Appendix 3.3.3 Background Riparian Information

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Riparian Functions and Values

Riparian values and functions derive from the hydrologic, geomorphic and biological processes that create riparian habitat. The interrelationship between riparian, stream and upland ecosystem processes structure and help determine riparian ecosystem functions which then determine the condition of riparian vegetation and soil. Consequently riparian function and value depends on the integrity of both upland and stream ecosystem processes.

Water Quality

Riparian vegetation both directly and indirectly influences the stream ecosystem. Riparian vegetation maintains water quality by controlling temperature, reducing sediment load and reducing and altering the quantity and quality of pollutants that reach the stream. Riparian vegetation provides shade which helps maintain appropriately cool water temperature. Net thermal radiation in relation to stream discharge is the most important determinant of water temperature. Thus vegetation that intercepts radiant light can greatly affect stream temperatures. Changes in water temperature can significantly impact stream community structure and function (Windell, 1992). Native stream biota only tolerate a specific temperature range. Temperatures that exceed a certain level or that change rapidly can be lethal to aquatic organisms. For instance optimum water temperature for western slope Colorado cutthroat trout is between 10.3^{o}C (50.5°F) and 17.0^{o}C (62.6°F) with an upper lethal temperature of 19.7^{o}C (67.5°F) while optimum temperature ranges for rainbow trout, a non-native competitor, are wider and are between 6.8^{o}C (44.2°F) and 18.2^{o}C (64.8°F) with an upper lethal temperature of 24^{o}C (75.2°F) (Bear et al., 2005). Numerous studies have demonstrated that the removal of riparian vegetation leads directly to elevated water temperatures; Burns (1972) observed a water temperature increase of 20^{o} F following the removal of riparian vegetation following road construction; Karr and Gorman (1975) recorded summer water temperatures for a wooded stream at 19^{o}C (66.2°F) compared to a nearby unshaded stream where water temperatures were 28^{o}C (82.4°F).

Riparian vegetation traps and retains sediment. Naiman and Decamps (1997) found that a riparian zone with diverse vegetation can trap 80 percent to 90 percent of sediments transported from adjacent fields. Excess sediment degrades water quality and impairs aquatic wildlife habitat by embedding stream substrate, filling pools and runs, and causing stream widening, shallowing and braiding. Excess sedimentation thereby reduces the amount and quality of habitat available to macroinvertebrates and fish for shelter, colonization, spawning, and egg laying and incubation.

Riparian vegetation and soils help maintain water quality through filtration, storage and/or transformation of pollutants. Decomposing plant material increases the organic content in soil and organic soils facilitate water purification. Organic matter helps capture and bind water borne contaminants and serves as a food resource for soil microbes that can decompose pollutants. For instance peat is a highly reactive material that has the ability to capture and hold many chemicals including nutrients, pesticides, heavy metals, and other contaminants that flow through riparian areas (Cohen, 1997).

Because of the position of riparian vegetation at the interface between upland and aquatic systems and because many of the sources of stream water quality impairment originate in upland habitat and flow downhill, riparian vegetation and soils provide essential pollution buffering and nutrient cycling functions without which stream habitat and water quality would be degraded. Peterjohn and Correll (1984) found that a 50 meter (164 feet) -wide riparian forest removed 89 percent of the nitrogen and 80 percent of the phosphorous transported in runoff from croplands into a Maryland river. A restored riparian buffer system being evaluated in central Iowa on Bear Creek was shown to remove 80 percent to 90 percent of nitrate-nitrogen and atrazine in the shallow groundwater prior to entering the stream (Schultz et al., 2007).

Water Quantity

Riparian vegetation regulates and maintains sustainable stream flows by increasing water storage and enhancing groundwater recharge. Riparian areas store water, recharge groundwater, and reduce flooding flows by acting as a sponge. During spring floods when snowmelt runoff is high and streams overflows their banks, adjacent riparian wetlands store excess runoff and overbanking floodwater which then replenish groundwater later in the season. Riparian vegetation and soil increase water storage by several processes. Above ground vegetation physically intercepts and slows runoff allowing more water to soak into the soil. Below ground plant roots increase soil porosity. Root systems of this vegetation keep pores of the soil open so that two to three times more water can enter the soil compared to a soil altered by cultivation or grazing (Schultz et al., 1995). Decaying roots and leaves of riparian vegetation, with the help of soil microbes, develop into an organic and porous riparian soil which is then able to conserve and store water. The effect is to raise the local groundwater table which then, throughout the rest of the year, discharges water back into the channel helping to maintain sustainable stream flows (Windell, 1992).

Channel Morphology and Stabilization

Riparian vegetation maintains the naturally sinuous shape of the stream channel, stabilizes streambanks, and prevents channel downcutting thus enabling a stream to overflow its banks. Overbanking flows are essential for replenishing groundwater, nutrients and sediment to riparian habitat. Vegetative root and leaf growth is thereby stimulated further increasing soil porosity, enhancing infiltration of overbank flows and precipitation runoff.

Conversely, where native vegetation has been removed and soils compacted runoff typically exceeds infiltration. By not enabling precipitation or overbank flows to infiltrate back into the aquifer the hydrologic cycle is disrupted – consequences include reduced groundwater recharge and a reduction or loss of baseflow, loss of pollution filtering function, and increased flooding. In an undisturbed forest infiltration rates are usually greater than rainfall intensity and runoff is minimal, typically less than 5 percent in a subsaturated forest (Smith, 1996; Frazer, 2005). In urban areas, where streets, buildings, and soil compaction reduce infiltration rates surface runoff can be up to 85 percent of the precipitation (Lull and Soper, 1969). In suburban residential areas infiltration rates are also low. Lawns have low infiltration rates due to soil compaction from frequent trampling and mowing (Felton and Lull 1963). In urban areas, 30 to 40 percent of rainfall runs directly into adjacent streams. Impervious surfaces can quickly trigger floods that produce their own environmental health hazards because runoff from an acre of pavement is about 10-20 times greater than the runoff from an acre of grass (Frazer, 2005).

Riparian vegetation plays a critical role in structuring the stream channel and maintaining a stable stream environment. In the arid West the two primary factors governing channel morphology are sediment supply and flow variability (Mitsch and Gosselink, 2000). Riparian vegetation functions to moderate and control both. Streams and their floodplains are maintained by a dynamic equilibrium between degradation and aggradation – between the building and removal of substrate. If either becomes excessive stream shape and function will be altered resulting in a state of disequilibria that is characterized by bank failure with excessive bank downcutting and/or lateral cutting. Riparian vegetation helps stabilize streambank soil and prevents excessive stream sedimentation by protecting banks from erosion. Native riparian plant species have deep, binding root systems that are capable of binding soil particles together and holding onto soil moisture. A diversity of native plants work together to hold streambank soils in place to prevent erosion and undercutting by floodwaters, transported woody debris or ice jams. The deep, penetrating roots of sedges, rushes, willow, native grasses and other herbaceous plants provide structural support for streambanks, while the thicker, harder roots of woody plants protect streambanks against bank scouring by floods and ice jams (Winward, 2000).

Channels form in response to the amount of discharge but the pattern and shape of the channel depend on the type, amount and duration of the sediment being carried (Windell, 1992). Riparian vegetation maintains the naturally sinuous channel shape by stabilizing streambank soil and by preventing upland-source sediment from being transported into the stream with runoff. However, changes in channel form may still occur owing to a gross change in the suspended sediment load induced by man (Carling, 1997). If upland or streambank erosion produces suspended sediment loads that are greater than the stream can carry the excess sediment drops out of the water column and is deposited in the channel. These deposits form small islands which tend to fill the channel, resulting in channel braiding and widening and stream shallowing. Braided streams are characterized by eroding banks, increased channel gradient, simplified instream habitat and excess sedimentation – characteristics that degrade stream functions and wildlife habitat.
On the other hand sinuous channels have high habitat diversity, are stable, absorb flood energy, have high functionality and provide high quality wildlife habitat. Riparian vegetation helps

maintain bank stability which is essential to maintaining a meandering form. The process of meandering produces a structurally complex stream with S-shaped bends and a diverse velocity/depth regime; on the concave (outer) bank of the meander bend deep pools develop, on the convex (inner) bank point bars develop and in between bends shallow riffles develop. Thus as sinuosity increases the diversity of other habitat characteristics also increases including variability in stream depth and stream velocity (Windell, 1992). The occurrence of variable patterns of velocity and depth in a stream reach relates to the streams ability to provide and maintain a stable aquatic environment (Barbour et al., 1999).

Riparian vegetation further increases habitat heterogeneity by supplying dead plant material to the stream. Downed logs and coarse woody debris play a major role in structuring the geomorphology of pristine streams (Harper et al., 1995). Downed logs and woody debris slow stream velocity, create deep pools and riffles, and increase habitat complexity. Pools create backwaters that provide critical summer and winter habitat, refugia and rearing areas for young fish (Wohl, 2005). Removal of woody debris eliminates or reduces these functions. When debris was removed from Clearwater Creek in Washington habitat complexity decreased as indicated by a decreased frequency of large pools and a decrease in pool depth (Lisle, 1995). Heterogeneous habitats also provide mechanisms that increase ecosystem stability; streams flows are moderated, nutrients are cycled more tightly, energy flow is moderated, and wildlife diversity potential is increased.

Wildlife Habitat

A major value of riparian wetlands is found in the enormous and essential nature of the benefits that are provided wildlife. Compared to upland habitats riparian habitats have an abundance of energy and nutrient resources which create an environment favorable to wildlife.

Habitat complexity increases the potential for species diversity and ecosystem stability. Riparian habitats are plant-species rich and structurally complex. Animal species richness is positively correlated with habitat structural complexity (Orians, 1997). Plants provide the structural complexity that enables the development of a species-rich terrestrial animal community. Native riparian vegetation provides wildlife with shelter, forage, nest and breeding sites, refuge from extreme temperatures and protected migratory passages. Meandering streams have been shown to have the highest biological diversity when compared to constrained or braided streams (Ward, 1998). One reason is due to the spatial heterogeneity created by the stream-floodplain system. Another is due to the development of a detrital food web that is extremely efficient in extracting chemical bond energy (Mitsch and Gosselink, 2000).

Biological productivity is higher in river-floodplain systems due to alternating wet-dry cycles. In riparian systems periodic flooding results in variable hydrologic conditions and higher productivity; flooding provides vegetation with water, nutrients, and oxygen, and carries away products of soil and root metabolic waste (Brinson et al., 1981). This “pulsing” of the stream discharge is the major force controlling biota in the river floodplain and lateral river-floodplain exchange is of enormous importance in determining the productivity of both the river and the adjacent riparian zone (Bayley, 1995). These flood-pulses optimize productivity and decomposition in both the littoral and riparian zones and optimize fish spawning and feeding due to the transport of nutrients, suspended solids, and dissolved oxygen between aquatic and riparian systems (Bayley, 1995).

Additionally, riparian vegetation moderates the microclimate (moisture and temperatures are more favorable) and shades the stream, so that the water is cooler and able to hold more oxygen. Roots stabilize banks and provide habitat for aquatic biota and leaf litter is the base of both the terrestrial and aquatic detrital food chains and provides surfaces for macroinvertebrate colonization. The presence of free water in streams is an important source of drinking water and habitat for aquatic and semi-aquatic wildlife; a source of prey for consumers such as waterfowl and fish-eating birds; a protected travel corridor for semi-aquatic species such as beaver and muskrat; and reproductive habitat for amphibians and fishes.

Riparian wetlands are also migratory passages and travel corridors between habitat islands. The linear nature of riparian wetlands provides connections from summer breeding grounds to winter resting and feeding habitat. These protected passages enable local elevational migrations of resident birds and mammals as well as the long-distance migrations of non-resident songbirds, waterfowl, shorebirds, hummingbirds, raptors, and more. As travel corridors between habitat islands riparian habitat helps prevent the insularization of natural populations and ensures genetic diversity (Donahue, 1999).

Threats to Riparian Functions and Values

Beaver eradication

Beaver dams create ponds that act as sediment traps, gradually filling with sediment to create a habitat mosaic of wet and mesic meadows, and open water habitat. Ponds and meadows provide flood control during spring snowmelt by slowing runoff which increases groundwater infiltration and by storing flooding flows in ponds. Additionally the stepped profiles of beaver-influenced rivers, with narrow, deep, sinuous reaches above the ponds and shallower reaches of swifter flow below the ponds, maximize the diversity of riparian and aquatic habitats (Wohl, 2005). Presettlement beaver populations were estimated to range from 60-400 million individuals. The Lewis and Clark expedition opened the West to settlement in 1806, by 1830 trapping had quickly led to extirpation of much of the beaver population. John Charles Fremont rarely saw an active beaver lodge during his journey through the Front Range of Colorado in 1842–1843, although he wrote of many abandoned beaver dams falling into disrepair (Wohl, 2005). Following near extinction the population is estimated to have recovered to between 6 and 12 million individuals today (Windell, 1992). With beaver extirpation came severe consequences to both stream and riparian habitat. River gradient and flow velocity likely increased due to the deterioration and failure of dams which consequently eliminated the stepped structure. When the dams failed sediment and nutrients that were stored in the dams were released downstream thereby altering the nutrient status of those stream reaches (Wohl, 2001). Riparian habitat that was dependent on beaver dams to increase out-of-bank flows also likely declined along with wildlife species that were dependent on that habitat.

Mining

Direct impacts from mining typically include upland and riparian deforestation with consequent hillslope and stream channel destabilization; sediment yield to the stream is greatly increased due to hillslope and streambank destabilization; and runoff from mine tailings and drainage from mine tunnels is often contaminated with toxic metals such as mercury and cadmium. Indirect impacts from mining occur due to the infrastructure associated with mining such as road and railroad building and also occur from degraded water quality that is inevitably associated with mining. Historically a vast infrastructure was dependent on trees for roads, railroads, buildings and smelters. As noted later in this section, deforestation ultimately results in increased runoff and decreased infiltration, slope destabilization and stream sedimentation (Wohl, 2005). The net effect has been to reduce habitat diversity and destabilize the riparian-stream ecosystem.

Transportation corridors

Road building in the mountains often necessitates road cuts that destabilize hill slopes. When road cuts are adjacent to a stream, destabilized hill slopes produce excessive amounts of sediment that are carried into the stream with runoff. Riparian habitat is frequently destroyed by road cuts and ongoing road maintenance activities, such as snow plowing, often prevent the natural revegetation of road cut slopes.

Road building also frequently results in changes to the stream channel such as stream straightening, bank armoring and constrictions at bridges. These channelizing activities alter stream functions including sediment transport, energy dissipation and the development and maintenance of riparian and fish habitat. Channelization inhibits meandering, increases stream gradient and velocity and reduces or eliminates the overbanking flows that are essential to maintaining riparian habitat. Consequently riparian and instream habitat is often eliminated, reduced or greatly simplified by channelization.

Roads also result in easier and consequently greater human access to rivers. Greater access has often resulted in increased disturbance to the stream bed and banks by people, mountain bikes, and off-road vehicles. These effects can be locally important due to resulting vegetation trampling and compacted streambank soil which causes increased runoff and bank erosion (Wohl, 2001). Bank erosion itself changes the shape and function of the channel and the eroding sediments are carried into the stream where they degrade macroinvertebrate and fish habitat.

Deforestation

Deforestation alters water and nutrient cycles and energy flow; modifies forest structure, function, and plant and animal species composition; and results in habitat loss and fragmentation. Deforestation disrupts the water cycle by altering the infiltration-runoff regime. Forests and their soils act like a sponge absorbing rainfall and snowmelt. Some precipitation water is taken up by trees and evaporated. In so doing the tree and the surrounding atmosphere is cooled. Without trees the habitat becomes warmer. Forest soils store precipitation from rainfall and snowmelt which is then gradually released with the result that stream peak flows are lower and flooding is attenuated. During the dry season the release of stored water helps to maintain sustainable stream flows. Water that is evaporated by vegetation cools to eventually form clouds. The hydrologic cycle is completed when rain drops form and fall to earth.

Deforestation results in increased runoff and decreased infiltration and thereby impacts groundwater recharge. Groundwater is an important source of water for riparian habitat. In the Roaring Fork Watershed many riparian wetlands are dependent on water from both uplandsourced groundwater discharge and overbanking stream flows. At North Star Nature preserve, Hickey et al., (2000) showed that surface and shallow ground water from the surrounding hill slopes, particularly during the snowmelt runoff period in the spring, was the main factor sustaining wetlands at North Star and that flows from the hill slopes were part of a larger regional system which sustains wetlands and river flow during times of drought.

Ski area development has resulted in extensive deforestation. One difference between ski area deforestation and logging for timber is that ski areas are maintained in a deforested condition with consequent ongoing impacts. A combination of degraded environmental and biological conditions at each of the ski areas in the watershed results in increased runoff, decreased infiltration and consequently reduced groundwater recharge and decreased stream base flows; soil condition at each of the ski areas in the watershed is severely degraded; non-native vegetation dominates the developed ski runs and large patches of bare soil are common; erosion is high; forest edges are maintained as “hard” edges; and habitat is maintained in an early successional condition. Consequently forest functions are severely degraded and negatively impact both riparian and stream habitat.

Grazing

Direct effects of domestic livestock grazing on riparian-stream ecosystems include elevated levels of fecal coliform bacteria and sediment in streams, soil compaction, degradation of stream banks and stream bottom, reduced shrub reproduction and increased shrub mortality (Donahue, 1999). Cattle grazing has been shown to prevent cottonwood regeneration, eliminate willow stands (Donahue, 1999), and alter vegetation communities by selective grazing on palatable species leaving unpalatable species to dominate the habitat. In general vegetation diversity decreases with grazing intensity with a few species becoming dominant. Because riparian values are intimately dependent on riparian vegetation characteristics, riparian functions are also altered.

Indirect effects of (cattle) grazing include changes in stream channel characteristics (straightening, widening, shallowing) and degraded water quality, altered precipitation infiltraton and evapotranspiraton regimes (due to soil compaction and vegetation loss) and accelerated soil erosion as a result of hillside trailing (Donahue, 1999). A cascade of ecosystem alterations follow from these grazing induced habitat changes. Bird species diversity is reduced, bird, mammal and plant community composition is altered and noxious weeds invade. For example, in Arizona in 1987, after cattle were removed from the San Pedro Riparian National Conservation Area, from 1986 to 1990 riparian vegetation density increased four- to six-fold and breeding birds had an average yearly increase of 23 percent in abundance (Krueper et al., 2003). At Sheep Creek, northwest of Fort Collins, deer mice (a habitat generalist) were more abundant on grazed plots but western jumping mice (a riparian habitat specialist) were more abundant in exclosures (Fitzgerald et al., 1994).

Habitat Loss and the Loss of Biological Diversity

The greatest threat to biological diversity is habitat loss, followed by habitat alteration and fragmentation of large habitats into small patches (Myers, 1997). Riparian habitats are disproportionately rich in biological diversity compared with the rest of the Rocky Mountain landscape. Because the majority of wildlife in the West is dependent on riparian habitat at some stage of their life history, the loss of riparian habitat has a disproportionately large impact on the survivability of natural wildlife communities in the West.

Habitat loss results primarily from disturbance that alters habitat and consequently the value of that habitat to wildlife. Riparian habitat-altering activities include disturbances caused by high impact ecosystem-altering activities such as urbanization as well as by relatively low impact recreational activities such as hiking (Youmans, 1999).

Loss of biodiversity is both an outcome of habitat loss and a source of further environmental stress. The loss of native biological diversity can reduce the quality and diversity of riparian habitat and can alter or even sever the ecological connections that enable essential ecosystem functions including energy flow and nutrient cycling. Many animals modify their habitat and by so doing increase habitat complexity and thus the potential for a greater biodiversity. For example, beavers build dams that create open water, that succeed to meadows and then forest. When beaver harvest riparian vegetation for their dams they open the canopy, which creates patches of habitat that are of a different type. Selective foraging characteristics of deer and elk create openings in the forest, alter the distribution of plant species, disperse seeds, and modify competitive interactions all which result in increased habitat patchiness. Northern pocket gophers increase habitat patchiness with their tunneling activities which have a profound and positive effect on soil development. Even the sap wells that red-naped sapsuckers drill increase habitat resource heterogeneity by creating a food resource for other bird species such as hummingbirds. All of these activities contribute to the development of a riparian landscape with a diversity of habitats and a greater diversity of wildlife.

Recreation

Recreation frequently results in altered vegetation and soil by processes including vegetation trampling and removal. Vegetation that is trampled is subjected to physical breakage and wounding which reduces photosynthetic surfaces (leaves), seed production, and energy reserves. Eventually stressed plants die. The primary impacts of trampling on soils are compaction and loss of the litter layer with consequent reduced precipitation infiltration, increased runoff and reduced nutrient cycling.

Soil degradation also results in a change in the plant community that can survive in degraded conditions – frequently noxious weeds have invaded these trampled sites. Thus trampling not only destroys vegetation in the near term but also has long-term consequences by reducing native plant vigor and altering plant community assemblage.

Trampling reduces or eliminates vegetation especially ground cover, seedlings, and saplings and degrades soil. Where riparian vegetation is required for bank stability, trampling-induced vegetation destruction has resulted in stream bank destabilization with consequent bank erosion and sedimentation corrupting instream habitat. Consequences include channel alteration and degraded water quality as sediment delivery increases and riparian shade decreases (Marion, 1998; James et al., 1979).

Recreation that occurs in riparian and stream ecosystems impacts wildlife. Kayakers and rafters disturb waterfowl, shorebirds, and songbirds birds that are foraging and nesting in bank vegetation; dippers and snipe abandon foraging for protective cover, and human-sensitive songbirds including many warblers and sparrows cease singing. Human activities that cause disturbance responses in wildlife, such as fleeing, cessation of foraging or singing, or which cause an animal to abandon a habitat, negatively impact survivability by increasing energy expenditures and reducing time spent in foraging, breeding and raising young (Malone, 2002).

Recreational trails provide a route for the invasion of noxious weeds, edge predators and nest parasites. Trails (and roads) fragment habitat and increase the amount of habitat edge; robins and cowbirds thrive but other species avoid these corridors (Miller and Knight, 1995). Unlike natural edges that are sealed by layers of shrubs and herbs, trails have “hard” edges that are open to and provide routes for invasion. Trails provide predatory and parasitic birds, such as magpies and cowbirds, and edge adapted mammalian predators, such as coyotes, with an opportunity to invade habitat interior wildlands where they prey on songbird eggs and nestlings. Trails also provide mammalian edge predators with an opportunity to invade interior forests where they compete with interior mammalian predators such as pine marten, resulting in an altered wildlife community composition (Malone, 2002).

Soil Degradation

Soil compaction occurs when any weight pushes the soil particles together and reduces the size of the pores between soil particles. Compaction can occur from even mildly concentrated use of hiking, biking and riding trails, off-road use of ATV's including snowmobiles, and heavy equipment such as snow-grooming machines. Compacted soils inhibit infiltration and so water flows across the soil surface resulting in erosion.

Disturbance or loss of litter and topsoil can affect the soil decomposer community. Roads, trails and campsites that are located in wildlands all disturb and frequently eliminate the soil litter layer. Soil macroinvertebrates such as earthworms and millipedes, and microorganisms such as bacteria and fungi, play a pivotal role in the ability of soil to process energy and nutrients. Macroinvertebrates are prey for vertebrate species such as ground foraging birds, small mammals and amphibians. Changes in the decomposer community may have negative consequences for the functioning of the entire ecosystem and the biological diversity in that system (Haskell, 1999).