysis should be directed toward development of quantitative relationships to supplement the “direction-of-change” qualitative relationships described under item 5.

A useful quantification tool for this item is the “reference reach” concept. The existing channel characteristics of channel dimension, pattern, and profile are compared to those in good condition for the same channel type in similar geology and watershed. The hydraulic parameters of top width, mean depth, and mean velocity may be compared from cross section to cross section throughout a watershed (main stem and tributaries) if flows of equal frequency of occurrence are compared for the various locations. Thus, if the mean annual discharge or the 2-year flood is compared at a number of cross sections throughout a drainage, the hydraulic parameters of top width, mean depth, and mean velocity may be systematically plotted as a function of discharge. The resulting quantitative relationships are referred to as the downstream hydraulic geometry of the stream system (Leopold 1994).

It is also possible to develop hydraulic geometry relationships relating bankfull channel characteristics to basin drainage area if field measurements of bankfull dimensions are grouped by stream type before plotting width (w), depth (d), and channel slope (S) versus drainage area (DA). Thus, in addition to providing a method for characterizing the landscape setting of a riparian corridor, stream classification also provides an organizational scheme for analyzing channel cross section and pattern data. Once field data are organized by stream type, general equations for bankfull dimensions may be developed as a function of drainage basin area. For example, the following equations could represent hydraulic geometry relationships for pool-riffle streams in watersheds less than 200 square miles in size:

$$w = 4.1\ DA^{0.52} \qquad R^2 = .94 \qquad (1)$$

$$d = 0.61\ DA^{0.42} \qquad R^2 = .91 \qquad (2)$$

$$S = .0049\ DA^{0.053} \qquad R^2 = .41 \qquad (3)$$

where R^2 is the coefficient of determination.

The power functions described by these hydraulic geometry relationships would be graphed as straight lines on a log-log plot of channel dimension versus drainage area. Thus, field measurements of width/depth ratios and channel slope (Harrelson et al. 1994) at a riparian-wetland site could be plotted against the general relations for that stream type to determine if the site under investigation deviates greatly from the general relationship for that drainage basin. Strong deviation from the general relationship does not necessarily mean that the stream is out of balance with its landscape setting, but it would indicate a potential anomaly that would warrant further investigation.

Item 4: Riparian-wetland area is widening or has achieved potential extent

Purpose

Degraded riparian-wetland areas recover by capturing sediment, which aids floodplain development and improves flood-water retention. This recovery is expressed by an increase in riparian-wetland vegetation. The intent of item 4 is to document that a riparian-wetland area is recovering or has recovered. At some point in time, all riparian-wetland areas achieve potential extent.

It is important to note that item 4 has two parts. Part one asks if a riparian-wetland area is widening, and part two asks if a riparian-wetland area has achieved potential extent. The reason for this separation is so a “yes” answer is always applied for a positive attribute or process (widening or achieved potential extent).

Examples

Evidence that a riparian-wetland area is widening/expanding may include an increasing amount of appropriate vegetation (i.e., sedges, rushes, and willow) that is replacing upland species, a rising water table, and the establishment of vegetation in soils deposited along a streambank. Any of this evidence would result in a “yes” answer to item 4. A major improvement in the width/depth ratio (narrower/deeper) of an active channel is another good indicator that a riparian-wetland area is widening and would also result in a “yes” answer.

Potential extent can be largely determined by the adjacent topography. If a riparian-wetland area has achieved potential extent, the answer to item 4 would be “yes.”

Evidence that a riparian-wetland area is narrowing may include an increase in upland vegetation (e.g., big sagebrush, cheatgrass, and rabbitbrush), and replacement of riparian-wetland species such as sedges and rushes by more drought-tolerant species like Kentucky bluegrass, western wheatgrass, and cheatgrass (especially on small raised areas). Any of this evidence would result in a “no” answer to item 4.

For channels that are steep, deeply entrenched, and confined (e.g., Rosgen’s A1 channel type), an “N/A” answer would be given because there is no potential for vegetation, as landform dictates functionality.

Supporting Science/Quantitative Methodologies

Riparian-wetland areas widen as a result of aggradation, along with natural stream adjustments such as lateral migration, channel narrowing, and floodplain development. Change in species composition from upland species like sagebrush to riparian-wetland species like Nebraska sedge is a good indicator that the riparian zone is widening. The *Integrated Riparian Evaluation Guide* (USDA Forest Service 1992) provides measurement techniques for cross-section composition of the riparian complex. Measuring change in the width/depth ratio over time would be another way to quantify the widening of the riparian zone (Rosgen 1996).

Aerial photos are a great tool for documenting changes in riparian widths (Clemmer 1994). The National Aerial Photograph Program (NAPP) provides coverage of the lower 48 states every 5 to 7 years.

Item 5: Upland watershed is not contributing to riparian-wetland degradation

Purpose

The condition of the surrounding uplands can greatly affect the condition of a riparian-wetland area. Changes in upland condition can change the discharge, timing, or duration of streamflow events, which can degrade a riparian-wetland area. The purpose of this item is to address whether there has been a change in the water or sediment being supplied to a riparian-wetland area and whether it is resulting in *degradation.* This item pertains to whether uplands are contributing to the *degradation* of a riparian-wetland area; it does not pertain to the condition of the uplands.

It is also important to note that this item is worded differently ("is not contributing") than the other items on the checklist and therefore should be answered carefully. The reason for this wording is to make this item consistent with the others so that a "yes" answer provides a positive indicator of functionality.

Examples

It is possible to have disturbances in the uplands and still not see major changes in discharge, timing, or duration of streamflows and no degradation to the riparian-wetland area. If there is no evidence of erosion/sediment deposits from the uplands that are *degrading* a riparian-wetland area, the answer to item 5 is "yes," even if the uplands are not in good condition. Evidence that a riparian-wetland area is being degraded would include braiding of what should be a single-thread channel, mid-channel bars, overloading of point bars, fan deposits from upland erosion that alter sinuosity, or cementing of a stream's substrate. If any of these characteristics are present, the answer to item 5 would be "no." Item 5 will never be answered "N/A"; it will always have a "yes" or "no" answer.

Supporting Science/Quantitative Methodologies

Stream channels are constantly adjusting to the water and sediment load supplied by the watershed. Channel conditions in a drainage network correspond to changes in streamflow and sediment supply in the basin, as well as human manipulation of the channels. Thus, an understanding of channel adjustments requires an understanding of changes in streamflow and sediment production throughout the drainage.

One of the earliest relations proposed for explaining stream behavior was suggested by Lane (1955), who related mean annual streamflow (Q_w) and channel slope (S) to bed-material sediment load (Q_s) and median particle size on the streambed (d_{50}):

$$(Q_w) * (S) \sim (Q_s) * (d_{50}) \qquad (4)$$

In this relationship, bed-material load is that portion of the sediment load that interacts with and comprises part of the streambed. It may be carried in suspension or in contact with the channel bottom. Bed-material load is distinguished from wash load, which is the component of the sediment load that washes through the system and does not appear in appreciable quantities in the streambed.

Lane's relationship suggests that a channel will be maintained in dynamic equilibrium when changes in streamflow and channel gradient are balanced by changes in sediment load and bed material size. For example, if the bed-material load supplied to a channel is significantly increased with little or no change in streamflow, either the stream will attempt to increase its gradient (e.g., by reducing its sinuosity), or the median particle size of the bed will decrease. If the additional sediment load is associated with a particular tributary, both channel adjustments frequently occur. Backwater upstream of the tributary delta will cause deposition of finer materials (smaller d_{50}), and stream slope will increase through the delta deposit as the main stem seeks to return to its original grade. If the delta includes substantial amounts of finer sediments, median particle size will also decrease downstream as these finer materials are intruded into the streambed.

Additional qualitative relations have been proposed for interpreting behavior of *alluvial channels (i.e., channels with bed and banks composed of sediments being transported by the river).* Schumm (1977) suggested that width (b), depth (d), and meander wavelength (L) are directly proportional, and channel gradient (S) is inversely proportional to streamflow (Q_w) in an alluvial channel:

$$Q_w \sim \frac{b,\ d,\ L}{S} \qquad (5)$$

Schumm (1977) also suggested that width (b), meander wavelength (L), and channel gradient (S) are directly proportional, and depth (d) and sinuosity (P) are inversely proportional to sediment discharge (Q_s) in alluvial streams:

$$Q_s \sim \frac{b,\ L,\ S}{d,\ P} \qquad (6)$$

Equations 5 and 6 may be rewritten to predict direction of change in channel characteristics, given an increase or decrease in streamflow or sediment discharge:

$$Q_w^+ \sim b^+, d^+, L^+, S^- \quad (7)$$

$$Q_w^- \sim b^-, d^-, L^-, S^+ \quad (8)$$

$$Q_s^+ \sim b^+, d^-, L^+, S^+, P^- \quad (9)$$

$$Q_s^- \sim b^-, d^+, L^-, S^-, P^+ \quad (10)$$

Combining equations 7 through 10 yields additional predictive relationships for the situation of concurrent increases or decreases in streamflow and/or sediment discharge, where F is the channel width/depth ratio at bankfull discharge and the other channel parameters are as defined above:

$$Q_w^+Q_s^+ \sim b^+, d^{+/-}, L^+, S^{+/-}, P^-, F^+ \quad (11)$$

$$Q_w^-Q_s^- \sim b^-, d^{+/-}, L^-, S^{+/-}, P^+, F^- \quad (12)$$

$$Q_w^+Q_s^- \sim b^{+/-}, d^+, L^{+/-}, S^-, P^+, F \quad (13)$$

$$Q_w^-Q_s^+ \sim b^{+/-}, d^-, L^{+/-}, S^+, P^-, F^+ \quad (14)$$

Research attempts to *quantify* channel response to *changes in streamflow* are numerous in the literature. Generally, such research has produced quantitative relationships between various channel parameters and some index of streamflow. Such relationships are summarized under item 3.

Research attempts to *quantify* channel response to *changes in sediment load* are far less numerous in the literature. Most efforts have focused on quantifying change in channel shape or pattern as a function of kind of sediment load. The parameter usually chosen to represent channel shape is the width-depth ratio at bankfull flow, and channel patterns are usually categorized as straight, meandering, or braided. The meandering pattern of relatively flat alluvial streams may be expressed as a riffle-pool or step-pool morphology in steeper mountain channels. Sediment load is usually characterized as suspended versus bedload, with percent of total load as bedload being a commonly used parameter. The percent of silt-clay in the channel bed and banks also is used as an indicator of importance of bed-material load.

The nature of the sediment load as suspended load or bedload has a significant influence on channel shape. Generally, channels with a high percentage of silt and clay in their bed and banks carry a predominantly suspended load and frequently display relatively low width-depth ratios (<12-15) at bankfull discharge. This is due, at least in part, to the cohesive nature of the sediments in transport. In contrast, channels with bedload discharge comprising a significant portion of the total sediment load (at least 10 percent of the total load) frequently display relatively high width depth ratios (>30) at bankfull discharge. The bed and banks of these channels are usually composed of sand and/or coarser materials.

Relations between kind of sediment load (i.e., particle size and mode of transport) and cross section shape are important for understanding channel behavior in any river system. Sediment load supplied to the river is a function of watershed geology, soils, vegetation, and land use, and mechanisms of weathering, detachment, and transport that govern delivery of sediment to the channel. Particle-size distribution and transport mode of watershed-derived sediments likely will determine if a river is relatively wide at bankfull stage or relatively narrow with steep, cohesive banks.

Channel characteristics identified on the right side of equations 5 through 14 above provide good indicators for evaluation of items 5 and 17 on the PFC checklist. Changes in width, depth, width/depth ratio, slope, sinuosity, and meander characteristics are indicative of changing conditions of water and sediment yield in the watershed. Changes in channel planform or pattern (e.g., straight, meandering, braided, riffle-pool, step-pool, or cascade) are also good indicators. Where such changes are observed over time and space, cause of the channel adjustment should be explored to determine if the upland watershed is contributing to riparian degradation and if the stream system is presently out of balance with the water and sediment being supplied by the watershed.

Channel adjustments through time may be identified for a particular stream reach by evaluating a sequence of aerial photos covering several years or decades. Alternatively, upstream and downstream reaches may provide a descriptive history of channel adjustments using a “space for time” substitution. Because most channel evolution occurs in an upstream direction (i.e., channel features like nickpoints, gullying, and widening tend to work upstream rather than downstream), earlier conditions for a stream reach likely resembled present conditions upstream of the reach. Similarly, channel evolution at a site would be expected to produce a future condition similar to that presently observed in downstream reaches. Thus, channel adjustment processes should be evaluated with respect to both time and spatial considerations.

A reference that is helpful in understanding watershed health and riparian-wetland condition is DeBano and Schmidt (1989). Other tools that can be used to judge impacts from uplands may include macroinvertebrates, pebble counts, embeddedness, and changes in the hydrograph.

B. Vegetation

Items 6-12 deal with vegetation attributes and processes that need to be in working order for a riparian-wetland area to function properly. While landform plays the major role in defining a riparian-wetland area’s setting, most riparian-wetland areas require some amount of vegetation to achieve functionality. Van Haveren and Jackson (1986) discuss the interdependence of bank alteration, vegetative bank protection, and subsurface water status in relation to hydrologic and geomorphic processes. These relationships have been analyzed by Jensen et al. (1989) relative to the progression of geomorphic states presented in TR 1737-9. Vegetation trends corroborate the progression of states identified from clustering and discriminant analysis. Deterioration corresponds with the: 1) elimination of or reduction in bank-forming vegetation, 2) encroachment of upland vegetation onto floodplains and levees, and 3) increase in the extent of eroded banks and stream bars at the expense of vegetated communities on levees and floodplains. An extensive field evaluation by an ID team covering virtually every Western State concluded that although there are many different progressions, depending on stream type and valley bottom setting, etc., the basic concepts affecting the states of progression are similar.

Factors such as the kind, proportion, and amount (cover or density) of vegetation in the riparian wetland community contribute to the assessment of bank-forming vegetation and the encroachment of upland vegetation. The linear distribution of vegetation is the primary factor affecting the extent of eroded banks/stream bars, assuming that the right kinds and proportions of species are in the community (or simply the inverse relationship—the amount of banks and bars lacking the right kind and amount of vegetation). Lateral distribution of vegetation determines the riparian-wetland area's ability to accommodate periods of floods (overbank flows) and drought (colonization and bank formation of a narrowed channel). In order to persist or improve, the plant species or communities of interest must be both healthy (vigorous) and replacing or increasing their numbers or extent through recruitment into the community.

The level III riparian area evaluation from the USDA Forest Service (1992) provides measurement techniques for cross-section composition of the riparian complex, vegetation composition within a complex and along the greenline, and woody species regeneration. Each item, except for item 10, can be quantified or interpreted from quantified information using these techniques. Another source that presents the greenline method is TR 1737-8, *Greenline Riparian-Wetland Monitoring* (Cagney 1993).

Item 6: There is diverse age-class distribution of riparian-wetland vegetation (recruitment for maintenance/recovery)

Purpose

For a riparian-wetland area to recover or maintain itself, it has to have more than one age class of riparian-wetland plants. This item is not asking whether all possible age classes are present; it is asking whether the number of age classes that provide recruitment to maintain an area or to allow an area to recover are present. Most riparian-wetland areas will recover or maintain themselves with two age classes, as long as one of the age classes is young (recruitment) and the other is middle-aged (replacement). Older age classes (mature) usually take care of themselves, as they are well-attached to existing water tables. Older age classes can persist even with degraded conditions.

Examples

For riparian-wetland areas that require woody vegetation to achieve functionality, a "yes" answer would be given if there are seedlings and saplings present on the reach being assessed. A "no" answer would be given if either recruitment or replacement age classes are absent.

Answering item 6 for riparian-wetland areas that only need herbaceous vegetation to achieve functionality is a little more difficult. Many of these plants expand or colonize a site by stem and root extension (e.g., Nebraska sedge). If there is a dense matting of these plants, the answer to item 6 would be "yes." If there are individual plants of Nebraska sedge scattered along the reach being assessed, the answer to item 6 would be "no."

Many riparian-wetland areas have potential for both woody and herbaceous vegetation. If a combination of woody and herbaceous plants, either young and/or middle-aged, are present, the answer to item 6 would be "yes."

It is important to note that this item is for evaluating diverse age class of riparian-wetland vegetation, *not* of upland vegetation. For example, if an area being assessed contains six age classes of upland plants and no age classes of riparian-wetland plants, the answer to item 6 would be "no." The same can be said for items 7-11.

An "N/A" answer would apply for channels that are entrenched and confined in bedrock (e.g., A1 channel type in Rosgen 1996).

Supporting Science/Quantitative Methodologies

The interrelationships of age structure can be quite complex, but general characterizations can be made of expanding, stable, and diminishing populations (Kormondy 1969). Expanding populations generally have a pyramid shape of age distribution, with many young forming a wide base, fewer middle-aged, and very few old at the top. Stable populations are more "bullet" shaped, with rather equal young and middle-aged groups forming the base and middle, then gradually diminishing to the oldest ages. Diminishing populations are more "urn" shaped distributions with a narrow base of young, widening toward the older age classes, then sharply narrowing with the oldest individuals. Of particular concern are indicators of diminishing populations of bank-forming species/communities. These indicators are generally low proportions or missing classes of young and/or middle-aged individuals.

Some judgement must be used in plant communities that establish as even-aged stands as a result of episodic events. Many woody species will establish in dense even-aged stands where past management has depleted or eliminated their presence and a change in management and climatic circumstances coincide for reestablishment. These stands may persist at an even age until disturbances open portions of the stand for additional recruitment.

Plant age is often difficult to establish, especially in the southwest. USDA Forest Service (1992) uses age class in reference to woody species only, and establishes a procedure based on number of stems and proportion of live stems for determination of age. Myers (1989) recommends the use of "stem age" for age-class analysis of woody plants. A high correlation between basal stem diameter and age for several riparian-wetland species is also presented.

For herbaceous species, the term age-class distribution is somewhat misleading, but the intent of identifying indicators of expanding, stable, or diminishing populations through recruitment/reproduction is the same. Dahl and Hyder (1977) discuss developmental morphology attributes that have implications pertinent to plant recruitment and maintenance. Indicators include ratio of vegetative to reproductive culms (for plants reproducing by seed), amount and degree of lateral shoot development and/or tillering, and types of vegetative shoots. Age-class distribution is often associated with vigor (item 10).

Item 7: There is diverse composition of riparian-wetland vegetation (for maintenance/recovery)

Purpose

Not only does a riparian-wetland area require a diverse age class, it has to have a diverse composition of vegetation if it is going to maintain itself or recover. This item is not asking whether all the plants that an area can support are present. The intent of item 7 is to document that the existing species composition is sufficient for maintenance or recovery. For most riparian wetland areas, this means having two or more riparian-wetland species present, depending on site potential and/or capability. The presence of only one species makes a site very vulnerable to disease or extreme changes in climate, which may result in degradation of an area. There are some areas, though, that will have only one species, but these are uncommon and usually limited as a result of a unique soil property, vegetative characteristics, or water regime.

Examples

Riparian-wetland areas that are slightly entrenched, meandering, and sand-dominated with well-developed flooplains (e.g., C5 channels in Rosgen 1996) require the appropriate vegetation to be present if they are to function properly. If a C5 reach is found to have peach leaf willow and coyote willow, the answer to item 7 would be “yes,” as this is sufficient composition to maintain or recover this reach. If this same reach contained only coyote willow, the answer to item 7 would be “no.”

Many channels can function properly with herbaceous vegetation and do not require woody riparian-wetland vegetation. Woody vegetation may be the desired condition. However, woody vegetation may not be necessary for the reach to function properly. In this case, if a reach contains Nebraska sedge and beaked sedge, the answer to item 7 would be “yes.” If the same reach contained only Nebraska sedge, the answer to item 7 would be “no.”

“N/A” would apply for those channel types that do not require vegetation to function properly.

Supporting Science/Quantitative Methodologies

Riparian-wetland sites are usually extremely heterogenous (Odum 1971). In general, ecosystem stability is characterized by an increase in species diversity, structural complexity, and organic matter (Kormondy 1969). The literature is replete with the virtues of biodiversity and the hazards and limitations of monocultures. In addition to the susceptibility of monocultures to disease, insect infestations, and extreme temperature fluctuations, riparian-wetland communities must be able to adapt to extremes in water availability and stresses associated with reduction/ oxidation phenomena in the rooting zone. In the northwestern U.S., 20 to 30 years out of the last 100 have had at least moderate drought (Leonard and Karl 1995). Distribution about the mean precipitation is approximately normal, with a nearly equal number of "wet" years. However, the period between successive drought (or wet) years is completely unpredictable and variable. Streamflow and attendant water tables may vary considerably over time in conjunction with precipitation and runoff. Therefore, composition (as opposed to traditional indices of diversity) of vegetation within the riparian zone must be diverse enough to accommodate substantial shifts in the water table or zone of saturation. Measurement of composition would be procedurally the same as for item 9.

Although thresholds for diversity are not established, it seems unreasonable, in most cases, that stability can be expected without at least two functional equivalents within a streamside or shoreline community and gradient of riparian-wetland plants away from the water's edge. Some variability must be allowed based on the expected juxtaposition of ecological sites within the geomorphic setting and the potential plant community of the sites. Diversity for maintenance or recovery applies primarily to the availability (presence) of those species with high erosion control potential within a community, while the extent is addressed in item 9 and amount in item 11.

Item 8: Species present indicate maintenance of riparian-wetland soil moisture characteristics

Purpose

The intent of this item is to look for evidence that the water table level is being maintained or is moving towards its potential extent as indicated by the presence of riparian-wetland vegetation. Maintenance or recovery of an existing water table is vital to the maintenance or recovery of a riparian-wetland area.

Riparian-wetland plants are divided into categories relative to the likelihood of their occurrence in wetlands or nonwetlands (e.g., Reed 1988). These categories are obligate wetland (OBL), facultative wetland (FACW), facultative (FAC), facultative upland (FACU), and obligate upland (UPL). Plants that occur in wetlands are hydrophytes, and they have to be in contact with the water table, which is why they can be used as indicators of soil moisture characteristics.

Examples

A "yes" answer would be given for item 8 when OBL or FACW plants are present on a perennial reach, as these plants usually occur under natural conditions in riparian-wetland areas. A "no" answer would be given if FACU or UPL plants dominated this reach, as these species occur most of the time in upland settings.

Some intermittent systems, depending on duration of flow, could be somewhat different, as their potential may be FAC plants. If this is the case and they are dominated by FAC plants, the answer to item 8 would be "yes." An intermittent riparian-wetland area dominated by FACU and/or UPL plants would be given a "no" answer.

It is important to note that if vegetation on a reach is dominated by mature OBL and FACW plants, it may not always indicate that soil moisture characteristics are being maintained. Mature plants that established contact with the water table long ago are able to maintain contact with a declining water table due to deep roots.

Supporting Science/Quantitative Methodologies

Myers (1989) and most of the classification literature mentioned in item 9 cite an increase in upland plants as indicators of declining water table.

Measurements of composition must be analyzed relative to soil-site and channel characteristics for quantitative analysis. Special care must be used in evaluating recovering systems. Depositional events may initiate a temporary shift toward early seral upland plants during the lag time required for a rising water table to "catch up."

Item 9: Streambank vegetation is comprised of those plants or plant communities that have root masses capable of withstanding high streamflow events

Purpose

Streambanks dominated by vegetation that lacks extensive root masses are undercut during high flow events and collapse. This collapse results in a change in the active channel's width/depth ratio, gradient, and sinuosity, which reduces a riparian-wetland area's ability to dissipate energy. The intent of item 9 is to document that the streambanks have the right plants or community types for recovery and maintenance of the riparian-wetland area.

Most plants that are OBL and FACW have root masses capable of withstanding high-flow events, while most plants that are FACU and UPL do not.

Examples

Riparian-wetland species, such as willow, alder, aspen, birch, and cottonwood, and/or deep rooted herbaceous species, such as sedges, rushes, bullrush, and some wetland grasses, have root masses capable of withstanding high-flow events. If these plants dominate plant communities along a streambank, the answer to item 9 would be "yes." Intermittent systems would be an exception. For many intermittent systems, the community domination of FAC plants is all that is required for a "yes" answer, as this is all these systems can produce.

Some species, such as Kentucky bluegrass, redtop, blue grama, and sagebrush, do not have the root masses capable of withstanding high-flow events. If these plants dominate plant communities along a streambank, the answer to item 9 would be "no."

There are exceptions, such as high gradient, bedrock, or boulder/cobble stream types (Rosgen 1996), where the vegetation community contributes little, if any, to bank stability. For these, the answer would be "N/A."

Supporting Science/Quantitative Methodologies

A good indicator for item 9 is the presence of cover of OBL and FACW species within present plant communities, as defined in regional plant lists published by the U.S. Fish and Wildlife Service (e.g., Reed 1988), because they have a high erosion control potential. Erosion control potential can be determined from rooting habits of individual species (Lewis 1958; Manning et al. 1989), or preferably from ratings or discussions of both species and community types, such as in Weixelman et al. (1996), Hansen et al. (1995), Manning and Padgett (1995), USDA Forest Service (1992), and Kovalchik (1987). Even though these publications are geographically specific, the species and similar community types occur broadly throughout the Western States. Again, there are exceptions, such as high gradient, bedrock, or boulder/cobble stream types (Rosgen 1996), where the vegetation community contributes little, if any, to bank stability.

Visual estimates of dominance have been described as acceptable for wetland determination in the 1987 Corp of Engineer's Wetland Delineating Manual. However, if quantitative measurements are required, vegetation composition can be calculated using measurements of cover from this manual, frequency (Weixelman et al. 1996), or production (Leonard et al. 1992). Bonham (1989) provides an in-depth discussion of the advantages and drawbacks of various measurement techniques for these as well as other vegetation and community attributes.

USDA Forest Service (1992) has developed stability ratings for community types and other bank features (barren, rock, etc.) that, when analyzed along a "greenline" transect, effectively provide a stability rating for a reach when analyzed in conjunction with item 11.

Item 10: Riparian-wetland plants exhibit high vigor

Purpose

The intent of this item is to ascertain if riparian-wetland plants are healthy and robust or are weakened/stressed and leaving the area. The aboveground expression is a reflection of the condition belowground and the ability for riparian-wetland species to hold an area together. As riparian-wetland plants weaken or leave an area, the area is subject to degradation.

Examples

This item is very important, but is difficult to answer. It is useful to separate woody plants and herbaceous plants when assessing vigor. For most riparian-wetland areas, plant size, shape, and leaf color during the growing season can be used to discern vigor. For example, if the willows for a given reach are well-rounded and robust, the answer to item 10 would be “yes.” If these same plants are highlined/ mushroom-shaped, contain a lot of decadent material, etc., the answer to item 10 would be “no.”

Another example of when this item would be answered “no” would be if the willow leaves are turning yellow during the growing season. This usually happens as a result of water being removed or added to a system, which stresses the plants. However, change in color can also indicate a disease problem or climatic factors.

Abundance of herbaceous plants can be used to assess vigor. If Nebraska sedge composes a dense mat on the reach being assessed, the answer to item 10 would be “yes.” If Nebraska sedge occurs as isolated plants or broken clumps that are not forming communities, the answer to item 10 would be “no.”

“N/A” would be used for riparian-wetland areas that have no potential to produce vegetation.

Supporting Science/Quantitative Methodologies

Vigor is difficult to quantify, possibly because the relative health of plants within a community can be expressed in many morphological and physiological forms. The reproductive indicators for herbaceous species discussed in item 6 (unhealthy plants don’t reproduce as well), as well as plant size, leaf area and size, and root growth are all associated with relative plant health or vigor. Reduced height or reduced leaf area (production) and signs of stress, such as chlorosis, have traditionally been used as indicators of reduced vigor on herbaceous species. Growth form (morphology), leader length, and the amount of dead or dying limbs (Cole 1958) are also long standing indicators of vigor for shrubs.

Weixelman et al. (1996) have established procedures for documenting mean rooting depth and expected ranges of rooting depth associated with various ecological conditions of specific riparian community types. Shallower rooting depths associated with the declining status of an ecological type can, in part, be a quantitative measure of the vigor of the community.

Item 11: Adequate riparian-wetland vegetative cover is present to protect banks and dissipate energy during high flows

Purpose

Vegetation filters sediment, aids floodplain development, protects streambanks, etc., all of which dissipate stream energies associated with high-flow events. But this can only happen if there are enough plants. The purpose of this item is to determine if there is an adequate *amount* of vegetation present to dissipate stream energies from high-flow events.

This item is crucial for areas where vegetation is required for proper functioning. For a riparian wetland area to recover, composition of the right plants, recruitment, etc., are necessary, but until the right amount is present, the riparian-wetland area will not cross the threshold that would allow it to function properly.

It is important to understand that item 11 deals with an *amount*, while items 6-10 deal with composition, age class, etc., not amount. Generally item 11 will be answered "no" if one or more of the other vegetation items are answered "no."

Examples

For a wide, flat valley bottom with a sinuous channel, 90 percent cover of streambanks within a reach may be required. If an area has the appropriate percent cover of riparian-wetland plants, the answer to item 11 would be "yes." For other valley bottom types and stream types with different site potential, a streambank may only need 70 percent cover for the answer to be "yes."

If a streambank for the reach being assessed is dominated by upland plants, the answer to item 11 would be "no." If this same streambank is 50 percent riparian-wetland plants and 50 percent upland plants, the answer to item 11 would still be "no."

Item 11 would be answered "N/A" for riparian-wetland areas that do not need vegetation to achieve PFC.

Supporting Science/Quantitative Methodologies

Streambank erosion is a physical process that occurs along virtually all natural channels. Not only is it a normal part of channel evolution and meander migration, but it is also essential for creating and maintaining a variety of aquatic and riparian habitats. But excessive bank erosion can also destroy significant channel and floodplain habitats, as these areas are excavated and sometimes buried under massive amounts of sediment. The best protection against such excessive erosion is the preservation of adequate vegetative cover to dissipate the erosive forces acting upon the channel banks during periods of high streamflows.

Bank erosion occurs when the eroding force (shear stress) of water moving along the bank exceeds those forces in the bank that are resisting the shear force (Figure 6). Shear force on the bank is directly proportional to the velocity gradient in the water; i.e., the rate at which velocity increases when moving away from the bank. Thus, if velocity increases very rapidly in the near-bank region, the velocity gradient is steep and shear stress is high. Conversely, if velocity increases slowly or not at all in the near-bank region, shear stress on the bank will be minimal or negligible.

Forces resisting bank erosion result from physical properties of the streambank and protection from erosive shear by overhanging vegetation. Physical properties of the bank are primarily related to cohesive strength of bank materials and other factors increasing bank tensile strength. Cohesive strength of bank materials is largely a function of soil texture (especially particle size), soil chemistry, and soil structure. Vegetation root mass is a key factor increasing tensile strength of the bank.

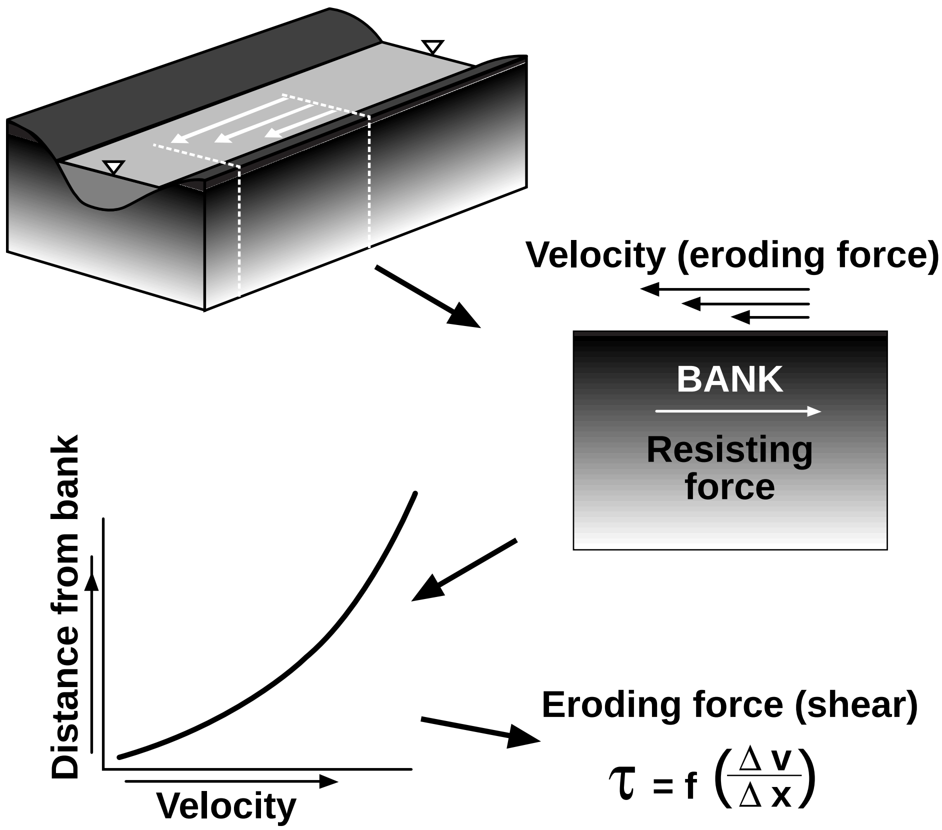

Figure 6. Bank erosion from force.

Vegetation has the potential to influence the balance of energy during high flows in at least two ways. First, living or dead vegetation (or any other cover, for that matter) that extends into the flow has the potential to reduce near-bank velocities, thus reducing erosive shear forces acting upon the bank. In an ideal situation, vegetation along the bank is sufficient to produce a zone of near-zero velocities near the bank, effectively moving the velocity profile away from the bank so that shear stress is dissipated in turbulent eddies in the flow. A similar process occurs in the overbank region when density of vegetation is sufficient to produce near-zero velocities in overbank flow during flood events.

Vegetation also influences the balance of energy during high flows by increasing resisting forces in the streambank. Particularly in noncohesive soils and sediments, the presence of vegetation may greatly increase binding forces in bank materials. Tensile strength provided by root masses of riparian vegetation may be the primary source of resistance in the alluvial sediments of many Western streams. Tensile strength will be dependent upon both the kind of vegetation present and the extent and density of root masses in the sediments. Determination of root-mass adequacy will be site-specific, as less cohesive sediments will require greater root mass to achieve the same level of stability as more cohesive sediments elsewhere.

The preferred method of quantification is calculation of a greenline stability rating (USDA Forest Service 1992 and similar documents). A stability rating of 7-10 would generally be considered adequate. However, there may be instances in low-energy *streams where a rating of 5-6 might suffice, but these are expected to be rare situations.*

Platts et al. (1987) provide the highest (best) rating for streambank alteration if less than 25 percent of the streambank is false, broken down, or eroding. In general, 70 percent cover of riparian wetland, bank-forming (high-stability) communities along 75 percent of a stream reach might be considered "adequate" in many cases. However, vegetation relationships with erosion/deposition characteristics should be scrutinized when there is less than 80 percent cover of riparian-wetland, bank-forming communities along 80 percent of the reach length, except for riparian-wetland areas where vegetation-controlling influence is negligible (A1-A6, B1, and B2 stream types in Rosgen 1996). For riparian-wetland areas where vegetation-controlling influence is very high (C3-C6, DA4-DA6, and E3-E6 stream types in Rosgen 1996), the 80 percent criteria may be marginal, depending on regional flow events, and the use of local comparison areas is highly recommended for determining cover/stability thresholds.

Item 12: Plant communities are an adequate source of coarse and/or large woody material (for maintenance/recovery)

Purpose

Streamside and upland vegetation produces the size of woody material over time that is required to capture bedload, aid floodplain development, and dissipate energy where appropriate for stream size and ecological setting and where woody material is required. Without course and/or large wood, these areas cannot handle normal high-flow events because of their intensity. *This wood has to be large enough to stay for a period of time to operate as a hydrologic modifier.*

Before answering item 12, it has to be determined if large wood is necessary for a given area to function properly. Many rangeland and meadow riparian-wetland areas do not require woody material to maintain channel stability.

Examples

If coarse and/or large woody material (LWM) is necessary and trees are present, it is important to then ascertain if they are sufficient in number and size. If a reach contains an adequate number of mature trees and they are large enough to serve as hydrologic modifiers, the answer to item 12 would be "yes."

If a stream reach requires large wood and there are no living mature trees present that will access the stream in the future, then the answer to item 12 would be "no." If there is only an isolated tree here and there, the answer to item 12 would still be "no."

This item will be answered "N/A" for many riparian-wetland areas throughout the West, as coarse and/or large wood is not required for these areas to dissipate energy and function properly.

Supporting Science/Quantitative Methodologies

Forested riparian-wetland areas depend on trees and LWM to maintain or achieve PFC, reach desired condition, and achieve potential. A large amount of literature has been produced that documents observations and measurements of forest riparian habitat, describes specific situations of functions, and describes the relative value of LWM and trees needed to maintain streams and create fish habitat.

The complexity of forest riparian environments has led researchers to study the hydrology, sediment delivery, vegetation, and biology of these systems to determine how each component affects specific products, such as water quality and fish. To visualize forest riparian/stream processes, it is necessary to consider each point of interest as interrelated to the whole stream continuum. The location of interest may be anywhere from the headwaters to the ocean. The way each part of the system functions changes as the streams merge and grow larger, and the enormous variety of stream slope, geology, hydrologies, vegetation types, etc., adds to the difficulty of describing how the whole system functions.

It is important to remember the following about the role of LWM in a stream:

1. LWM and living trees are essential to development and maintenance of some forested riparian stream ecosystems from their headwaters to the downstream end of the forest stream continuum.

2. The riparian/stream continuum is in a state of dynamic stability when it is functioning properly and the movement of LWM down the stream system is normal and necessary. The function of LWM in the stream and on the floodplain changes from the headwaters to the wider downstream valleys.

3. Floods, fires, windthrow, torrents, landslides, and normal tree mortality are essential delivery mechanisms needed to maintain and restore the riparian stream system's functionality.

4. The temporal processes of the forest riparian/stream system must be measured in decades and centuries.

5. The spatial location of LWM is continually shifting during annual and episodic events. This spatial movement replenishes materials that are broken down or flushed out of the system.

Appendix F contains further discussion of the role large wood plays relative to headwater streams, alluvial fans, 3rd-6th-order streams, and large streams.

C. Erosion/Deposition

Items 13-17 deal with erosion/deposition attributes and processes that have to be in working order for an area to function properly. Many of the documents referenced in the introduction to the Hydrology and Vegetation sections are appropriate here.

Item 13: Floodplain and channel characteristics (i.e., rocks, overflow channels, coarse and/or large woody material) are adequate to dissipate energy

Purpose

For riparian-wetland areas to function properly, energy has to be dissipated during high-flow events. These areas reduce energy by accessing a floodplain, which spreads high flows, thus reducing the energy, or through channel characteristics that create forces resistant to downstream movement.

Channel characteristics vary by channel type so they must be identified before this item is answered. For example, a B2 channel type (Rosgen 1996) is moderately entrenched, typically located in or on coarse alluvial fans, and has a limited floodplain. B2 channel types have channel characteristics of boulders and small cobble to dissipate stream energy. A C4 channel type (Rosgen 1996) is a slightly entrenched and gravel-dominated stream, which has to have access to a floodplain and channel characteristics such as backwater areas, oxbows, and overflow channels to dissipate stream energy.

Examples

The answer to this item would be “yes” for channels with high sinuosity, slight to moderately steep gradients, and very low channel width/depth ratios if there is ready access to the floodplain and secondary channels during high-flow events. The answer to this item would be “no” if this system is downcut (incised) and no longer has access to its floodplain or secondary channels during high flow events.

For areas that require woody material, the answer would be “yes” if wood is in place and is large enough to remain in place during high-flow events, thus dissipating energy. For systems lacking large wood to act as hydrologic modifiers and thus dissipate energy, the answer would be “no.”

Item 13 will never be answered “NA”; it will always have either a “yes” or “no” answer.

Supporting Science/Quantitative Methodologies

One of the three governing laws of fluid mechanics is that total energy (i.e., potential energy due to height above some datum, kinetic energy due to velocity of flow, and pressure energy due to depth of flow) must be conserved as water moves downstream through a channel. However, even in the case of uniform flow, where both velocity and depth are unchanged in the downstream direction, potential energy is lost as water moves from a higher position to a lower one. This energy loss is a result of forces acting at the channel boundary to resist the downstream movement of water. Various hydraulic equations have been developed to quantify this energy loss and to predict the stable depth of flow for a specified discharge in a channel.

The most used equation is the Manning equation:

$$Q = 1.49/n \, A \, R^{2/3} \, S^{1/2} \tag{15}$$

where Q is discharge, A is area, R is hydralic radius, and S is slope.

The Manning equation incorporates a resistance coefficient, known as a Manning's n-value, to quantify energy loss and boundary resistance at uniform flow conditions. This resistance coefficient can take on a range of values, depending upon channel configuration, bed and bank materials, and other obstructions to flow. As such, the Manning's n-value, or roughness coefficient, is one measure of channel characteristics and their influence on dissipation of energy.

The best method for determining a resistance coefficient for a channel is to obtain a measurement of stream discharge at or near bankfull conditions and solve the Manning equation for the roughness coefficient (n), knowing all the other variables. This procedure yields an exact solution for the roughness coefficient, subject to measurement error. Resistance coefficients may be determined as such for a number of streams in an area, and the resulting n-values may be related to other stream characteristics (e.g., drainage area, stream type, channel slope, bankfull depth, etc.) to develop diagnostic tools for determining functioning condition. For example, once resistance coefficients for bankfull conditions have been determined for a particular stream type in an area, it may be possible to predict a bankfull n-value for a given stream based on contributing drainage area and channel slope. Stream channels with n values falling below the expected range of resistance coefficients may indicate channel characteristics inadequate to dissipate the energy of flow.

Methods have also been developed for predicting Manning's n-values (i.e., resistance coefficients) without field measurements of discharge. Cowan (1956) proposed a formula for estimating n values based on observed channel characteristics:

$$n = (n_0 + n_1 + n_2 + n_3 + n_4)m \tag{16}$$

where: n_0 = base value of n for a straight, uniform, smooth channel in natural materials;
n_1 = correction for effect of surface irregularities;
n_2 = correction for variation in cross-section size and shape;
n_3 = correction for obstructions;
n_4 = correction for vegetation and flow conditions; and
m = correction for degree of channel meandering.

Base values of n range from 0.020 for smooth, straight, uniform channels in earth to about 0.036 for straight, uniform channels in coarse cobbles or boulders. Table 2 [taken from Aldridge and Garrett (1973)] may be used to estimate each of the above correction factors to produce a final estimate of n.

For diagnostic purposes, resistance coefficients should be determined for bankfull conditions for a wide variety of stream types. The data should be segregated by

Table 2. Factors that affect roughness of the channel (modified from Aldridge and Garrett, 1973, Table 2).

	Channel conditions	n value adjustment[1]	Example
Degree of irregularity (n_1)	Smooth	0.000	Compares to the smoothest channel attainable in a given bed material.
	Minor	0.001-0.005	Compares to carefully dredged channels in good condition but having slightly eroded or scoured side slopes.
	Moderate	0.006-0.010	Compares to dredged channels having moderate to considerable bed roughness and moderately sloughed or eroded side slopes.
	Severe	0.011-0.020	Badly sloughed or scalloped banks of natural streams; badly eroded or sloughed sides of canals or drainage channels; unshaped, jagged, and irregular surfaces of channels in rock.
Variation in channel cross section (n_2)	Gradual	0.000	Size and shape of channel cross sections change gradually.
	Alternating occasionally	0.001-0.005	Large and small cross sections alternate occasionally, or the main flow occasionaly shifts from side to side owing to changes in cross-sectional shape.
	Alternating frequently	0.010-0.015	Large and small cross sections alternate frequently, or the main flow frequently shifts from side to side owing to changes in cross-sectional shape.
Effect of obstruction (n_3)	Negligible	0.000-0.004	A few scattered obstructions, which include debris deposits, stumps, exposed roots, logs, piers, or isolated boulders, that occupy less than 5 percent of the cross-sectional area.
	Minor	0.005-0.015	Obstructions occupy less than 15 percent of the cross-sectional area and the spacing between obstructions is such that the sphere of influence around one obstruction does not extend to the sphere of influence around another obstruction. Smaller adjustments are used for curved smooth-surfaced objects than are used for sharp-edged angular objects.
	Appreciable	0.020-0.030	Obstructions occupy from 15 to 20 percent of the cross-sectional area or the space between obstructions is small enough to cause the effects of several obstructions to be additive, thereby blocking an equivalent part of a cross section.
	Severe	0.040-0.050	Obstructions occupy more than 50 percent of the cross-sectional area or the space between obstructions is small enough to cause turbulence across most of the cross section.

Table 2 *(continued)*. Factors that affect roughness of the channel (modified from Aldridge and Garrett, 1973, Table 2).

	Channel conditions	n value adjustment[1]	Example
Amount of vegetation (n_4)	Small	0.002-0.010	Dense growths of flexible turf grass, such as Bermuda, or weeds growing where the average depth of flow is at least two times the height of the vegetation; supple tree seedlings such as willow, cottonwood, arrowweed, or saltcedar growing where the average depth of flow is at least three times the height of the vegetation.
	Medium	0.010-0.025	Turf grass growing where the average depth of flow is from one to two times the height of the vegetation; moderately dense stemmy grass, weeds, or tree seedlings growing where the average depth of flow is from two to three times the height of the vegetation; brushy, moderately dense vegetation, similar to 1- to 2-year-old willow trees in the dormant season, growing along the banks and no significant vegetation along the channel bottoms where the hydraulic radius exceeds 2 feet.
	Large	0.025-0.050	Turf grass growing where the average depth of flow is about equal to the height of vegetation; 8- to 10-year-old willow or cottonwood trees inter-grown with some weeds and brush (none of the vegetation in foliage) where the hydraulic radius exceeds 2 feet; bushy willows about 1 year old intergrown with some weeds along side slopes (all vegetation in full foliage) and no significant vegetation along channel bottoms where the hydraulic radius is greater than 2 feet.
	Very large	0.050-0.100	Turf grass growing where the average depth of flow is less than half the height of the vegetation; bushy willow trees about 1 year old intergrown with weeds along side slopes (all vegetation in full foliage) or dense cattails growing along channel bottom; trees intergrown with weeds and brush (all vegetation in full foliage).
Degree of meandering[1] (adjustment values apply to flow confined in the channel and do not apply where downvalley flow crosses meanders)(m)	Minor	1.00	Ratio of the channel length to valley length is 1.0 to 1.2.
	Appreciable	1.15	Ratio of the channel length to valley length is 1.2 to 1.5.
	Severe	1.30	Ratio of the channel length to valley length is greater than 1.5

[1] Adjustments for degree of irregularity, variations in cross section, effect of obstructions, and vegetation are added to the base n value before multiplying by the adjustment for meander. If point bars are without vegetation, the correct answer to item 14 would be "no." If point bars are dominated by upland plants, the answer would still be "no."

stream type to produce an expected range of resistance coefficients for each type. Data segregated by stream type may be related to other basin and/or channel parameters to develop predictive equations for Manning's roughness coefficient for bankfull conditions. Functionality assessments then attempt to identify streams falling outside the expected range of conditions to determine if such channels have suitable floodplain and channel characteristics to adequately dissipate the energy of flow.

The geomorphic effects of in-channel obstructions, including large woody debris are reviewed in Smith (1996). Debris flows, debris removal, obstruction-pool interactions, obstruction-channel morphology interactions, mechanisms of pool scour, and scour in obstruction-related pools are also discussed. Several questions are posed related to information needs required for widespread application of the turbulent scour model in forest streams.

Item 14: Point bars are revegetating with riparian-wetland vegetation

Purpose

Formation/extension of point bars is a natural depositional process for some channel types. For channel types that have point bars, it is very important that vegetation colonizes deposits as they extend over time to maintain a balance. If vegetation cannot maintain a balance, energies during high flows accelerate erosion, which affects sinuosity, gradient, and access to floodplain and results in the degradation of a riparian-wetland area. This vegetation has to be riparian-wetland plants that have root masses capable of withstanding high-flow events. The intent of item 14 is to establish the fact that riparian-wetland vegetation is capturing recent deposition on point bars and maintaining this balance.

Examples

Point bars are an important characteristic for some B and most C channel types (Rosgen 1996). If point bars are vegetated by riparian-wetland plants like willows and sedges, the answer to item 14 would be “yes.”

A confined and/or high-gradient channel type such as an A1 (Rosgen 1996) has no potential for point bars; this item would be answered “N/A” for this channel type.

Supporting Science/Quantitative Methodologies

This item assesses whether or not vegetation is colonizing and stabilizing a point bar, so the same quantification methods used in items 7 and 9 can be used here. Plant lists published by the U.S. Fish and Wildlife Service (e.g., Reed 1988) provide indicators for the plants that have high erosion control potential. If quantitative measurements are required, vegetation composition can be calculated using measurements of cover as discussed in items 7 and 9.

Item 15: Lateral stream movement is associated with natural sinuosity

Purpose

Streams located within landforms that are not confining move back and forth across the valley floor over time. This lateral stream movement is a natural process. This process has been described as snaking through the landscape, patterned after how a snake moves over land.

When excessive, this movement can have serious impacts on the overall function of a riparian wetland area, limiting its ability to dissipate energies. The intent of item 15 is to document if this process of lateral movements is normal or has been accelerated.

Examples

If the lateral movement of an active channel is slowly progressing across its valley floor, the answer to item 15 would be "yes." Indicators of natural progression could include maintenance of a single thread channel; stable streambanks, especially on straight segments between meanders; natural deposition with no change in bed elevation; and movement of the active channel with no change in sinuosity, gradient, or width/depth ratio.

If an active channel within a riparian-wetland area relocates itself with every high-flow event, the answer to item 15 would be "no." Indicators would be the reverse of the items listed above.

Some channel types are limited to lateral movement by existing landform, and for these types, the appropriate answer could be "yes" or "N/A."

Supporting Science/Quantitative Methodologies

Lateral movement of stream channels is a natural phenomenon in many environments, and must be considered relative to the normal adjustment processes of a stream. Because sinuosity and lateral stream movement are a function of landscape setting, item 15 is strongly related to item 3. Lateral stream movement usually occurs through bank erosion; thus, item 15 also is strongly influenced by responses to items 9, 11, and 14.

Lateral movement of stream channels (bank erosion) is influenced by many factors, especially stream type, nature of bank materials, and kinds and amount of vegetation on the streambank. Bank erosion must be evaluated relative to stream type, particularly as a stream type manifests itself in the bank material sizes present at a site. For example, a meandering riffle-pool stream channel likely will exhibit higher bank erosion rates in areas of sandy materials than in areas where silts and clays provide some cohesiveness to the bank. Thus, "natural" rates of channel migration will vary by stream type and material, and must be determined empirically through regional studies linked to these factors.

Measurement of lateral stream movement (bank erosion rates) is relatively straightforward, but annual measurements should be related to magnitude and duration of high-flow events. Where bank erosion is low (i.e., less than a few feet per year), erosion may be quantified using bank pins or bank profiles, such as those described by Rosgen (1996). Where bank erosion is high (i.e., more than a few feet per year), erosion may be quantified using surveyed cross sections or sequences of aerial photographs. In some cases, erosion rates may remain low for a period of years until some threshold of flow is exceeded, after which erosion may increase by one or more orders of magnitude. Thus, it is important to maintain a record of the duration and magnitude of high flows sufficient to initiate lateral movement of the channel.

Erosion rates for typical stream types and bank materials may be used to determine expected ranges of lateral stream movement. Erosion rates near the high end of the range, as well as outliers and bimodal distributions, may indicate lateral stream movement beyond that normally associated with natural sinuosity. Obviously, such an assessment must consider the recent history of high-flow events, and should rely heavily on determinations made for items 3, 9, and 11 as well.

Item 16: System is vertically stable

Purpose

It is the nature of stream channels to transport water, sediment, and other materials out of the watershed, thus reducing the overall elevation of the landscape, including the valley bottom. This channel lowering, although part of the natural cycle of landscape evolution, usually occurs at rates that are detectable only over very long periods of time (i.e., hundreds of years or more). Occasionally, natural disturbances or human activities are significant enough to produce rapid vertical adjustments of a channel or channel network that are measurable (several feet or more) in relatively short periods of time (decades or less).

The intent of item 16 is to document if channel lowering adjustments are occurring at a "natural" or an accelerated rate. It is also important to understand that this item addresses vertical adjustments occurring today, not those that have occurred in the past. *It is also important to understand that this item deals only with the lowering of a streambed and not aggradation (aggradation is addressed in item 17).*

Examples

If a riparian-wetland area has no evidence of any rapid vertical adjustments (headcuts) and the right kind of vegetation exists along its streambanks, the answer to item 16 is "yes."

If a riparian-wetland area is downcut but has started to develop a new floodplain (State D in Figure 2) the answer to item 16 would be "yes."

For a reach containing an active headcut that is resulting in a rapid vertical adjustment, the answer to item 16 would be "no."

If a riparian-wetland area's soil type is such that it requires riparian-wetland plants to maintain vertical stability, and its streambanks are dominated by upland plants, the answer to item 16 would be "no."

If a riparian-wetland area's stability is controlled by bedrock, item 16 could be answered "yes" or "N/A."

Supporting Science/Quantitative Methodologies

If vertical instability of the stream is suspected, it may be useful to determine if adjustments in bed elevation are the result of local conditions or systemwide instability. Adjustment processes that affect entire fluvial systems often include upstream-progressing degradation (lowering of the channel bed with time), downstream aggradation (raising of the channel bed with time), channel widening or narrowing, and changes in the magnitude of the sediment load. These processes differ from localized processes such as scour and fill, which can be limited in magnitude and extent. Scour and fill occur over periods of hours to days and affect local areas in response to stormflow. In contrast, processes of degradation and aggradation usually affect long stream reaches or entire drainage basins and may be most noticeable over a period of several years. Long term adjustment processes such as degradation and aggradation can exacerbate local scour problems, and sufficient bed-level adjustments of any kind may result in bank instability and changes in channel pattern.

It is often difficult to differentiate between local and systemwide processes without extending the investigation upstream and downstream of the site in question. This is because channel adjustments migrate over time and space and may affect previously undisturbed reaches. Stage of channel evolution is the primary diagnostic tool used to differentiate between local and systemwide stability problems.

During basinwide adjustments, the stage of channel evolution will usually vary systematically with distance upstream and downstream. For example, a well-vegetated stream having frequent interaction with its floodplain often will undergo bed-level lowering following a perturbation (e.g., channel disturbance or change in land use). This downcutting usually results from excess stream power in the disturbed reach. Bed-level lowering eventually leads to oversteepening of the banks, and when critical bank heights are exceeded, bank failures and mass wasting lead to channel widening. As mass wasting and channel widening proceed upstream, an aggradation phase follows in which a new low-flow channel begins to form in the sediment deposits. Upper banks may continue to be unstable at this time. The final stage of evolution is the development of a channel within the deposited alluvium with dimensions and capacity similar to the predisturbance channel. The new channel is usually lower than the predisturbance channel, and the old floodplain now functions primarily as a terrace. Where vertical channel adjustments are systemwide, this sequence of evolution usually manifests itself longitudinally along the stream profile and often along the tributaries as well (Figure 2).

In contrast to general aggradation and degradation, the lack of a systematic relation between stage of channel evolution and distance upstream or downstream generally indicates that stability problems are due to local conditions. Local channel instabilities can often be attributed to redirection of flow caused by debris, structures (e.g., beaver dams), or the approach angle from upstream. During moderate and high flows, obstructions often result in vortexes and secondary flow cells that produce local scour, erosion of bank toes, and ultimately, bank failures. Constrictions in the cross section from debris accumulations or structures also can cause a backwater condition upstream, with acceleration of flow and contraction scour through the constriction.

Vertical channel adjustments of a magnitude and rate sufficient to be easily measurable frequently (but not always) are indicative of system instability. In many instances (e.g., the development of an extensive gully network or a major headcut), vertical instability is both obvious and measurable as the rate of network extension or headcut migration. However, care must be exercised when interpreting changes in bed elevations along sand-bed channels. Scour and fill in some sand channels may approach 10 feet or more during the passage of a single flood event, with virtually no long-term change in streambed elevation. While such channels may be considered vertically unstable with respect to bed elevations, they may or may not be functioning properly for their landscape setting.

Determination of vertical stability in a stream system is most easily documented through repeated measurements of bed elevation through time. Monumented cross sections should be established using a stable reference point as a permanent benchmark. The cross sections are resurveyed at various intervals, depending on a number of factors, such as perceived instability of the site and magnitude and frequency of high-flow events. Where streamgaging stations are present, a procedure known as specific gage may be used to document vertical channel adjustments through time. The gaging-station datum and stage-discharge rating tables are used to document change in water surface elevation of some index flow (e.g., mean annual flow or annual low flow) through time. When current meter measurements of the index flow are available, average bed elevation may be obtained by subtracting mean depth of the measurement from water surface elevation of the index flow. The resulting mean bed elevations are then plotted against time to document trends of bed-level adjustment.

As with most of the checklist items, it is important to determine bed stability in relation to the landscape setting of the stream. Channel lowering of 1 or 2 feet over a decade or more may be normal for headwater channels in high-relief environments dominated by noncohesive sediments. While such streams are likely to be considered vertically unstable, this criterion should not be considered independently of all others for determining the functioning condition of a stream.

Additional information on riparian management and channel evolution can be found in USDI Bureau of Land Management (1989).

Item 17: Stream is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition)

Purpose

Streams transport water and sediment out of a watershed. Excessive erosion or deposition indicates that this process is out of balance. The intent of item 17 is to look for evidence that a riparian wetland area is out of balance, thus degrading the riparian-wetland area.

Natural channels can be classified as either single thread or braided channels. While some braided channels are natural, most braided channels reflect unnaturally high sediment loads. A good example of a naturally braided system would be a glacial outwash stream in Alaska. These are characterized by high bank erosion, large deposition occurring as both longitudinal and transverse bars, and annual shifts of the bed location (Rosgen 1996). Similar systems can be found in the deserts of the Southwest where sand is the dominant bed material. It is important to remember that each riparian-wetland area is rated according to its capability and potential.

Since water and sediment are supplied from the watershed, this item is closely tied to item 5, and sediment from channel erosion is related to item 3.

Examples

If a riparian-wetland area is a single thread channel (not braided), shows no evidence of mid channel bars, and is not aggrading as a result of excess sediment from the watershed, the answer to item 17 would be "yes." If the flow in this stream is doubled from a transmountain diversion, and excessive erosion or deposition is taking place as a result of this increased flow, the answer to item 17 would be "no." Indicators of excessive erosion can include mid-channel bars, braiding, and unstable streambanks.

If a channel is found to be braided and has high streambank erosion, and these conditions are the result of natural adverse conditions that produce channel braiding and erosion, the answer to item 17 would be "yes." If these conditions are the result of the operation of a dam (not natural), the answer to item 17 would be "no."

Item 17 should never be answered "N/A"; it will always have a "yes" or "no" answer.

Supporting Science/Quantitative Methodologies

As stated earlier, stream channels are constantly adjusting to the water and sediment being supplied by the watershed. Changes in channel conditions correspond to changes in streamflow and the sediment being supplied. Understanding of channel adjustments requires an understanding of changes in streamflow and sediment production throughout the drainage. Quantification for item 17 can be achieved by using much of the science described for items 3, 5, 13, and 16.

One method worth noting again is the use of aerial photos. Aerial photos that cover several years or decades can identify channel adjustments through time for a particular reach. Information on how aerial photos can be used is provided in TR 1737-10 (Clemmer 1994) and TR 1737-12 (Prichard et al. 1996).

It is also important to remember that channel adjustment processes should be evaluated with respect to both time and spatial considerations.

VI. Summary

The BLM and the FS, working with the NRCS, have initiated an effort to restore and manage riparian-wetland areas in 11 Western States. To be effective, these agencies have established common terms and definitions, as well as a method for evaluating the condition of these areas, which has been extensively reviewed and tested. This method involves assessing whether an area is in proper functioning condition (see BLM's TR 1737-9).

The method for assessing PFC is a qualitative, yet science-based process that considers both abiotic and biotic factors as they relate to physical function. It facilitates communication about the condition of a riparian-wetland area and focuses attention on the physical process before considering values. A standard checklist is used to ensure consistency in reporting the condition of riparian-wetland areas.

The PFC method is straightforward: *review existing documents, analyze the PFC definition, and assess functionality using the checklist.* The assessment requires the use of an ID team. To assess the condition of a riparian-wetland area, an ID team has to understand its capability and potential and identify the attributes and processes that transpire. If an ID team does not spend the time to develop this understanding, their judgement about PFC will be incomplete and may be incorrect.

Riparian-wetland areas are rated in four categories: proper functioning condition, functional—at risk, nonfunctional, and unknown. The condition of some riparian-wetland areas will be relatively easy to discern, while the condition of others will be less evident. Occasionally, items on the checklist will have to be quantified to determine how they should be answered. There are numerous ways these items can be quantified, including those summarized in this document.

For areas that are functional—at risk, trend should be identified, as it is a key consideration in interpreting data. At-risk areas 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. At-risk areas with an upward trend are often a priority for monitoring efforts. Monitoring these areas assures that they continue to improve.

Conversely, trend is not determined 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 rating 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.

The lack of specific information will place many riparian-wetland areas into the category of unknown. 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.

To manage riparian-wetland areas successfully requires a state of resiliency that allows an area to hold together during frequent high-flow events. When a riparian-wetland area's physical aspects are in working order, then channel characteristics are maintained that sustain the area's ability to produce values. Function comes first, then values (desired condition).

Managing riparian-wetland areas does not cease once PFC is achieved—it has just started. Existing and potential resource values and the plant communities necessary to support these values have to be identified. Once these values have been identified, then specific objectives can be derived to ascertain desired condition. Management actions to achieve desired condition can then be designed and set in place.

Appendix A:
Riparian-Wetland Functional Checklist

General Instructions

1) This checklist constitutes the **Minimum National Standards** required to determine proper functioning condition of lotic riparian-wetland areas.

2) As a minimum, an **ID team** will use this checklist to determine the degree of function of a riparian-wetland area.

3) An ID team **must review existing documents**, particularly those referenced in this document, so that the team has an understanding of the concepts of the riparian-wetland area they are assessing.

4) An ID team **must determine the attributes and processes important** to the riparian wetland area that is being assessed.

5) Mark one box for each element. Elements are numbered for the purpose of cataloging comments. The numbers do not declare importance.

6) 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.

7) Based on the ID team's discussion, "**functional rating**" will be resolved and the checklist's summary section will be completed.

8) Establish photo points where possible to document the area being assessed.

Standard Checklist

Name of Riparian-Wetland Area:____

Date:__________________ Segment/Reach ID: ____________________________

Miles:__________________ Acres:_________________

ID Team Observers: ____

Yes	No	N/A	HYDROLOGY
			1) Floodplain above bankfull is inundated in “relatively frequent” events
			2) Where beaver dams are present they are active and stable
			3) Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region)
			4) Riparian-wetland area is widening or has achieved potential extent
			5) Upland watershed is not contributing to riparian-wetland degradation

Yes	No	N/A	VEGETATION
			6) There is diverse age-class distribution of riparian-wetland vegetation (recruitment for maintenance/recovery)
			7) There is diverse composition of riparian-wetland vegetation (for maintenance/recovery)
			8) Species present indicate maintenance of riparian-wetland soil moisture characteristics
			9) Streambank vegetation is comprised of those plants or plant communities that have root masses capable of withstanding high-streamflow events
			10) Riparian-wetland plants exhibit high vigor
			11) Adequate riparian-wetland vegetative cover is present to protect banks and dissipate energy during high flows
			12) Plant communities are an adequate source of coarse and/or large woody material (for maintenance/recovery)

Yes	No	N/A	EROSION/DEPOSITION
			13) Floodplain and channel characteristics (i.e., rocks, overflow channels, coarse and/or large woody material) are adequate to dissipate energy
			14) Point bars are revegetating with riparian-wetland vegetation
			15) Lateral stream movement is associated with natural sinuosity
			16) System is vertically stable
			17) Stream is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition)

(Revised 1998)

Remarks

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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 the control of the manager?

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 B:
Potential and Capability Examples

The following examples show how to fill out the checklist and determine functioning condition for a variety of scenarios, and explain how to consider and apply potential and capability:

Example 1: Assessing functionality of a bedrock-controlled system that is at potential.

Example 2: Assessing functionality of a bedrock-controlled system that is not at potential.

Example 3: Assessing functionality of a braided glacial system that is at potential.

Example 4: Assessing functionality of a braided system that is not at potential.

Example 5: Assessing functionality of a system that is at potential for vegetation but not for channel characteristics.

Example 6: Assessing functionality of a system that is limited by a railroad and a highway.

Example 1. Assessing functionality of a bedrock-controlled system that is at potential: This riparian-wetland area is deeply entrenched. The channel is dominated by bedrock with some accumulations of boulders, cobble, and gravel.

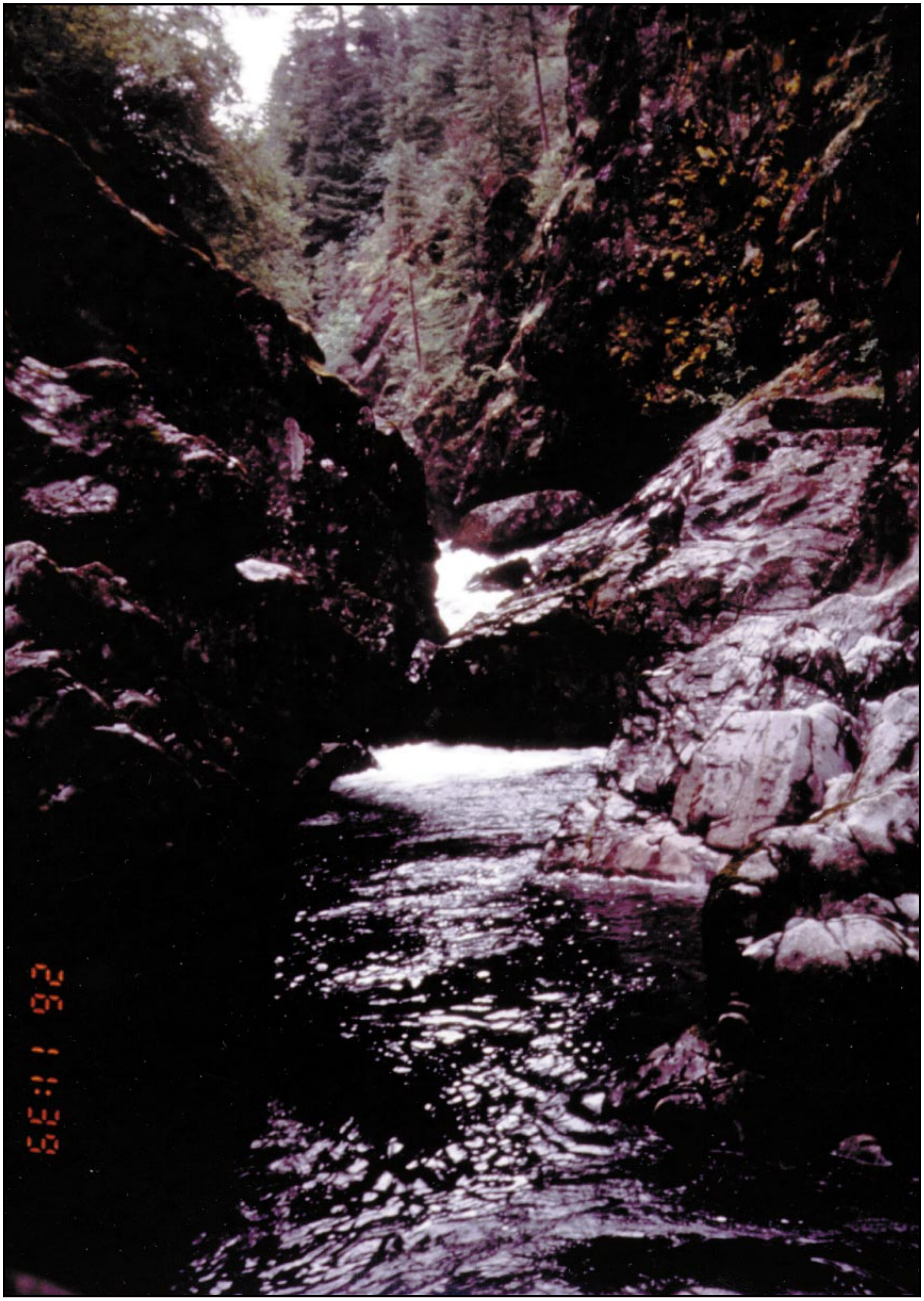


Figure B1. Little North Fork Santiam, Cascade Range.

Yes	No	N/A	HYDROLOGY
		X	1) Floodplain above bankfull is inundated in "relatively frequent" events
No floodplain is expected in this bedrock gorge.			
		X	2) Where beaver dams are present they are active and stable
Beaver would not be expected in this reach, even if they are present in the basin.			
X			3) Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region)
Sinuosity and width/depth ratio match the regional curves defined as typical for this stream type.			
X			4) Riparian-wetland area is widening or has achieved potential extent
Due to the bedrock-controlled channel and banks, this system has little or no potential for a riparian-wetland area.			
X			5) Upland watershed is not contributing to riparian-wetland degradation
Even if the watershed was in very poor condition, it would not likely affect this reach.			

Yes	No	N/A	VEGETATION
		X	6) There is diverse age-class distribution of riparian-wetland vegetation (recruitment for maintenance/recovery)
This system has little potential for riparian-wetland vegetation, and therefore, riparian wetland vegetation is not necessary for channel stability.			
		X	7) There is diverse composition of riparian-wetland vegetation (for maintenance/recovery)
See #6.			
		X	8) Species present indicate maintenance of riparian-wetland soil moisture characteristics
See #6.			
		X	9) Streambank vegetation is comprised of those plants or plant communities that have root masses capable of withstanding high-streamflow events.
See #6.			
		X	10) Riparian-wetland plants exhibit high vigor
See #6.			
		X	11) Adequate riparian-wetland vegetative cover is present to protect banks and dissipate energy during high flows
See #6.			
		X	12) Plant communities are an adequate source of coarse and/or large woody material (for maintenance/recovery)
See #6.			

Yes	No	N/A	EROSION/DEPOSITION
X			13) Floodplain and channel characteristics (i.e., rocks, overflow channels, coarse and/or large woody material) are adequate to dissipate energy
This item is answered yes based on the channel characteristics. The bedrock and boulders in the channel are adequate to dissipate energy.			
		X	14) Point bars are revegetating with riparian-wetland vegetation
Point bars are not characteristic of this stream type.			
X			15) Lateral stream movement is associated with natural sinuosity
X			16) System is vertically stable
The coarse material and bedrock in the channel result in this being a vertically stable system.			
X			17) Stream is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition)

Summary Determination

Functional Rating:

Proper Functioning Condition ____X____
Functional—At Risk _________
Nonfunctional _________
Unknown _________

Trend for Functional—At Risk:

Upward _________
Downward _________
Not Apparent _________

Rationale For Rating: This system is in proper functioning condition because the checklist items have been answered “yes” or “NA.” The system is functioning “as best it can” within its attributes and processes defined by the current geoclimatic setting.

Are factors contributing to unacceptable conditions outside the control of the manager?

Yes ___
No _X_

If yes, what are those factors?

___ Flow regulations ___ Mining activities ___ Upstream channel conditions
___ Channelization ___ Road encroachment ___ Oil field water discharge
___ Augmented flows ___ Other (specify)________________________________

Example 2. Rating functionality of a bedrock-controlled system that is not at potential: This area is deeply entrenched and bedrock-controlled with gentle gradients. The channel is dominated by bedrock with some accumulations of boulders, cobble, and gravel and finer sediments in pools and backwater eddies. Potential for this reach is a complex of logjams tied to the bank and uplands that allows the system to capture and store sediment. Those sediments are colonized by vegetation, causing the riparian-wetland area to widen and create more diverse habitat. As older jams are lost or "blown-out," stabilized sediment "wedges" become terraces, and loose woody material is captured by firmly anchored jams downstream.

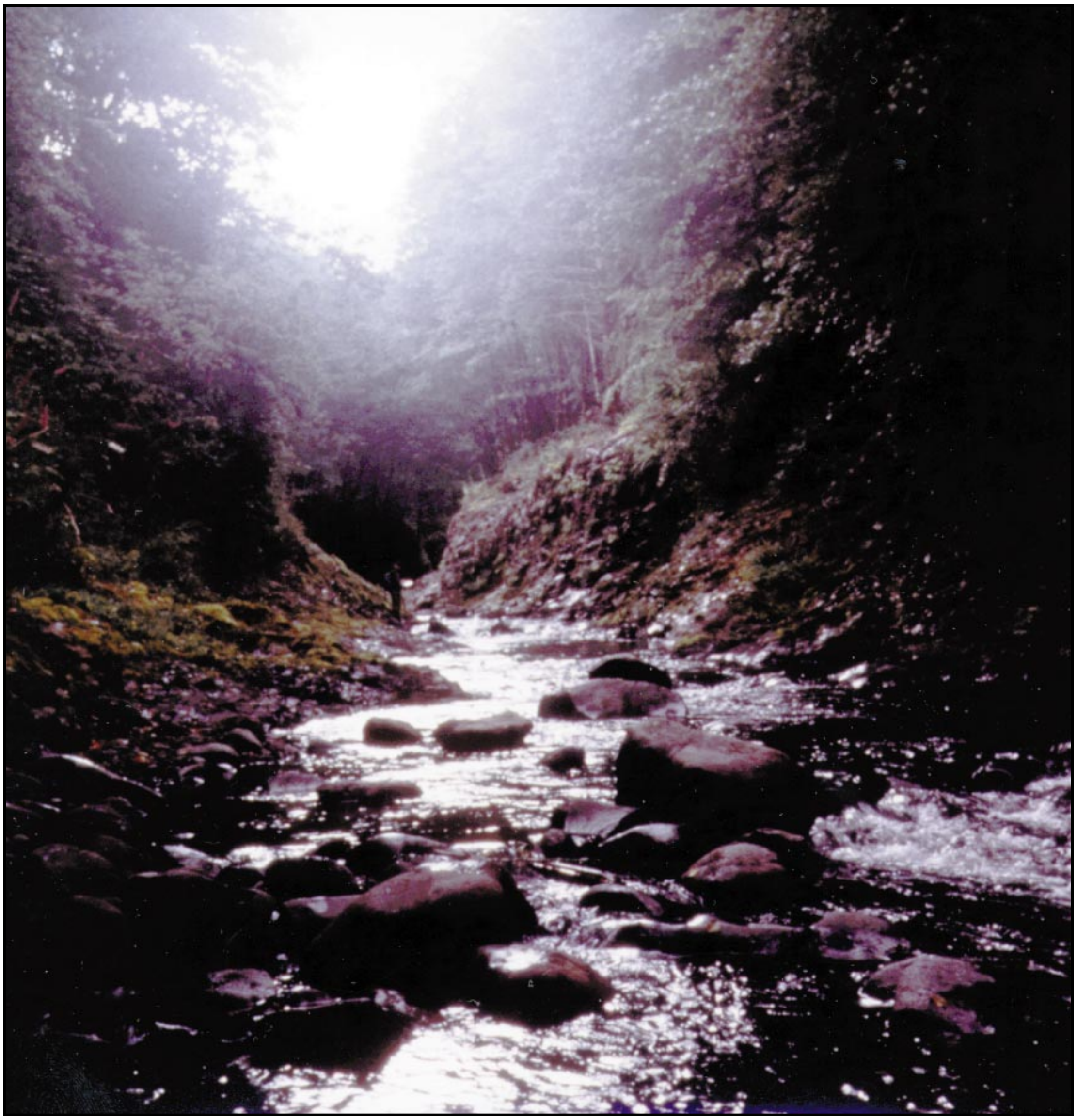


Figure B2. Wilson Basin, Coast Range.

Yes	No	N/A	HYDROLOGY
	X		1) Floodplain above bankfull is inundated in “relatively frequent” events
There is a “level” area above bankfull that is currently bedrock, but at one time was likely covered with a finer substrate and functioned as a floodplain.			
		X	2) Where beaver dams are present they are active and stable
Even though beaver are present in the basin, they are not expected due to the size of this channel.			
	X		3) Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region)
The width/depth ratio is not in balance with its setting.			
	X		4) Riparian-wetland area is widening or has achieved potential extent
The riparian-wetland area has narrowed due to the lack of suitable substrate.			
	X		5) Upland watershed is not contributing to riparian-wetland degradation
Lack of large wood in the system is caused by extensive logging in the watershed.			

Yes	No	N/A	VEGETATION
	X		6) There is diverse age-class distribution of riparian-wetland vegetation (recruitment for maintenance/recovery)
There are few, if any, young conifers within the deciduous canopy.			
	X		7) There is diverse composition of riparian-wetland vegetation (for maintenance/recovery)
The woody component is lacking.			
	X		8) Species present indicate maintenance of riparian-wetland soil moisture characteristics
The potential is for the streambanks to support riparian-wetland vegetation; however, scouring of the channel has removed the substrate necessary to support streambank vegetation.			
	X		9) Streambank vegetation is comprised of those plants or plant communities that have root masses capable of withstanding high-streamflow events.
See #8.			
X			10) Riparian-wetland plants exhibit high vigor
The few riparian-wetland plants that are present appear vigorous.			
	X		11) Adequate riparian-wetland vegetative cover is present to protect banks and dissipate energy during high flows
See #8.			
	X		12) Plant communities are an adequate source of coarse and/or large woody material (for maintenance/recovery)
This area is highly dependent on large wood for capturing and stabilizing sediment. Large, mature or old growth conifers are needed, with anchor points (large, living trees or boulders) within the riparian-wetland area or adjacent uplands which are lacking. Such anchor points are lacking.			

Yes	No	N/A	EROSION/DEPOSITION
	X		13) Floodplain and channel characteristics (i.e., rocks, overflow channels, coarse and/or large woody material) are adequate to dissipate energy
Large wood is needed to adequately dissipate energy.			
		X	14) Point bars are revegetating with riparian-wetland vegetation
Point bars are not characteristic of this stream type.			
X			15) Lateral stream movement is associated with natural sinuosity
X			16) System is vertically stable
The coarse material and bedrock in the channel result in this being a vertically stable system.			
	X		17) Stream is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition)
Lack of large wood is resulting in excessive erosion.			

Summary Determination

Functional Rating:

Proper Functioning Condition ________
Functional—At Risk ________
Nonfunctional ___X___
Unknown ________

Trend for Functional—At Risk:

Upward ________
Downward ________
Not Apparent ________

Rationale For Rating: This system is nonfunctional. Recovery requires large woody material that is presently not available within the system.

Are factors contributing to unacceptable conditions outside the control of the manager?

Yes ___
No _X_

If yes, what are those factors?

___ Flow regulations ___ Mining activities ___ Upstream channel conditions
___ Channelization ___ Road encroachment ___ Oil field water discharge
___ Augmented flows ___ Other (specify)________________________

Example 3. Assessing functionality of a braided glacial system that is at potential: This system contains a large, braided, glacial channel that functions as a sediment deposition system. It is a low-gradient system with low stream energy, and carries extremely large sediment loads, resulting in a braided channel network and extensive floodplain. Floodflows are poorly contained. Channel aggradation and scour processes are very active due to the extremely large sediment loads. Riparian-wetland plant communities are dominated by alder and willow shrub communities. Some areas have a spruce-cottonwood/alder plant community.

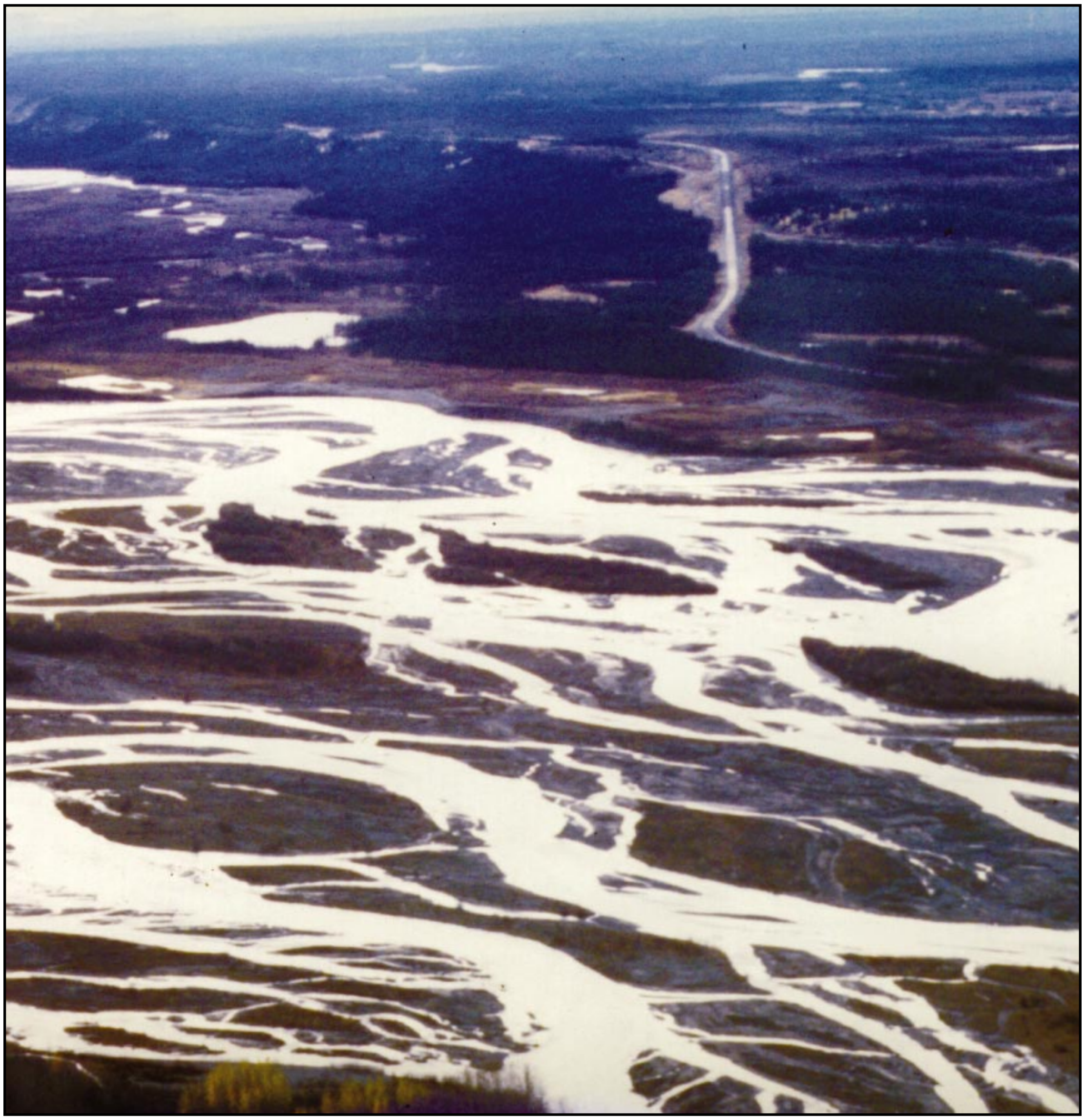


Figure B3. Copper River.

Yes	No	N/A	HYDROLOGY
X			1) Floodplain above bankfull is inundated in "relatively frequent" events
		X	2) Where beaver dams are present they are active and stable
Beaver dams are not expected and would not persist in this channel type.			
X			3) Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region)
Sinuosity and width/depth ratio match the regional curves defined as typical for this stream type.			
X			4) Riparian-wetland area is widening or has achieved potential extent
X			5) Upland watershed is not contributing to riparian-wetland degradation
There is no visual degradation in the riparian-wetland area that could be attributed to upland impacts.			

Yes	No	N/A	VEGETATION
X			6) There is diverse age-class distribution of riparian-wetland vegetation (recruitment for maintenance/recovery)
X			7) There is diverse composition of riparian-wetland vegetation (for maintenance/recovery)
X			8) Species present indicate maintenance of riparian-wetland soil moisture characteristics
X			9) Streambank vegetation is comprised of those plants or plant communities that have root masses capable of withstanding high-streamflow events.
X			10) Riparian-wetland plants exhibit high vigor
X			11) Adequate riparian-wetland vegetative cover is present to protect banks and dissipate energy during high flows
Natural aggradation, scour, and shifting channels affect the ability of the riparian-wetland area to establish vegetative cover; however, cover (alder, willow) is within the expected range.			
		X	12) Plant communities are an adequate source of coarse and/or large woody material (for maintenance/recovery)

Yes	No	N/A	EROSION/DEPOSITION
X			13) Floodplain and channel characteristics (i.e., rocks, overflow channels, coarse and/or large woody material) are adequate to dissipate energy
Energy is dissipated as the water spreads out over the flat extensive floodplain surface and in numerous side channels. Mid-channel bars resulting from the extremely high sediment loads serve primarily to redirect energy.			
		X	14) Point bars are revegetating with riparian-wetland vegetation
Well-defined point bars are not characteristic of this stream type.			
X			15) Lateral stream movement is associated with natural sinuosity
Lateral stream movement is part of this system's potential (i.e., it is expected in this system and is associated with natural sinuosity).			
X			16) System is vertically stable
X			17) Stream is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition)
This is a low-gradient system with low stream energy and extremely large sediment loads. Channel deposition and erosion are considered part of this system's potential.			

Summary Determination

Functional Rating:

Proper Functioning Condition ____X____
Functional—At Risk _________
Nonfunctional _________
Unknown _________

Trend for Functional—At Risk:

Upward _________
Downward _________
Not Apparent _________

Rationale For Rating: This system is rated as PFC because it is at potential and functioning as expected according to the attributes and processes defined by its setting.

Are factors contributing to unacceptable conditions outside the control of the manager?

Yes ___
No _X_

If yes, what are those factors?

___ Flow regulations ___ Mining activities ___ Upstream channel conditions
___ Channelization ___ Road encroachment ___ Oil field water discharge
___ Augmented flows ___ Other (specify)___________________________

Example 4. Assessing functionality of a braided system that is not at potential: This system is slightly entrenched and gravel-dominated, with lesser amounts of cobble, sand, and silt and a developed floodplain. Sediment supply is moderate to high, making this system very susceptible to shifts in both lateral and vertical stability. Stability is governed by the presence and condition of riparian-wetland vegetation. When riparian-wetland vegetation conditions are poor, erosion/deposition is accelerated and the system trends toward being braided instead of a single thread. When riparian-wetland vegetation conditions are good, sediment is captured and lateral and vertical adjustments are diminished.

Figure B4. Badger Creek as a braided stream type (*upper photo*), recovering to a single channel type (potential)(*lower photo*).

Yes	No	N/A	HYDROLOGY
X			1) Floodplain above bankfull is inundated in "relatively frequent" events
		X	2) Where beaver dams are present they are active and stable
	X		3) Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region)
The braiding results in a channel area that is too wide, and what should be a narrow, deep channel is instead characterized by mid-channel bars. The channel has a very high width/depth ratio where moderate to high width/depth ratio is expected.			
	X		4) Riparian-wetland area is widening or has achieved potential extent
The channel area has widened and the areas capable of sustaining riparian-wetland vegetation have shrunk.			
X			5) Upland watershed is not contributing to riparian-wetland degradation
There is no visual degradation in the riparian-wetland area that could be attributed to upland impacts.			

Yes	No	N/A	VEGETATION
	X		6) There is diverse age-class distribution of riparian-wetland vegetation (recruitment for maintenance/recovery)
Most of the riparian-wetland vegetation has been lost from this system as a result of past management practices. This loss of vegetation has resulted in the channel widening and forming mid-channel bars. The remaining vegetation is dominated by upland species.			
	X		7) There is diverse composition of riparian-wetland vegetation (for maintenance/recovery)
See #6.			
	X		8) Species present indicate maintenance of riparian-wetland soil moisture characteristics
See #6.			
	X		9) Streambank vegetation is comprised of those plants or plant communities that have root masses capable of withstanding high-streamflow events.
See #6.			
	X		10) Riparian-wetland plants exhibit high vigor
See #6.			
	X		11) Adequate riparian-wetland vegetative cover is present to protect banks and dissipate energy during high flows
Excessive aggradation, scour, and shifting channels have affected the ability of the riparian we land area to establish and maintain adequate vegetative cover during periods of normal or high flows.			
		X	12) Plant communities are an adequate source of coarse and/or large woody material (for maintenance/recovery)

Yes	No	N/A	EROSION/DEPOSITION
	X		13) Floodplain and channel characteristics (i.e., rocks, overflow channels, coarse and/or large woody material) are adequate to dissipate energy
Because of excessive erosion, the water cannot move all of the bedload and mid-channel bars have developed.			
	X		14) Point bars are revegetating with riparian-wetland vegetation
Point bars have largely been lost as the channel shifts its bed. Excessive aggradation and scour prevent establishment of vegetation.			
	X		15) Lateral stream movement is associated with natural sinuosity
The removal of the willow has destabilized the banks. Lateral stream movement is the result of this destabilization and the inability of the banks to absorb or dissipate the stream's energy.			
X			16) System is vertically stable
No present downcutting was observed. Apparent downcutting is primarily the lateral instability as the stream widens and cuts into adjacent terraces.			
	X		17) Stream is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition)
Erosion and deposition are excessive for the potential (expected) stream type.			

Summary Determination

Functional Rating:

Proper Functioning Condition ________
Functional—At Risk ________
Nonfunctional ________
Unknown ___X___

Trend for Functional—At Risk:

Upward ________
Downward ________
Not Apparent ________

Rationale For Rating: There are multiple channels where only one is expected. Erosion rates are high, deposition (mid-channel bars) is excessive, bed locations are shifting, and sediment supply is high. This system is clearly not providing adequate vegetation to dissipate stream energies associated with high flows and thus is not reducing erosion, filtering sediment, aiding

Are factors contributing to unacceptable conditions outside the control of the manager?

Yes ___
No _X_

If yes, what are those factors?

___ Flow regulations ___ Mining activities ___ Upstream channel conditions
___ Channelization ___ Road encroachment ___ Oil field water discharge
___ Augmented flows ___ Other (specify)________________________________

Example 5. Assessing functionality of a system that is at potential for vegetation but not for channel characteristics: This system has a C6 stream type. Rosgen (1996) describes a C6 channel as having a broad, gentle valley with depositional soils, where silts and clays predominate; however many are associated with a high organic component, including peat. The C6 channel evolved within a previous F6 channel that had downcut in the depositional material. An F6 channel is one that is deeply entrenched in alluvium, and has silt and clay (Rosgen 1996). It appears that the C6 channel is continuing to evolve to a narrow, deeper, and more sinuous channel (E6). In other areas, the C6 channel has already completed its evolution to an E6 channel. Rosgen (1996) describes an E6 as a channel having gentle slopes in a broad river valley that can be contained within a downcut valley, evolving to a channel inside a previous channel (e.g., an E inside an F channel). An E6 has silt-clay-dominated materials with accumulations of organic material including peat and dense root mat on the streambanks. Evolution and riparian restoration occur rapidly due to the large amount of fine sediments in this system. The riparian-wetland area shown below has filled in with 3 feet of fine sediments, from the downcut F6 channel stage, as its functioning condition improved. It has since filled in with over 7 feet of sediment.

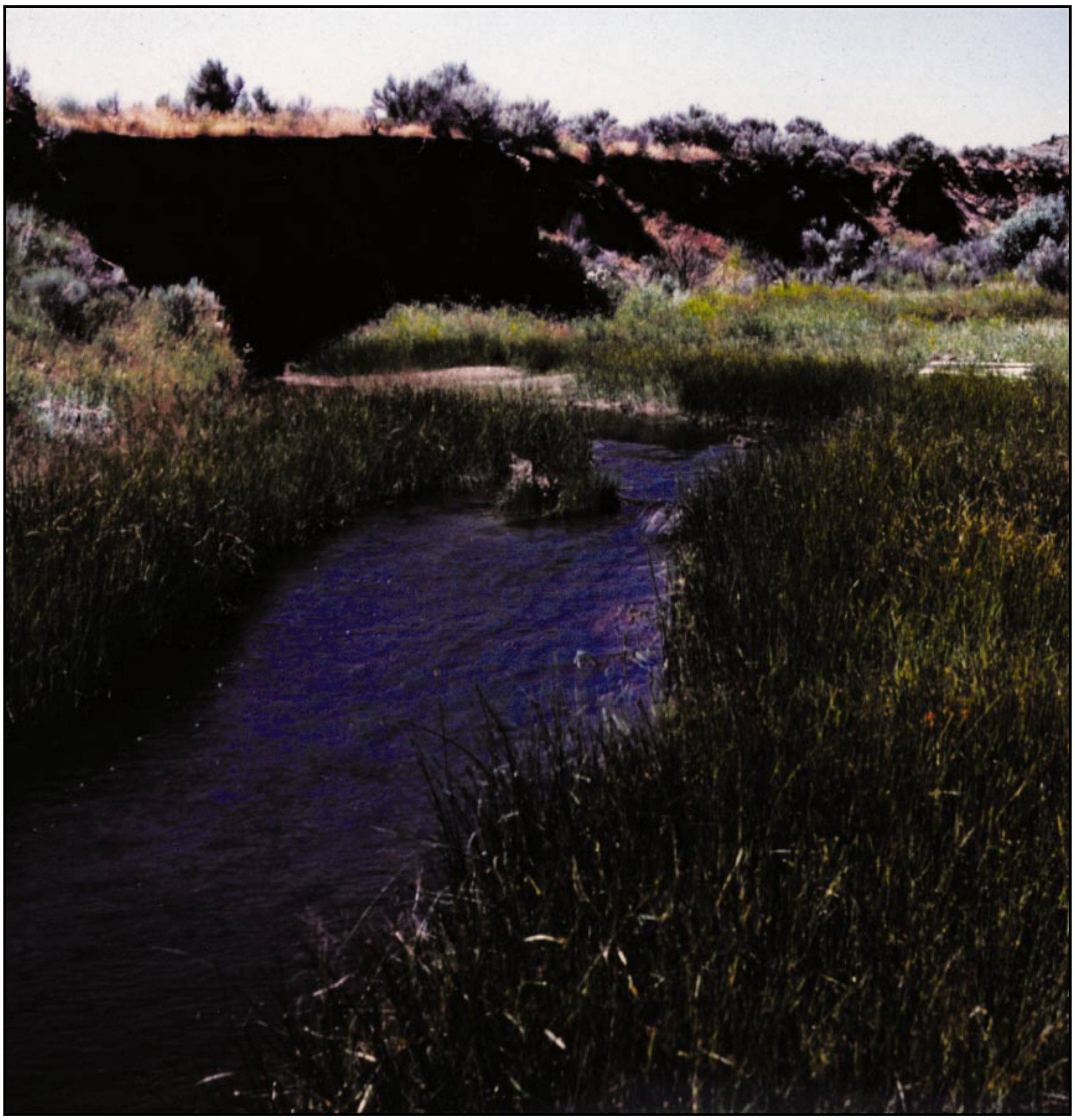


Figure B5. West Fork Camp Creek, July 1984.

<table>
<tr><th>Yes</th><th>No</th><th>N/A</th><th>HYDROLOGY</th></tr>
<tr><td>X</td><td></td><td></td><td>1) Floodplain above bankfull is inundated in “relatively frequent” events</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td></td><td></td><td>X</td><td>2) Where beaver dams are present they are active and stable</td></tr>
<tr><td colspan="4">Beaver dams are not present, but this system has the potential for beaver.</td></tr>
<tr><td></td><td>X</td><td></td><td>3) Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region)</td></tr>
<tr><td colspan="4">It appears that this channel has the potential to become narrower, deeper, and more sinuous and to further decrease its gradient within its landscape setting, as compared with similar areas (similar stream type and land type) that are further along in their recovery/evolution. However, if it wasn’tclear that the potential for this system was an E channel, this item could be answered yes, as it is in balance for a C channel.</td></tr>
<tr><td>X</td><td></td><td></td><td>4) Riparian-wetland area is widening or has achieved potential extent</td></tr>
<tr><td colspan="4">The riparian zone is widening.</td></tr>
<tr><td>X</td><td></td><td></td><td>5) Upland watershed is not contributing to riparian-wetland degradation</td></tr>
<tr><td colspan="4">There is no visual degradation in the riparian-wetland area that could be attributed to upland impacts.</td></tr>
<tr><th>Yes</th><th>No</th><th>N/A</th><th>VEGETATION</th></tr>
<tr><td>X</td><td></td><td></td><td>6) There is diverse age-class distribution of riparian-wetland vegetation (recruitment for maintenance/recovery)</td></tr>
<tr><td colspan="4">The potential for this system is a sedge-rush community, which means that recruitment for maintenance and recovery is the most important consideration. Recruitment is evident.</td></tr>
<tr><td>X</td><td></td><td></td><td>7) There is diverse composition of riparian-wetland vegetation
(for maintenance/recovery)</td></tr>
<tr><td colspan="4">There are at least seven sedge and rush species in the riparian communities. Because of the high clay content and saturated soils in this low-gradient system, willow is not expected.</td></tr>
<tr><td>X</td><td></td><td></td><td>8) Species present indicate maintenance of riparian-wetland soil moisture characteristics</td></tr>
<tr><td colspan="4">Species are dominated by obligate or facultative wet species.</td></tr>
<tr><td>X</td><td></td><td></td><td>9) Streambank vegetation is comprised of those plants or plant communities that have root masses capable of withstanding high-streamflow events.</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>X</td><td></td><td></td><td>10) Riparian-wetland plants exhibit high vigor</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>X</td><td></td><td></td><td>11) Adequate riparian-wetland vegetative cover is present to protect banks and dissipate energy during high flows</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td></td><td></td><td>X</td><td>12) Plant communities are an adequate source of coarse and/or large woody material (for maintenance/recovery)</td></tr>
<tr><td colspan="4">Even though the potential for this system includes woody shrubs, they are not necessary for physical function.</td></tr>
</table>

Yes	No	N/A	EROSION/DEPOSITION
X			13) Floodplain and channel characteristics (i.e., rocks, overflow channels, coarse and/or large woody material) are adequate to dissipate energy
Floodplain width is not to potential, but is adequate to dissipate energy associated with this system. Overflow channels are well-vegetated with a sedge-rush community.			
X			14) Point bars are revegetating with riparian-wetland vegetation
X			15) Lateral stream movement is associated with natural sinuosity
Lateral movement is slow and is associated with the channel increasing its sinuosity.			
X			16) System is vertically stable
The channel is underlain by approximately 3 feet of fine textured material. The sedge-rush mat has completely cradled the bottom of the channel and is the only reason this system is vertically stable.			
X			17) Stream is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition)
There is no visible deposition (side channel and mid-channel bars).			

Summary Determination

Functional Rating:

Proper Functioning Condition ___X___
Functional—At Risk _________
Nonfunctional _________
Unknown _________

Trend for Functional—At Risk:

Upward _________
Downward _________
Not Apparent _________

Rationale For Rating: Even though the channel has not reached its potential and will likely continue to evolve towards an E type channel, the riparian-wetland area is at a point where it is resilient enough to withstand a high flow event.

Are factors contributing to unacceptable conditions outside the control of the manager?

Yes ___
No _X_

If yes, what are those factors?

___ Flow regulations ___ Mining activities ___ Upstream channel conditions
___ Channelization ___ Road encroachment ___ Oil field water discharge
___ Augmented flows ___ Other (specify)________________________________

Example 6. Assessing functionality of a system that is limited by a railroad and a highway: This riparian-wetland area is narrow and moderately steep colluvial valley with channel materials that are predominantly cobbles (with lesser amounts of boulders, gravel, and sand). The construction of a railroad and highway has limited the channel's ability to access its historic floodplain. The location of the railroad tracks has effectively narrowed the existing floodplain and valley bottom and restricted the natural meandering of the channel. This has steepened the channel and resulted in less sinuosity.

The locations of the railroad and highway are limiting factors that make it necessary to consider the capability of this riparian-wetland area when completing the checklist. This constraint to the area's potential cannot be affected by the land manager. The checklist items are answered according to the area's potential or it's capability. The question "Are factors contributing to unacceptable conditions outside the control of the manager?" is answered "yes," and the factors involved checked to show that the new capability is beyond the ability of the land manager to change.

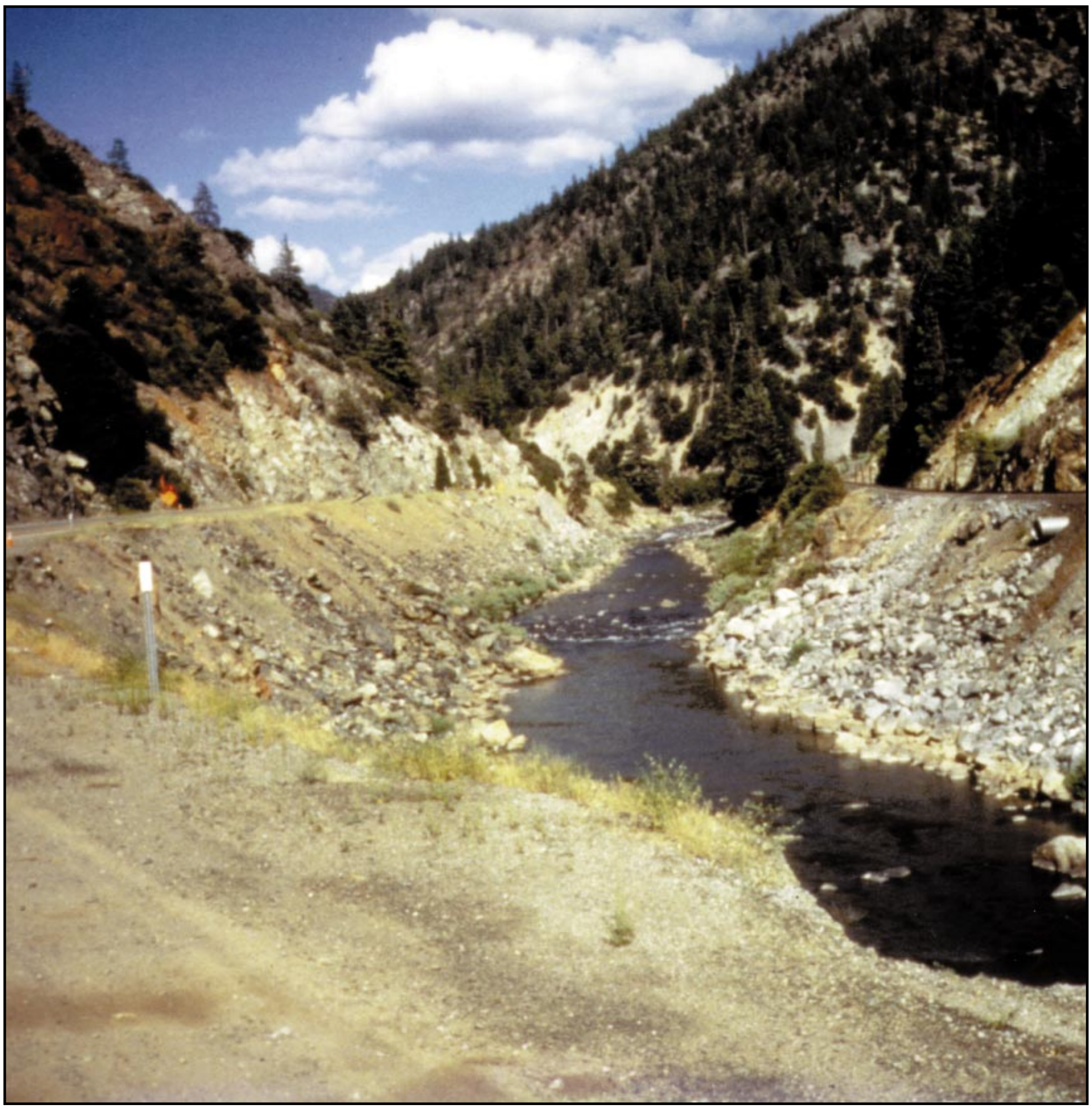


Figure B6. Seather River, California.

Yes	No	N/A	HYDROLOGY
	X		1) Floodplain above bankfull is inundated in “relatively frequent” events
Construction of the railroad and highway has all but eliminated this system’s floodplain.			
		X	2) Where beaver dams are present they are active and stable
Beaver dams are not present in this riparian-wetland area.			
	X		3) Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region)
Sinuosity and width/depth ratio are not in balance according to what would be expected for this stream type, due to the location of the tracks and the highway. These factors have decreased the sinuosity and increased the channel gradient.			
	X		4) Riparian-wetland area is widening or has achieved potential extent
The size of the riparian-wetland area has decreased from historical extent and from its potential. The downcutting has altered the drainage and resulted in the encroachment of upland species.			
	X		5) Upland watershed is not contributing to riparian-wetland degradation
There is visual degradation in the riparian-wetland area that can be attributed to the railroad and highway.			

Yes	No	N/A	VEGETATION
	X		6) There is diverse age-class distribution of riparian-wetland vegetation (recruitment for maintenance/recovery)
There are no young age classes of woody riparian-wetland vegetation. Sedges and rushes are sparse indicating little recruitment.			
	X		7) There is diverse composition of riparian-wetland vegetation (for maintenance/recovery)
No riparian-wetland species are present.			
	X		8) Species present indicate maintenance of riparian-wetland soil moisture characteristics
See #7.			
	X		9) Streambank vegetation is comprised of those plants or plant communities that have root masses capable of withstanding high-streamflow events.
See #7.			
	X		10) Riparian-wetland plants exhibit high vigor
See #7.			
	X		11) Adequate riparian-wetland vegetative cover is present to protect banks and dissipate energy during high flows
See #7.			
	X		12) Plant communities are an adequate source of coarse and/or large woody material (for maintenance/recovery)

Yes	No	N/A	EROSION/DEPOSITION
	X		13) Floodplain and channel characteristics (i.e., rocks, overflow channels, coarse and/or large woody material) are adequate to dissipate energy
Much of the historical floodplain has been removed by the construction of the railroad and highway and is no longer adequate.			
	X		14) Point bars are revegetating with riparian-wetland vegetation
Channelization of the stream from the railroad and highway is preventing establishment of vegetation.			
	X		15) Lateral stream movement is associated with natural sinuosity
The railroad and highway preclude any attempt by the stream to reestablish its natural sinuosity by cutting into the adjacent banks at meander intervals.			
X			16) System is vertically stable
This system appears to still be vertically stable.			
X			17) Stream is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition)
There does not appear to be any excessive erosion and deposition.			

Summary Determination

Functional Rating:

Proper Functioning Condition _________
Functional—At Risk _________
Nonfunctional ____X____
Unknown _________

Trend for Functional—At Risk:

Upward _________
Downward _________
Not Apparent _________

Rationale For Rating: This system is nonfunctional. Limiting factors outside of management control have altered this system and there are no options available to management to improve this system.

Are factors contributing to unacceptable conditions outside the control of the manager?

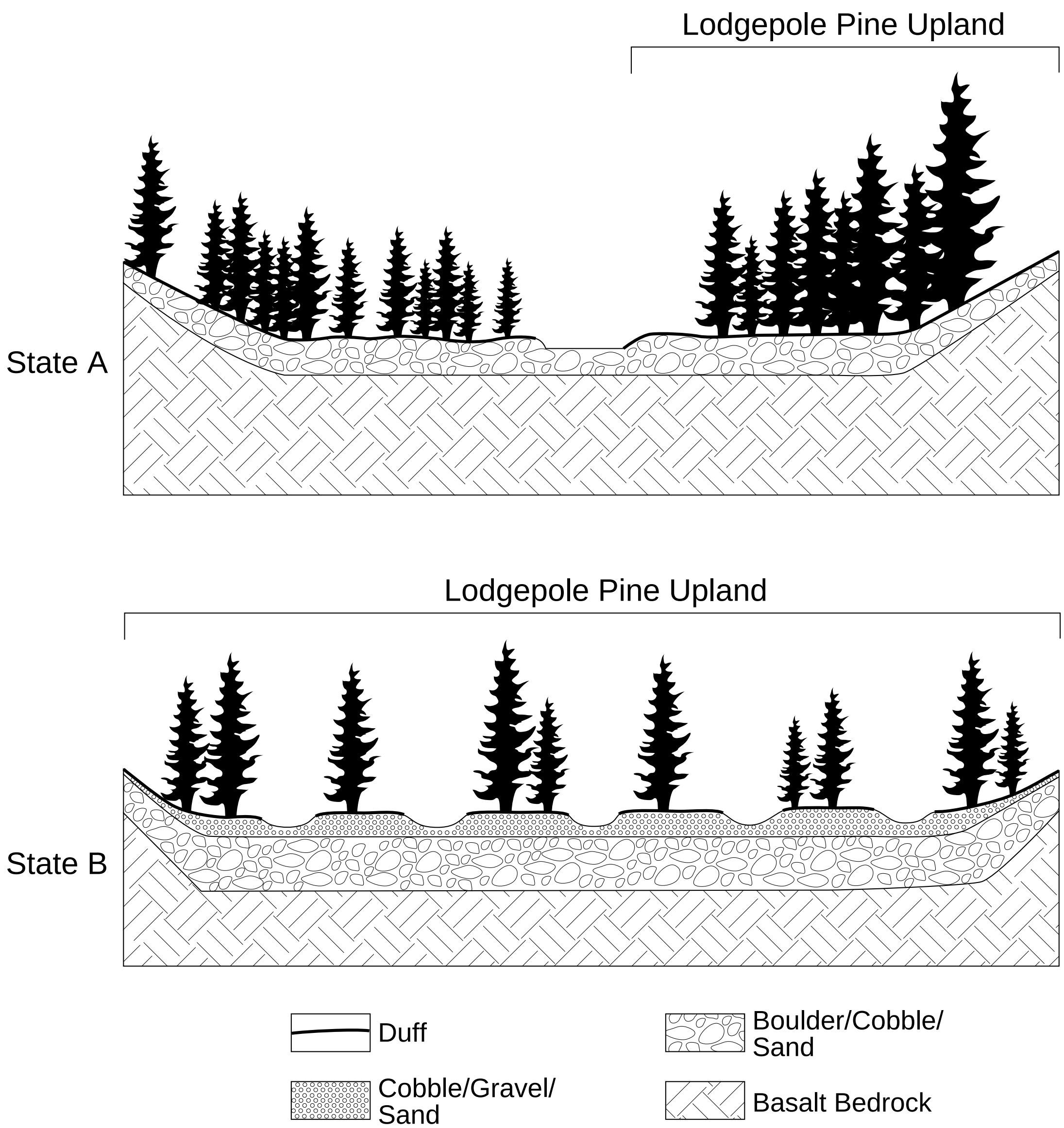
Yes _X_
No ___

If yes, what are those factors?

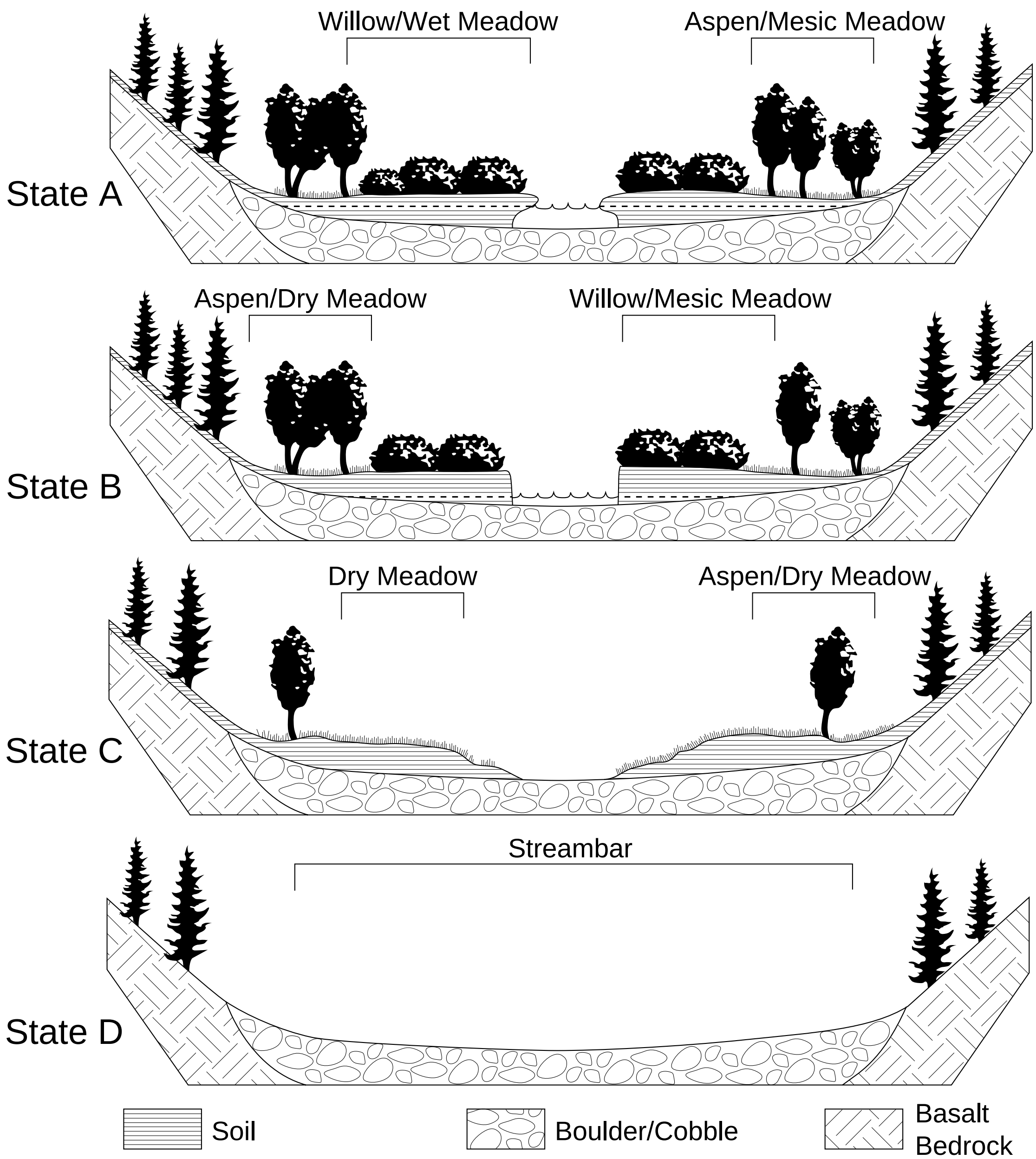
___ Flow regulations ___ Mining activities ___ Upstream channel conditions
_X_ Channelization ___ Road encroachment ___ Oil field water discharge
___ Augmented flows _X_ Other (specify) Railroad and highway alignment

Appendix C:
Channel Evolution Examples

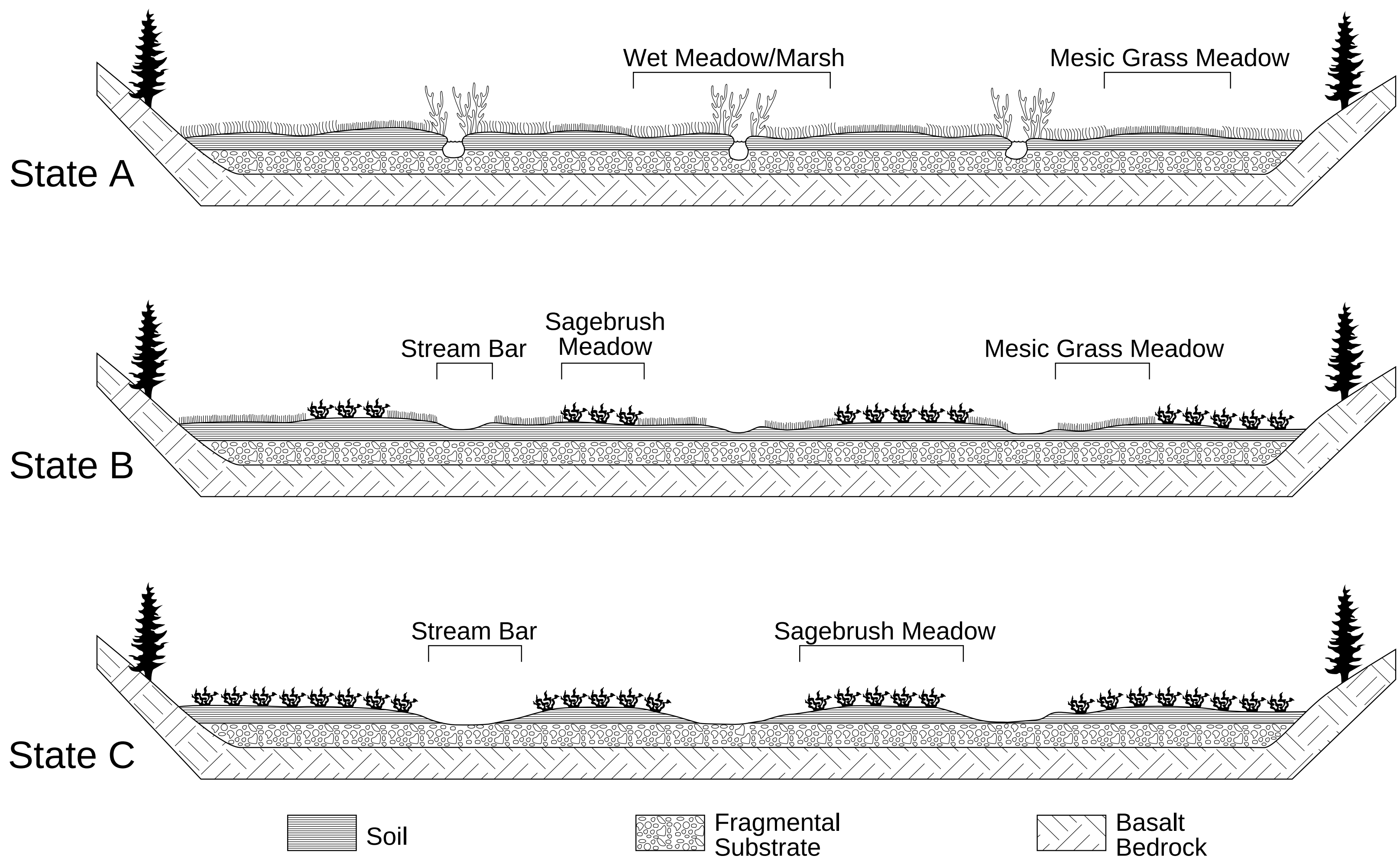
Glacial Valley-Bottom Type



Succession of States for Fluvial/V-Shaped Depositional Valley-Bottom Type



Succession of States for Alluvial/Graded Valley-Bottom Tyupe



Appendix D:
Riparian-Wetland Examples

Texas Creek—Colorado
September 1976
Nonfunctional

Texas Creek, located in south-central Colorado on public lands administered by the BLM Canon City District Office, would have been rated ***nonfunctional*** in 1976 based on the PFC 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 above photograph clearly demonstrates why Texas Creek would have been rated ***nonfunctional***. This riparian-wetland 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 of 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 above photo displays the results. In June 1978, Texas Creek would have been rated as ***functional—at risk***, 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 had 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 stream-banks against cutting action.

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 3 in the Functioning Condition section. Using the PFC definition, Texas Creek would have had a rating of ***PFC*** in October 1978. *Yet, by no means had Texas Creek achieved its potential. However, it may have achieved its management objectives and obtained its desired plant community (early seral versus potential).* The early seral vegetation community that had established itself in the above 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 ***proper functioning condition*** may not always be easy. For Texas Creek it was easy because 12 years of data had been collected. However, most areas will not have that amount of data on which to base the rating, which underscores *the necessity of having an ID team perform this assessment.* For some areas, the only way to assess functionality is through an interdisciplinary effort like ESI.

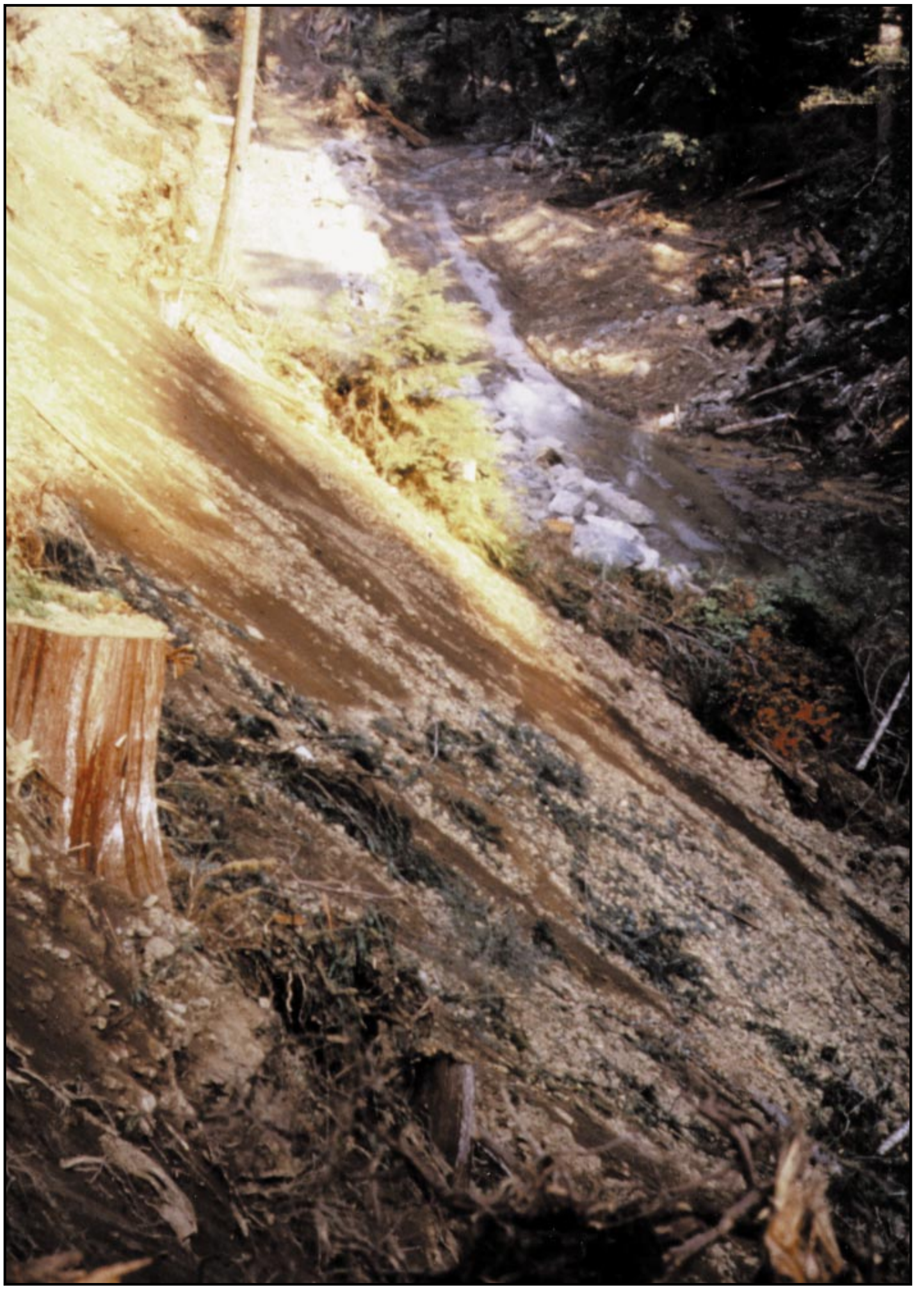
Texas Creek—Colorado
July 1987
Proper Functioning Condition

Areas that have achieved a late seral state or potential, as Texas Creek had in this July 1987 photo, are easy to rate. According to the 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 in an early seral state for 1978 and a late seral state for 1987. However, both communities were functioning properly.

Management defines the desired condition for an area, which in turn defines management options. For example, bighorn sheep and brown trout are present in the Texas Creek watershed. If the desired species to manage for is bighorn sheep, which prefer early seral vegetation around watering sites, the desired condition 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 states. 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 for most seral states, thus providing greater management flexibility.

Forested Coastal Stream—Oregon
Nonfunctional



The above photograph gives an example of a coastal stream, located in Oregon, that would be rated as ***nonfunctional***. The riparian-wetland 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

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; 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 its physical function, this area would be rated as ***functional—at risk*** because a vegetation and hydrologic attribute still make it 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 of this will occur before optimal numbers of wildlife and fish species (greater biodiversity) are achieved.

Forested Coastal Stream—Oregon
Proper Functioning Condition

The above photograph 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.

Appendix E:
PFC—What It Is and What It Isn't

PFC is: A methodology for assessing the physical functioning of riparian-wetland areas. The term PFC is used to describe both the **assessment** process, and a defined, on-the ground **condition** of a riparian-wetland area. In either case, PFC defines a minimum level or starting point for assessing riparian-wetland areas.

The PFC **assessment** provides a consistent approach for assessing the physical functioning of riparian-wetland areas through consideration of hydrology, vegetation, and soil/landform attributes. The PFC assessment synthesizes information that is foundational to determining the overall health of a riparian-wetland area.

The on-the-ground **condition** termed PFC refers to *how well* the physical processes are functioning. PFC is a state of resiliency that will allow a riparian-wetland area to hold together during a high-flow event, sustaining that system's ability to produce values related to both physical and biological attributes.

PFC isn't: The sole methodology for assessing the health of the aquatic or terrestrial components of a riparian-wetland area.

PFC isn't: A replacement for inventory or monitoring protocols designed to yield information on the "biology" of the plants and animals dependent on the riparian-wetland area.

PFC can: Provide information on whether a riparian-wetland area is physically functioning in a manner that will allow the maintenance or recovery of desired values (e.g., fish habitat, neotropical birds, or forage) over time.

PFC isn't: Desired condition. It is a prerequisite to achieving desired condition.

PFC can't: Provide more than strong clues as to the actual condition of habitat for plants and animals. Generally a riparian-wetland area in a physically nonfunctioning condition will not provide quality habitat conditions. A riparian-wetland area that has recovered to *proper functioning condition* would either be providing quality habitat conditions, or would be moving in that direction if recovery is allowed to continue. A riparian-wetland area that is functioning at-risk would likely lose any habitat that exists in a high-flow event.

Therefore: To obtain a complete picture of riparian-wetland area health, including the biological side, one must have information on *both* physical status, provided through the PFC assessment, and biological habitat quality. Neither will provide a complete picture when analyzed in isolation. In most cases, proper functioning condition will be a prerequisite to achieving and maintaining habitat quality.

PFC is: A useful tool for prioritizing restoration activities. By concentrating on the "at-risk" systems, restoration activities can save many riparian-wetland areas from degrading to a nonfunctioning condition. Once a system is nonfunctional, the effort, cost, and time required for recovery is dramatically increased. Restoration of nonfunctional systems should be reserved for those situations where the riparian-wetland has reached a point where recovery *is possible*, when efforts are not at *the expense* of "at-risk" systems, or when unique opportunities exist. At the same time, systems that are properly functioning are not the highest priorities for restoration. Management of these systems should be continued to maintain PFC and further recovery towards desired condition.

PFC is: A useful tool for determining appropriate timing and design of riparian-wetland restoration projects (including structural and management changes). It can identify situations where instream structures are either entirely inappropriate or premature.

PFC is: A useful tool that can be used in watershed analysis. While the methodology and resultant data is "reach based," the ratings can be aggregated and analyzed at the watershed scale. PFC, along with other watershed and habitat condition information helps provide a good picture of watershed health and the possible causal factors affecting watershed health. Use of PFC will help to identify watershed-scale problems and suggest management remedies and priorities.

PFC isn't: Watershed analysis in and of itself, or a replacement for watershed analysis.

PFC is: A useful tool for designing monitoring plans. By concentrating implementation monitoring efforts on the "no" answers, greater efficiency of resources (people, dollars, time) can be achieved. The limited resources of the local manager in monitoring riparian-wetland parameters can be prioritized to those factors that are currently "out of range" or at risk of going out of range. The role of research may extend to validation monitoring of many of the parameters.

PFC isn't: Designed to be a long-term monitoring tool, but it may be an appropriate part of a well-designed monitoring program.

PFC isn't: Designed to provide monitoring answers about attaining desired conditions. However, it can be used to provide a thought process on whether a management strategy is likely to allow attainment of desired conditions.

PFC can: Reduce the frequency and sometimes the extent of more data- and labor-intensive inventories. PFC can reduce time and cost by concentrating efforts on the most significant problem areas first and thereby increasing efficiency.

PFC can't: Eliminate the need for more intensive inventory and monitoring protocols. These will often be needed to validate that riparian-wetland area recovery is indeed moving toward or has achieved desired conditions (e.g., good quality habitat) or simply to establish what the existing habitat quality is.

PFC is: A qualitative assessment based on quantitative science. The PFC assessment is intended for individuals with local, on-the-ground experience in the kind of quantitative sampling techniques that support the checklist. These quantitative techniques are encouraged in conjunction with the PFC assessment for individual calibration where answers are uncertain or where experience is limited. PFC is also an appropriate starting point for determining and prioritizing the type and location of quantitative inventory or monitoring necessary.

PFC isn't: A replacement for quantitative inventory or monitoring protocols. PFC is meant to complement more detailed methods by providing a way to synthesize data and communicate results.

Appendix F:
Large Wood

The complexity of forest riparian environments has led researchers to study the hydrology, sediment delivery, vegetation, and biology of these systems to determine how each component affects specific products, such as water quality and fish. In the late 1960's and early 1970's, temperature studies showed conclusively that stream temperature was controlled by canopy cover (Brown and Krygier 1970). Subsequently, laws and regulations were implemented to leave trees along streams to maintain cool temperatures for salmonids. Other studies showed that clearcutting affected water yield and landslide frequency (Meeham 1991). This resulted in a redesign of road building and cutting methodologies. Later studies found that LWM was essential for fish habitat quality and influenced in-channel processes for pool and riffle development (Sedell et al. 1984). This resulted in the implementation of projects to replace LWM lost due to stream cleaning and other practices common in the Pacific Northwest. The recognition of in-channel processes and their effect on fisheries production also led to extensive stream survey efforts by both State and Federal agencies.

Forest inventories have been ongoing for many decades, but they have not recognized the riparian zone as a unique or separate forest type. The collection of massive databases for stream channels has concentrated on the area between the banks and provided limited riparian data (USDA Forest Service 1995). Only recently have scientists begun to understand and quantify forest riparian wetland areas. The long timeframes required to grow a forest to PNC or late seral stage (old growth) make it challenging for scientists to describe the processes that affect and govern forest streams. Observations must be based on a series of “snapshots-in-time” rather than long-term observational studies. Studies such as the Alsea Study lasted little more than a decade and focused on the effects of clearcutting on fish production (Krygier and Hall 1971). Subsequent studies on stream temperature and shade effects, avalanches, water yield, and sediment production have all provided important information that defines how specific components of the riparian zone/stream function. These studies were accomplished in a few years and relied on information from forests that changed little during the studies. Most of these forest stream and riparian studies have originated in the last three decades.

Because catastrophic events are major factors that drive a forest riparian system, scientists must visualize past events as well as events several centuries ahead to understand forest riparian functions. Fire, floods, avalanches, windstorms, and landslides may only occur in any watershed once in a hundred years or longer. Accounting for these events in spatial and temporal context requires decades and centuries rather than the typical planning horizon of a few years. Unfortunately, the sciences that deal with the riparian/stream function are relatively new and most of the major watersheds of the U.S. were modified before any precise record of their condition could be made (Sedell and Luchessa 1982). This makes it challenging to develop models for riparian/stream function.

To visualize forest riparian/stream processes, it is necessary to consider each point of interest as interrelated to the whole stream continuum. The location of interest may be anywhere from the headwaters to the ocean. The way each part of the system functions changes as the streams merge and grow larger, and the enormous variety of stream slope, geology, hydrologies, vegetation types, etc., adds to the difficulty of describing how the whole system functions. In forest-influenced streams, the trees and LWM generated interact with the geomorphology, soils, and hydrograph to regulate stream functions. The stream system interacts with wood and trees very differently in the small creeks and rills of the headwaters than it does in the large flat gradient streams of the valleys they service (Swanston 1991). The processing of LWM from the forest to the sea has been described by Maser et al. (1988). Debris torrents and avalanches that move organic and inorganic material down from the headwaters are the subject of numerous studies (Swanston 1991).

Headwater Streams

For many years, forest managers and stream habitat specialists failed to connect function of the first- and second-order streams with the proper function of the whole system. It was believed that careful harvest of trees that prevented accelerated erosion was sufficient to protect stream function and water quality. With careful logging, most of these streams remained cool. Brush or other ground covering vegetation provided shade and filtered sediment. However, the important functions of sediment storage and LWM processing were yet to be fully appreciated (Krygier and Hall 1971).

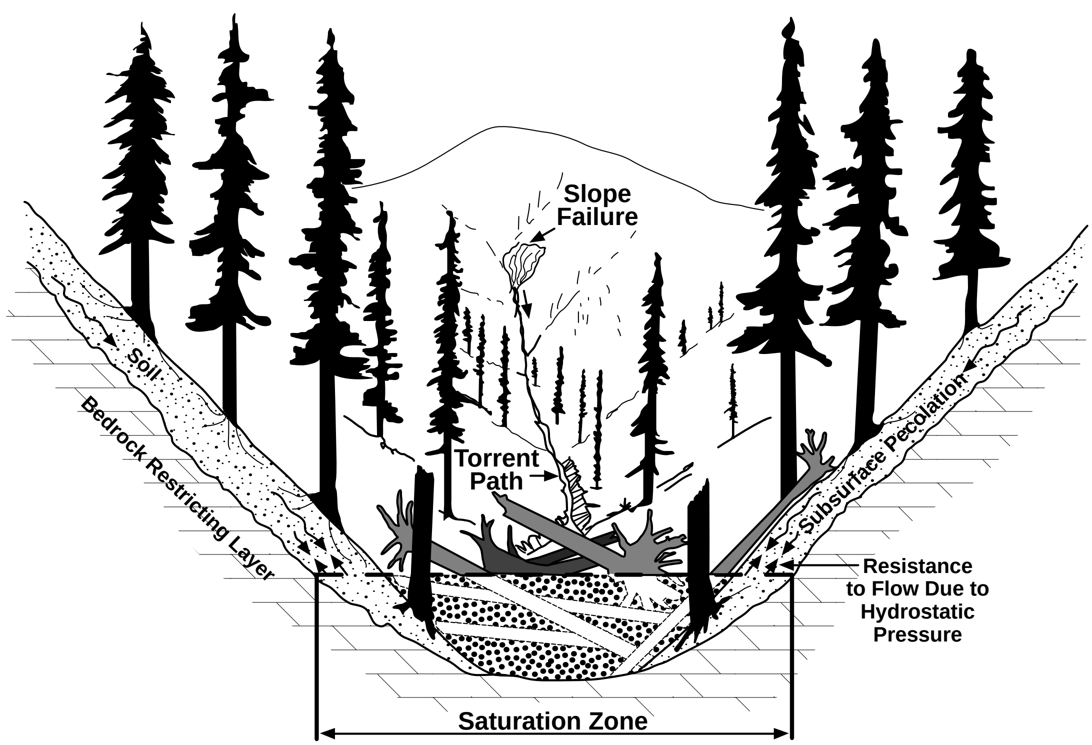
These first- and second-order steep gradient streams provide much of the LWM that is essential to larger stream functions. Over long periods, tree boles collect in the steep draws following large and small catastrophic events and normal mortality. The forest continually sloughs off organic material seasonally, but the main contributions come from fire, windthrow, torrents, and mortality from disease and insect attacks. As the pieces of wood and whole trees collect, so does the sediment moving into the channel during annual rainfall and snowmelt events. This process of accumulating sediment and organic material in a steep channel may continue for centuries.

Once the channel has accumulated a critical mass of material, it becomes a huge wet sponge that stores water. It also acts as a drain plug that retards the side slope subsurface flow to the channel. This ensures longer periods of soil saturation both in the channel and on the adjacent slopes (Figure E1). Debris loading sets the stage for LWM delivery to downstream channels, including the main river. Historically the rate of delivery was much less frequent than in the last 100 years. Watershed activities, such as road construction, have triggered a release of debris torrents that far exceeds the historic level (Swanston and Swanson 1976). Large rainstorms, or rain-on-snow events, lubricate these heavily loaded channels and their adjacent slopes. Mass movements can then be triggered by events such as heavy rain- and windstorms, or even earthquakes, during high saturation (Swanston 1991).

The movement of soil, rocks, and wood from the headwaters to the larger streams includes both old wood and green trees. These mass deliveries replenish materials that are needed further down the stream continuum for normal stream function. In a sense, the stream continuum can be viewed as a relentless conveyor belt of water and organic and inorganic material moving to the sea. The conveyor is moved by sporadic surges from thousands of tributaries, but only a relatively small number of the total will discharge any year, decade, or century. The deliveries may come from dozens of drainages during a major storm or from only one. The discharge of LWM may be concentrated in a few subwatersheds or spread across an entire drainage.

These debris movements have a significant effect on wood delivery and floodplain/terrace development. Debris avalanches are composed of a mixture of tree boles, limbs, rocks, silt, and everything organic and inorganic that has accumulated in the channel and anything along the banks that can be captured by the moving mass. Logjams frequently form at constrictions in the channel or lower gradient areas, causing the avalanche to come to rest. These jams will move again at some time in the future when other avalanches collide with them or peak flow events erode some key materials to release the logs or rocks holding the jam in place.

A common occurrence in mature late seral stage forests is the formation of a logjam and upstream sediment wedge (Swanston 1991). The jam may last for decades or burst during the same event that temporarily deposited it. Sometimes, the logjam may remain suspended above the channel and only part of the sediment wedge will erode. The erosion of the center of the wedge frequently leaves a terrace on each side of the channel. This may gradually evolve into a high bench sufficient to grow upland trees like Douglas fir. These benches or terraces can be found along many steep gradient channels where they were left long ago by logjams that have moved (Figure E2, a-d). This process of building riparian forest terraces may occur in single events (instantaneous) or over a long period of decades, but the result is the same.



Accumulated LWM material from a torrent acting as a sponge to slow flows and store water in a typical forested steep gradient channel system.

Figure E1.

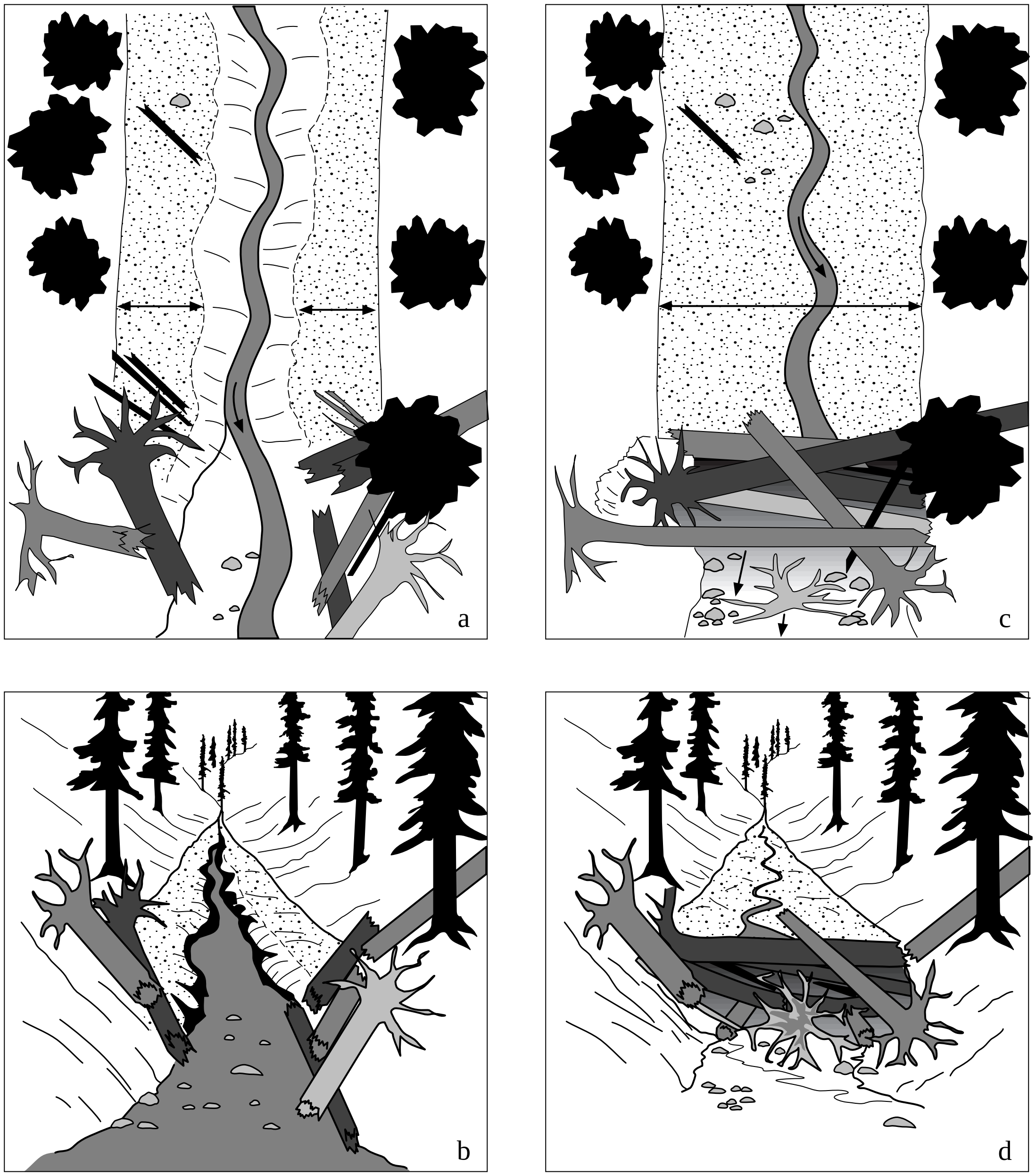


Figure E2. (a-d)

Alluvial Fans

The avalanches, coupled with normal erosion, replenish and build alluvial fans at the confluence of the steeper small streams and larger systems (Benda 1985). These fans are a common collection area for huge quantities of wood and geologic material that is moving out of the headwater streams. The periodic pulsing of material from the headwaters can either build or diminish the fans. Frequently these fans are hotspots for aquatic and terrestrial species production due to their complexity. Alluvial fans are usually moist and provide superior growing sites for riparian tree species like bigleaf maple, red alder, western red cedar, spruce, and hemlock. The growth of huge trees on these sites sets the stage for LWM to enter the larger streams. There is a strong potential for aging and dead trees to fall from the alluvial fan into adjacent larger streams. However, the potential for an avalanche several hundred years after the one that created the fan provides a source for even greater input of LWM. Some events are large enough to uproot dozens or even hundreds of mature trees and push them into the main stream systems (Figure E2, a-d). In the winter of 1996-97, numerous torrents across alluvial fans delivered massive quantities of LWM to streams and rivers in Oregon and Washington.

3rd-6th-Order Streams

As the streams become progressively larger, their gradients become lower. These have been classified as B4 and C type channels (Rosgen 1996). The LWM interacts with these streams and riparian zones in a different way than it did in the first- and second-order streams with Rosgen's A and B type headwater channels. The third- and fourth-order systems can float mature trees, but most move as materials that are broken into logs and pieces. Whole "old-growth" trees move less frequently in these smaller streams. The so-called "25- to 50-year flood events" are required for whole trees to move. Logjams frequently form behind large-diameter tree boles spanning channels where they are lodged tightly in place. Frequently the downed boles will lodge between living trees on the bank to create a barrier that is a combination of live and dead trees.

Trees lining the adjacent banks and slopes are a significant source of LWM for larger streams. Windthrow or fires frequently cause major pulses of whole live trees to enter the streams. Often these two events happen in sequence. Fires often kill some trees in a stand. The roots of the dead trees lose the majority of their strength within 7 years. When a significant windstorm event occurs, it will blow many of these dead trees into the channel. This also results in some live trees and limbs being taken down by the falling snags, which adds to the organic input. Trees that are gradually undercut by the stream also add to the LWM input. Frequently, these trees may linger, tethered by some remaining roots or branches, to act as bank armor.

In larger streams, logs from broken and whole trees are pushed together or floated downstream by subsequent flood events to form jams. The logjams will create sites that pond water and accumulate gravel. If the valley is wide enough, the stream may cut around the jam and leave it abandoned (Swanston 1991). The abandoned jams and sediment wedge form the beginning of a new floodplain that will grow a riparian forest over several hundred years (Abbe and Montgomery 1996).

A key factor in channel shifting is related to live tree stem density and size and down trees on the riparian forest floor. During flood events, streams in unconstrained channels normally come out of their banks and spread into the forest (Rosgen's low-gradient B and C types). The floodwaters are slowed and quieted by the mass of vertical and horizontal tree bole and understory vegetation of the riparian forest. The vertical live tree structure acts to arrest the movement of down trees. In their early stages, down trees have limbs and rootwads attached that also act to hold them in place and create roughness elements to slow the flows. The horizontal pieces of LWM on the floodplain act to slow flows and trap floating organic material that later contributes to soil development. The root masses in the soil work with the aboveground boles to bind the soils in place.

On the Queets River in Washington State, it was noted that patches of timber over 300 years old had been provided long-term hydraulic refugia by logjams that formed the original sediment depositional area (Abbe and Montgomery 1996). These islands were developed when logs and whole trees were stranded on shallow bars in the river. New islands with dense cottonwood stands were observed to be developing around groups of drifted conifers in the lower Salmon River on Vancouver Island (Anderson 1996). These trees had become stranded on bars and the bars had been colonized by dense cottonwood stands. The age of the colonizing vegetation progressed with the river's abandonment of these gravel and sand bars. The oldest cottonwoods were on the oldest bars and seedlings were on the most recent depositions. The lower Salmon River was extensively logged over 80 years ago and is laterally unstable. Channel braiding and aggrading provide the opportunity for cottonwood, willow, and red alder colonization on bars, on islands, and in side channels. These areas were abandoned or left above the (1-3-year) bankfull level by the shifting river. Mature galleries of cottonwood and conifers that line the river show extensive evidence of having originated during these same bar stabilizing processes following the logging of the river corridor (Anderson 1996).

The combination of trees, roots, and down wood on the floodplain not only holds the soil in place, it causes deposition. The quiet floodwaters carry organic and inorganic materials that are deposited. The inorganic materials are graded during flood events with the coarser rocks and gravels staying within the active channel while silts and sands are deposited in the forest floodplain. Over decades, the silts and sand, combined with organic material from the forest, will bury logs and other material. As the stream moves back and forth in its floodplain, over the centuries it will continue to reprocess this material. The cutbacks and freshly eroded channel (most easily observed following a major channel erosion event) often reveal exposed logs and trees buried for centuries.

Large Streams

The movement of individual pieces of wood and whole trees is important to a large stream's state of dynamic equilibrium. Trees, fallen and living, provide the processes that build floodplains and maintain them over centuries. It is essential that the LWM be continually replenished to provide more building material for riparian/stream maintenance and recovery.

As pieces of wood float or are dragged with roots attached down the channels of larger streams, they are systematically sorted and deposited. The sorting of LWM is similar to the sediment sorting processes. The larger particles of rock are found in the mid-channel, with the smaller gravels, sands, and silts sorted toward the edge. Large logs and whole trees tend to lodge closer to the mid channel than the smaller trees and woody pieces that distribute closer to the stream's edge. The major deposition area for wood and sediment is on point bars of rivers and streams. The rivers continually rework their sediments along the cutbacks and deposit the material on the opposite point bars. The point bars are the area of quietest water, resulting in gravel deposition. The helical flow (screwlike pattern) of the stream works to sort and move material away from the cutback of the river and place it on the point bars

(Leopold et al. 1964). The shallow water caused by accumulating sediments tends to strand whole trees with their rootwads acting as anchors (Abbe and Montgomery 1996; Anderson 1996). The most common configuration for these trees in the channel is with the rootwad upstream facing the current and the bole projecting downstream. The rootwads not only act to anchor the trees, they create hydraulic modifiers that split the flows, dissipate stream energy, and increase sediment deposition. This helps accelerate point bar stabilization and maturation. In destabilized systems, it is common for whole trees to accumulate on mid-channel bars that recruit bedload and debris and later become islands. As the tree's succession matures, these islands may reconnect to the bank of the river again. As smaller pieces of wood float by, they accumulate on the point bars and are snagged by the rootwads and boles of trees to create driftjam (Figure E3, a-b).

The driftjams can span the river, but most will frequently accumulate on the point bars. When enough sand and silt are accumulated on and around these jams, riparian plant communities are generated. Willow, cottonwood, and alder are the most common colonizers on the new point bars. When these plants mature, they create the vertical structure that will lock the driftjam in place. Gradually, the floods will build the riparian terrace along the river. As the river continues to move, the floodplain will be colonized by riparian coniferous species, such as red cedar, hemlock, and spruce. Eventually, as the point bar evolves into a floodplain that increases in height, it may become colonized by Douglas fir, lodgepole pines, or ponderosa pines that are less water-tolerant.

The cutting of the streambank across the channel from the point bar is necessary for the proper functioning of the stream channel. The rate of bank cutting is related to the root strength and mass of forest trees that line the bank and the geologic material composing the bank. In constrained reaches with steep gradients, the underlying parent material (such as bedrock or boulders) controls the rate of stream cutting. In unconstrained reaches, the stream would be free to cut away the bank at its leisure, but the live and dead vegetation hinders its progress. The mature trees on a streambank have the greatest root mass and greatest holding ability against the perpetual erosion of the stream's flowing water. Younger trees and shrubs have less capability to withstand the erosional forces. There is a direct relationship between tree size and root mass. Approximately two-thirds of a tree's mass is below ground. The size of the stream influences the time required by the stream to undercut trees along the bank. Alder trees can be sufficient to hold a third-order and smaller streambank together during high-flow events, while a fourth- or fifth-order stream may take out whole galleries of alders during a similar flood event. Mature conifers are needed to hold the larger stream systems together. The removal of mature forests through timber harvest has caused many miles of riparian/stream continuum to be downcut and/or to widen in the Pacific Northwest.

Inevitably, trees will be taken down by undercutting of the stream. The stream must perpetually adjust itself. However, the rate of adjustment is normally very gradual and involves decades or even centuries. When the trees fall from undercutting by the stream, the majority fall into the stream and are swept against the bank where they may cling by some remaining roots or the shear mass of the rootwad. The

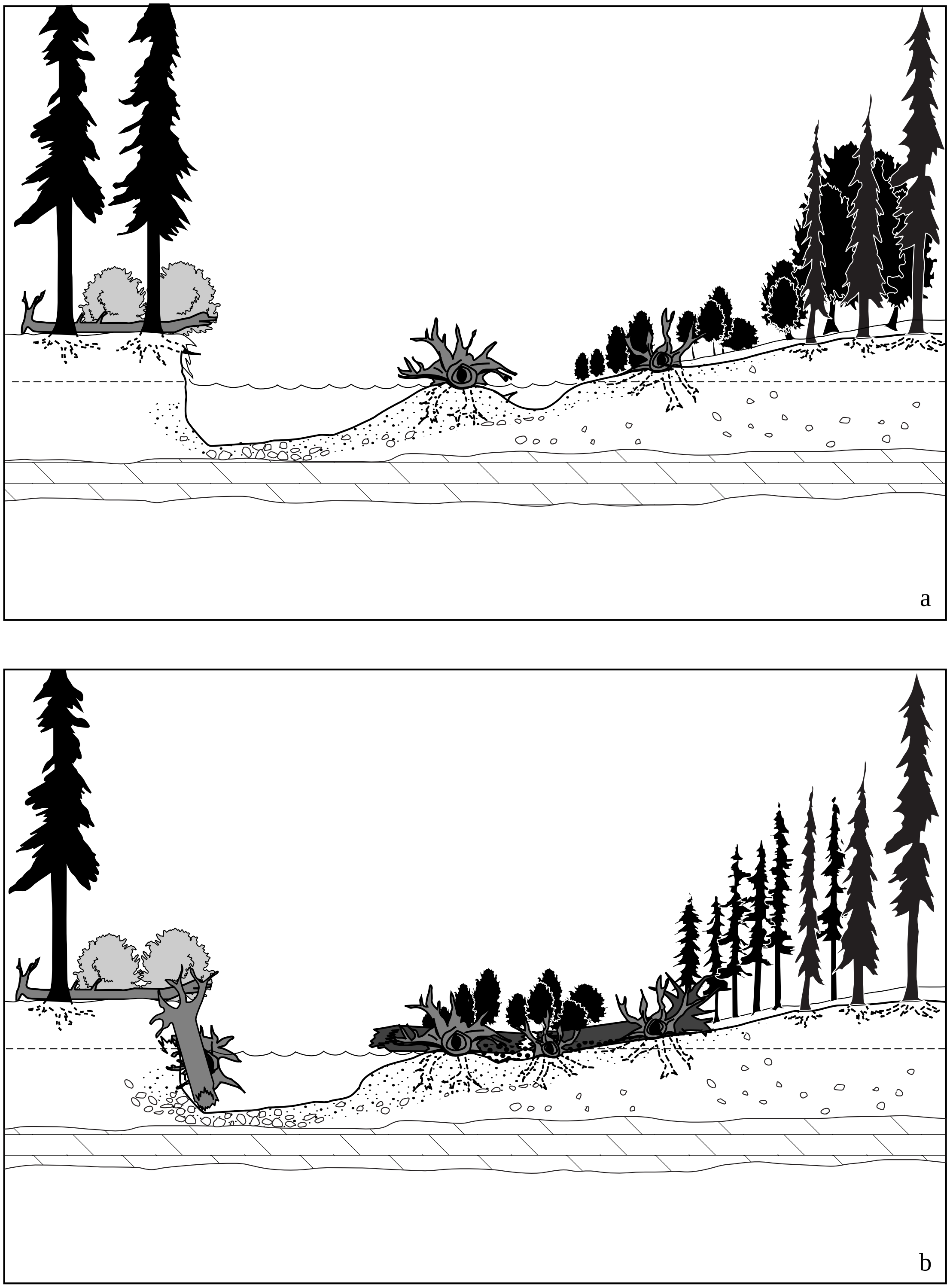


Figure E3. (a-b)

masses of tree limbs also act to prevent the stream from easily transporting the tree from the site. These trees then become flexible bank armor. Unlike boulder riprap used to protect roads, dikes, and bridges, trees are a flexible armor that works to reduce the stream energy rather than deflect it.

Trees will be dragged away or broken into pieces that move downstream to serve other functions in the channel or on the floodplain. The trees usually lay close to their origin and remain for a few years or even several decades to slow the river's advance. The interlocked root masses of the mature riparian forest, combined with this natural bank armor, create a formidable barrier to the stream's advance.

The delay of the cutting action by fallen trees along the cutbank and the trees deposited on the opposite point bar serve to balance the cut and fill process at each bend. The growth and colonization of the forest on the point bar side of the river will then keep pace with the cutting away of the forest on the other side without the river changing width (Figure E3, c-d).

Reaction to LWM, driftjams, and bank erosion has often been to remove trees from the banks and the channel to "protect the stream" or remove the "perceived threat" to downstream facilities. To maintain riparian/stream continuum in a state of relative stability, it is essential to retain not only the live trees, but all of the stages following their death.

Removal of "offending" down trees has frequently led to destabilizing of the channel, the exact opposite effect from what was desired. Without LWM, trees, and root masses to armor banks and stabilize point bars, a stable floodplain cannot be sustained, even in the steeper stream channels that are dependent and connected to the stream continuum by trees and LWM.

In summary it is important to remember that:

1. LWM and living trees are essential to development and maintenance of some forested riparian stream ecosystems from their headwaters to the downstream end of the forest stream continuum.

2. The riparian/stream continuum is in a state of dynamic stability when it is functioning properly and the movement of LWM down the stream system is normal and necessary. The function of LWM in the stream and on the floodplain changes from the headwaters to the wider downstream valleys.

3. Floods, fires, windthrow, torrents, landslides, and normal tree mortality are essential delivery mechanisms needed to maintain and restore the riparian stream system's functionality.

4. The temporal processes of the forest riparian/stream system must be measured in decades and centuries.

5. The spatial location of LWM is continually shifting during annual and episodic events. This spatial movement replenishes materials that are broken down or flushed out of the system.

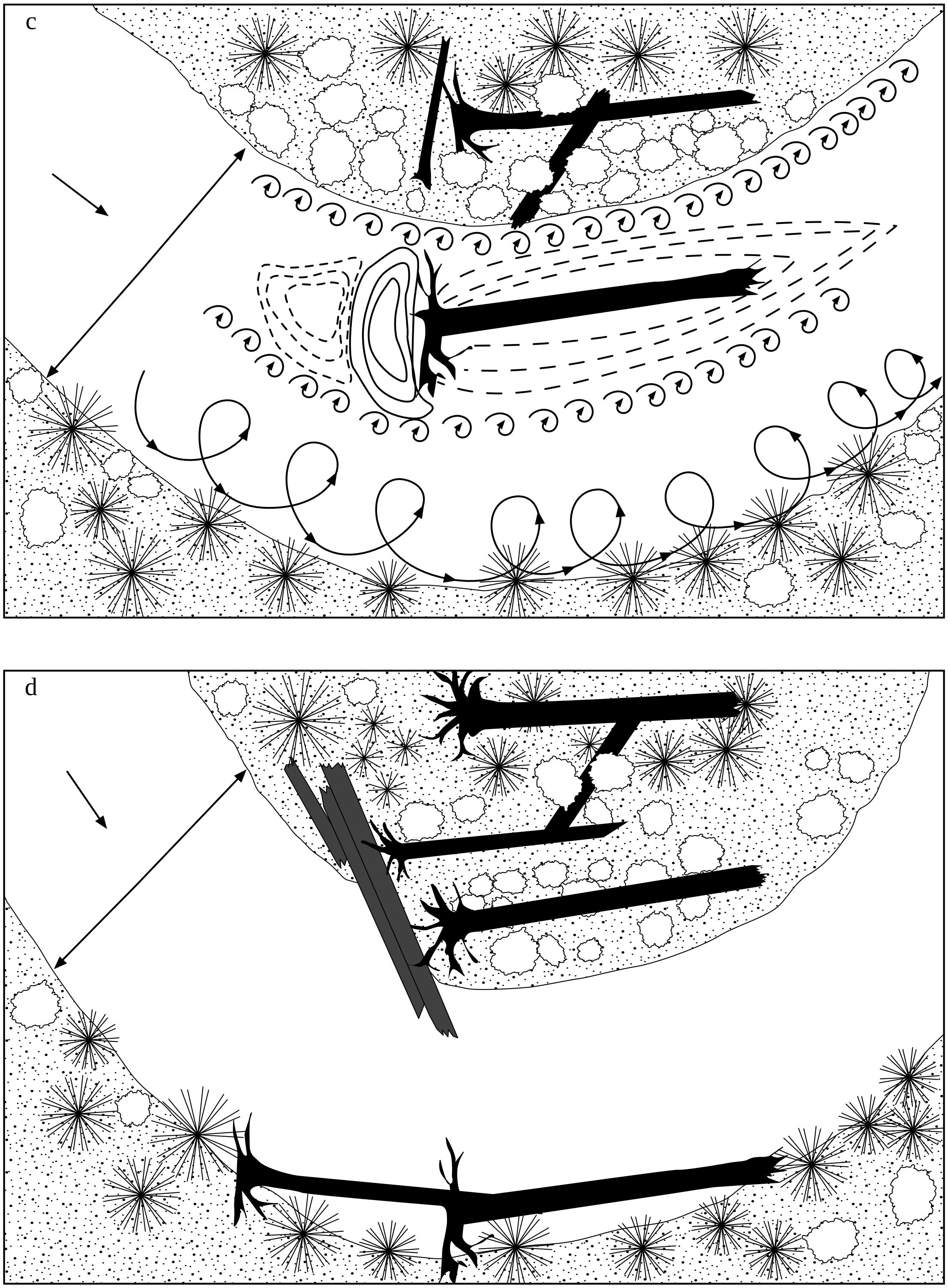


Figure E3. (c-d)

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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 biotic 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.

Alluvial - Deposited by running water.

Coarse Wood - Often used interchangeably with the term large wood; however, for the purposes of this document, coarse wood is considered simply to be smaller pieces of wood which create hydraulic modifiers in a manner similar to large wood. Due to increasing stream energies with increasing stream size, coarse wood is usually only of importance in smaller streams, and then typically only when trapped in jams.

Community Dynamics (Vegetation) - 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.

Ecological Site (Riparian-Wetland) - 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.

Facultative (FAC) Species - Plant species that are equally likely to occur in wetlands or nonwetlands (estimated probability 34-66 percent).

Facultative Upland (FACU) Species - Plant species that usually occur in nonwetlands (estimated probability 67-99 percent), but occasionally are found in wetlands (estimated probability 1-33 percent).

Facultative Wetland (FACW) Species - Plant species that usually occur in wetlands (estimated probability 67-99 percent), but occasionally are found in nonwetlands.

Floodplain - A relatively flat landform adjacent to a stream that is composed of primarily unconsolidated depositional material derived from the stream and that is subject to periodic flooding.

Fluvial - Shaped by the movement of water.

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.

Large Wood - Pieces of wood in a stream that affect channel morphology by splitting flows, dissipating stream energy, and capturing and storing sediment/bedload. Beyond a minimum threshold, size varies with stream size but generally can be described as large enough to have low probability of being moved by the stream (Bilby and Ward 1987). Pieces with a length of one-half the channel width or larger are generally considered as stable (Bisson et al. 1987).

Obligate Upland (UPL) Species - Plant species that occur in wetlands in another region, but occur almost always (estimated probability >99 percent) under natural conditions in nonwetlands in the region specified.

Obligate Wetland (OBL) Species - Plant species that occur almost always (estimated probability >99 percent) under natural conditions in wetlands.

Potential Plant Community (PPC) - Represents the seral stage the botanical community would achieve if all successional sequences were completed without human interference under the present environmental conditions.

Potential Natural Community (PNC) - The biotic community that would become established if all successional sequences were completed without interferences under the present environmental conditions.

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 Succession - Primary succession is a sequence of plant community changes from the initial colonization of a bare soil toward a PPC. Secondary succession may involve sequences of plant community change from PPC due to perturbations, or a sequence toward PPC 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 PPC of an ecological site.

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13. ABSTRACT *(Maximum 200 words)*
The Bureau of Land Management and Forest Service, working with the Natural Resources Conservation Service, have established a method for evaluating the condition of riparian wetland areas. The method involves assessing whether an area is in proper functioning condition. This qualitative, yet science-based process considers both abiotic and biotic factors as they relate to physical function. It facilitates communication about the condition of a riparian-wetland area and focuses attention on the physical process before considering values. A standard checklist is used to ensure consistency in reporting the condition of riparian-wetland areas. Occasionally, items on the checklist will have to be quantified to determine how they should be answered, and numerous methods of quantification are provided.

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