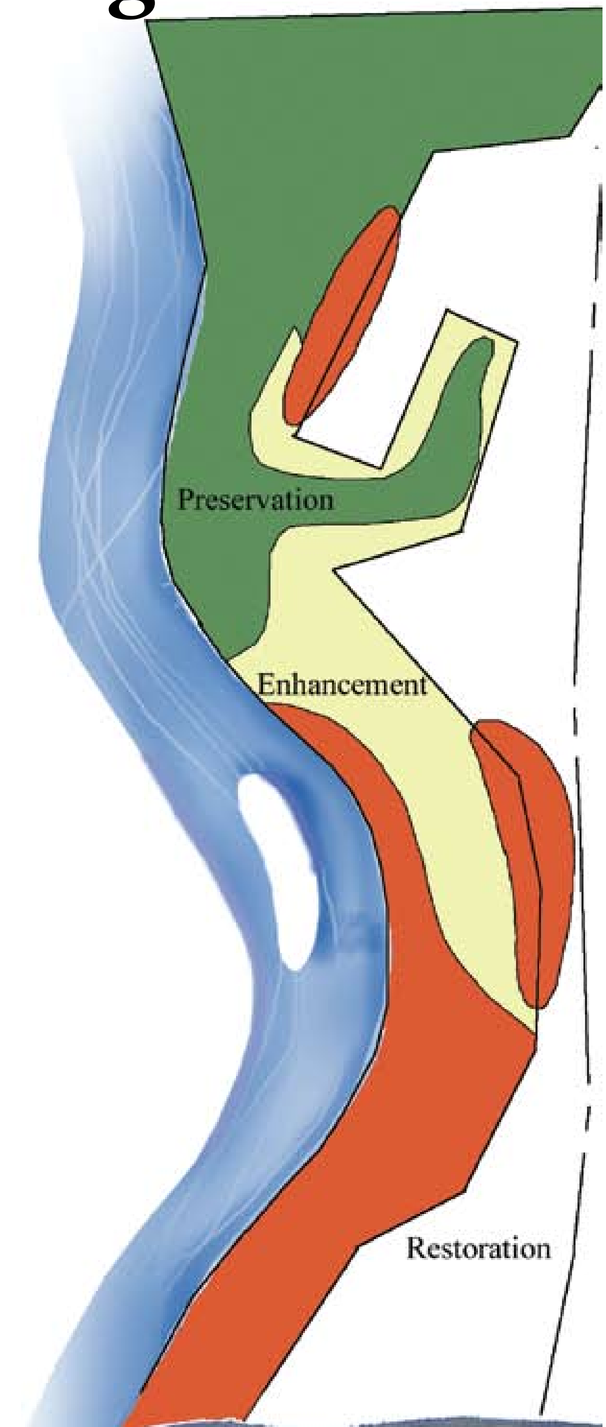
Riparian Buffer Design Guidelines

For Water Quality and Wildlife Habitat Functions on Agricultural Landscapes in the Intermountain West

Craig W. Johnson and Susan Buffler



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Abstract

Intermountain West planners, designers, and resource managers are looking for science-based procedures for determining buffer widths and management techniques that will optimize the benefits riparian ecosystems provide. This study reviewed the riparian buffer literature, including protocols used to determine optimum buffer widths for water quality and wildlife habitat functions. We selected an existing protocol for determining buffer widths for water quality functions that could be readily adapted for use in this region. The protocol is based on the best available science, uses existing or easily obtained data, and is practical for in-field applications. The protocol was modified to accommodate Intermountain West landscape attributes. In addition, a companion protocol was developed to determine buffer widths for wildlife habitat tiered to landowner willingness to participate in wildlife conservation. The research findings of this study have been compiled in handbook format. This handbook provides the user with a step-by-step protocol for determining optimal (variable) buffer widths for water quality and wildlife that maximize riparian ecosystem benefits and minimize the loss of productive farm and ranch land. It also includes a companion CD including a case study, data forms, worksheets, reference appendices, and other informational material to assist the user.

Keywords: riparian buffers, water quality, wildlife, Intermountain West, agriculture, habitat

Authors

Craig W. Johnson is a Professor in the Department of Landscape Architecture and Environmental Planning at Utah State University. He received his BS in landscape architecture from Michigan State University, an MLA from the University of Illinois, and an MS in wildlife biology from South Dakota State University. He has been teaching and doing research at Utah State University for 40 years.

Susan Buffler is currently an Adjunct Instructor in the Department of Landscape Architecture and Environmental Planning at Utah State University. She holds a BFA degree in photography from the University of Minnesota and an MS in forage agronomy from the University of Connecticut with a research emphasis on management intensive rotational grazing. She earned her MLA in 2005 from Utah State University focusing on water quality issues.

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Michele Schoeneberger, Research Soil Scientist—Research Program Leader

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David Bell—Extension Landscape Architect, Utah State University

Dr. F.E. "Fee" Busby—Professor, College of Natural Resources, Utah State University

Wendell Gilgert—Wildlife Biologist, USDA, Western Tech Support Center, Portland, OR

Dr. Paul Grossl—Soil Scientist, Utah State University

Dr. Hank Henry—Terrestrial Ecologist, USDA, Eastern Tech Support Center, Greensboro, NC

Dr. Richard Koenig—Soil Scientist, Washington State University

Dr. Mike Kuhns—Extension Forestry Specialist, Utah State University

Dr. James MacMahon—Ecologist, Utah State University

Nancy Mesner—Extension Water Quality Specialist, Utah State University

Dr. Terry Rich—Wildlife Biologist, US Fish and Wildlife Service, Boise, ID

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Preface

Water quality, water quantity, and wildlife have moved to the top of the resource conservation agenda in the Intermountain West (the study region). Why? A protracted drought, growing numbers of impaired streams, declining populations of many riparian habitat dependent wildlife species, and rapidly expanding water hungry urban and exurban growth are a few of the primary reasons.

More than 70 percent of riparian areas in the United States (Obedzinski and others 2001) and an estimated 50 percent of streams in the Great Basin (Chambers and Miller 2004) are classified as impaired to some degree. According to a 1992 US Environmental Protection Agency (USEPA) report, irrigated cropland is estimated to account for 89 percent of water quality impaired river miles (CFIFCD 1996). Although riparian areas constitute less than 5 percent of the land area of the United States, it is estimated that about 95 percent of native riparian vegetation has been lost (National Research Council 2002). According to a recent study by the Bureau of Land Management (USDI BLM 1998) in the Great Basin, thirteen riparian habitat obligate or dependent birds were listed as requiring conservation action because of declining populations. Populations of over 50 percent of grassland and shrubland bird species in the same area are in decline (Paige and Ritter 1999). Many of these species are dependent in part on riparian areas for their life requisites. The five states in the application area are among the fastest growing in the country. A significant portion of new growth is occurring in riparian corridors or adjacent to lakes and reservoirs (Johnson and Toth 2004). To summarize in a phrase—critical riparian habitats are under siege!

Impaired streams and riparian areas are commonplace in the western United States. *Photo by Susan Buffler.*

There is no simple solution to these problems to which land managers can turn. It is now apparent that solutions will require a creative assemblage of policies, programs, and practices including the preservation, enhancement, restoration, or creation of riparian buffers.

Natural riparian buffers are linear patches of vegetation adjacent to streams, lakes, reservoirs, or wetlands. In the study area, they vary in width from a few feet along the margins of high elevation meadow creeks to hundreds of feet in lower elevation floodplains. Riparian plant communities are populated by species dependent on moist soils, surface water, or a high water table, and for many species, the presence of periodic flooding. The transition from riparian to upland vegetation may be abrupt or gradual depending upon site specific environmental conditions.

Research suggests that continuous, ecologically functioning riparian corridors have beneficial effects on water quality, wildlife and fish habitat, overall ecosystem function, and landscape aesthetic quality (Forman and Godron 1986). Functioning riparian corridors act as buffers between streams, wetlands, lakes or reservoirs, and the adjacent upland landscape. Acting as sinks, they trap sediments, recharge ground water, and immobilize contaminants that originate in the upland matrix. At the water's edge, riparian vegetation stabilizes banks and reduces water temperatures that may contribute to eutrophication in nutrient-stressed waters. Riparian plants return beneficial nutrients in the form of leaves, needles, and branches back into the aquatic system, thus helping sustain aquatic organisms. Because of these and other riparian buffer benefits, riparian corridors have become the focus of many conservation efforts in the Intermountain West. **However, it should be noted that riparian buffers are not a substitute for employing best management practices to all land uses in a watershed** (USDA NRCS 1999; Wigington and others 2003).

The majority of riparian buffer research related to agricultural landscapes has been conducted in the East, Midwest, and West; limited research has been done in the Intermountain West. There is a need to assess the applicability of riparian buffers as a conservation tool to address water quality and wildlife issues in agriculturally dominated areas of this unique landscape. The questions land planners and managers frequently ask include:

How do we evaluate the functional condition of existing riparian buffers?

How wide do riparian buffers need to be to accomplish a function or set of functions?

Should riparian buffers vary in width to accommodate adjacent upland conditions?

What vegetative structural characteristics are required to best facilitate a buffer function or set of functions?

Planners and resource managers would like answers to these questions based on scientifically defensible research that is organized in an easy-to-use protocol adapted for use in the field.

The USDA National Agroforestry Center (NAC), a partnership between US Forest Service and the Natural Resources Conservation Service, is dedicated to answering research questions and providing information to landowners and conservation partners engaged in natural resource activities associated with agricultural production. NAC works closely with the resource conservation professionals to implement on-the-ground conservation projects based on the best scientific information available. NAC authorized this project in response to the need for research-based riparian buffer information specific to the Intermountain West.

This handbook has been prepared for resource conservation professionals in the Intermountain West; however, the concepts, principles, and procedures presented are applicable in other regions. Information in the handbook is intended to help facilitate planning and design of riparian buffers for water quality and wildlife habitat on private property and is primarily directed at riparian corridors in agriculturally dominated landscapes. The handbook is a resource for:

- Assessing the functional condition of existing riparian buffers and the off-site conditions to be buffered.
- Determining the applicability of buffers to address these conditions.
- Determining buffer appropriateness, general buffer design guidelines, and management strategies.
- Describing buffer configuration and delineating structural characteristics to meet water quality and wildlife objectives.

For those familiar with riparian corridors in the application area, it is evident that every riparian buffer and adjacent site condition will have unique aspects. Consequently, it is difficult to develop universally applicable planning and design guidelines. Complex, data-intense computer models have been developed to address the intricacies of riparian buffer design in other regions. However, they have limited utility for practical in-field application in rural Intermountain West counties where resource data and personnel time are limited and high powered computers, skilled programmers, and planning funds are scarce (Bentrup 2003).

Fortunately, the literature review, expert comments, and familiarity with riparian corridors in the region suggest that many riparian buffers and adjacent site characteristics are relatively similar throughout the study area (Buffler 2005). In these settings, the riparian buffer design protocol and guidelines presented in this handbook can be used by resource managers. Clearly, atypical riparian buffer situations will be encountered. Under these circumstances, handbook users are encouraged to call upon state NRCS resource specialists, extension water quality and wildlife specialists, and conservation partners to work with landowners, communities, or counties to plan and design appropriate riparian buffers. Riparian buffer planning and design, like other aspects of ecologically based planning and restoration, is an evolving area of resource management and remains both an art and science.

"The land speaks to us through gestures. If we listen to the land, we will know what to do." Terry Tempest Williams (1991). *Photo by Susan Buffler.*

Contents

Introduction

The application area includes sections of northern Utah and Nevada, eastern Oregon, and southwestern Montana and Wyoming (fig. 1). It is large and complex—a picturesque landscape with valleys of varying sizes and broad plains enclosed or edged by tall mountains. Elevations range from over 13,000-foot mountain peaks to valleys at 3,000 ft. Precipitation varies from more than 50 inches in upper watersheds to less than 6 inches at lower elevations and in mountain rain shadow areas. Desiccating winds are strong and persistent. Wind and runoff generated soil erosion is prevalent on open exposed landscapes throughout the application area.

Forest and range land, most in public ownership, predominate in the upper reaches of area watersheds. Range land is also dominant in the broad lower elevation plains and drier southern and western sections. Rolling foothills and relatively flat valleys, often with fertile soils, with a sufficient growing season and access to water for irrigation are typical of cropped lands in lower reaches of most watersheds.

Agriculturally productive lower elevation landscapes support row crops, orchards, and dairy and ranching activities. Riparian buffers in these working landscapes are the focus of this project. Working landscapes in the application area are populated by scattered farms and ranches supported by small rural communities. Historically, agriculture, ranching, and tourism have been the mainstays of the Intermountain West economy. However, a transformation is in progress fueled by a declining farm and ranch economy. Regional economies are diversifying. Unprecedented urban and exurban growth, much of it occurring along riparian corridors, is consuming farm and ranch land and wildlife habitat, converting it to suburban tracts and upscale ranchettes. This new land use dynamic, combined with old riparian resource issues (grazing, logging, mining, and recreation), present planners and resource managers with complex challenges.

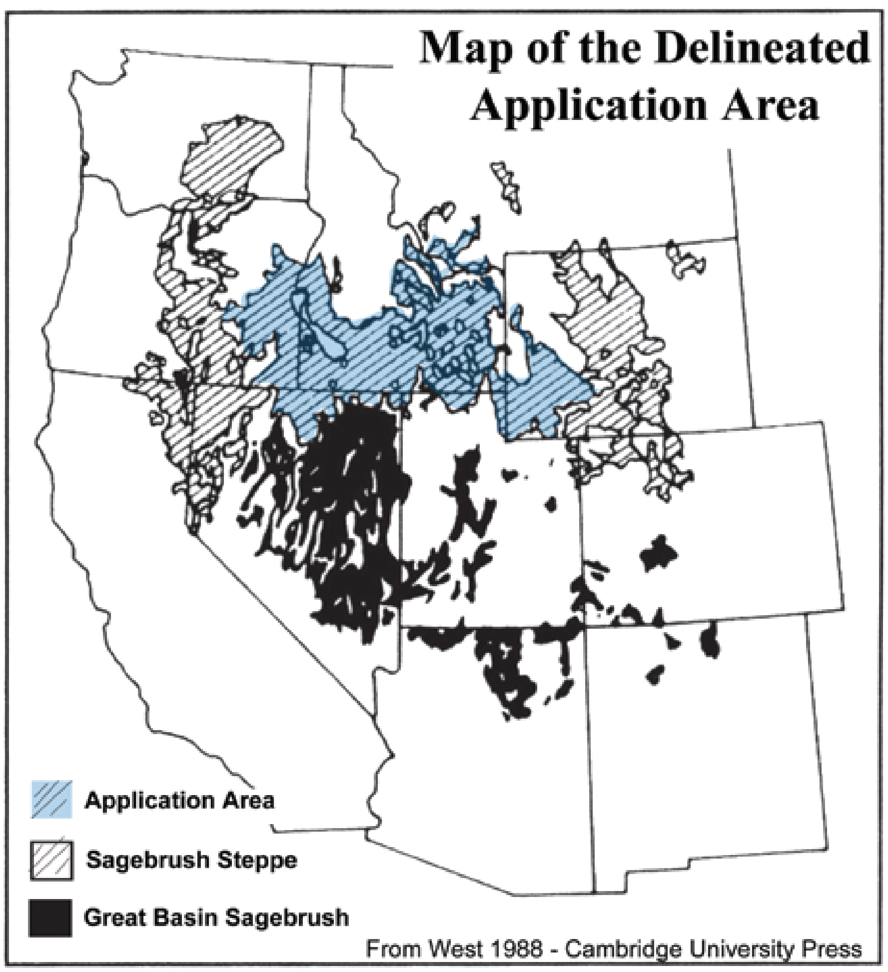

Figure 1. Map of the delineated application area. Adapted from West (1988).

Detailed Application Area Characteristics

Stream Hydrology

A longitudinal profile of a stream in the application area reveals three distinct subdivisions or zones: Zone 1, headwaters; Zone 2, transfer zone; and Zone 3, deposition (fig. 2). Most streams at higher elevations in the mountains in the Intermountain West originate on public land. Headwater streams are swift with steep gradients frequently creating waterfalls and rapids. Estimated annual runoff ranges from 10 to 20 inches with additional flow augmentation from subsurface sources. In Zone 1 headwater locations, the US Forest Service (USFS), National Park Service (NPS), and Bureau of Land Management (BLM) are typically the agencies responsible for management of riparian corridors. Some streams in Zone 1 are dammed or have water diverted from them.

Most of the streams in the application area are in Zones 2 and 3. In Zone 2, stream gradients are reduced, flood plains are evident, and stream channels are frequently meandered. Surface runoff is typically less than 10 inches per year. Most streams are dammed or have water diversions at one or more locations. Return irrigation flows augment in-stream flows on some stream reaches. Adjacent land is typically in private ownership and committed to farm, ranch, suburban, or urban land uses. Some stream reaches in Zone 2 have undergone channel modifications to reduce bank erosion or flooding.

In Zone 3, stream flow velocity is further reduced and the stream channel may become braided with broad flood plains and numerous oxbows. Stream flow volume is often highly variable based on upstream diversions and downstream irrigation demands. Runoff rates and adjacent land uses are similar to those described for Zone 2. Stream channel modification to accommodate adjacent land uses and urban infrastructure is common on many streams in Zone 3.

Modified flows characteristic of streams in the application area have significantly altered the width, vegetative structure, diversity, and age characteristics of the riparian plant community and the wildlife it supports. In some streams, it has also affected the fishery.

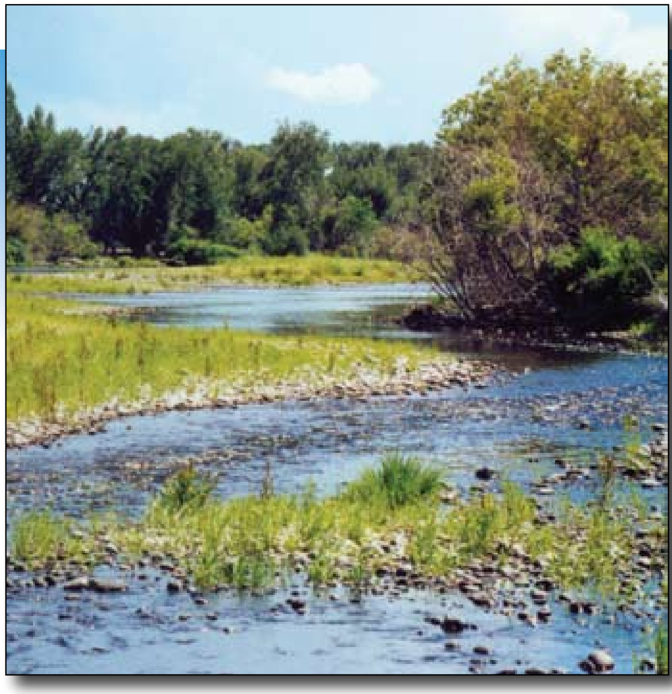

Figure 2. Stream hydrology and geomorphology are quite variable within the application area. *Photo by Craig Johnson*.

Climate

Long, cold winters, hot, dry summers, and persistent winds characterize the climate of much of the Intermountain West. Annual precipitation averages 9.6 inches in the north, and varies from 6.2 to 16.4 inches in the south (West 1988). Most of the annual precipitation comes in the form of snow or early spring rain. Less than half the annual precipitation falls during the growing season. Summer storms are infrequent and of short duration, but they can be intense. Localized areas may experience severe soil erosion during intense late summer monsoonal storms.

Higher levels of precipitation occur in foothill locations outside mountain rain shadows. Runoff from cultivated fields, pastures, and feedlots is highest in the early spring when fields have just been planted and fall planted grains are still in the boot stage. Many of the native plant species in existing riparian buffers are just breaking dormancy and their effectiveness in trapping sediments and nutrient sequestration/uptake is limited. Long-term climatic cycles can be dramatic. Dry periods persisting for up to 5 years are not uncommon. Droughts lasting 10 years, and wet cycles of 2 to 4 years, have been recorded (West 1988). Protracted droughts of 100 years have also been recorded (Connely and others 2003). These cycles affect agriculture production and practices, stream hydrology, vegetation, and expansion or contraction of riparian plant communities and associated wildlife populations.

Figure 3. Agricultural practices and land uses are highly diversified in the application area. *Photo by Richard Toth*.

Agricultural and Land Management

Agricultural practices in the study area are highly diversified (fig. 3). Production occurs on both irrigated and non-irrigated land, from the foothills to valley bottoms. Irrigation water may be applied on the soil surface via ditches or increasingly by sprinkler systems; an estimated 3.7 percent of the application area is irrigated (USEPA 2000). The dominant crops produced are winter wheat (*Triticum secale*), other small grains, alfalfa (*Medicago sativa*), hay, potatoes (*Solanum tuberosum*), and sugar beets (*Beta vulgaris*). Lesser acreages are planted in a variety of bean (*Phaseolus* spp.), corn (*Zea mays*), vegetable, fruit, and specialty crops. On non-irrigated sites, winter wheat and hay are the predominant crops.

Dairy farming is important in many valleys within the application area and includes both confined and more traditional open pasture operations. Many pastures are located near rivers, streams, and wetlands where high water tables support wet meadow vegetation and water is available for irrigation. Manure from dairy operations is typically used to fertilize croplands in the region. Where these conditions exist, contamination of both surface and subsurface water persists. An estimated 95 percent of the Intermountain West is classified as having excess nutrients in streams and rivers (USEPA 2000).

Most ranching in the Intermountain West can be characterized as cow/calf (*Bos taurus*) or ewe/lamb (*Ovis aries*) operations. Livestock, including both cows and sheep, are over-wintered in lower elevation valleys in confined paddocks, open pasture feedlots, or, in the case of sheep, on open range. Adult and young cattle and sheep are typically moved to higher elevation pastures, often on public land, for the summer and returned to valley locations in the fall. On a few ranches where summer forage is adequate and can be irrigated, livestock are pastured all summer on lower elevation valley sites. Often, these pastures are located near streams and wetlands that cattle access for water. These traditional ranching practices create buffer design and management issues affecting water quality and wildlife.

Geology and Soils

Soils across such a large study area are variable, yet common characteristics support the dominant shrub-steppe plant community. Soils in the study area are a product of several geological and hydrologic processes. Post-glacial streams transported higher elevation materials downstream and deposited coarser material in broad fans where streams exited the foothills. Finer material spread across valley bottoms with deeper deposits of alluvium in valley floodplains. Along the southern boundary of the study area, soils evolved from beach, delta, and lake bottom deposits associated with ancient Lake Bonneville. In general, fine textured clay soils in the study area have low infiltration capacities and moderate to high erodibility when slopes exceed 10 percent. In upland shrub-steppe areas that have not been extensively disturbed by grazing or human activity, biological (cryptogamic) soil crust persists. This little understood fragile community of cyanobacteria, fungi, and lichens may play an important role in stabilizing soil, thus reducing wind and water erosion (Paige and Ritter 1999).

In some locations, glacial melt waters have scoured the landscape to bedrock, exposing basalt and sedimentary rock. Frequently in these areas, bedrock is overlaid with varying depths of loess or soils of volcanic origin. Although uncommon, sandy soils and dune complexes, such as the St. Anthony, Idaho, dunes, persist. Wetland soils are relatively uncommon but do occur in old oxbows, seeps, playas, and mineral flats within the shrub-steppe complex. Wetland soils are often a product of human activity, dam and pond construction, irrigation, and leaky canals.

Vegetation

Shrub-steppe was the predominant pre-European settlement plant community in valley locations within the application area with sagebrush steppe occurring in the north and Great Basin sage in the south (Kuchler 1970) (fig. 4). Sagebrush (*Artemesia* spp.) constitutes the dominant plant cover. Antelope bitterbrush (*Purshia tridentata*), rabbitbrush (*Chrysothamnus nauseosus*), winterfat (*Eurotia lanata*), greasewood (*Sarcobatus vermiculatus*), and shadscale (*Atriplex* spp.) were also common shrub species. Varying densities of grass (*Poaceae*), sedge (*Carex* spp.), rush (*Juncus* spp.), and forb species, depending on soil and other microsite features, are interspersed in the shrub-dominated matrix. Ground cover ranges from 50 to 75 percent (Mee and others 2003).

At higher elevations and in northern sections of the study area, shrub-steppe is integrated with the mountain brush community comprised of serviceberry (*Amelanchier alnifolia*), mountain mahogany (*Cercocarpus* spp.), chokecherry (*Prunus virginiana*), snowberry (*Symphorocarpus* spp.), and scattered aspen (*Populus tremuloides*) stands. In the southern half of the study area, gambel oak (*Quercus gambelii*), juniper (*Juniperis* spp.), and bigtooth maple (*Acer grandidentatum*) may also be present and aspen (*P. tremuloides*) drops out. Ground cover ranges from 45 to 75 percent (Mee and others 2003).

On private property in valley locations, most of the shrub-steppe and mountain brush plant communities have been removed to accommodate agricultural practices or have been significantly altered by grazing (Paige and Ritter 1999). Other vegetative modifications include clearing large areas of shrub-steppe and reseeding with non-native grasses such as crested wheatgrass (*Agropyron desertorum*). In addition, aggressive non-native weedy plant species, such as cheatgrass (*Bromus tectorum*), yellow starthistle (*Centaurea solstitialis*), knapweed (*Centaurea* spp.), and dyer's woad (*Isatis tinctoria*), have colonized nearly 40 percent of the shrub-steppe community and are an increasing problem in agricultural lands (Paige and Ritter 1999). Small degraded remnants of shrub-steppe in the study area are less capable of supporting indigenous wildlife.

The dendritic pattern of rivers and streams that descend from the mountains and flow out onto the valley floor create linear environments suitable for riparian vegetation when streams are not dewatered for irrigation. Dominant riparian species change along elevation gradients, and they are different in the northern and southern halves of the application area. At higher elevations and in the north, aspen (*P. tremuloides*), alder (*Alnus* spp.), and western water (river) birch (*Betula occidentalis*) are the dominant overstory species with willow (*Salix* spp.) dominating the understory. At lower elevations and in the south, cottonwood (*Populus* spp.) and boxelder (*Acer negundo*) dominate the overstory. Midstory and understory species include willow (*Salix* spp.), river hawthorn (*Crataegus* spp.), silver buffaloberry (*Shepherdia argentea*), chokecherry (*Prunus virginiana*), red-twig dogwood (*Cornus sericea*), currant (*Ribes* spp.), and woods rose (*Rosa woodsii*).

Figure 4. Shrub-steppe vegetation. *Photo by Craig Johnson.*

Most riparian buffers in the application area have been degraded to varying degrees by water projects, grazing, agriculture, and recreational activities (Forman and Godron 1986). Aggressive non-native plant species, such as Russian olive (*Elaeagnus angustifolia*), saltcedar (*tamarix*), teasel (*Dipsacus sylvestris*), common reed (*Phragmites australis*), and white top (*Cardaria draba*), have colonized and now dominate many reaches of rivers and streams. The diversity of native plants has declined and plant community structure has been simplified (Gardner and others 1999). Many riparian plant communities are also narrower and more fragmented than they were prior to development. Because of fragmentation, degradation of plant communities, and reduced width, many riparian buffers in the study area are less efficient as sinks for nutrients and sediment. They are also less capable of supporting a diversity of wildlife and support smaller populations of the species that remain (Fahrig 1997; Harris 1984).

Figure 5. Many birds, such as this Northern saw-whet owl (*Aegolius acadicus*), rely on riparian habitats for food and cover. Photo by Craig Johnson.

Wildlife and Fish

The Intermountain West is rich in wildlife and fish resources (fig. 5). Research suggests that wildlife in the study area are most dependent upon shrub-steppe/big sage and riparian plant communities for their life requisites. Over 100 species of birds and 70 species of mammals inhabit shrub-steppe and big sage dominated landscapes (Paige and Ritter 1999). Lower elevation shrub-steppe is important habitat for antelope (*Antelocapra americana*) and numerous small mammals as well as reptiles. It is also critical winter range habitat for deer (*Odocoileus* spp.) and elk (*Cervus elaphus*). Because of fragmentation and degradation, populations of many shrub-steppe/big sage dependent species are declining. Seventeen species of birds that are shrub-steppe/big sage obligate or dependent are listed as species of concern by Partners in Flight (Paige and Ritter 1999). An estimated 1 percent of the application area is classified as riparian, yet wildlife uses riparian vegetation more than any other vegetation type (Gardner and others 1999; Rich 2002). Birds, particularly neotropical migrants, are dependent on riparian resources. Over 60 percent use riparian areas for breeding or nesting (Gardner and others 1999). Eighty-two percent of all birds in the Great Basin are dependent to some degree on riparian habitats (Gardner and others 1999), and a recent study found that 77 bird species were either obligate or dependent on riparian vegetation (Rich 2002). Riparian vegetation is also home to numerous species of reptiles, amphibians, and insects, several of which are threatened or endangered.

Cold water fisheries in the study area, some of the very best in the world, are an important cultural and economic resource. For most area residents and tourists, native and non-native trout, steelhead, salmon (*Oncorhynchus* and *Salmo* spp.), and whitefish (*Coregonus* spp.) are the region's most important sport species (Sigler and Miller 1963). Other ecologically important cold water fish include several species in the minnow (*Cyprinidae*), sucker (*Catostomidae*), and sculpin (*Cottidae*) families. Warm water fish species have been introduced to many reservoirs and ponds in the application area. Introduced species include representatives from the catfish (*Ictaluridae*), killifish (*Cyprinodontidae*), bass (*Percichthyidae*), sunfish (*Centrarchidae*), perch (*Percidae*), and pike (*Esocidae*) families. Sturgeon (*Acipenseridae*) are present in the lower Snake and Columbia Rivers (Sigler and Miller 1963). Thirteen species of fish in the study area are listed as threatened or endangered, and another 17 are listed as state species of concern. Research suggests that both water quality and quantity are important in maintaining and improving fisheries in the application area (Sperry 1999).

Riparian buffers are the most critical habitat component for the greatest number of wildlife and fish species in the Intermountain West (Buffler 2005; Gardner and others 1999). To conserve wildlife and fish, researchers recommend that existing riparian buffers in proper functional condition be preserved and degraded buffers be enhanced or restored (Gardner and others 1999). They also suggest that riparian buffers be protected from adverse impacts that originate in the adjacent matrix.

Project Goal

The goal of this project was to develop a protocol for determining appropriate riparian buffer widths and guidelines for protection of water quality and conservation of riparian habitat on agricultural lands in the Intermountain West.

There is considerable agreement among stakeholders in the application area on the value of riparian buffers. Most stakeholders in the region believe that implementing riparian buffer projects will require regulations and guidelines that are reasonable and consistent with a sustainable economic return to landowners and at the same time, protect water and wildlife resources (Johnson and Toth 2004). Creating a sustainable future is the challenge facing stakeholders, planners, and policy makers. Implementation of riparian buffers and best management practices in the agricultural, range, and urban matrices will be among the most important tools.

The protocol for determining the width of buffers whose main purpose is water quality protection should facilitate a balance between resource protection and agricultural production. Balanced buffer features include:

- Narrow semi-fixed width section
- Variable width section
- Zones of use and use regulations
- Conservation recommendations for matrix adjacent to the buffer

The protocol and guidelines must respond to a variety of western riparian ecosystem characteristics including: hydrological characteristics of the watershed; adjacent land use and land management practices; general soil characteristics; slope gradients and lengths; vegetation, fish, and wildlife species' needs; climate and runoff characteristics; and recreation activities.

The protocol must be useful to resource managers in determining appropriate buffer widths and structures that respond to typical site conditions encountered in the field. It must be simple and robust given limited fiscal and technological resources.

The NRCS planning process detailed in the National Planning Procedures Handbook (NPPH) (USDA NRCS 2003) was the framework selected to structure a general riparian buffer planning framework within which to house a detailed protocol. The NPPH is a document that NRCS field staff and their conservation partners use regularly when executing conservation projects.

The ultimate goal of this handbook is to assist resource planners and conservation partners in implementing riparian buffer projects on private property throughout the application area. Implementation implies landowner or public willingness to participate in a riparian buffer project.

The process for determining riparian buffer widths has been designed to facilitate the delineation of buffers that maximize buffer benefits and minimize the loss of productive farm and ranch land thus making buffer projects more attractive to landowners.

Specific riparian buffer functional goals addressed in the proposed planning protocol include:

- Reduce sedimentation and pollution of surface water and contamination of groundwater.
- Provide habitat for wildlife, fish, and beneficial insects.
- Accommodate wildlife species' migration and dispersal.
- Enhance scenic quality.
- Minimize the loss of productive farm and range land devoted to buffers.
- Foster buffer sustainability.

Implementing riparian buffers that incorporate these functions will capture, for the landowner, the multiple benefits that buffers afford.

Method

The literature review and summary of findings can be found in Synthesis of Design Guidelines and Experimental Data for Water Quality Function in Agricultural Landscapes in the Intermountain West (Buffler 2005). This valuable resource can be downloaded from **http://www.unl.edu/nac/research/2005Buffler.pdf**.

Several tasks were required to achieve these broad goals. The first task was the delineation of the application area within the Interior Western states. Criteria for inclusion in the application area included general similarity in soils, climate, vegetation, wildlife, and cropping and grazing systems. Other regional physiographic delineations were consulted as references. The literature review and consultation with regional experts were the largest tasks in this research effort. Included were reviews of books, journal articles, technical publications, and gray literature related to wetland and riparian buffers; in-field conservation practices; and habitat needs of riparian dependent wildlife in the Intermountain West.

In addition, soil scientists, range scientists, ecologists, and wildlife biologists from the Intermountain West with expertise in conservation buffers were interviewed. In addition, several protocols for estimating the general condition of riparian habitat ecosystem functions and structure were reviewed, including:

- Riparian Area Management: Process for Assessing Proper Functioning Condition (USDI BLM 1998)
- USDA NRCS Stream Visual Assessment Method (SVAP) (USDA NRCS 1998)
- EPA Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macro invertebrates, and Fish (Barbour and others 1999)
- California Rapid Assessment Method (CRAM) for Wetlands, Draft v 3.0: User's Manual and Scoring Forms (Collins and others 2004)

Findings from riparian buffer research in other regions of the country, as described in the literature, were compiled in tables. Site attributes that were identified as having the greatest impact on buffer effectiveness for water quality buffering and wildlife habitat functions were highlighted (Buffler 2005). The tables correlate research-specific or recommended riparian buffer widths and vegetative structure with evaluated buffer functions and site conditions. Particular attention was paid to the Intermountain West. The tabular data was queried for trends in buffer width and structure related to site characteristics and function. The data sets were also queried for comparability of research site characteristics with site characteristics in the application area.

Several buffer planning protocols were reviewed. Of the protocols reviewed, the protocol developed by Klienschmidt Associates (1999) in the **Method to Determine Optimal Buffer Widths for Atlantic Salmon Habitat Protection** best matched the goals of the Riparian Buffer (RB) Handbook. The protocol combines visual estimates, readily available resource data, and easily measurable attributes, and requires field verification of all mapped information. The protocol incorporated measurable buffer attributes and used sampling plots (buffer measuring units) that could be adapted to western landscape characteristics. The protocol emphasized keys and tables that expedite data collection, recording, and calculations and facilitate replication. Buffer attributes keys and tables in the Kleinschmidt protocol were easily modified to accommodate unique Intermountain West landscape attributes. Lastly, the Kleinschmidt protocol adopted by the state of Maine to protect spawning habitat for the endangered Atlantic salmon was thoroughly scrutinized and approved by resource experts and regulatory agencies.

The protocol for determining buffer widths and structural characteristics for wildlife was patterned after USDI BLM (1998), Bergland (1999), Kleinschmidt Associates (1999), and Johnson and others (2005). Riparian buffer planning protocols and design guidelines were responsive to:

- Stream hydrology
- Slope characteristics
- Soil characteristics
- Vegetation
- Surface roughness
- Adjacent land use
- Land management practices
- Wildlife and fish
- Recreation

"Learn to read the book of external nature and the book of our own nature to discern common patterns and harmonies." Rene Dubos (1973). *Photo by Susan Buffler.*

Regional resource experts were asked to critically review the proposed protocol and recommend changes as necessary. The NAC staff also critically reviewed the guidelines and the practicality of the protocol recommended for use by NRCS staff and other conservationists. The protocol was also tested in the field. Review comments and field test results were incorporated into the protocol's final format.

Handbook Organization

Coordinating riparian buffer projects, whether at the farm, ranch, or watershed scale, requires a focused yet flexible process. As previously noted, the NRCS planning process described in the National Planning Procedures Handbook provides a useful framework for guiding riparian buffer planning. This iterative process identifies nine steps carried out in three phases.

NPPH Process Outline

Phase 1 Data Collection and Analysis

- **Step 1 Identify Problems and Opportunities**
- **Step 2 Determine Objectives**
- **Step 3 Inventory Resources**
- **Step 4 Analyze Resources**

Phase 2 Decision Support

- **Step 5 Formulate Alternatives**
- Step 6 Evaluate Alternatives
- Step 7 Make Decision

Phase 3 Implementation

- Step 8 Implement Plan
- **Step 9 Evaluate Plan**

Note: **Bold** steps are addressed in this Riparian Buffer (RB) Handbook.

This RB Handbook will focus on the first two phases and five steps detailed in the NPPH; however, brief discussions of Step 9 (Evaluate Plan), and an additional step (Adaptive Management), are included because of their relevance to the overall intent of the RB Handbook. The discussion below applies to those riparian buffer planning projects most commonly undertaken by resource managers—projects that do not require an Environmental Assessment (EA) or Environmental Impact Statement (EIS). However, becoming familiar with the material in this Handbook will help conservationists, planning partners, and landowners in preparing an EA or EIS for a riparian buffers project, should it be required.

The Planning Process application section of this handbook has been divided into two sections:

Section A is the protocol for determining appropriate buffer widths, land use zones, and accompanying use regulations to meet water quality objectives. It includes related data collection forms and reference materials.

Section B is the protocol for determining appropriate buffer width to meet wildlife habitat, target species habitat, and wildlife migration or dispersal functions related to specific landowner wildlife conservation objectives. Further, habitat recommendations, lands use zones, and accompanying use recommendations are included. Section B also includes wildlife habitat related data collection forms and reference materials.

Section A: Water Quality Planning Process—Discussion and Rationale

The most common reason for implementing riparian buffers and other in-field conservation practices in the application area is to meet water quality objectives (fig. 6). Buffer designs are tailored to address one or more non-point sources of pollution: sediments, nutrients, agricultural chemicals, and animal waste. A 10-year study on Rock Creek, Twin Falls, Idaho (Maret 1991), documented significant improvement in water quality when Best Management Practices (BMP) including riparian buffers were implemented.

This same study noted that pollution carried by irrigation return flows was not affected by riparian buffers if the flow was routed through channels or ditches and bypassed the buffer areas. Addressing this important source of pollution is beyond the scope of this project; it remains a research topic for others.

Figure 6. Riparian buffers protect water quality by filtering, trapping, and transforming pollutants. *Photo by Susan Buffler.*

Phase 1: Data Collection and Analysis

Prior to planning a buffer project, several pre-planning procedures should be implemented as described below.

Delineate the Planning Area

The planning area is much larger than the project area and includes the watershed (regional) context. The function and structure of riparian buffers at the project scale is directly affected by stream hydrology and adjacent terrestrial resources or features at the watershed scale. Thus, the delineated planning area should be large enough to include potentially impacted hydrologic, terrestrial, and cultural resource features at the watershed or sub-watershed scale.

Ideally, the planning area would include the entire watershed of the stream for which riparian buffers are being planned. Referencing general watershed scale information helps put a specific riparian buffer project within its regional context. It defines potential problems and opportunities that exist beyond the bounds of the specific project site—a longitudinal perspective of changes in water quality to which the project site contributes. Of particular importance, because of potential impacts on riparian vegetation, are upstream dams, diversions, and irrigation return flows that modify normal stream flow, water chemistry, and temperature. Important watershed scale information to be reviewed includes:

- Upstream water quality
- Political subdivisions: counties, cities, and unincorporated areas
- Local policies, ordinances, and regulations
- Urban growth trends
- Roads and streets
- Canals and ditches
- Dams and diversions
- Natural and introduced vegetation
- Wildlife
- Topography
- Farm and rangeland
- Irrigated/non-irrigated land
- Feedlots
- Land management practices
- Flood zones
- Groundwater recharge areas
- Soil types
- Soil conditions—possibility of erosion, phosphorus, and nitrogen levels
- Sediments delivered to streams

Recording the above information on maps is the best way to illustrate the relationship between information items and their relationship to the project site. USGS 7.5 minute quadrangle maps at 1:24,000 scale are often appropriate for watershed scale planning, particularly when noting and mapping potential problems and opportunities outside the project site.

All states in the study area have resource data in Geographic Information System (GIS) format that can be overlaid on 7.5 minute quad sheets (see Appendix A-9 for state sources of GIS data). The availability and quality of watershed scale information, particularly in Geographic Information System (GIS) format, will vary among states and watersheds. Consult your state planning office for more information. Additional electronic sources of resource information are available on numerous websites (Appendix A-9).

Delineate the Project Boundary

Watershed scale information describes riparian buffer project context, but does not provide sufficient information for determining appropriate buffer widths at specific locations. Thus, the question remains, "How large should the specific project boundary be immediately adjacent to the river or stream?" There are several steps to complete, and several factors that affect, this decision:

1. Create a Project Base Map

To delineate a riparian buffer planning project boundary, it is necessary to create a base map. The map should include all land inside the proposed project and adjacent areas broad enough to encompass important landscape features within the sub-watershed. Include on the base map such features as topography, drainage ways, large patches of native vegetation, wetlands, irrigation canals, urban areas, and transportation corridors. In some instances, it may also be necessary to include administrative delineations such as land ownership and jurisdictions, soil and water conservation districts, and irrigation company boundaries.

Most riparian buffer projects are at a sub-watershed stream reach scale. Most conservation plans for riparian buffers prepared by the NRCS are drawn at 1:660 scale, the same scale as NRCS Soil Survey's maps and aerial photographs. This is the most appropriate base map scale for specific riparian buffer projects. Much of the watershed data collected and mapped at 1:24,000 scale can be transferred to 1:660 scale base maps as needed.

2. Classify Valley and Stream Geomorphology

Classify the stream geomorphology along the reach that includes the project sites. Valley and stream geomorphology provides a general characterization of the topographic and fluvial features of a riparian buffer site related to channel relief, pattern, shape, and dimension (Rosgen 1994). This integrated perspective includes the aquatic and terrestrial factors that affect the ecological function and structure of riparian buffers—ideal characteristics for delineating the basic configuration of a project boundary.

The Rosgen (1994) classification system was selected as an important tool for delineating a project boundary in this study. It provides a practical classification protocol that is adapted for use in the field. Diagrams for determining classification are included in Appendix A-11.

3. Make Final Adjustments to the Project Area Boundary

Frequently, the project boundary, as initially delineated on the 1:660 scale base map, must be modified (and often expanded) to respond to specific site conditions that may affect buffer function. The project boundary may need to be expanded to include:

- Seeps or springs within 300 ft of the mean high water level.

- Significant sand or gravel aquifers that abut the stream or are within 300 ft of the mean high water level.
- Agricultural, range, or urban uses within 300 ft of the mean high water level.
- Canals, ditches, and irrigation return flows within 300 ft of the mean high water level.
- Landward boundary of slopes greater than 25 percent.
- Landward boundary of highly erodible and low infiltration capacity soils (hydrological groups C and D).

Recommendations for adjusting a project boundary for each of the factors above should be incorporated as necessary. Additional factors that can lead to expanded project area boundaries include:

a. Adjacent Land Use and Management Practices

It is important to evaluate adjacent land use and management practices and extend the project boundary to include an interface with them. Many, if not most, of the non-point source pollutants that enter a stream originate in the uplands as a result of agriculture, ranching, logging, urban uses, recreation, and land management practices. By including adjacent land use interfaces within the project boundary, the sources, types, and quantities of pollutants flowing through the riparian buffer can be identified and measured. Later, these criteria will become important in determining buffer width and structure.

There is another reason to expand the project boundary to include portions of the adjacent land use matrix. In many instances, the most effective way to improve water quality is to apply best management practices in the matrix whether the matrix is agriculture, ranching, or urban land use. **The causes of water quality problems must be addressed as close to the source as possible in order to reduce stress on the riparian buffer.**

b. Project Objectives

Project objectives can have a significant effect on buffer width and consequently, on the size of the project boundary. Typical buffer widths required to achieve water quality objectives reported in the literature range from 25 to 375 ft (Buffler 2005; Chase and others 1997) depending on site conditions and the contaminants being buffered. Wider project boundaries are required when wildlife objectives are combined with project water quality objectives. For a comprehensive review of research related to water quality objectives and buffer widths, see Buffler (2005).

Most of the project boundary delineations and final adjustments can be done in the office working from aerial photographs, topographic maps, NRCS soil surveys, and USGS quad sheets referencing slopes greater than 25 percent, flood plains, wetlands, springs and seeps, soils, land use, and other cultural features. Other features that affect buffer design, such as vegetation and surface roughness, must be estimated in the field. The final project boundary is drawn on the base map and validated in the field (see Appendix A-10).

Products

- ○ Mapping format, scale, precision, and role of technology are determined.
- ○ Base maps with planning area boundary and delineated project boundary.

Step 1: Identify Problems and Opportunities

Planning Standard

The planning group or landowner water quality problems and opportunities are clearly identified and documented.

Typically, the landowner, resource professionals, and other conservation partners will be involved in identifying the problems and opportunities in the buffer area (fig. 7) An example of a water quality problem would be where several small eroded gullies run through the proposed riparian buffer site and convey pollutants directly to the stream. An opportunity would be the possibility of redirecting polluted runoff from a grassed waterway into to a riparian buffer for pollutant removal.

Public participation in Step 1 may be required on some projects depending on landownership, funding, and the nature of the project.

Problems and opportunities should be mapped and verified in the field. Useful data sources for this step include research reports, scientific studies, expert opinion, and in-field observations. Additional studies may be recommended if existing data sources are insufficient. Applicable problems and opportunities should be noted where they occur on a copy of the project area 1:660 scale base map. Problems and opportunities that do not lend themselves to mapping should be recorded in a short report. Additional problems and opportunities may be uncovered during Step 4—Analyze Resources.

Products

- Preliminary identification of water quality problems and opportunities documented on base maps and field notes.

Step 2: Determine Objectives

Planning Standard

Planning objectives are clearly stated and documented.

Landowners or other stakeholders initiate a riparian buffer planning project mainly because they wish to change the existing condition to some desired future condition. Two commonly stated desired future conditions for water quality buffer function projects in the application area are:

To improve the water quality of runoff that leaves upland agricultural, rangeland or urban sites and moves through a riparian buffer and enters adjacent streams or riparian-related wetlands.

To protect the function and structure of existing or proposed riparian buffers from adverse impacts originating in the adjacent matrix (buffer the buffer).

These desired future conditions are often developed into a vision statement. For example, a statement may describe the vision for the proposed buffer as follows: "Using riparian buffers and other best management practices to reduce by 75 percent the sediments originally in fields 1 and 2 that reach the stream. The buffer plan will conserve all existing native plants in good condition and control invasive species. New plantings will be comprised of native, upland, and riparian species-buffer vegetation and will be self-sustaining."

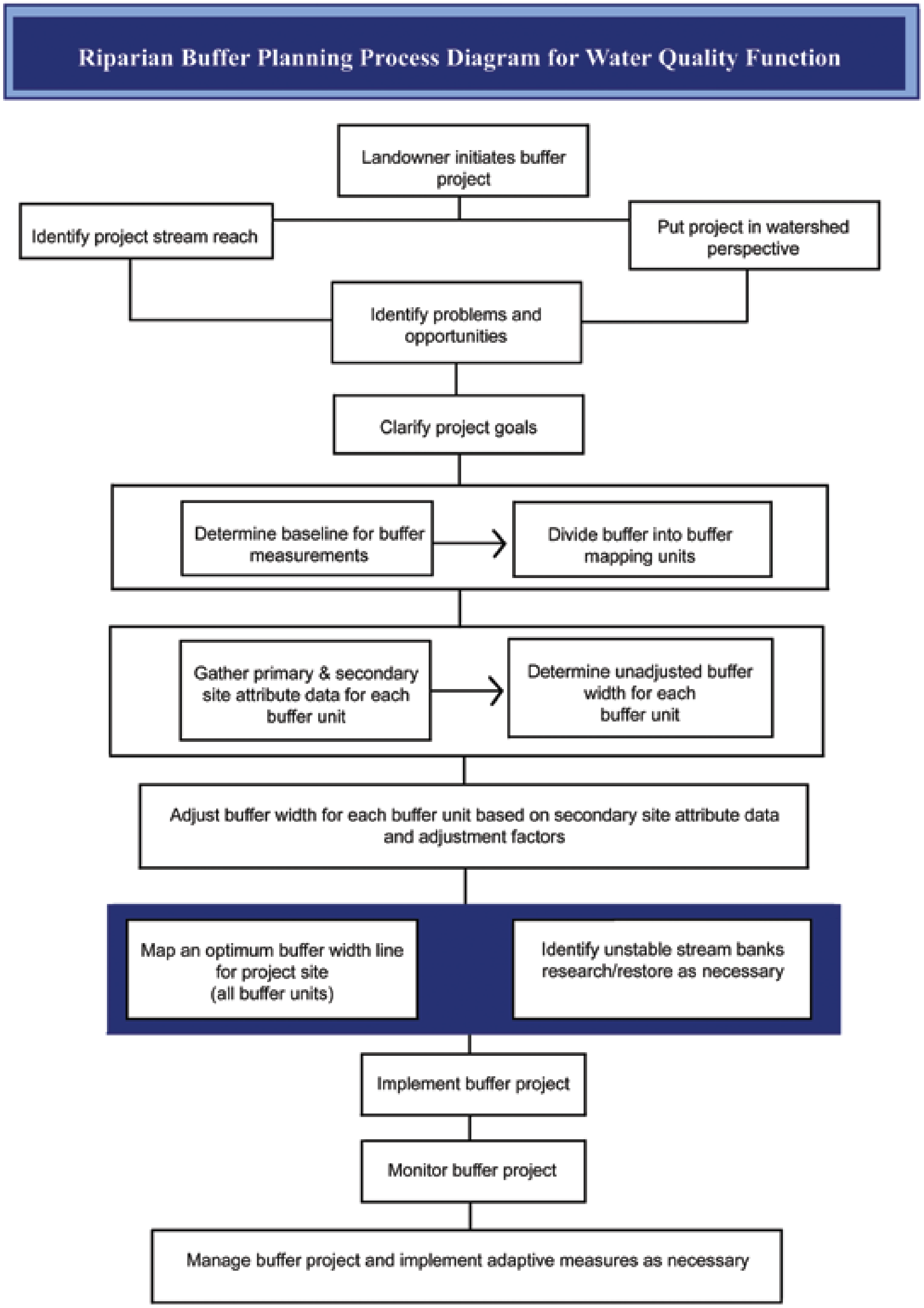

Figure 7. Flow chart for riparian buffer planning for water quality.

The objectives will be project specific. Objectives may be mandated and compliance required for the objectives of an overall watershed plan or the water quality standards that are specified by federal or state regulatory agencies. Specific water quality objectives common to most projects in the application area include reduction of sediment and related pollutants, reduction or maintenance of water temperature, and reduction of pathogens from animal waste entering streams or wetlands from adjacent uplands.

Clearly stated in the objectives are the desired levels of remediation for sediments, phosphorus, nitrogen, pesticides, and bacteria. Final water quality objectives are established by the landowner in collaboration with water quality professionals and frequently, other Non-Governmental Organizations (NGO) conservation partners. Riparian buffers are considered a cost-effective tool among a suite of tools used to achieve these objectives. To assess buffer effectiveness, post-project water quality levels will be compared against desired target levels.

Step 3: Inventory Resources

Planning Standard

Sufficient data and information are gathered to analyze and understand water quality and buffer conditions in the planning area.

The general intent of the resource inventory is to describe existing (benchmark) conditions within the buffer project boundary. A systematic data collection and mapping procedure is required to assemble and map resource information.

Buffer Mapping Units

To inventory existing specific buffer project site conditions, a sampling protocol developed by Kleinschmidt Associates (1999) was adapted for Intermountain West conditions (Buffler 2005). The protocol uses a *buffer mapping unit* as the basic sampling plot (fig. 8). Buffer mapping units are the survey plots within which resource attributes are inventoried and the findings recorded on base maps. Buffer mapping units are also used during analysis and design steps.

A discrete buffer unit is greater than or equal to 300 ft in length as measured parallel to the mean high water mark of the reach of river being buffered. Buffer unit width is measured perpendicular to the stream beginning at the mean high watermark or the landward edge of an active flood plain or wetland. Buffer widths are variable.

See reference diagrams in Appendix A-10 and the case study for examples. Use Appendix A-3 to determine preliminary buffer widths for resource inventory purposes.

The dimensions of a buffer unit, as described, were determined to provide sufficient detail and accuracy for analysis and planning for water quality buffer functions (Buffler 2005; Haberstock and others 2000, Kleinschmidt 1999). Buffer units are described in detail in Step 5-Formulate Alternatives.

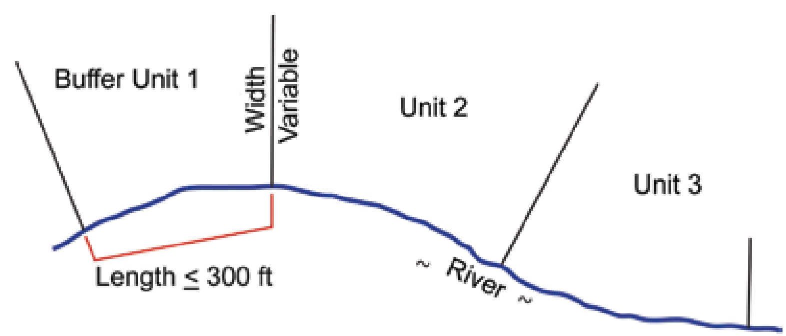

Figure 8. Buffer mapping unit diagram.

Site Attributes

Primary and secondary site attributes selected for use in this buffer planning protocol were based on the research findings compiled by Buffler (2005). The attributes discussed on the following pages are adapted from Kleinschmidt Associates (1999).

Primary Site Attributes

Slope

There is a direct relationship between slope and erosion potential, conversion of nutrients, and retention of nutrients. A steeper slope usually results in higher erosion potential and lower nutrient conversion and retention. In riparian areas, slope from the normal high water mark to the top of bank (TOB) is typically steeper, more sensitive, and more erosion prone than the adjacent landward slope. Slope categories selected for use in this study are 0 to 5 percent, greater than 5 to 15 percent, greater than 15 to 25 percent, and greater than 25 percent. These categories reflect study area geomorphology and the general categories used by NRCS to classify regional soils.

Objective: Determine average slope for each buffer unit.

Data Source: Map resources (NRCS Soils surveys, USGS) or field measurement

The easiest way to determine slope is to use NRCS Soil Surveys and/or USGS maps. The slope classes chosen for the buffer width key were specifically selected to coincide as much as possible with soils mapping units used in USDA County Soils Surveys. In most cases, a buffer unit will consist of a single soil unit. If there are one or more soil units, the slopes should be averaged according to the approximate percent of the buffer unit occupied by each soil type. Alternatively, slope can be calculated using USGS maps or can be measured in the field. Since USGS maps use 20-ft contours, only the steeper slopes may be accurately determined. One technique of approximating slopes from USGS maps is to draw in 10-ft contour intervals exactly half-way between each 20-ft contour interval. Finally, slope can be measured in the field using standard surveying equipment or a clinometer (preferably with percent slope, as well as degrees). This technique is the best way to delineate top of bank, which is a feature used in determining buffer width in later steps. Use of digitized (scanned) soils maps and other resource maps can be used in conjunction with GIS if these tools are available to the evaluator; however, these graphical display and analysis tools are not required.

Soils Infiltration

In general, soils with low infiltration rates (USDA NRCS hydrological groups C and D) have a reduced capacity to trap, absorb, or filter pollutants. They are less effective than soil groups A and B at reducing concentrated runoff flows and the export of sediments and nutrients, such as phosphorus, that bind to sediments.

Objective: Determine soil hydrologic group for each buffer unit.

Data Source: Map resources (NRCS Soil Surveys, Surficial Geology) or field determination.

Soil hydrologic group is best determined using NRCS Soil Surveys. There is a hydrologic group (A through D) designated for each soil series. Where the hydrologic group is assigned as a combination (for example, C/D), the more restrictive group (in other words, D) should be used. As with slope, if more than one soil type occupies the buffer unit, the different hydrologic groups can be averaged to approximate average hydrologic group for the entire buffer unit. For example, if approximately 50 percent of a buffer unit is hydrologic group B and 50 percent is hydrologic group D, the average would be C. If 20 percent is C and 80 percent is D, D would be used. Impervious surfaces, such as roads, houses, and parking areas, should be counted as hydrologic group D. For those areas where soil surveys are not available, a soil scientist can make soil hydrologic group determinations in the field.

Surface Roughness

Surface roughness in this study is estimated as the degree of ground cover (perennial vegetation, boulders, herbaceous litter, woody debris, and micro topography). Sites with greater than 65 percent surface roughness break up surface flows and encourage infiltration. Sites with less than 50 percent surface roughness are less effective at retarding overland flows.

Objective: Determine the degree of surface roughness for each buffer unit.

Data Source: Field determination only.

Use Appendix A-6 (Surface Roughness Guidelines) for this determination. The degree of surface roughness is related to the amount of microtopographic complexity, the condition of the duff layer (surface organic horizon), and the amount of coarse woody debris and woody and herbaceous vegetation. Forested buffers with undulating or pit-and-mound topography, dense and/or low vegetation, a high degree of dead and down wood (or other features such as boulders), and an intact duff layer have a high degree of surface roughness. Buffers with a low degree of surface roughness lack these features. High degrees of surface roughness are limited to complex riparian systems lacking exposed mineral soils and roads or other slowly permeable or impermeable land use features.

The guidelines in Appendix A-6 specify surface roughness categories that leave little room for interpretation, can be easily replicated, and reflect conditions found in the study area.

Note: Exposed mineral soils present in a buffer unit, which resulted from land use practices, automatically result in a low surface roughness rating. If exposed mineral soils have resulted from tip-ups (toppled trees where the root crown has been ripped out of the earth exposing mineral soil horizons) or other natural phenomena, then the organic horizon can be considered intact.

Stream Flow (Not Inventoried)

Stream flow for the stream adjacent to the riparian buffer is considered a Primary Site Attribute, but flow data are not required for determining the riparian buffer width (it is indirectly addressed in floodplain and wetland attributes). However, stream flow data are required to calculate total maximum daily load (TMDLs) used to estimate water quality as part of post project monitoring.

Secondary Site Attributes

Surface Water Features

Surface water features include perennial and intermittent streams, ditches, canals, and drainage ways. These features rapidly convey concentrated flow of sediments and other pollutants to the receiving stream. Buffer widths should be expanded to compensate for the buffer bypass characteristics of these features.

Objective: Determine the location and type (for example, perennial stream, intermittent stream, or pond) of surface water features within the buffer.

Data Source: Map resources (USGS, National Wetland Inventory [NWI], NRCS Soil Surveys, aerial photos) and field determination.

Identify surface water features in the field, if possible, or by using desktop resources such as NWI maps, recent aerials, NRCS Soil Surveys, and USGS maps. In addition, ditches, canals, and swales (for example, for storm water management) are included since such features are potential conduits for water quality contamination. Anything that appears on USGS maps as a solid or broken line, whether perennial or intermittent, should be included. Many, but not all, streams that meet state definitions are indicated on USGS maps, so if possible, field work should also be used to indicate unmapped surface water features.

Groundwater Seepage or Springs

Seeps and springs are common in many riparian buffers in the application area. Some seeps are natural. Many are associated with up-gradient irrigated landscapes where ground water is near the soil surface. Buffer widths should be widened to accommodate these attributes, particularly to protect springs from contamination. Deep-rooted phreatophytic riparian buffer vegetation, often associated with seep and springs, plays an important role in withdrawing nutrients and other pollutants in the ground water.

Objective: Determine if groundwater discharge from springs or seeps is present within the buffer.

Data Source: Field determination.

This feature can only be accurately determined with a field visit. Only those situations where the underlying aquifer clearly intercepts the land surface should be counted. Perched wetlands and seeps from shallow subsurface runoff not having direct connection to the underlying aquifer, such as often occurs on irrigated compacted tills, should not be counted. A field indicator of springs is consistent discharge of cool water to the surface. The temperature of groundwater varies little through the seasons and is typically within a few degrees of mean annual air temperature (spring water feels cool in summer). Springs often occur on the side slopes of river valleys and it is common for small spring-fed creeks, rivulets, or seepage wetlands to emerge immediately below them. Sand and gravel aquifer maps, surficial geology maps, and soils maps may be helpful, but it is not possible for evaluators to definitively identify springs using these resources alone.

Sand and Gravel Aquifers

There is a high probability that surface runoff that flows over sand aquifers will percolate directly into the ground water. Ground water in the study area typically discharges into down-gradient streams. Consequently, nutrients, chemicals, and other pollutants have a direct and unbuffered route to the stream. Buffer widths around sand and gravel aquifers need to be widened to intercept and remediate surface flows before they reach aquifer sites.

Objective: Determine if significant sand and gravel aquifers are present within the buffer.

Data Source: Map resources (Surficial Geologic Surveys, NRCS Soil Surveys).

Significant sand and gravel aquifers are identified in NRCS Soil Surveys. Such deposits typically contain water tables near the surface in valley bottoms such as riparian areas adjacent to larger streams.

Floodplains

In this protocol, floodplains, delineated as areas with alluvial soils and associated wetlands, are considered an integral part of the stream being buffered (fig. 9). The baseline for measuring buffer width begins at the landward edge of the floodplain.

Objective: If present, determine the location of floodplain adjacent to the stream reach being evaluated.

Data Source: Map resources (NRCS soil surveys) and/or field measurement.

For areas where NRCS soil survey data are available, identification of floodplains is as straightforward as identifying those soil series that are derived from recent alluvial deposits or those areas where soil surveys are not available. Field work by soil scientists or consultants may be the only alternative to determining the extent of floodplains. A reliable determination cannot be made using NWI maps, USGS maps, or Federal Emergency Management Agency (FEMA) floodplain maps. Flood plains field

Figure 9. Floodplains are an integral part of the stream being buffered. *Photo by Craig Johnson.*

indicators include drift lines; sediment deposits; water marks on trees, shrubs, or rocks; soils derived from alluvial sediments; and floodplain vegetation (for example, cottonwood [*Populus* spp.], willow [*Salix* spp.], alder [*Alnus* spp.], water [river] birch [*Betula occidentalis*], dogwood [*Cornus serecia*], river hawthorn [*Crataegus* spp.], nettle [*Urtica dioica*], sedges, salt grass [*Distichlis spicata*], and rushes [*Juncus* spp.]).

Wetlands

Wetlands in, or adjacent to, riparian buffers are important ecological sinks, trapping sediments, sequestering nutrients and pollutants, and converting available nitrogen to a gaseous form. Wetlands abutting the stream are considered part of the resource being protected. All wetlands within 300 ft of the stream should also be incorporated into the buffer.

Objective: Determine the location and type of wetland being evaluated, both within the buffer and immediately adjacent to the stream reach.

Data Source: Map resources (NWI, NRCS Soil Surveys, and USGS) or field measurement.

Wetlands are identified using NWI maps, which are available for most of the study area. Field evaluators may, at times, find that existing wetland types or locations have changed relative to NWI maps (for example, succession or stream hydrology has resulted in a change from depressional to riverine) or that wetlands are present that are not identified on NWI maps. In the case where a field assessment of wetlands differs from NWI maps, assessment information should be used. Wetlands that are hydrologically connected by surface drainage (including intermittent or seasonal drainage) to the in-stream habitat under protection should be differentiated from isolated wetlands.

Stream Order

Objective: Determine the stream order (optional).

Data Source: Map resources (USGS topographic map).

Stream order is determined using USGS maps. Although stream order does not affect the optimal buffer width, this information may be useful with respect to prioritizing the acquisition and/or protection of critical riparian buffer habitats. For example, buffers on smaller order streams may be targeted for protection before buffers on larger order streams because they may be more sensitive to land use impacts (Davies and Sowles 1997).

Tertiary Site Attribute

Stream Bank Condition

The stream bank forms the aquatic edge of the riparian buffer. Well-vegetated, stable stream banks perform important buffer functions and reduce sediment loading from bank erosion. However, eroding stream banks caused by human-induced disturbance are a major source of sediment loading in streams in the application area.

The area of exposed stream bank varies during the course of a year. During spring runoff, or following a storm event, streams flow at bank full stage and little bank area is exposed. By late summer, streams flow at base flow or lower levels. The maximum area of bank is exposed and prone to erosion by surface disturbances such as trampling by cattle or sheet and rill erosion during storm events. Input from geomorphologists and hydrologists is important in determining what, if any, remediation measures should or can be implemented.

Objective: Identify unstable streambanks caused by human disturbance in the project area.

Data Source: Field determination.

Streambank condition is determined by observation in the field. Although streambank condition does not affect optimum buffer width initially, it can have a significant effect in the future. Identification of unstable banks will be useful in highlighting sites for further hydrological and ecological study and potentially future restoration.

Products—(see case study on CD)

- Maps depicting the primary, secondary, and tertiary site attributes that affect water quality buffer function within the buffer unit.

Step 4: Analyze Resources

Planning Standard

The benchmark conditions of riparian buffer attributes in the planning area are documented. The causes of buffer function attributes are identified.

In the analysis step, the conservationist evaluates the inventory data and considers the implications of the existing primary and secondary attributes on water quality buffer functions. The protocol in the RB Handbook addresses the analysis questions below that respond to the three non-point sources of pollutants that may impact stream pollutants that originate on adjacent lands, in the riparian buffer itself, or from the stream bank or bed.

- What are the types and quantities of pollutants reaching the stream that are a concern of the landowner?
- What adjacent land uses and management practices contribute pollutants to the stream?
- What locations within the riparian buffer contribute pollutants?

- Is the streambank contributing pollutants to downstream reaches?
- Are there pathways for pollutants, in other words, rills or gullies that bypass the proposed buffer? (A buffer is not effective in protecting water quality in these cases.)
- What buffer type and width are required to address the issues identified in answering the questions above and to meet specified water quality objectives?

In Step 3 (inventory), both Primary and Secondary Site Attributes are mapped for each buffer unit as part of the inventory process. As part of the water quality buffer analysis protocol in Step 4, tables and keys are used to analyze primary and secondary site attribute inventory data for each buffer unit. Worksheets are provided to record analysis information that estimates existing functional characteristics. Primary site attributes, those attributes with the highest probability of effecting water quality, are highlighted on analysis maps. Collectively (all buffer units combined), the configuration of primary attributes along the entire riparian buffer will delineate the unadjusted buffer width required to meet water quality objectives on the project site.

Secondary site attributes have a less significant effect on water quality but become important modifiers to the unadjusted buffer width. Secondary attributes, mapped for each buffer unit in the inventory, are also analyzed using keys and tables. Adjustments to buffer width are made considering secondary attributes based on primary characteristics.

Products (see case study on CD)

○ Maps depicting the benchmark condition of buffer attributes in the each buffer unit. Individual buffer unit results are combined and the adjusted buffer width for the entire project is delineated.

Phase 2: Decision Support

Step 5: Formulate Alternatives

Planning Standard

Alternative plans (treatments) are developed to meet water quality criteria and objectives of the riparian buffer project.

The emphasis of the RB Handbook is on developing a protocol for determining appropriate riparian buffer width and recommending design guidelines for agricultural landscapes in the Interior West. Consequently, procedures for generating alternatives are not included. Presented in the following Buffer Planning Protocol for Water Quality section is a science-based buffer planning process for determining variable width riparian buffers responsive to project site landscape attributes and varying client objectives. The process is an alternative to Euclidian, single width buffers. In addition, it addresses the lack of buffer regulations common in county and city zoning ordinances in the application area.

The key outcome of the protocol is a variable width buffer for the project site that meets the objectives stated in Step 2. The idea of variable width buffers with zones of regulated land use and activity has been suggested in the research literature and proposed in numerous projects (Kleinschmidt Associates 1999). Variable width buffers, unlike the fixed width buffers, provide better conservation of water quality and wildlife habitat without over regulation of the resource. They also typically reduce the amount of productive land dedicated to buffer functions, an overriding goal of this project.

The optimum water quality buffer widths generated by the RB Handbook protocol are divided into two zones with a recommended third management zone outside the buffer (adapted from Klienschmidt Associates 1999).

- **Zone 1**, closest to the stream, is a no disturbance zone that should remain intact (fig. 10). The primary functions of Zone 1 are to protect the ecological integrity of the riparian plant community, stabilize stream banks, and provide a final barrier to potential water quality contaminants. Land use activities are restricted to necessary site restoration and management as dictated by initial analysis or later evaluation/monitoring. Zone 1 is a semi-fixed width, extending from the mean high watermark landward to TOB + 35 ft or 70 ft, whichever is greater, or landward 35 ft from the

Figure 10. Zone 1 is adjacent to a stream and is a no disturbance zone. *Photo by Kathy Allen.*

edge of floodplains or wetlands adjacent the stream. Zone 1 may also include 50-ft buffers adjacent to springs, streams, drainage swales, and canals or other surface water features.

- **Zone 2** is of variable width and extends from the landward boundary of Zone 1 to the landward edge of the calculated optimum buffer width. The primary function of Zone 2 is to provide sediment filtering and other water quality functions. Limited land use activities that would not impair buffer functions described above are permitted in Zone 2. Land use specification for Zone 1 and 2 are described in detail in Appendix A-8.
- **Zone 3**, a zone outside the calculated buffer width, includes adjacent land uses. For Zone 3, Best Management Practices are recommended.

Products

- ○ The buffer plan and land use zones for the entire project site are depicted on a map.

Step 6: Evaluate Alternatives

Step 7: Make Decisions

Step 6, Evaluate Alternatives, and Step 7, Make Decisions, are not included in the RB Handbook as they are not directly related to its intended purpose. These steps are implemented by NRCS personnel, conservation partners, and landowners when the riparian buffer has been planned and designed.

Phase 3: Application

Step 8: Implement Plan

Step 8 is not included in the Handbook for reasons stated in steps 6 and 7.

Step 9: Evaluate Plan

A detailed discussion of plan evaluation is beyond the intended scope of this handbook. However, several important points should be mentioned.

Riparian buffers implemented for water quality need to be evaluated/monitored to determine if project water quality objectives are being achieved and to guide future management activities. The following monitoring activities are recommended:

- Consult with a state NRCS or state extension water quality specialist to develop a water quality monitoring program designed specifically to assess buffer performance relative to buffer water quality objectives.
- Monitor water quality annually in wetlands, creeks, seeps, and springs within the riparian water quality buffer for progress toward buffer objectives. Water quality analysis of these in-buffer water features should be conducted using a protocol specified by water quality consultants as noted above. Annual results should be compared with pre-implementation data. Over a period of years, a comparative analysis of assembled data will suggest whether or not the buffer is functioning as expected, or if additional research to determine causes of declining water quality is required or adaptive management strategies are necessary.
- Review water quality data for the receiving stream annually. In many cases, the causes of declining water quality may be outside the buffer or project boundary or they may not be readily apparent. Additional research may be required before the cause(s) is identified and an appropriate solution is found. Frequently, the solution involves cooperation from adjacent land owners or government agencies.
- Monitor surface roughness annually. Surface roughness is the primary buffer attribute most likely to change over time. Use the same procedures previously described to estimate surface roughness (Step 3). A trend over several years indicating decreasing levels of surface roughness suggests that adaptive management may be necessary to restore buffer effectiveness. The source(s) of impact must be mitigated to prevent further riparian buffer degradation.
- Monitor invasive exotic plant species and populations annually. Invasive herbaceous species are typically more shallow rooted than native grasses and forbs (Bergland 1999, Paige and Ritter 1999) thus reducing buffer effectiveness and increasing the probability of surface erosion. Common invasive woody species (salt cedar and Russian olive) are either allelopathic (salt cedar) or produce dense shade that eliminates many understory species, an important component of surface roughness.

To monitor changes in percent ground cover of invasive exotic species in the buffer, repeat the visual estimate protocol used in Step 3 (Appendix B-5). Consultation with a NRCS biologist or County Extension weed specialist is recommended.

Additional Recommended Step: Adaptive Management

Riparian buffers for water quality, like other NRCS conservation practices, require long-term management if they are to continue to provide the functions for which they were designed. Management techniques should respond to changes in buffer function and structure within and outside the buffer as evidenced in monitoring data. In the study area, the most common causes of change in buffer function and structure include:

- Agricultural practices
- Unmanaged livestock grazing
- Dams and diversions
- Recreation
- Urbanization
- Road construction
- Wildlife

(Western Division of American Fisheries Society 1982, as cited in Gardner and others 1999)

Adaptive management in riparian buffers can involve the use of both active and passive techniques. Passive techniques typically involve protection of the buffer from adverse impacts, often by fencing, thus allowing natural revegetation and succession to occur. Passive techniques are most applicable in buffers that have not been seriously degraded, in other words, stream flows have not been altered, the channel is not incised, the native plant species seed bank is intact, and there are few invasive plant species present. In degraded buffers, more active restoration measures may be necessary and include, but are not limited to:

- Prescribed burns
- Forestry practices
- Vegetation plantings
- Structures
- Beaver management
- Control of invasive plants
- Simulated flooding
- Upland management
- Grazing strategies
- Bank stabilization

(adapted from Gardner and others 1999)

Summary of Section A

The protocol in this RB handbook generates recommended buffer widths for specific Intermountain West buffer conditions that will facilitate protection of water quality. There is not a large literature base indicating buffer widths required specifically to protect or improve water quality in the Intermountain West. However, studies from other geographic locations in agriculturally dominated landscapes serve as a good basis for estimating optimal widths for the study region. Modifications to buffer width recommendations in these studies were required to address Intermountain West climatic, soil, topographic, and vegetative conditions.

The range of recommended optimal buffer widths generated by the protocol used in this handbook is from 70 to more than 300 ft, within the range of recommended buffer widths for other applications found in the literature, which ranged between 25 and 450 ft. Maintaining optimal riparian buffer widths may also preserve the ecological integrity of the buffered stream for non-target biota. Note that the larger recommended widths found in the literature are generally for wildlife corridor buffer functions (USEPA 1995).

Many existing riparian zones in the application area are degraded to varying degrees. Rather than becoming sinks for sediments, nutrients, and other pollutants, these degraded riparian zones often become sources. Stream bank slopes are often steep because of channel incision. Surface roughness is low as a result of poorly managed grazing systems, agricultural activities, or recreation uses.

Consequently, riparian buffer widths for this application area, generated by the RB Handbook protocol, are slightly wider on average than those associated with less extreme climatic and landscape conditions in other regions. This suggests that reclamation of existing riparian zones by altering present land use and management practices, recontouring, revegetating, or applying other bioengineering techniques will be critical to water quality protection. Over time, after remediation as buffer vegetation becomes established, buffer widths could be reduced and former buffer lands put back into production.

The determination of optimum buffer widths for water quality protection provides conservationists with a unique opportunity to accommodate the habitat needs of wildlife within the buffer for water quality.

The following are the protocol steps in the water quality buffer planning process. They are discussed in detail in the preceding Buffer Planning Protocol—Water Quality Section.

1. Complete pre-planning steps.
2. Identify the stream reach to be protected and the planning area on resource maps.
3. Identify and locate on the base map specific problems and opportunities.
4. Review project objectives and highlight those that can be implemented within the riparian buffer and those that should be addressed outside the buffer.
5. Determine the baseline for buffer measurement.
6. Divide the buffer evaluation area into discrete buffer mapping units for evaluation and determine width for data collection.
7. Gather primary site attribute data using data sheets for each buffer unit.
8. Determine the unadjusted optimal buffer width for each buffer unit using the key.
9. Adjust the width generated from the key according to the secondary site attribute data affecting buffer function (an optimum width for each buffer unit).
10. Map a continuous optimal buffer width line over the entire riparian buffer area (all buffer units) under evaluation.
11. Identify on the base map unstable stream banks for each buffer unit.

The complete set of data forms, keys, tables, and reference materials organized in the order in which they are used in the protocol are included in Appendix A. Section B of the RB handbook presents additional site attributes critical to wildlife that can be tiered to the water quality protocol detailed above to address wildlife issues.

"It is unfortunate, perhaps, that no matter how intently one studies the hundred little dramas of the woods and meadows, one can never learn all the salient facts about any one of them." Aldo Leopold (1933). *Photo by Peter Kimble*.

The following protocol (adapted from Klienschmidt Associates 1999) was modified to accommodate the terrestrial, aquatic, geologic, and hydrologic conditions of the application area. Trained resource professionals, and frequently, other conservation partners will be conducting the riparian buffer evaluation. In general, desktop components of the evaluation can be completed by a non-scientist, but field evaluation components require trained resource professionals (ecologists, wetland scientists, soil scientists, hydrologists, water quality specialists, wildlife biologists, or a resource trained landscape architect).

Protocol Steps

1. Identify the stream reach to be protected and delineate the planning area boundary (1:24,000 scale) as described in the Pre-Planning Section. Identify and address all relevant planning area (watershed) issues that will affect the buffer project. Resource maps to complete this task include, but are not limited to:

a. Aerial photographs
b. Soil survey
c. National Wetland Inventory
d. USGS topographic maps
e. Significant sand and gravel aquifer
f. Surficial geology
g. State GIS maps

2. Delineate the project area boundary and prepare base map(s) as previously described in the Pre-Planning Section.
3. Identify and locate on the 1:660 scale base map place-specific problems and opportunities that were identified in Step 1.
4. Review project objectives described in Step 1 and highlight those that can be best implemented within the riparian buffer and those that should be addressed in the adjacent upland or off site.
5. Determine the baseline for buffer measurement. Where there are floodplains and/or slope, depression, or riverine wetlands immediately adjacent to the stream channel, the baseline (start point) for measuring riparian buffer widths and buffer characteristics is the landward edge of these features (fig. 11).
6. Divide buffer project area into discrete buffer units for evaluation. The normal high water mark of the stream serves as a baseline (start point) for measuring riparian buffer widths where floodplain and open (non-forested) wetlands are not present immediately adjacent to the stream (fig. 12).

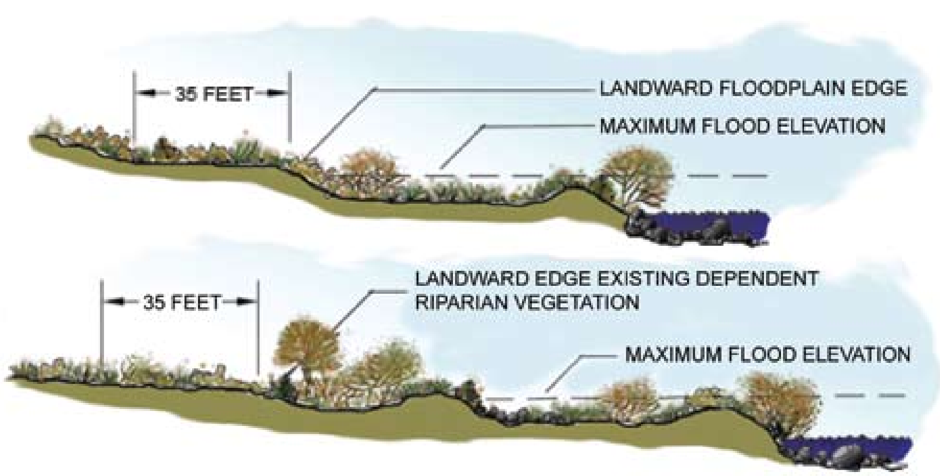

Figure 11. Cross section for Rosgen stream types C, D, and E.

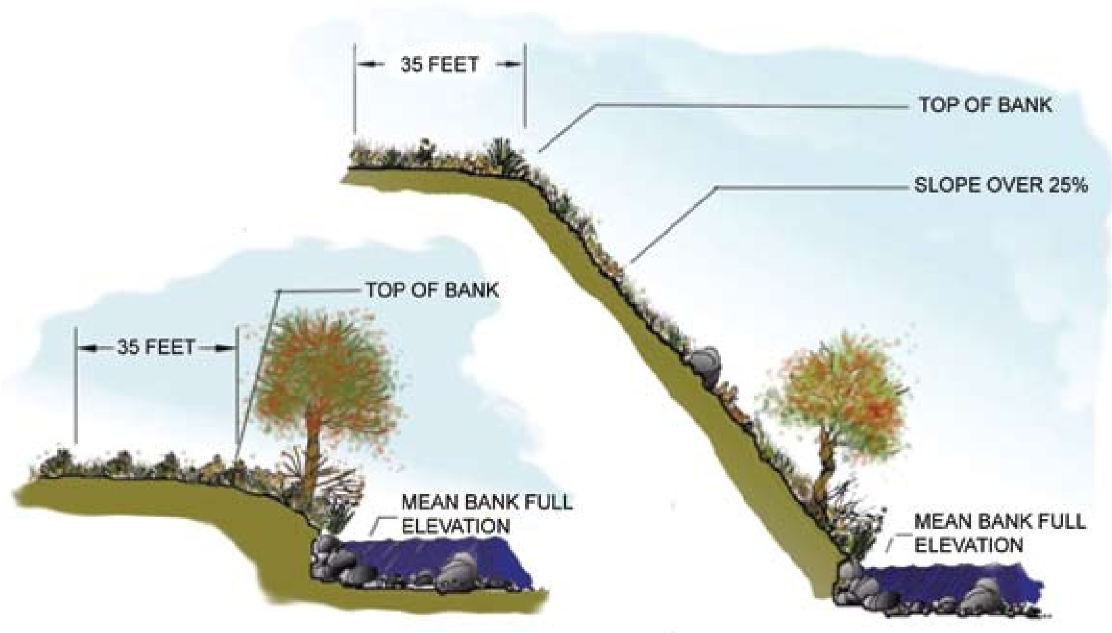

Figure 12. Cross section for Rosgen stream types Aa+, A, B, F, and G.

The length of buffer units, as measured parallel to the baseline, depends on the size of the parcel being evaluated and possible other factors (for example, land ownership/permission to enter the property). As a general rule of thumb, divide buffer evaluation areas into units that are no more than 300 ft along the stream. Smaller buffer unit lengths result in a more refined determination of optimal buffer width. If the area of interest is 3,000 ft along the stream, at least 10-buffer units should be evaluated. The last buffer unit will be less than 300-ft long unless the length of evaluation area along the stream is exactly divisible by 300. Buffer evaluators should not feel constrained by the 300-ft increments, but should use this as a maximum. In situations of high landscape variability, evaluators should divide buffer units at natural break points such as changes in slope, soil type, vegetative cover, or stream classification type or sharp bends in the river.

In order to determine the width of the riparian buffer in which to gather attribute data, refer to the table in Appendix A-3. In this table, width is a function of slope in the buffer unit.

At the start of the evaluation, the optimal buffer width is not yet known. Since slope is the most important readily measurable buffer attribute affecting buffer function, it is a good way to get a quick initial approximation of the ultimate outcome as an indication of how far landward to measure buffer attributes. As a consequence, the optimal buffer width generated may not be identical to the width of buffer being measured, but should be similar.

Measure buffer widths perpendicular to the baseline (or, if floodplains or open wetlands are not present, measure perpendicular to the stream axis) and on a horizontal plane. Also, establish the lines separating buffer units perpendicular to the baseline.

7. Gather buffer attribute data using data sheets for each buffer unit (Appendix A). Data collection consists of both desktop and field determinations.

8. Determine the unadjusted optimal buffer width for each buffer unit using the Optimal Buffer Width Key (Appendix A-4) (fig. 13).

9. Adjust the number generated from Optimal Buffer Width Key according to additional factors affecting buffer function (Appendix A-5). Adjustment factors include

Figure 13. Sample portion of Optimal Buffer Width Key.

The buffer width key is structured much like a plant key and utilizes three primary attributes: slope, soil hydrologic group, and surface roughness. The key generates an "unadjusted" buffer width that is subsequently adjusted up or down depending on additional important buffer attributes. The unadjusted recommended buffer widths range from a low of 70 ft for buffers with gentle slopes (0-5%), soils with a high infiltration capacity (hydrologic group A or B soils) and high surface roughness, to a high of 220 ft for buffers with very steep slopes (>25%), low infiltration capacity (hydrologic group D soils), and low surface roughness. Slope is weighted most heavily, followed by soil hydrologic group and surface roughness, based on their relative influence on buffer effectiveness as indicated in the literature.

Ideally, slopes, soil types and surface roughness should be determined. However, the key is designed to be flexible and can be used if only one or two of the three variables are known. If the only information known, for example, is that slopes are >5-15%, the unadjusted recommended buffer width would be 130 ft which is the average width for the >5-15% slope portion of the key. A sample portion of the Optimal Buffer Width Key is below. See Appendix A-4 for the complete key.

1. Slopes 0-5%
   2. hydrologic **group A and B** soils
      3. high surface roughness .... 70 ft
      3. moderate surface roughness .... 80 ft
      3. low surface roughness .... 90 ft
      → **Or** top of bank or landward edge of floodplain or wetland plus 35' whichever is greater
   2. hydrologic **group C** soils
      3. high surface roughness .... 90 ft
      3. moderate surface roughness .... 100 ft
      3. low surface roughness .... 110 ft
      → **Or** top of bank or landward edge of floodplain or wetland plus 35' whichever is greater
   2. hydrologic **group D** soils
      3. high surface roughness .... 110 ft
      3. moderate surface roughness .... 120 ft
      3. low surface roughness .... 130 ft
      → **Or** top of bank or landward edge of floodplain or wetland plus 35' whichever is greater

1. Slopes 5-15%
   2. hydrologic **group A & B** soils
      3. high surface roughness .... 100 ft
      3. moderate surface roughness ....110 ft
      3. low surface roughness ....120 ft
      → **Or** top of bank or landward edge of floodplain or wetland plus 35' whichever is greater
   2. hydrologic **group C** soils
      3. high surface roughness ....120 ft
      3. moderate surface roughness ....130 ft
      3. low surface roughness ....140 ft
      → **Or** top of bank or landward edge of floodplain or wetland plus 35' whichever is greater
   2. hydrologic **group D** soils
      3. high surface roughness ....140 ft
      3. moderate surface roughness ....150 ft
      3. low surface roughness ....160 ft
      → **Or** top of bank or landward edge of floodplain or wetland plus 35' whichever is greater

surface water features, groundwater seeps/springs, significant sand and gravel aquifers, and wetlands.

10. Map a continuous optimal buffer width line over the entire riparian buffer area (all buffer units) under evaluation. Do this by plotting data points representing optimal buffer width for each buffer unit, as well as the shared lines between buffer units, and connect them. Extend the optimal buffer width line upstream beyond the critical in-stream habitat being protected for a distance equal to the width of the most upstream buffer unit in an arc. Also, map a continuous line that delineates Zone 1 using criteria detailed in Appendix A-8.

11. Identify on the base map unstable stream bank segments if any are present.

After completing the 11 steps, a riparian buffer for water quality on the project site will be delineated.

Section B: Riparian Buffer Design for Wildlife Habitat

In addition to implementing a riparian buffer for water quality functions, the landowner may want to preserve, enhance, reclaim, or restore habitat for wildlife in the riparian zone. These two objectives can be compatible if additional planning and design measures for wildlife are implemented (USDA NRCS 1999).

Buffers planned for water quality will have varying levels of habitat value for different wildlife species depending on buffer width, connectivity with other habitats, and structural characteristics of existing or introduced vegetation. Water quality buffers, which are typically rather narrow, may be sufficient to meet the habitat needs of some small bodied bird and mammal species, reptiles, amphibians, and insects (fig. 14). However, for most species, narrow buffers are a small but critical component of larger, more complex home ranges or lengthy migration corridors.

Nevertheless, implementing a buffer to improve water quality is an important first step in conserving habitat for wildlife. Water quality buffers protect critical watershed functions essential to maintaining healthy riparian ecosystems and thus, productive habitat. **Completing Section A is a first step in developing a riparian buffer plan for wildlife habitat.**

For user convenience, Section B will use the same three phase nine step NPPH process and water quality buffer evaluation protocol detailed in Section A. Thus, planning a riparian buffer for water quality and wildlife habitat can be done simultaneously. To eliminate duplication, only those wildlife and wildlife habitat data requirements that must be added and integrated into the Section A planning process will be discussed below.

Figure 14. Narrow riparian buffers can provide habitat needs for a variety of species. *Photo by Susan Buffler.*

Phase 1: Data Collection and Analysis

Document Landowner's Level of Participation

The possibilities for preserving, enhancing, or reclaiming/restoring wildlife habitat in riparian buffers designed to meet water quality objectives are highly dependent on landowner willingness/ability to participate in wildlife conservation. Landowner willingness/ability has been grouped into three levels as described below.

Level 1—the landowner's primary objective is to improve water quality. Thus, a buffer designed for water quality meets landowner objectives. The landowner is not willing, does not have the resources, or cannot afford the removal of additional land from production to conserve wildlife in the project site.

Level 2—the landowner's primary objective in implementing a riparian buffer is to improve water quality. They are also willing or able to preserve, enhance, or reclaim/restore wildlife habitat within the confines of the buffer planned for water quality. The landowner may specify buffer habitat for a particular species (for example, Columbia sharptail grouse) or may simply want to improve habitat for a diversity of species. However, the landowner cannot afford, or does not want, to widen the riparian buffer designed for water quality functions that accommodate wildlife.

Level 3—the landowner has co-equal objectives for implementing a riparian buffer-improving water quality and habitat for wildlife. The landowner is willing to preserve, enhance, reclaim/restore, and where required, widen the buffer to conserve wildlife habitat. In addition, the landowner is willing to consider connecting the riparian buffer to other habitat patches, corridors, and conservation practice areas on his/her property, and where practical, connects to adjacent property owned by others.

The three levels of landowner willingness/ability to participate in wildlife conservations as described above will be used later in the protocol worksheet to match level of willingness/ability with appropriate land use and management practices for each of the three riparian buffer use zones. However, NRCS biologists and conservation partners are encouraged to discuss with those landowners participating at Level 1 the additional economic, environmental, social, and psychological benefits of participating at Level 2 or 3. A summary of these benefits is available in USDA NRCS (1999).

Delineate the Planning Area

For most wildlife species, the project site will be a fraction of the larger landscape that meets their life requisites. The project site will also be a component of the larger landscape structure comprised of patches and corridors and a matrix that sustains a diverse community of plant and wildlife populations. Thus, it is important to place the habitat characteristics of the riparian buffer project site within its watershed context. Delineating the general planning area boundary to include watershed scale context is particularly important for Level 3 landowners with wildlife conservation as a primary riparian buffer objective. When delineating a riparian buffer planning area boundary for wildlife, add the following to the watershed scale data list recommended for water quality buffers in Section A:

- Location(s) of threatened or endangered species (T or E) primary or secondary habitat
- Location(s) of stated listed S-1, S-2, or S-3 species of concern
- Wildlife migration corridors
- Critical wildlife summer or winter range(s) and traditional nesting, calving, fawning, or birthing sites

- State delineated Wildlife Management Units
- Public or private lands managed for wildlife

Information sources for the items listed above include US Fish and Wildlife Service, State Division of Wildlife Resources, State GAP maps and related data, and State Natural Heritage Program databases.

Adjustments to Planning Area Boundary

Frequently, when planning a riparian buffer for wildlife, the planning area boundary must be expanded to respond to a particular species' habitat requirement or landscape-scale conditions that affect buffer habitat function (for example, an upstream dam or water diversion). Often, adjustments to the planning-area boundary are required when a species of conservation interest has a large home range, accommodating migration routes within the watershed, or considering linkages between the project site and adjacent habitat patches.

Delineate the Project Area

In most cases, the project boundary will be the same boundary delineated for water quality. However, it may be necessary to expand the boundary for landowners participating in wildlife conservation at Level 3.

Create a Base Map

The same base map(s) (1:660 scale) created for a water quality buffer project that includes a watershed scale map (1:24,000 scale) can be used for planning wildlife habitat in riparian buffers.

Products

- ○ Landowner's level of commitment to wildlife conservation is documented.
- ○ Mapping format, scale, and precision and role of technology are determined.
- ○ Base map(s) with planning area boundary and project boundary.
- ○ Preliminary identification of wildlife habitat problems and opportunities documented on base map(s) and in-field notes.

Step 1: Identify Problems and Opportunities

Planning Standard

Planning group or landowner wildlife and wildlife habitat problems and opportunities are clearly identified and documented.

The landowner, resource professionals, and if the project is a collaborative effort, other conservation partners should all be involved in identifying wildlife habitat problems and opportunities within the project boundary.

A common example of a problem in the application area is a water quality buffer within which the dominant vegetation is an invasive species (for example, Russian olive or salt cedar) or a species of little habitat value for wildlife. An example of an opportunity would be the possibility of linking the riparian buffer to an adjacent large patch of ungrazed shrub-steppe. Procedures for identifying problems and opportunities for wildlife and water quality can be conducted simultaneously.

Step 2: Determine Objectives

Planning Standard

Planning objectives are clearly stated and documented.

The level of landowner willingness/ability to participate in wildlife conservation as part of a water quality riparian buffer project, as previously described in the Pre-Planning Step, establishes the baseline objective. For those landowners participating at Level 1 and 2, the buffer planned for water quality delineates the footprint within which management activities designed to meet more specific wildlife objectives can occur. For Level 3, it defines the management core that may be expanded and connected to other on- and off-site habitats. Landowners willing to participate at Level 2 or 3 may specify more specific wildlife and habitat objectives.

Landowners within the application area frequently specify objectives that emphasize game species and the habitat that supports them. Typical landowner objectives include:

- Protect existing high quality game species habitat.
- Increase particular habitat characteristics such as food, cover, reproductive sites, or security that are presently limiting the population of game species.
- Increase and maintain game species populations at carrying capacity levels.

Protection of T or E species and their habitats becomes an objective if they are present in the project area because the law mandates it. In projects where T or E species are involved, formal consultations are required. The US Fish and Wildlife Service will respond to the action agencies' Biological Assessment with their own Biological Opinion. The Biological Opinion will identify "reasonable and prudent" conservation alternatives from which NRCS (or other consulting agency) can select or use as a basis for negotiation.

Protection of state listed species of concern and their habitat, if present in the project area, should also become an objective. Further, ecologists and wildlife biologists suggest that the typical game species-focused objectives of landowners in the application area be expanded to accommodate a diversity of native non-game species. Of particular importance are individual species that are sensitive to habitat fragmentation and human disturbance.

Final wildlife and wildlife habitat objectives are established by the landowner in collaboration with biologists and frequently, other Non-Governmental Organization (NGO) conservation partners. The planning team will develop wildlife and wildlife habitat objectives that are realistic, specific, and measurable, such as restoring a specified percent of the project site to native riparian habitat within 5 years, controlling an invasive non-native plant species, or increasing a specified percent of the number of nesting birds of a particular species. These types of objectives become the benchmark for evaluating project success.

Products

- ○ A vision statement (future desired condition) for wildlife and its habitat.
- ○ Measurable objectives for wildlife and wildlife habitat.

Step 3: Inventory Resources

Planning Standard

Sufficient data and information are gathered to analyze and understand wildlife and wildlife habitat conditions in the planning area.

The general intent of the wildlife and wildlife habitat resource inventory is to describe existing (benchmark) habitat conditions within the riparian buffer project boundary.

Buffer Mapping Units

The buffer mapping units used as sampling plots in the water quality buffer inventory are widened and used for the wildlife habitat inventory and analysis. The buffer unit is an appropriate sampling scale to generate data of sufficient detail and accuracy for the final analysis and planning of wildlife habitat buffer functions (Buffler 2005; Rich 2002) (fig. 15). Width adjustments to buffer units for wildlife habitat inventory and analysis include the following:

- Extend the buffer unit width to the landward side of the buffer boundary delineated for water quality projects where the landowner is participating at Level 1 or 2.
- Extend the buffer unit width to the project boundary for landowners participating at Level 3.

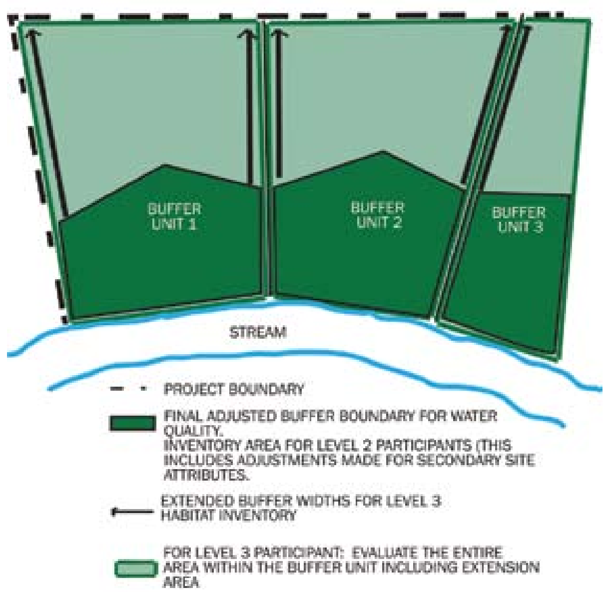

Figure 15. Buffer width adjustment diagram.

The discussion of Step 3—Inventory Resources and Step 4—Analyze Resources reflects the design of the Wildlife Habitat Data form, which combines both Inventory (data collection) and Analysis (rating for each of the Primary Site Attributes and Adjustment Factors) in a matrix format. The protocol used to inventory, analyze, and map existing condition for water quality is used for wildlife habitat. Inventory and Analysis data are recorded for each buffer mapping unit on Wildlife Habitat Data forms. Wildlife Habitat Data forms and useful references are included in Appendix B.

Numerous researchers have established a correlation between the condition of ecological functions in riparian and wetland ecosystems and their value as habitat for wildlife (Bergland 1999; Chambers and Miller 2004; Hammer 1992; Keate 2004; Rich 2002; Weller 1987). Paige and Ritter (1999) suggest a similar correlation between habitat condition and habitat value for shrub-steppe plant communities. A subset of the site attributes (primary site attributes) abstracted from the literature (Bergland 1999; Paige and Ritter 1999; Rich 2002; USDA NRCS 1999; USDI BLM 1998) has been developed to estimate ecological functioning condition and wildlife habitat value for plant communities in the application area.

Primary site attributes are defined as an individual site attribute (for example, percent of invasive exotic plant species in the overall plant community found in the buffer unit) or a composite of several attributes (for example, plant community vigor) that are reliable predictors of the general functional condition of a plant community. Primary site attributes selected for use in this protocol include:

- Plant community vigor:
    - Hydrology (riparian)
    - Natural disturbance regimes (upland)
    - Native vegetation
    - Vegetation structure
    - Range of age classes (dominant riparian woody plants)
- Level of disturbance/fragmentation
- Abundance of exotic plants
- Ratio of observed to expected riparian obligate and dependent breeding land bird species

Primary site attributes and mapping categories are described below.

Primary Physical and Biological Site Attributes (Buffer Unit Scale)

Plant Community Vigor

Plant community vigor is a composite of several hydrologic and ecological factors including hydrological processes (riparian zone), natural disturbances (uplands), native vegetation, vegetative structure, and range of age classes of dominant woody riparian plants. A diverse community of native plant species (greater than 90 percent of sample plot), with the appropriate vegetative layers for the plant community type and natural disturbances (flooding) operative, support a greater diversity of wildlife than sites without these characteristics (McMahon 1987; Paige and Ritter 1999; Rich 2002).

Level of Human Induced Disturbance/Fragmentation

Human-induced disturbance/fragmentation alters natural ecological functions (Harris 1984). In general, landscapes with high levels of human induced disturbance/ fragmentation (for example, structures, roads, dams, diversions, trails, agriculture, and unmanaged grazing) are reduced in habitat value for most native wildlife species (Gardner and others 1999; Keate 2004; Paige and Ritter 1999; Soule 1991).

Relative Abundance of Invasive Plants

Invasive exotic plants (for example, salt cedar, common reed, leafy spurge, white top, cheat grass, and many others) have become significant problems in the application area. With few exceptions, invasive plants are of little value for native wildlife (Keate 2004; Paige and Ritter 1999). High populations of invasive plants (greater than 25 percent surface coverage of buffer unit) are indicative of ecosystem dysfunction (Keate 2004; Paige and Ritter 1999).

Ratio of Expected Mid to Lower Elevation Riparian Obligate and Dependent Breeding Land Birds to Birds Observed (inventoried at buffer unit scale, used in planning at project scale)

A variety of indices (Karr and Dudley 1981; Karr 1991) have been developed to assess a site's biological integrity. Biological integrity is defined as the ability of a site to support and sustain a community of organisms that is integrated, adaptive, and balanced with a species composition and diversity, function, and structure comparable to that of a natural undisturbed site in the region (Karr and Dudley 1981). Rich (2002) suggests that comparing a list of riparian obligate and dependent breeding land birds that would be expected to nest in a region with a list of birds observed in riparian habitats in the same region can be used to measure the biological integrity of riparian habitat. Further, he suggests that knowledge of the ecology of those species present and absent can be used to determine conservation priorities and restoration needs.

Most riparian obligate and dependent breeding land birds are small bodied, have small territories, cohabit riparian patches with other species, and respond quickly to changes in habitat quantity and quality. A diverse assemblage of riparian obligate and dependent species can inhabit relatively short lengths—300 to 600 lineal ft of high quality riparian habitat (Rich 2002). Rich (2002) reports a strong correlation between riparian obligate and dependent breeding land birds and the functional condition of riparian plant communities in the western United States. He suggests that, when greater than or equal to 80 percent of expected breeding land birds are observed in riparian habitat, the habitat could be considered to be in proper functioning condition. When less than 60 percent were observed, the habitat could be considered non-functional.

Note: Shrub-steppe obligate and dependent land breeding birds were not used to estimate the functional condition of upland segments of buffers. Most shrub-steppe birds are area sensitive. They require large patches of shrub-steppe to meet their life cycle requisites. The area of shrub-steppe habitat in most riparian buffer project sites is insufficient in extent for shrub-steppe birds. However, it remains an important habitat component for some riparian species.

Primary Project Site Attribute (Project Scale)

Diversity of Age Classes in Stand Age

Diversity of age classes of dominant woody riparian species along a reach of river is an indicator of a healthy riparian plant community (USDI BLM 1998). In the application area, stand age diversity occurs over longer rather than shorter distances, particularly on streams with low sinuosity. Riparian plant communities with a diversity of age classes within the application area provide numerous niches for a diversity of riparian obligate and dependent breeding land birds (IDFG 1999). Riparian plant communities that lack diversity of age classes in the application area do not have the number or niches necessary to sustain a diversity of species.

The protocol for inventorying and mapping Primary and Secondary Site Attributes at both buffer and project site scales (measures of existing wildlife habitat condition) includes several inventory matrices and rating keys that the evaluator completes for each buffer unit. The rating information is used later in Step 4 to estimate and map the functional condition of riparian/wetland and upland plant communities in each buffer unit. Wildlife Habitat Data forms and useful references are included in Appendix B.

Target Species

Some Level 2 and Level 3 participants may specify habitat improvement for a particular species (target species) as a project objective. In these cases, a target species habitat model (a description of food cover, space, and other life requisites of the target species) should be prepared. The model will aid evaluators in identifying landscape attributes and other factors that need to be inventoried and mapped in addition to Primary Site Attributes. See Appendix B-2 for an example of a species habitat model.

A comprehensive list of wildlife species and habitat data needs is included in Appendix B-3. This inventory list will be of value to conservationists when preparing detailed management plans or designing specific restoration/reclamation projects as well as habitat enhancement plans for target species.

Products (see case study on CD)

○ Completed Wildlife Habitat Data Forms

If a target species is specified, complete Species/Habitat Model.

Step 4: Analyze Resources

Planning Standard

The benchmark conditions for wildlife and wildlife habitat in the project area are documented. Results are displayed in easily understood formats depicting current natural resource conditions, physical characteristics of the planning area, and potential conditions.

In the Analysis step, the evaluator uses the data collected on wildlife habitat data forms and recorded on maps to rate the ecological functioning condition of the plant communities within each buffer mapping unit. Buffer mapping unit ratings are aggregated for the entire project area and ratings for the entire project area are mapped. Professional expertise, handbooks, manuals, web sites, and worksheets are used in the analysis process.

The protocol for analyzing inventory data is patterned after "A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas" (USDI BLM 1998) with additional adaptations from Montana Wetland Assessment Method (Berglund 1999) and UDOT Wetland Functional Assessment Method (Johnson and others 2005).

The analysis step in the protocol estimates the functional condition of the riparian/wetland and upland plant communities of each buffer unit using the previously described Primary Site Attributes. Evaluators review inventory maps and data forms completed in Step 3 for each buffer unit. The Ecological Functional Condition Matrix is used to combine and analyze these attributes and estimate a functional condition for each buffer unit. Evaluators use references, reference sites, and best professional judgment in interpreting the inventory data. In projects where more than one evaluator is doing the assessment, discrepancies in ratings among evaluators will inevitably occur. When they do occur, evaluators should review field notes and through discussion, agree on a rating for the buffer unit in question. Three categories of functioning condition are used in the rating system (after USDI BLM 1998):

- Proper Functioning Condition
- Functional-at risk
- Non-Functional

Definitions follow for each of the three rating categories used by BLM and RB Handbook rating guidelines, which use data and maps previously described.

Proper Functioning Condition (PFC)

Definition—A properly functioning riparian/wetland community will "dissipate stream energy associated with high water flows thereby reducing erosion and improving water quality, filter sediments, capture bed load and aid floodplain development, improve flood water retention and ground water recharge, and develop root masses that stabilize stream banks against cutting action in accordance with its capacity and potential. It has a high potential to withstand relatively high energy flows" (USDI BLM 1998).

General RB Handbook Rating Guidelines

(PFC-Riparian/Wetland)

The riparian/wetland plant community in a buffer unit is considered to be in Proper Functioning Condition if it meets the following criteria: plant and plant community vigor is high, the level of human induced disturbance is low, invasive exotic plant species occupy less than 10 percent of the riparian/wetland community in the buffer unit, and there is a diversity of stand ages. The ratio of observed to expected riparian obligate or dependent breeding land birds is greater than 80 percent. Areas within a buffer unit or the project site that are in proper functioning condition are assumed to have the highest habitat value for native wildlife species and should be preserved.

(PFC-Upland)

An upland plant community is considered to be in Proper Functioning Condition if it meets the following criteria: plant community vigor in the buffer unit is rated high, the level of human disturbance/fragmentation is low, and less than 10 percent of the buffer unit is occupied by invasive exotic plant species.

Functional-At Risk (FAR)

Definition—A Functional-At Risk (FAR) riparian/wetland plant community may possess some or even most of the elements of a PFC community but at least one of its attributes/processes gives it a high probability of degradation with a relatively high flow rate (USDI BLM 1998).

General RB Handbook Rating Guidelines

(FAR-Riparian/Wetland)

The riparian/wetland plant community in a buffer unit is considered to be Functional-At Risk if it meets the following criteria: plant community vigor is rated as moderate, human induced disturbance/fragmentation is moderate, greater than 10 percent but less than 25 percent of the buffer unit contains invasive vegetation, and the ratio of observed to expected riparian obligate and dependent breeding land birds is less than 80 percent to greater than 60 percent. A diverse stand age may or may not be present. Areas within the buffer unit and project site rated as Functional-At Risk are assumed to have moderate habitat value and could be enhanced through proper management.

(FAR-Upland)

An upland plant community is considered to be Functional-At Risk if it meets the following criteria: plant community vigor in the buffer unit is rated moderate, level of human induced disturbance/fragmentation is moderate, and greater than 10 to less than 25 percent of the buffer unit is occupied by invasive plants.

Nonfunctional (NF)

Definition—A Nonfunctional riparian/wetland plant community clearly lacks the elements listed in the PFC definition (USDI BLM 1998).

General RB Handbook Rating Guidelines

(NF-Riparian/Wetland)

A Nonfunctional riparian/wetland plant community would meet few of the criteria above. Rather it would be characterized by low plant community vigor, a high level of human induced disturbance, greater than 25 percent of the buffer unit is occupied by invasive exotic plant species, and the ratio of observed to expected riparian obligate and dependent breeding land birds is less than 60 percent. Areas rated as nonfunctional require substantial reclamation if they are to be of value to a diversity of wildlife species.

(NF-Upland)

An upland plant community is considered Non-Functional when it clearly fails to meet the upland PFC criteria above.

Adjustment Factors

In addition to Primary Site Attributes, two additional factors are used to refine the delineation of Ecological Functional Condition Ratings on the base map. The first adjustment is made for large patches of invasive exotic plant species. The second adjustment refines the mapped outlines of Ecological Functional Condition Ratings across buffer mapping unit boundaries. The two adjustments result in a final map that more accurately reflects on-site conditions. A brief discussion of adjustment factors follows.

There may be large patches of invasive exotic vegetation that adversely affects ecological function and wildlife habitat quality. When analyzed in detail, these specific areas may warrant a functional condition rating that differs from the general (unadjusted) rating for the buffer unit within which it resides. Specific area, single attribute adjustments are made by using the Ecological Functional Condition Adjustment Key.

On the Unadjusted Ecological Functional Condition Ratings Map, ratings for plant communities are artificially delineated by buffer unit boundaries. Abutting buffer units may have different functional condition ratings for a plant community and the change is shown graphically to occur at the buffer unit boundary (for example, PFC abuts FAC). The buffer unit construct and graphic presentation does not reflect the biomorphic patterns of ecological change that occur in the natural landscape.

To more accurately portray on-site ecological conditions, adjustments to the mapped pattern of functional condition ratings need to be made at the project scale across buffer unit boundaries. Procedures for making these adjustments accompany the Ecological Function Condition Adjustment Key.

The evaluator completes the Analysis Step by using the Ecological Functional Condition Rating section of the above Data Form and the rating guidelines to estimate the functional condition of the riparian/wetland and upland plant communities in the buffer unit. The unadjusted and adjusted functional condition ratings are then mapped on separate base sheets.

Products (see case study on CD)

- Completed Functional Rating Forms and Maps of Unadjusted and Adjusted Functional Condition Ratings

Phase 2: Decision Support

Step 5: Formulate Alternatives

Planning Standard

Alternative plans (treatments) are developed to meet the wildlife and wildlife habitat objectives of the riparian buffer project.

The emphasis of Section A of the RB Handbook was on the proposed protocol for determining appropriate riparian buffer widths and recommending land use and management design guidelines for riparian buffers for water quality functions in agricultural landscapes. **Section B presents a science-based protocol for determining wildlife habitat conservation and management recommendations responsive to**

project site functional conditions and varying levels of landowner willingness/ability to participate in wildlife conservation. The protocol for planning for wildlife and wildlife habitat is tiered to Section A Water Quality Protocol.

The protocol for determining appropriate conservation and management recommendations and land use zones for wildlife and wildlife habitat in riparian buffers facilitates a balance between riparian protection and agricultural production. A balance between conservation and production is achieved in several ways:

- Variable levels of participation in wildlife conservation based on landowner objectives
- Core habitat (water quality buffer)
- Habitat conservation and management responsive to existing buffer plant community functional condition
- Recommended (Level 1) and regulated zones of use within the buffer (Levels 2 and 3)
- Conservation and habitat management recommendations for the agricultural, ranching, or exurban matrix (Level 3)

Developing wildlife habitat management recommendations responsive to existing habitat functional conditions and wildlife populations is fundamental to wildlife conservation (Leopold 1933). The concept of variable-width buffers for wildlife conservation with variable management strategies and zones of regulated land use is well developed in research literature (Knight and Gutzwiller 1995; Soule 1991; Thomas and others 1979).

Variable-width buffers, unlike fixed-width buffers, provide better conservation of water quality and wildlife habitat without over regulation of the resource. The RB Handbook protocol specifies three general wildlife habitat management directives:

- Preservation
- Enhancement/rehabilitation
- Reclamation/restoration

These management directives are commonly used by the NRCS and conservation partners when developing conservation plans. Definition of these terms and illustrations follow.

Preservation (PFC)—The protection of PFC plant communities to conserve their inherent value as habitat for native wildlife species through management and land use specifications. Land use Zone 1 with accompanying regulations (fig. 16).

Enhancement/Rehabilitation (FAR)—The stabilization of plant communities to arrest their declining value as habitat for native wildlife species and initiate a successful trajectory toward properly functioning condition through revegetation and land use specifications. Land use Zone 2 with accompanying regulations (fig. 17).

Reclamation/Restoration (NF)—The reconstruction of riparian and upland landscapes and plant communities to prevent further degradation (fig. 18).

Products (see case study on CD)

○ A map delineating general wildlife habitat management guidelines and land use zones with accompanying recommendations (including target species when specified) for the buffer unit tiered to the level of landowner willingness/ability to participate in wildlife conservation.

Figure 16. Example of riparian buffer with a preservation directive. *Photo by Craig Johnson*.

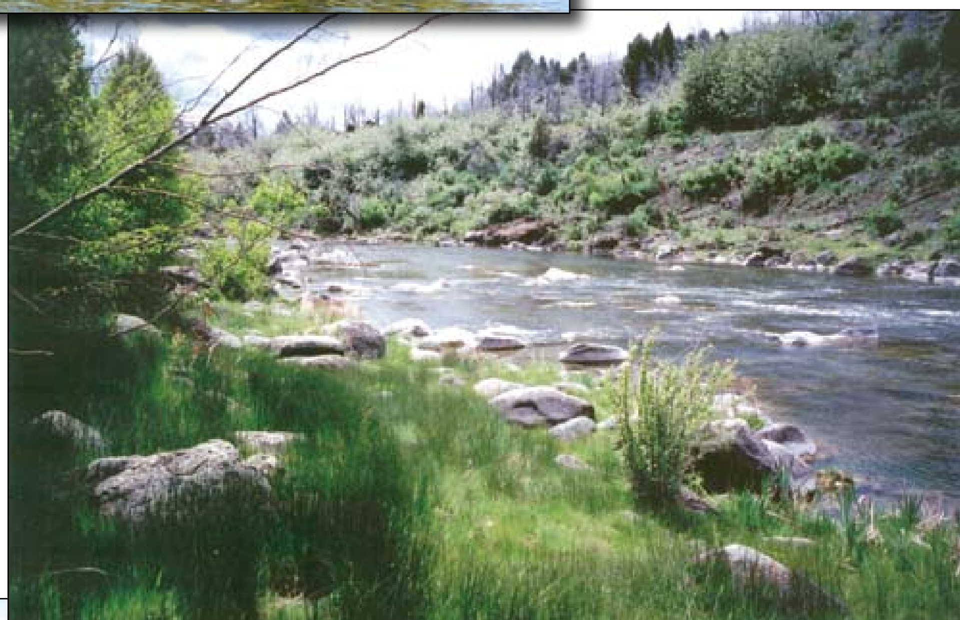

Figure 17. Example of a riparian buffer with an enhancement/ rehabilitation directive. *Photo by Craig Johnson*.

Figure 18. Example of a riparian buffer with a reclamation/restoration directive. *Photo by Susan Buffler*.

Buffer Planning Protocol—Wildlife Habitat

The following protocol has been adapted from Kleinschmidt Associates (1999), Bergland (1998), and Johnson and others (2005) and modified to accommodate application area hydrologic, ecological, and habitat requirements of riparian obligate and dependent breeding land birds after Rich (2002).

The protocol assigns habitat management directives and land use specifications to riparian and upland plant communities identified in each buffer unit. Habitat management directives and land use zones are tiered to landowner willingness/ability to participate in wildlife conservation. In addition, the protocol recommends management directives for target species (when specified by the landowner) tiered to plant community function rating.

Trained NRCS field staff and frequently, other conservation partners, will be conducting the riparian buffer evaluation. In general, desktop components of the evaluation can be completed by non-scientists, but field evaluation components require trained NRCS professionals or other qualified scientists (for example, ecologists, wildlife biologists, or resource trained landscape architects).

General Note: The buffer evaluation protocol for wildlife is the same as the protocol used for water quality. The first 11 steps are used in both water quality and wildlife protocol. The following steps are added to specifically address wildlife objectives, levels of landowner participation in wildlife conservation, ecological functioning condition of plant communities, zones of use, and management recommendations. Completion of the buffer planning protocol for water quality is required before initiating buffer planning for wildlife habitat.

Protocol Steps

Pre-Planning Steps

- On the base map, locate specific problems and opportunities for wildlife and/or habitat.
- Articulate all general wildlife conservation objectives (and species specific objectives, if applicable).
- Delineate the boundaries of riparian/wetland and upland plant communities in the buffer unit. Use aerial photography, NRCS soils maps, plant lists in Appendix B-4, and field reconnaissance to complete this task.

Planning Steps

1. Determine the landowner willingness/ability to participate in wildlife conservation.
2. Determine whether or not federally listed T and E plant or wildlife species are present on the project site.
3. Determine whether or not state listed plants or wildlife species of concern are present on the project site.
4. Complete the Plant Community Vigor inventory matrix for each buffer unit. Refer to Appendix B-5 for plant survey protocol and Appendix B-4 for lists of native riparian and upland plants.
5. Complete the Plant Community Vigor Rating matrices (one for riparian and one for upland) using responses from Step D above for each buffer unit.
6. Complete the Level of Human Induced Disturbance matrix for the buffer unit.
7. Complete, for each buffer unit, the Invasive Exotic Vegetation matrices (one for riparian and one for upland).
8. Complete the Habitat Suitability Rating for Riparian Obligate and Dependent Breeding Land Birds matrix. Refer to Appendix B-6 for the land bird survey protocol

and Appendix B-7 for a list of riparian obligate and dependent breeding land birds native to riparian habitat in the study area.

9. Answer the age class diversity question for the riparian plant community in the buffer unit Primary Project Scale Attribute Section. The evaluator will fill in the rating box after all buffer units have been inventoried and a determination has been made regarding diversity of age classes for the entire project site. If the observed stand age diversity is less than expected, the buffer unit percent total function points will be modified in Step 10 below.
10. Use the Ecological Function Condition Key to calculate the Unadjusted Ecological Functional Condition Rating for the riparian/wetland and upland plant communities for the buffer unit. Map the Unadjusted Ecological Functional Condition Ratings for buffer unit on the base map. The Unadjusted Ecological Functional Condition Rating for riparian/wetland and upland plant communities is a generalized rating that considers the relatedness of four Primary Site Attributes and one Primary Project Scale Attribute within the buffer unit. When individual buffer units are aggregated and mapped, the composite picture is useful in characterizing the functional condition of the two plant communities across the project site.
11. Adjust the Unadjusted Ecological Functional Condition Ratings for the riparian/wetland and upland communities for all buffer units (the project sites) using the two step process described in the Ecological Functional Condition Adjustment Key. Map the Adjusted Ecological Functional Condition Ratings for the entire project site. The mapped adjustments are required to increase functional condition map accuracy and facilitate the preparation of appropriate place specific wildlife habitat recommendations.
12. Use the Wildlife Habitat Management Recommendations and Land Use Zone Key to delineate wildlife habitat management and land use zones tiered to landowner willingness/ability to participate in wildlife conservation. Map the Wildlife Habitat Recommendations and Land Use Zones for the landowner level of participation in wildlife conservation. **When all 12 steps are completed, a riparian buffer for wildlife tiered to landowner willingness to participate will be delineated.**

Step 6: Evaluate Alternatives

Step 7: Make Decisions

These two steps are not included in the RB Handbook as they are not directly related to the intended purpose of the Handbook. These steps are implemented by NRCS personnel, conservation partners, and landowners when the riparian buffer has been planned and designed.

Phase 3: Application

Step 8: Implement Plan

Step 8 is not included in the RB Handbook for reasons stated above.

Step 9: Evaluate Plan

A detailed discussion of plan evaluation is beyond the intended scope of this handbook. However, several important points should be mentioned.

Once implemented, riparian buffers for wildlife conservation (for Level 2 or 3 participants) should be monitored and evaluated to determine if project wildlife objectives are being achieved and to guide future management activities. The following monitoring activities are recommended:

- Annual monitoring of plant community composition and structure within the buffer. Consult NRCS field biologists when monitoring the project site. The protocol described in Appendix B-5 or an appropriate alternative NRCS protocol should be used. Data collected over a period of years can be used to estimate trends in plant community vigor and by inference, habitat value for riparian obligate or dependant species.
- Annual monitoring of riparian obligate or dependent breeding land birds. Monitoring should estimate changes within the buffer in species composition and abundance. The protocol detailed in Appendix B-6 or other appropriate protocols as described in Ralph and Scott (1981) should be used. State Division of Wildlife Resource biologists should be consulted when designing and implementing a monitoring program. Trends in bird species composition within buffer units or the project site suggested by the data collected can be indicative of changes in habitat and may suggest the need for adaptive management.

An informational note: Riparian obligate or dependant birds respond quickly to changes in the riparian plant community (Rich 2002) and are a useful measure of habitat condition. However, a species absence from a project site or low population densities could be a response to numerous factors, including large numbers of predators, limited aerial extent of riparian vegetation, or high levels of human activity (Rich 2002). Further, some species response to vegetation change may be delayed for years until vegetation has matured.

- Annual monitoring of populations of a target species. If the landowner has identified increasing populations of a specific species as a project objective, trends in the population of that species should be monitored in the project area. Using previously identified protocols and consulting with a wildlife biologist is recommended.
- Annual monitoring of invasive exotic plant species populations. Invasive plants are a significant problem in riparian and wetland ecosystems in the application area and are a serious threat to wildlife habitat integrity. Consult with NRCS biologists and county extension agents when monitoring invasive plant species.

Adaptive Management

Riparian buffers for wildlife conservation, like other NRCS conservation practices, require long term management if they are to continue to provide the functions for which they were designed. Management techniques should respond to changes in buffer function and structure, both within and outside the buffer, as evidenced in monitoring data. In the application area, the most common causes of change in function and structure include:

- Agricultural practices
- Unmanaged livestock grazing
- Dams and diversions
- Urbanization
- Road construction
- Recreation
- Wildlife

(Western Division of American Fisheries Society, 1982 as cited in Gardner and others 1998)

The source(s) of impact must be dealt with to prevent further riparian buffer habitat degradation. In some cases, the causes of habitat degradation may be outside the buffer or project boundary or they may not be readily apparent. Additional research may be required before the cause(s) is identified and an appropriate solution is found. Frequently, the solution involves cooperation from adjacent landowners or government agencies.

Adaptive management in riparian buffers can involve the use of both active and passive techniques. Passive techniques typically involve protection of the buffer from adverse impacts, often by fencing, thus allowing natural revegetation and succession to occur. Passive techniques are most applicable in buffers that have not been seriously degraded, in other words, stream flows have not been altered, the channel is not incised, the seed bank is intact, and there are few invasive plant species present. In degraded buffers, more active restoration measures may be necessary and include, but are not limited to, the measures listed in the following column (Gardner and others 1999) (the list has been modified for the RB Handbook) (fig. 19).

Adaptive management in degraded buffers:

- Prescribed burns
- Forestry practices
- Vegetation plantings
- Site grading
- Beaver management
- Upland management
- Mitigation wetland construction
- Grazing strategies
- Recreation planning
- Bank stabilization

Additional recommendations:

- Simulated flooding
- Control of invasive species
- Artificial nesting structures
- Bat boxes

Figure 19. Active restoration, such as planting willow stakes, may be necessary in some riparian buffers. *Photo by Gary Bentrup.*

Summary of Section B

Numerous studies suggest a relationship between buffer width, functional and structural conditions of riparian buffer, and buffer value as habitat for wildlife (Rich 2002; Yahner 1988) (fig. 20). Research studies have been conducted to determine adequate riparian buffer widths for various wildlife species in many geographic areas (Fischer and Fischenich 2000). Recommended buffer widths range from 30 to greater than 600 ft depending on wildlife species, riparian plant community type, and other factors.

For most wildlife species, and in most riparian plant communities, buffer widths for wildlife conservation are larger than those recommended for water quality functions (Kleinshmidt Associates 1999).

The real issue affecting riparian buffer width for wildlife conservation in working landscapes is landowner willingness/ability to participate in wildlife conservation. Most landowners are hesitant to participate if wildlife conservation buffers require taking additional land out of production—land beyond what would be required to satisfy water quality buffer functions. Thus, landowner willingness/ability to participate in implementing buffers for wildlife is, in reality, the principle determinate of buffer width. Levels of landowner willingness/ability have been grouped into three categories: Level 1-buffer designed and managed for water quality only; Level 2-wildlife conservation within water quality buffer footprint; and Level 3-wildlife conservation within and beyond water quality buffer footprint.

Numerous studies suggest that, like width, the ecological structure and functional condition of riparian buffers are significant factors affecting wildlife habitat value (Gardner and others 1999; Rich 2002). Because buffer width is largely determined by landowner willingness/ability to commit land to wildlife conservation, the protocol in the RB Handbook has emphasized assessment of existing buffer functional condition as a measure of present habitat value. Existing buffer functional condition is also used to determine wildlife habitat management recommendations and land use specifications.

The habitat value of existing vegetation and abiotic features in the buffer are assessed by estimating plant community vigor (a composite of hydrologic and ecological factors), level of human disturbance/fragmentation, relative abundance of invasive vegetation, and presence or absence of riparian obligate or dependent breeding land birds. These individual factors, when combined in a matrix, are used to estimate the ecological functional condition of the riparian buffer (PFC, FAR, or NF). Estimated functional condition is used as a surrogate measure for habitat quality. The assumption is that riparian buffers in PFC are more likely to provide habitat for native riparian obligate and dependent species, particularly birds, than FAR or NF habitats (Rich 2002). Functional condition ratings are then tiered to management recommendations (preservation, enhancement/rehabilitation, or restoration/reclamation), zoning, and land use specifications similar to those for water quality. When the buffer assessment is completed, functional conditions across the buffer are mapped. Use zone with land use specifications and management recommendations are also mapped.

Figure 20. Larger wildlife generally requires wider riparian buffers. *Photo by Dick Rol.*

References

Barbour, M.T.; Gerritsen, J.; Snyder, B.D.; Stribling, J.B. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish. EPA 841-B-99-002. Washington, DC: U.S. Environmental Protection Agency, Office of Water. [Not paged].

Bentrup, G. 2003. Personal communication. USDA National Agroforestry Center, Lincoln, NE.

Berglund, J. 1999. Montana wetland assessment method. Helena, MT: Montana Department of Transportation. 27 p.

Buffler, S. 2005. Synthesis of design guidelines and experimental data for water quality function in agricultural landscapes in the Intermountain West. Logan, UT: Utah State University. 48 p. Thesis. http://www.unl.edu/nac/research/2005Buffler.pdf [Date accessed: May, 2007].

Chambers, J.C.; Miller, J.R. 2004. Great Basin riparian ecosystems: ecology management, and restoration. Washington, DC: Island Press. 320 p.

Chase, V.P.; Deming, L.S.; Latawiec, F. 1997. Buffers for wetlands and surface waters: a guidebook for New Hampshire municipalities. Audubon Society of New Hampshire. 82 p.

CFIFCD. 1996. A new era for irrigation. Committee on the Future of Irrigation in the Face of Competing Demands. Washington, DC: National Academy Press. 216 p.

Collins, J.N.; Stein, E.; Sutula, M. 2004. California rapid assessment method (CRAM) for wetlands, v 3.0: user's manual and scoring forms. Oakland, CA: Southern California Coastal Water Research Project and San Francisco Estuary Institute http://www.wrmp.org/docs/cram/DRAFT_CRAMv3.pdf [Date accessed: February, 2005].

Connely, J.W.; Reese, K.P.; Schroeder, M.A. 2003. Monitoring of greater sage-grouse habitats and populations. Pub. 80. Moscow, ID: University of Idaho, College of Natural Resources Experiment Station. 54 p.

Davies, S.; Sowles, J. 1997. The value of headwater streams and the effects of forest cutting practices on stream ecology. Augusta, ME: Maine Department of Environmental Protection. 10 p.

Dubos, R. 1973. A god within. New York, NY: Scribner Book Company. 326 p.

Fahrig, L. 1997. Relative effects of habitat loss and fragmentation on population extinction. Journal of Wildlife Management. 61(3): 603-610.

Fischer, R.A.; Fischenich, J.C. 2000. Design recommendations for riparian corridors and vegetated buffer strips. EJMRRP Technical Note Series, TNEMMRP-S1-09. Vicksburg, MS: US Army Corps of Engineer Research and Development Center. 17 p.

Forman, T.T.; Godron, M. 1986. Landscape Ecology. New York, NY: John Wiley and Sons. 619 p.

Gardner, P.A.; Stevens, R.; Howe, F.P. 1999. A handbook of riparian restoration and revegetation for the conservation of land birds in Utah with emphasis on habitat types in middle and lower elevations. Pub. 99-83. Salt Lake City, UT: Utah Division of Wildlife Resources. 48 p.

Haberstock, A.E.; Nichols, H.G.; DesMeulus, M.P.; Wright, I.; Christensen, I.M.; Hudnut, D.H. 2000. Method to identify effective riparian buffer widths for Atlantic Salmon habitat protection. Journal of the American Water Resources Association. 36(6): 1271-1286.

Hammer, D.A. 1992. Creating freshwater wetlands. Ann Arbor, MI: Lewis Publishers. 448 p.

Harris, L.D. 1984. The fragmented forest: island biogeography theory and the preservation of biotic diversity. Chicago, IL: University of Chicago Press. 211 p.

IDFG. 1999. Long range management plan: Sand Creek wildlife management area. Boise, ID: Idaho Department of Fish and Game.

Johnson, C.W.; Toth, R.E. 2004. Henry's Fork agricultural corridor wildlife habitat conservation case study. Washington, DC: USDA Natural Resources Conservation Service, Watershed Science Institute. 43 p.

Johnson, C.W.; Pitts, R.; Porreca, L. 2005. Wetland functional assessment method. Salt Lake City, UT: Utah Department of Transportation.

Karr, J.R. 1991. Biological integrity: a long neglected aspect of water resource management. Ecological Applications. 1(2): 66-84.

Karr, J.R.; Dudley, D.R. 1981. Ecological perspectives on water quality goals. Environmental Management. 5(1): 55-68.

Keate, N. 2004. Functional assessment of Great Salt Lake ecosystem slope and depressional wetlands. Unpublished paper for the U.S. Environmental Protection Agency Region VIII on file at Utah Department of Natural Resources, Division of Wildlife Resources, Salt Lake City, UT.

Kleinschmidt Associates. 1999. Methods to determine optimal riparian buffer widths for Atlantic Salmon habitat protection. Report to the Maine State Planning Office, Augusta, ME. 100+ p.

Knight, R.L.; Gutzwiller, K. 1995. Wildlife and recreationists: coexistence through management and research. Washington, DC: Island Press. 389 p.

Kuchler, A.W. 1970. Potential natural vegetation map (scale 1:7,500,000). In: The national atlas of the U.S.A. Washington, DC: U.S. Geological Survey. Plates 90-91.

Leopold, A. 1933. Game management. New York, NY: Scribners Sons. 481 p.

Lowther P.E.; Douglas, H.E. III; Gratto-Trevor, C.L. 2001. Willet (*Catoptrophorus semipalmatus*). In: A. Poole and F. Gill [eds.], The birds of North America, No. 579. Philadelphia, PA: The Birds of North America, Inc. 32 p.

MacMahon, J.A. 1987. Disturbed lands and ecological theory: an essay about a mutualistic association. In: Jordan, W.R.; Gilpin, M.E.; Aber, J.D., eds. Restoration ecology. Cambridge, U.K: Cambridge University Press. 221-238.

Maret, T. 1991. Rock Creek, Idaho, after ten years: RCWP achieves on-farm success but off-site benefits marginal. EPA News-Notes. 15: 9-10.

Mee, W.; Barnes, J.; Sutton, R.; Kjelgren R.; Cerny, T.; Johnson, C.W. 2003. Water wise: native plants for intermountain landscapes. Logan, UT: Utah State University Press. 256 p.

National Research Council. 2002. Riparian areas: function and strategies for management. Washington, DC: National Academy Press. 440 p.

NatureServe. 2006. NatureServe Explorer: An online encyclopedia of life [web application]. Version 6.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: March 20, 2007).

Obedzinski, R.A.; Shaw, C.G.; Neary, D.G. 2001. Declining woody vegetation in riparian ecosystems of the western United States. Western Journal of Applied Forestry. 16(4): 169-181.

Paige, C.; Ritter, S.A. 1999. Birds in a sagebrush sea: managing sagebrush habitats for bird communities. Boise, ID: Partners in Flight Western Working Group. 52 p.

Ralph, C.J.; Scott, J.M. 1981. Estimating numbers of terrestrial birds. Studies in Avian Biology No. 6. 630 p.

Ratti, J.T.; Rocklage, A.M.; Giudice, J.H.; Garton, E.O.; Golner, D.R. 2001. Comparison of avian communities on restored and natural wetlands in North and South Dakota. Journal of Wildlife Management. 65(4): 676-684.

Rich, T.D. 2002. Using breeding birds in the assessment of western riparian systems. Wildlife Society Bulletin. 30(4): 1128-1138.

Rosgen, D.L. 1994. A classification of natural rivers. Catena. 22(3): 169-199.

Rosgen, D.L. 1996. Applied river morphology. Fort Collins, CO: Wildland Hydrology.

Schnepf, M.; Cox, C. eds. 2006. Environmental benefits of conservation practices on cropland: the status of our knowledge. Ankeny, IA: Soil and Water Conservation. 326 p.

Sigler, W.F.; Miller, R.R. 1963. Fishes of Utah. Salt Lake City, UT: Utah State Department of Fish and Game. 203 p.

Soule, M.E. 1991. Land use planning and wildlife maintenance: guidelines for conserving wildlife in urban landscapes. Journal of American Planning Association 57(3): 313-323.

Sperry. 1999. Personal communication. Program Director, Henry's Fork Foundation, Ashton, ID.

Stokes, D.; Stokes, L. 1996. Stokes field guide to birds western region. New York: Little, Brown and Company. 560 p.

Thomas, J.W.; Maser, C.; Rodick, J.E. 1979. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. USDA Agricultural Handbook No. 53. Washington, DC: U.S. Department of Agriculture, Forest Service.

USDA NRCS. 1998. Stream visual assessment protocol. Tech. Note 99-1. Washington, DC: U.S. Department of Agriculture, Natural Resources Conservation Service, National Water and Climate Center. 42 p.

USDA NRCS. 1999. Conservation corridor planning at the landscape level: managing for wildlife habitat. 190-VI-NIBH. Part 614.4. Washington, DC: U.S. Department of Agriculture, Natural Resources Conservation Service. 128 p.

USDA NRCS. 2003. National planning procedures handbook amendment 4. 180-VI-NPPH, Amend. 4. Washington, DC: U.S. Department of Agriculture, Natural Resources Conservation Service. 161 p.

USDI BLM. 1998. A user guide to assessing proper functioning condition. Technical Reference 1737-9. Denver, CO: U.S. Department of Interior, Bureau of Land Management. 35 p.

USEPA. 1995. Water quality functions of riparian forest buffer systems in Chesapeake Bay Watershed. EPA 903-R-95-00. Washington, DC: U.S. Environmental Protection Agency.

USEPA. 2000. 2000 National water quality inventory. Washington, DC: U.S. Environmental Protection Agency. http://www.epa.gov/305b/2000report/appendixa.pdf. [Date accessed: August 13, 2005].

Weller, M.W. 1987. Freshwater marshes: ecology and management. Minneapolis, MN: University of Minnesota Press. 192 p.

Welsch, D.J. 1991. Riparian forest buffers: function and design for protection and enhancement of water resources. NA-PR-07-91. Randor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry. 24 p.

West, N.E. 1988. Intermountain deserts, shrub steppes and woodlands. In: Barbour, M.G.; Billings, W.D. eds. North American terrestrial vegetation. Cambridge, UK: Cambridge University Press. 255-284.

Wigington, P.J., Jr.; Griffith, S.M.; Field, J.A.; Baham, J.E.; Horwath, W.R.; Owen, J.; Davis, J.H.; Rain, S.C.; Steiner, J.J. 2003. Nitrate removal effectiveness of a riparian buffer along a small agricultural stream in western Oregon. Journal of Environmental Quality. 32(1): 162-170.

Williams, T.T. 1991. Refuge: an unnatural history of family and place. New York, NY: Pantheon Books. 336 p.

Yahner, R.H. 1988. Changes in wildlife communities near edges. Conservation Biology. 2(4): 333-339.

Glossary

Abiotic: The non-living, or physical and chemical, portion of an organism's environment.

Agronomic: Referring to a branch of agriculture dealing with field-crop production and soil management.

Alluvial: Referring to alluvium; soil particles or similar detrital material deposited by running water.

Aquatic organisms: Organisms associated with, or living in water.

Bacteria: Single-celled or noncellular spherical or spiral or rod-shaped organisms lacking chlorophyll that reproduce by fission; important as pathogens and for biochemical properties.

Basalt: A dark gray to black dense to fine-grained (igneous) rock formed by volcanic activity.

Best management practices: Schedules of activities, prohibitions of activities, maintenance procedures, and other management activities that prevent or reduce water pollution (EPA) or other environmental concerns.

Biotic: The living portion of the environment.

Bole: The trunk of a tree.

Bureau of Land Management: An agency within the U.S. Department of the Interior that administers 261 million surface acres of America's public lands located primarily in 12 Western States.

Channelization: To straighten a moving body of water.

Coniferous forest: Forests consisting mainly of cone bearing, mostly evergreen trees and shrubs.

Conservation: A careful preservation and protection of something; planned management of a natural resource to prevent exploitation, destruction, or neglect.

Contaminants: Substances that spoil the purity of something or make it poisonous.

Cow/calf operation: An agricultural production system where cows and calves remain together until weaning.

Clinometer: Any of various instruments for measuring angles of elevation or inclination.

Critical habitat: The specific areas within the geographic area occupied by a species on which are found those physical and biological features essential to the conservation of the species, and that may require special management considerations or protection; and specific areas outside the geographic area occupied by a species at the time it is listed, upon determination that such areas are essential for the conservation of the species.

Cryptogamic soil: A thin crust made up of mosses, lichens, algae, and bacteria.

Cyanobacteria: Bacteria belonging to a large group that have a photosynthetic pigment, carry out photosynthesis, and were classified in the past as blue-green algae.

Depressional wetland: A wetland that lay within a depression in the landscape, generally draining a small surface area.

Dissolved solids: Matter suspended or dissolved in water or wastewater.

Diversion: The removal of water from a stream or river mainly for irrigation purposes.

Drift line: Evidence of flood path after receding flood water.

Duff: The partly decayed organic matter on the forest floor.

Ecosystem function: The manner in which natural assemblages process resources, affect the physical environment, and interact with other species.

Environmental Impact Statement (EIS): Analysis of the expected effects of a development or action on the surrounding natural and fabricated environment. Such statements are required for many federally supported developments under the National Environmental Policy Act of 1969.

Erosion: The process of gradual removal or rubbing away, particularly of rock and soil.

Eutrophication: The process by which a body of water becomes enriched in dissolved nutrients that stimulate the growth of aquatic plant life usually resulting in the depletion of dissolved oxygen.

Ewe/lamb operation: An agricultural production system where ewes and lambs remain together until weaning.

Exurban: A region or settlement that lies outside a city and usually, beyond its suburbs.

Feedlot: A plot of land on which livestock are usually confined and fattened for market.

Flood zone (floodplain): A plain built up by stream deposition.

Fluvial: Of, found in, or produced by a river.

Forage: Food for animals, especially when taken by browsing or grazing.

Forb: Any broad-leaved herbaceous plant that is not a grass, especially one that grows in a prairie or meadow.

Fragmentation: Breaking up of a habitat or cover type into smaller, disconnected parcels.

Functioning condition: The physical functioning of ecosystems through consideration of hydrology, vegetation, and soil/landform attributes as an assessment of health.

Fungi: Any of a major group (Fungi) of saprophytic and parasitic spore-producing organisms usually classified as plants that lack chlorophyll and include molds, rusts, mildews, smuts, mushrooms, and yeasts.

Geographic Information System (GIS): A system of computers, software, hardware, and personnel to help manipulate, analyze, and present information that is tied to a specific location.

Geomorphology: The study of the origin, development, and configuration of topographic forms.

Gray literature: Any documentary material that is not commercially published and is typically composed of technical reports, working papers, business documents, or conference proceedings.

Groundwater: Water beneath the earth's surface, often between saturated soil and rock, that supplies wells and springs.

Habitat: The place where organisms live.

High watermark: A line marking the level reached by a body of water.

Hydrology: The scientific study of the properties, distribution, and effects of water on the earth's surface in the soil, underlying rocks, and atmosphere.

Intermountain West: A large, dry territory of the United States, between the Rockies to the east and the Sierra Nevada and Cascades to the west, characterized by cold dry deserts.

Lake Bonneville: A large, ancient lake existing from about 32 to 14 thousand years ago. It occupied the lowest, closed depression in the eastern Great Basin and at its largest extent covered about 20,000 square miles of western Utah and smaller portions of eastern Nevada and southern Idaho.

Lacustrine wetland: Wetlands around lakes and reservoirs larger than 20 acres, or areas containing water depths of 6 ft that are exposed to wave action.

Lichens: A fungus, usually of the class Ascomycetes, that grows symbiotically with algae, resulting in a composite organism that characteristically forms a crustlike or branching growth on rocks or tree trunks.

Matrix: Background cover type in a landscape, characterized by extensive cover and high connectivity; not all landscapes have a definable matrix.

Micro environment: A small or relatively small, usually distinctly, specialized and effectively isolated habitat.

Microtopography: Surface features of the earth of small dimensions, commonly less than 50 ft.

Mineral flat: Wetlands recognized by their mineral soils on broad flats with 0 to 2 percent slope.

Monsoonal storms: Short duration, intense rain storms occurring during the season of high temperatures and high winds (usually July and August).

National Park Service: A U.S. agency of the Interior Department responsible for the National Parks.

Nitrogen: A common, normally colorless, odorless, tasteless, and mostly inert diatomic non-metal gas that makes up 78 percent of the Earth's atmosphere.

Neotropical: Of, relating to, or constituting the biogeographic region that extends south, east, and west from the central plateau of Mexico.

Non point source pollution: Pollution originating from many diffuse sources caused by rainfall or snowmelt moving over pollution and through the ground.

NRCS Soil Survey: The investigation, inventory, documentation, classification, and interpretation of soils.

Nutrients (for example, N, P): Any substance that plants or animals need in order to live and grow.

Oxbow: A bend in a river shaped like an oxbow (a collar for an ox used as a draft animal, consisting of a U-shaped piece of wood attached to a yoke) or the land found in the bend of a river.

Pasture: Land or a plot of land used for grazing.

Patch: A nonlinear surface area differing in appearance from its surroundings.

Perched aquifer: An aquifer that is separated from another water-bearing stratum by an impermeable layer.

Permeability (soils): The rate that a substance passes through porous medium.

Pesticide: A chemical substance used to kill harmful insects, small animals, wild plants, and other unwanted organisms.

Phosphorus: A chemical compound that performs vital functions in all known forms of life and is applied as fertilizer to crops.

Phreatophytic vegetation: Deep-rooted plants that obtain their water from the water table or the layer of soil just above it.

Physiographic region: Regions classified by their similar topographic and geologic features.

Plant key: A step by step "if/then" process of elimination to identify plants.

Playa: A nearly level area at the bottom of an undrained desert basin, sometimes temporarily covered with water.

Rain shadow: An area having relatively little precipitation due to the effect of a barrier, such as a mountain range, that causes the prevailing winds to lose their moisture before reaching it.

Ranchette: Residential land with acreage usually for a few horses or other livestock.

Remediation: The removal of pollution or contaminants from land.

Restoration: A return to an original form or condition.

Return flows: Surface and subsurface water that leaves the field following application of irrigation water.

Rill erosion: Rill erosion is the removal of soil by concentrated water running through little streamlets or headcuts.

Riparian: Transitional areas between terrestrial and aquatic ecosystems that are distinguished by gradients in biophysical conditions, ecological processes, and biota.

Riparian buffer: An area that is managed to reduce impacts of an adjacent land use.

Riparian corridor: A perennial or intermittent water body, its lower banks and upper banks, and the vegetation that stabilizes the slopes, protects the waterway from erosion and sedimentation, provides cover and shade, and maintains the fish and wildlife habitat.

Riparian dependent: These are bird species that locate 60 to 90 percent of their nests in riparian vegetation, or 60 to 90 percent of their abundance occurs in riparian vegetation during the breeding season. (Rich 2002).

Riparian obligate: These are bird species that locate greater than 90 percent of their nests in riparian vegetation, or greater than 90 percent of their abundance occurs in riparian vegetation during the breeding season. (Rich 2002).

Riverine wetland: A class of wetland that has a floodplain or riparian geomorphic setting. The water sources for the riverine class are precipitation, surface flow, and groundwater discharge. Riverine wetlands occur in floodplains and riparian corridors in association with stream and river channels.

Root crown: A mass of woody tissue from which roots and stems originate, and which are often covered with dormant buds.

Rosgen stream: A stream classification system developed by D.L. Rosgen that categorizes streams based on channel morphology so that consistent, reproducible, and quantitative descriptions can be made through field measurements. Variations in stream processes are grouped into distinct stream types.

Sand and gravel aquifer: An underground, water-bearing layer of earth, porous rock, sand, or gravel through which water can seep or be held in natural storage. Aquifers generally hold sufficient water to be used as a water supply.

Scat: Animal feces.

Sedimentary rock: Rock, most commonly sandstone, shale, and limestone, formed by the hardening of material deposited in some process.

Sedimentation: Sedimentation is the removal, transport, and deposition of detached sediment particles by wind or water.

Seeps: A spot where water trickles out of the ground to form a pool.

Sheet erosion: Removal of a fairly uniform layer of soil from the land surface by runoff water without the development of conspicuous water channels.

Shrub-steppe: A region with moisture levels adequate to support an appreciable cover of perennial grasses but not arborescent vegetation.

Sink: A process that acts to absorb or remove energy or a substance from a system.

Slope: The variation of terrain from the horizontal; the number of feet rise or fall per 100 ft measured horizontally, expressed as a percentage.

Slope wetland: Wetlands that occur where the groundwater emerges at the surface of the ground, usually on a slope or stratagraphic change.

Soil hydrologic group: A group of soils having similar runoff and infiltration potential under similar storm and cover conditions.

Soil infiltration capacity: The ability of water to move through the soil surface.

Springs: Any place where ground water discharges onto the land surface due to the intersection of the water table with the ground.

Stakeholder: Any organization, governmental entity, or individual that has a stake in, or may be impacted by, a given approach to environmental regulation, pollution prevention, energy conservation, and so forth.

Structural characteristics: The classification of vegetation by its morphological features.

Surface roughness: Irregularities of the terrain surface that determine runoff potential.

Surface water: All water naturally open to the atmosphere, concerning rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, and wetlands.

Stream impairment: Reduction in the natural functions of a stream.

Threatened and Endangered Species (T&E species): A species that is listed in the Threatened and Endangered Species Act. Endangered species are in danger of becoming extinct throughout a significant portion of their habitat range (the areas where it lives). Threatened species are those that are likely to become endangered in the foreseeable future.

Understory: The smaller vegetation (shrubs, seedlings, saplings, and small trees) within a forest stand occupying the vertical zone between the overstory and the herbaceous plants of the forest floor.

Upland land uses: Land uses in the area outside the riparian zone, generally upslope.

Urban: Relating to, or concerned with, a city or densely populated area.

Water quality : A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

Watershed: The specific land area that drains water into a river system or other body of water.

Wetlands: Lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface.

Wetland soils: Soils that are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation.

Wildlife: All living things (except people) that are undomesticated.

Zoning ordinance: Local ordinance that defines and implements land use and design standards, such as permitted uses, lot sizes, setbacks, and so forth.

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