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A REVIEW OF RIPARIAN FUNCTIONS AND MANAGEMENT

Focused on the Fairbanks North Star Borough, Alaska

COMPLETED FOR TANANA VALLEY WATERSHED ASSOCIATION, FAIRBANKS, ALASKA, MARCH 2009

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All photos by the author, unless noted otherwise.

COVER PHOTO. *Chena River State Recreation Area.*

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Executive Summary

This review was commissioned by the Tanana Valley Watershed Association (TVWA), a non-profit group based in Fairbanks, Alaska, and funded in part by the Fairbanks Fish and Wildlife Field Office of the US Fish and Wildlife Service, and by the Fairbanks Soil and Water Conservation District. The objectives of the review were to (1) increase understanding of the value of riparian areas, particularly for the Fairbanks North Star Borough; (2) summarize findings from the scientific literature on the effectiveness of buffers (or set-backs) to protect riparian functions; and (3) describe regulations and other methods that have been used by governments and others to protect the functions of riparian areas. It is hoped that this review will assist citizens and governments within the Fairbanks North Star Borough in their efforts to better manage riparian areas.

Riparian refers to the areas along rivers and streams. Riparian areas generally have distinct vegetation and landforms compared to the surrounding uplands. Riparian areas are dynamic because they are formed and affected by rivers that change and move over time. It is valuable to understand the natural processes of riparian areas and rivers because many communities, particularly in Alaska, exist along rivers. These streamside areas are also called floodplains because recurring floods create relatively flat landforms next to the river. Floodplains are indicators of past flooding, and that future flooding will likely occur. Over time the channel moves across the floodplain, a natural process that is represented by oxbows and abandoned channels. As channels erode streambanks they naturally migrate across the floodplain, although this is generally a slow or episodic process. On the other hand, high flows also move and deposit sediment on the floodplain which is followed by the establishment of riparian vegetation. There is a natural give and take between the river and the riparian area.

RIPARIAN FUNCTIONS

Many important functions are provided by riparian areas in Interior Alaska, and in the Fairbanks North Star Borough in particular, which have both social and ecological benefits. Some of the primary functions of riparian areas are:

- Streambank stability;
- Floodwater storage;
- Contaminant filtering and storage; and
- Habitat for fish and wildlife.

Streambank stabilization is one of the most important functions for communities built along rivers. Riparian vegetation stabilizes streambanks in the following ways:

1. Root structures bind soil together.
2. Above-ground vegetation creates resistance to flow and dissipates stream energy against plants rather than soil.
3. Vegetation acts as a buffer against transported materials, preventing scouring of the bank.
4. Vegetation in the stream margin causes sediment deposition by decreasing water velocity and shear stress.

Floodwater storage occurs in riparian areas because they act as a sponge and capture and store water during high flows. Over time some of the water is released back to the stream, which for small or dryland streams helps maintain perennial flows.

Contaminant filtering and storage occurs when vegetation slows or stops the movement of water and sediment that transport contaminants toward waterways. Plants act as a physical barrier, they bind the soil that has contaminants, and in some cases the contaminants are taken up by plant roots.

Habitat for fish and wildlife is enhanced by riparian vegetation which provides cover, shelter and food for animals. In particular, fish habitat is enhanced by numerous influences of riparian vegetation, such as shade, organic matter inputs, insects associated with vegetation, and prevention of sediment and pollutants from moving into rivers. It is noteworthy that most of the mainstem rearing habitat for Chinook salmon in some Alaska rivers (such as the Kenai River) occurs in a narrow strip along the river bank, most likely because of the benefits of cover, organic matter, and slower flows created by riparian vegetation on the river bank.

Recreational opportunities (picnicking, wildlife viewing, fishing, etc.) and **aesthetic values** for property owners and communities (in the form of parks and natural areas) are also provided by functioning riparian areas.

HUMAN IMPACTS TO RIPARIAN AREAS

While damage or destruction of riparian vegetation occurs naturally from floods and other natural disturbances, excessive alteration or destruction from human activities can decrease the ability of riparian areas to perform the natural functions described above. A significant impact to riparian areas is the removal of vegetation — for construction of roads, houses and other buildings, or to create views of the river — which can lead to increased bank erosion and property loss. In addition to the economic costs of property loss, the removal of vegetation can also cause negative impacts to wildlife habitat, water quality and recreational opportunities.

The Fairbanks North Star Borough has experienced significant construction of homes and buildings along some waterways, particularly the Chena and Tanana Rivers and in localized areas of other rivers. In many cases the natural vegetation has been removed, and there has been increased bank erosion and loss of property. As a result, there have been various efforts to protect riverbanks and riparian areas in the Fairbanks North Star Borough. Many homeowners and businesses along the Chena and Tanana Rivers have undertaken costly measures (bioengineering, riprap, retaining walls, etc.) with uncertain long-term benefits to stabilize riverbanks and protect their property.

In addition, the Chena River, Chena Slough, Noyes Slough, and Goldstream Creek are all listed as impaired waters (category 5 waters under Section 303-d of the Clean Water Act) for a variety of parameters. These waterways could benefit from improved management of riparian areas to minimize the contamination of the waterways.

RESTORATION AND PROTECTION

There is a growing recognition of the value of riparian areas and concern about the destruction of riparian areas. This has led to increased efforts to protect and restore riparian areas. Various terms have been used to describe efforts to protect and restore riparian areas, such as riparian management areas, riparian habitat conservation areas, floodplain management, and riparian buffers.   In this report the term riparian buffers is used to represent all of these concepts of riparian protection.

PASSIVE RESTORATION

Passive restoration, which is the elimination of activities that cause negative impacts, is the simplest way to restore riparian areas. If site conditions are favorable for natural recovery, passive restoration should be the first attempt at restoration.

ACTIVE RESTORATION

In some cases a site cannot be restored with passive restoration and active restoration is necessary to restore the desired conditions. With active restoration there is always the risk that the effort will be ineffective or that the problems will be worsened. Active restoration is also more expensive than passive restoration.

One form of active restoration is bioengineering, which involves the use of plant material (living or non-living) and mechanical elements to control erosion and to increase streambank stability. Bioengineering has the benefit of mimicking the natural processes and thereby providing many of the benefits that are provided by natural riparian areas.

A more extreme form of active management is bank hardening. This technique seeks to halt or prevent erosion with the use of rock, cement, and other materials that “harden” the river banks. Bank hardening involves removal of some vegetation which eliminates the ecological benefits of that vegetation. In addition, bank hardening deflects the stream, maintaining high flow velocity and transfering the erosive force of the river to properties downstream.

Urban areas present unique challenges in balancing ecological and social objectives. For many people it is desirable to live adjacent to rivers and streams, but that creates potential damage to property from flooding and bank erosion. In many urban settings there are already buildings and other structures in the floodplain, very close to rivers and in these settings it is often desirable to maintain or increase the stability of the river bank. Ideally, any bank stabilization effort will include native riparian vegetation because those plants typically are capable of binding the soil and stabilizing the banks, in addition to providing wildlife habitat.

The preferred management of riparian areas is to leave all the vegetation, which will provide the most benefit for bank stability, floodwater storage, and wildlife habitat. If this is not practical, some trimming or thinning may be done, as long as most of the vegetation remains intact. Where trees are the prevalent vegetation, some trimming of lower branches could be done (to improve views or for other reasons), but understory vegetation (especially ground cover) should be left intact to minimize erosion.

RIPARIAN BUFFERS

The establishment of riparian buffers is considered to be an effective way to protect riparian areas and associated aquatic habitats. There are two aspects of buffers for riparian management: (1) the width of the buffer; and (2) the allowable activities within the buffer.

The width of the buffer is the distance from the stream (moving away from the channel) to the buffer edge. The size of the buffer depends on the local environment and the objectives. Different sizes are necessary to protect different functions, with larger buffers protecting more functions. Buffers can be a set distance or the distance can be variable -- determined by site conditions. A set distance is easier to establish and apply therefore many government entities use set buffer widths. The alternative is a variable width buffer, which takes into account the local conditions of the stream and streamside setting. A variable width buffer could result in different buffer widths from site to site along a given stream, which can be difficult to determine and enforce.

The second issue for riparian buffers is determining what activities will be allowed within the buffer. The buffer could be completely protected, meaning that no alteration or destruction

by humans would be allowed. Or some activities might be allowed such as limited trimming or removal of vegetation, small structures to access water (such as docks), trails and other minor impacts. Activities that are generally not allowed in riparian buffers, at least the portion closest to the channel, include: clearing of vegetation, paving, large structures (houses and buildings), and hazardous material storage.

Various factors will influence the buffer width. Wider buffers are desirable for the following settings: large and dynamic rivers, critical wildlife habitat, areas with adjacent wetlands, the outside of river bends, areas with fish populations, and where there is intensive land use in watershed (such as extensive impervious surface area). Reasons for establishing narrower buffer widths could include: impractical to implement larger buffers, low priority stream, minimal flow and small peak (flood) flows.

This report summarizes recommendations from the scientific literature for riparian buffer widths for a number of different functions such as streambank stability and contaminant filtering and storage. There are a wide range of buffer width recommendations in the literature for the different riparian functions. This report also summarizes existing regulatory buffer widths from across the United States, which vary for different and objectives.

Of the municipalities and boroughs in Alaska that have riparian buffer policies, a 50-foot riparian buffer is common. The Fairbanks North Star Borough has a “Waterways Setback overlay zoning designation” that is intended to restrict most structural development within 25 feet of the ordinary high water mark. The setback has not been applied generally and it currently exists only along a very short length of the Chena River and its tributaries.

Introduction

This report is for the Tanana Valley Watershed Association (TVWA), as part of their efforts to promote improved management of riparian areas in the Tanana Watershed, and specifically to provide guidance for the Fairbanks North Star Borough in their development of a "Riparian Management Plan" in accordance with their Regional Comprehensive Plan (p. 26 of FNSB 2005a).

The historical meaning of the word riparian is "pertaining to the banks of a river or stream" (Webster's New Millennium Dictionary of English). A more scientific definition of the term riparian area is the area adjacent to flowing water, which exhibits distinct vegetation and soils due to the interaction with water from the stream or from elevated ground water (Naiman and Decamps 1997). There are numerous other terms that have similar definitions as riparian area, such as riparian zone and riparian corridor. In this report the term riparian area is used exclusively, in an effort to avoid confusion which can arise when many terms are used for the same concept. The only exception is when quoting sources that use another similar term.

There are many different types of riparian areas, such as the narrow ribbons of vegetation (dominated by grasses, sedges, rushes, willows, and cottonwoods) along streams of the arid Southwestern US, to the forested riparian areas (dominated by willow, alder, and spruce) associated with large glacial-fed rivers of the colder regions of Alaska (as described in Section 1). Sometimes wetlands and lakeshores are considered riparian, but this report focuses on areas adjacent to streams and rivers.

Often it is easy to define the extent of the riparian area, such as when there is a change in topography and vegetation moving away from the stream, which creates a distinct riparian-upland boundary. In such cases the riparian area is generally associated with a flat valley bottom or floodplain, that is bordered by steeper hillslopes. In other cases it can be difficult to define an exact line between riparian and uplands, as when there is no distinct change in topography or vegetation between the upland and riparian area, as is sometimes the case in Alaska.

Riparian areas in Interior Alaska, and in the Fairbanks North Star Borough in particular, provide many important functions such as streambank stability and filtering of contaminants, as described in Section 2. Riparian areas associated with watercourses like the Chena River provide essential breeding, rearing and feeding habitat for numerous species of fish, birds and other wildlife, because of the combination of water, diverse woody plant growth, high primary productivity, and associated insects and other invertebrates that provide abundant food and cover. Humans are also attracted to riparian areas (Figure 1) because of their beauty and recreational opportunities, but with the use of these riparian areas there can be negative impacts to the functions. One of the most significant impacts to riparian areas is the removal of vegetation — for construction of houses and other buildings or to create views of the river — which can lead to decreased bank stability, increased

FIGURE 1.
Examples of how rivers and riparian areas in the Tanana Watershed are used.

bank erosion and property loss. In addition to the financial cost of property loss, the removal of vegetation can also cause negative impacts to wildlife habitat, water quality and recreational opportunities.

There is a growing recognition of the value of riparian areas and the need to manage them wisely. Various ways to describe riparian management have been used, such as riparian management areas, riparian habitat conservation areas, floodplain management, and riparian buffers. Techniques for maintaining or restoring riparian functions are described in Section 3. The effectiveness of various management practices, based on the scientific literature, is summarized in Section 4. Regulations on managing riparian areas throughout the US, and for Alaska in particular, are summarized in Section 5.

SECTION I. Characteristics of Interior Alaskan River Ecosystems

The conditions of Interior Alaska have led to distinctive channel types, hydrology, vegetation, and soils. Some good overviews of Alaska and river ecosystems can be found in Chapters 1 and 13 of Milner and Oswood (1997) and Oswood et al. (2006). Overviews that focus on the Tanana Watershed and its river systems can be found in the following books or reports:

- *Water Quality and Ecology of the Chena River, Alaska* (Oswood et al. 1992)
- *Chena River Watershed Study: Reconnaissance Report* (US Army Corps of Engineers 1997)
- *Flooding and ecosystem dynamics along the Tanana River* (Yarie et al. 1998)
- *Environmental and Hydrologic Overview of the Yukon River Basin, Alaska and Canada* (Brabets et al. 2000)
- *Floodplain Forests Along the Tanana River, Interior Alaska, Terrestrial Ecosystem Dynamics and Management Considerations* (Magoun and Dean 2000)
- *Assessment of Fish Habitat, Water Quality, and Selected Contaminants in Streambed Sediments in Noyes Slough, Fairbanks, Alaska, 2001-2002* (Kennedy et al. 2004)

The Tanana Basin is very large, with about 44,500 square miles in Alaska and about 576 square miles in Canada according to Magoun and Dean (2000) who give the following description of the Tanana Basin:

> The Tanana River flows northwestward approximately 531 river miles (850 km) from its headwaters near Northway, Alaska to the Yukon River near the town of Tanana, Alaska. Glacial-fed tributaries drain northward from the Alaska Range and nonglacial streams drain southward from the Yukon-Tanana Uplands. Upstream of Fairbanks, the river is strongly braided and characterized by unstable, unvegetated gravel bars and multiple channels. Below Fairbanks, the river meanders across the floodplain with one or more major channels and stable, vegetated islands. Soils on the floodplain are a mixture of alluvial deposits and colluvial material from the uplands. Vegetation communities are largely primary successional stands on riverbars that form during repeated periods of high water.

The Tanana River is primarily of glacial origins, with 85% of its flow coming from the glacial-fed tributaries flowing out of the Alaska Range (Yarie et al. 1998). The tributaries that enter the Tanana from the north are not glacial-fed, and are a smaller percentage of Tanana water (Yarie et al. 1998).

There are countless numbers of small streams that flow from the mountains and through the valleys of Alaska (Oswood 1997). The Fairbanks North Star Borough, which only covers about 17% of the Tanana Basin, has over 9,000 miles of watercourses according to Bob Henszey, ecologist with the US Fish and Wildlife Service and TVWA (personal communication, April 2008).

CLIMATE

Interior Alaska has a cold-dominated climate, with long cold winters and short summers, which shapes the ecosystems and has slowed human population growth and associated alteration of those ecosystems. There is a dramatic temperature range in Interior Alaska with an average low temperature for January of -19° F to an average high temperature for July of 71° F (Shulski and Wendler 2007). The cold conditions affect rivers in a variety of manners, such as low solar insulation, ice in both aquatic and terrestrial systems, and limits on biological processes (Oswood 1997). Climate controls discharge rate of rivers because of air temperature and precipitation (Yarie et al. 1998).

Interior Alaska is relatively dry, with only 4 to 12 inches of precipitation per year, half of which comes in the summer months as a result of storms that gain moisture in the Bering Sea and then track eastward (Shulski and Wendler 2007). Snowfall occurs during much of the year, with the first snowfall typically in early October and the last snowfall typically in late April (Shulski and Wendler 2007).

Indicators of climate change are being studied in Alaska stream systems because of their sensitivity to temperature changes and their nearly pristine conditions (Oswood 1997). As temperatures warm, increased melting of glaciers and permafrost might increase runoff to rivers in the short term. Over the longer term it is unclear how warming would affect river flows. Warming could also influence factors controlling carbon storage in the soil.

Many glaciers in Alaska are losing mass (receding) and there is growing concern regarding the short- and long-term effects on summer streamflow of glacier-fed rivers. Because glaciers store precipitation as snow and ice during winter and release it via meltwater during summer, glacier meltwater sustains streamflow during warm dry-weather conditions, preserving downstream aquatic habitat, especially during drought conditions. Glaciers also erode terrain and glacier meltwater typically carries high concentrations of fine suspended sediment.

A considerable portion of the Tanana River headwaters originate in glacier-fed catchments and glacier meltwater currently contributes substantial suspended sediment and streamflow to the Tanana River during mid to late summer. There is some indication that further increases in the rate of climate warming may temporarily stabilize or even increase summer streamflow in glacier-fed streams. Increased and extended seasonal temperatures would likely result in short-term increased meltwater contributions from high mountain glaciers. However, coupled modeling of glacier mass balance and streamflow response to future climate scenarios are needed to predict basin-specific short-term changes. Nonetheless, over the long-term, as basin glacier coverage decreases, the contribution of glacier meltwater to summer streamflow will also decrease.

Streamflow trend analysis for records of the last three decades from glacier-fed streams revealed predominantly decreasing streamflow across British Columbia during the month of August when glacier melt contribution is largest (Stahl and Moore 2006). The negative streamflow trends in British Columbia glacier-fed catchments suggest that, should the current warming trend continue, and glaciers continue to recede, mid- to late-summer streamflow in glacier-fed rivers of Alaska will likewise decline. Expected long-term impacts to the Tanana River would include (1) decreased contribution of glacier meltwater to summer streamflow and (2) decreased contribution of fine suspended sediment to the alluvial system.

HYDROLOGY

The sources of water for Alaska rivers include the following, based on Milner et al. (1997):

- Glacial-fed – from glacial meltwater
- Clear-water – from precipitation and shallow groundwater
- Brown-water – from peaty soils
- Springs/groundwater – from deep aquifers
- Lake outlet – from lake outflow

Glacier-fed rivers, such as the Tanana, have a heavy sediment load and variable discharge. Deposited alluvium creates terraces where early successional plant communities are established; vegetation, flooding and sediment deposition control soil development (Yarie et al. 1998). Clear-water rivers, like the Chena, typically carry less sediment than glacier-fed rivers, so sediment deposition and point-bar development are less pronounced. The Chena River basin is only about five percent of the Tanana watershed but encompasses Fairbanks and most of the surrounding communities. Fairbanks is built on the alluvial plain of the Chena and Tanana Rivers. Many businesses and homes are located along the banks of the Chena River and associated sloughs.

The history of the lower Chena and Tanana Rivers is summarized herein from Burrows et al. (2000) and Kennedy et al. (2004) without citation. The Tanana River flows from the southeast out of the Alaska Range toward the foothills north of Fairbanks and then turns west along the south side of the hills. The Tanana has been forced into this position along the north edge of its valley by the extensive alluvial outwash from the glacier-fed streams of the Alaska Range. Before 1945, a channel of the Tanana River, called the Chena Slough, branched off the main river upstream from Moose

Creek Bluff. The upper part of Chena Slough was also known as Piledriver Slough, named after a roadhouse on the Old Richardson Trail. Water in this channel flowed northward, then westward through Fairbanks, and back into the Tanana River near Chena Ridge. According to a 1940 map of Fairbanks, the Chena River entered Chena Slough about 7 miles east of Fairbanks.

In the spring of 1933 Fairbanks was inundated by a large flood. Local residents expressed concern that the Tanana River was enlarging the entrance of Chena Slough and that increasing flow from the Tanana was occurring in Chena Slough. These conditions indicated that the Tanana River might reestablish its main channel farther to the north, thereby jeopardizing Fairbanks. Moreover, flows from both the Chena and Tanana Rivers were contributing to frequent flooding in Fairbanks.

The proposed solution to reducing the flow contributed to Chena Slough by the Tanana River was to construct an earth-and-rock dike across the slough extending from Moose Creek Bluff westward to the Tanana River. This dike was constructed during 1940–45, although additional work on it may have been done as late as 1947. The dike cut off the flow from the Tanana River into the Chena Slough. Some seepage still occurs through the dike, and some subsurface flow enters the channel of the old Chena Slough from the dike downstream to the confluence of the Chena River.

In August of 1967, a large flood occurred on the Chena River at Fairbanks. After this flood, the Chena River Lakes Flood Control Project was designed and built by the U.S. Army Corps of Engineers to prevent further flooding in the greater Fairbanks area. The project was completed in 1979 and included a diversion dam and control structure on the Chena River upstream from Fairbanks near Moose Creek Bluff, a floodway and spillway leading to the Tanana River, and a raised levee along the north side of the Tanana River. In the event of a major flood on the Chena River, water is impounded behind the Moose Creek Dam and diverted into the Tanana River. During lesser floods, water is impounded behind the dam without spilling into the Tanana River and is regulated down the Chena at levels below flood stage until the impounded floodwater drains. Such regulation of the Chena River has been applied on several occasions since completion of the flood control structures in 1979. Fairbanks is protected from high water events of the Tanana River by the raised levee along the north side of the river which extends from the Chena Lakes spillway near North Pole, to downstream of Fairbanks near the confluence of the Chena and Tanana Rivers.

CHANNEL DYNAMICS

Alaska has many large rivers, such as the Yukon and Kuskokwim that carry large volumes of water and sediment, and have large deltas formed by sediment deposition where they enter the sea. These rivers typically meander across the valley bottom and have many side channels and sloughs (Figure 2). This meandering pattern is due to the natural erosion of banks that typically occurs on the outside of bends, where the flow is the fastest (high stream power), and occurs in all streams

FIGURE 2.
Example of meandering river pattern, with oxbows and other relict channels (photo by Bob Henszey).

and rivers, but is most noticeable in low-gradient channels. Deposition occurs on the inside of bends where the flows are slowest. This migration of the channel is a natural process that can be observed over long time periods, or through the evidence of old oxbows and abandoned channels (Figure 2). Therefore the location of a channel is not fixed, but will move back and forth across the floodplain over time.

River channels develop a dynamic equilibrium that is a function of stream slope, flow, sediment size, and sediment load (Rosgen 1996). Deposition (or aggradation) occurs in sections of river where there is insufficient energy from the flowing water to transport all the sediment in the channel (typically where the gradient changes and the energy decreases). This often occurs with glacial-fed rivers like the Tanana, which carry high volumes of sediment from glacial melt-water. The large quantities of silt and gravel lead to braided channels with sediment regularly deposited on the floodplain or along the insides of bends and island bars during high flows (Yarie et al. 1998). Maximum erosion occurs at the outside of bends where the flow is the fastest. Such erosion is a natural process along rivers, although it can be exacerbated by human activities like removing or reducing the protective riparian vegetation along the bank. Bank erosion rates can be high on the Tanana River, as observed by Collins (1990) in (Yarie et al. 1998). This dynamic nature of rivers is visible in Figure 2 which shows many relict channels created by the channel eroding into and eventually cutting off one meander while creating a new meander.

VEGETATION

The floodplain forests of Interior Alaska are some of most productive forests in the taiga, or boreal forest of the northern latitudes. The plants that typically establish along the rivers of Interior Alaska are light-seeded, flood tolerant plants that can tolerate sedimentation and high-salt content, particularly willows and cottonwoods. Over time the plants and soils change, along a successional pathway that proceeds from willows and cottonwoods to alders and other woody shrubs and eventually to coniferous forests of white and eventually black spruce, as described by Magoun and Dean (Magoun and Dean 2000) and summarized in Box 1. This succession can also be observed spatially, with bands of successively older vegetation (shrubs and trees) typically moving away from the river, with each band formed by a flow event that allowed seeds to be deposited and grow. These bands are also shaped by high flows that eroded the plants or soil.

SOILS

The Tanana River valley is covered by hundreds of feet of sediment (sand, gravel and finer sediments) deposited by river and glacial activity (Mulligan 2004). The hilltops and slopes of the Tanana Basin are covered with a few feet of windblown silt (loess), which has also eroded and accumulated in some valleys (Mulligan 2004). Organic layers within the Greater Fairbanks area are generally less than a foot deep, and often less than 4 inches (Mulligan 2004), suggesting that roots are relatively shallow. Therefore when streams erode their banks the plants are often vulnerable to being undercut and falling into the channel (Figure 3).

Permafrost is an important aspect of many Interior Alaska soils, and discontinuous permafrost covers approximately one-third to one-half of the Tanana Basin (Mulligan 2004). The presence of vegetation, particularly forest cover, helps maintain permafrost because it insulates the soil and prevents solar radiation from warming the soil in summer. The removal of vegetation along rivers can lead to melting of permafrost and possible increased bank erosion (Bray and Kellerhals 1979). The relationship of perennially frozen ground and streambank erosion are discussed by Lawson (1983) who reported that no data could be found on whether perennially frozen streambanks increase or decrease erosion. Permafrost could be a cause for either extreme bank stability or instability (Pinney 2000). Pinney concludes that the net effect of permafrost is probably to increase bank stability. Although permafrost might exacerbate bank erosion if conditions lead to melting of permafrost, when there could be increased slumping and meltwater erosion (Pinney 2000). Permafrost might not be particularly common along rivers in the Tanana Basin, except where the channel is actively migrating into areas with more permafrost.

BOX I

Twelve successional stages of plant communities along the Tanana River as described by (Magoun and Dean 2000):

I. Bare soil (riverbank and bar), with a few light-seeded dispersers.
II. Plant colonization begins with willows, balsam poplar, and other light-seeded plants, including shrubs and herbaceous species.
III. Willows are the dominant vegetation. Balsam poplar seedlings and suckers grow rapidly, and thinleaf alder becomes more common. A well developed shrub layer forms with the addition of several species.
IV. Shrub canopy closes when alder and willow reach about 8 ft., and a dense alder/willow thicket forms. Balsam poplar also grows rapidly. White spruce seedlings establish.
V. About 25–30 years after establishment, balsam poplar stems are higher than the alder canopy and succession moves into an open balsam poplar stand with a dense alder understory.
VI. Balsam poplar canopy is closed and white spruce grows in the understory.
VII. Transition between deciduous forest and coniferous forest occurs as white spruce replaces balsam poplar in the canopy. Thinleaf alder begins to decline in importance, and wild rose and highbush cranberry are common.
VIII. Development of closed white spruce stands, with a thick mat of feathermosses and organic litter.
IX. White spruce stands become more open and uneven-aged.
X. Open mixed white and black spruce stands are underlain by permafrost, with an active layer of only a few feet. The tall shrub layer is sparse.
XI. In the primarily black spruce stands of Stages XI and XII, there is a shift in shrub species, with willows becoming common. Feathermosses still dominate the moss layer, but sphagnum, indicator of waterlogged soils and permafrost, become established.
XII. Sedge tussock, sedge meadow, and sphagnum bog community types are found in Stage XII in addition to the open black spruce stands of Stage XI.

FIGURE 3.
Chena River upstream of Nordale Road Bridge, showing shallow rooting of trees and vulnerability to erosion.

SECTION 2. Riparian Area Functions

Riparian areas provide many functions that are important to physical and biological processes. Many of these functions relate to maintaining habitat for aquatic and terrestrial organisms. Riparian areas also provide many benefits for society, such as recreation (fishing, camping, bird-watching, and other activities), floodwater storage, and filtering of contaminants. In scientific terms, the functions that riparian areas provide fit under three categories: (1) hydrology and sediment dynamics; (2) biogeochemistry and nutrient cycling; and (3) habitat and food web maintenance (National Research Council 2002). To put these in more common terms that are discussed throughout this report, the primary functions that riparian areas provide are:

- Streambank stability
- Floodwater storage
- Contaminant filtering and storage
- Habitat for fish and wildlife

There are a number of review articles and books that provide detailed descriptions of the functions of riparian areas, which are listed below (chronologically). There are also a number of bibliographies on riparian-related publications, which are listed below.

JOURNAL ARTICLES ON RIPARIAN FUNCTIONS AND MANAGEMENT

- *An Ecosystem Perspective of Riparian Zones: Focus on links between land and water* (Gregory et al. 1991)
- *Riparian and Watershed Systems: Degradation and Restoration* (Elmore and Kauffman 1994)
- *The Hydrological and Geomorphological Significance of Forested Floodplains* (Gurnell 1997)
- *Floodplain Biogeomorphology* (Hughes 1997)
- *The Ecology of Interfaces: Riparian Zones* (Naiman and Decamps 1997)
- *Development, maintenance and role of riparian vegetation in the river landscape* (Tabacchi et al. 1998)
- *Riparian Ecology and Management in the Pacific Coastal Rain Forest* (Naiman et al.2000)
- *Impacts of Riparian Vegetation on Hydrological Processes* (Tabacchi et al. 2000)
- *Riparian and aquatic habitats of the Pacific Northwest and southeast Alaska: ecology, management history, and potential management strategies* (Everest and Reeves 2006)

BOOKS ON RIPARIAN FUNCTIONS AND MANAGEMENT

- *Riparian Landscapes* (Malanson 1993)
- *Wetlands* (Mitsch and Gosselink 2000) chapter 15
- *Riparian Areas: Functions and Strategies for Management* (National Research Council 2002)
- *Wetland and Riparian Areas of the Intermountain West: Ecology and Management* (McKinstry et al. 2004)
- *Riparia: Ecology, Conservation, and Management of Streamside Communities* (Naiman et al. 2005)

BIBLIOGRAPHIES ON RIPARIAN FUNCTIONS AND MANAGEMENT

- *A Bibliography of Riparian and Related Topics with Emphasis on the Intermountain West* (Clifton and Thomas 1988). Lists 332 publications and the general topics.
- *A Bibliography of Riparian Research and Management: Fish, Wildlife, Vegetation, and Hydrologic Responses to Livestock Grazing and Other Land Use Activities* (Van Deventer 1992)
- *Region III Forest Resources & Practices Riparian Management Annotated Bibliography* (Freeman 2000) for the Alaska Board of Forestry, Alaska Department of Natural Resources. Includes annotations on a few hundred publications, some based on research in Alaska, on topics such as buffers, streambanks, and large woody debris.
- *Managing for Enhancement of Riparian and Wetland Areas of the Western United States: An Annotated Bibliography* (Koehler and Thomas 2000). Includes annotations of 1,905 publications.
- *Vegetated Stream Riparian Zones: Their Effects on Stream Nutrients, Sediments, and Toxic Substances* (Correll 2003). Includes very brief annotations and indexing of 890 articles from around the world.
- *Relevant Literature for an Evaluation of The Effectiveness of The Alaska Forest Resources And Practices Act: An Annotated Bibliography* (Ott et al. 2005). Includes annotations of 621 publications (276 on Alaska) addressing forestry impacts on fish.
- *Threats Assessment for Western Riparian Ecosystems: An Annotated Bibliography* (Poff et al. 2008). Includes annotations of 425 publications.

The following presents information and a few citations on the riparian functions: streambank stability, floodwater storage, contaminant filtering and storage, and habitat for fish and wildlife. For each function general information is provided including a description of any reviews or bibliographies, followed by a summary of relevant studies in Alaska, and other studies from the primary literature. While many of the functions have not been studied in Alaska, the results from other regions are still useful for understanding the ecological processes and functions of riparian areas and streams in Alaska.

STREAMBANK STABILITY

Riparian vegetation plays an important role in stabilizing streambanks, and preventing bank erosion. The mechanisms by which vegetation can stabilize streambanks is described by Thorne (1990). Vegetation stabilizes streambanks, as described by Allen and Leech (Allen and Leech 1997) based on Klingeman and Bradley (1976) by:

1. Root structure binding soil together.
2. Above-ground vegetation creating resistance to flow and dissipating stream energy against plants rather than soil.
3. Vegetation acting as a buffer against transported materials.
4. Dense vegetation in the stream margin causing sediment deposition by decreasing water velocity and shear stress.

ALASKA STUDIES

Streambank stability is an issue of concern for Alaska rivers and riparian areas as described in (and evidenced by) the publication entitled “Streambank Revegetation and Protection: A Guide for Alaska” (Walter et al. 2005). This document describes the importance of vegetation in maintaining streambank stability, and the associated benefits for fish, wildlife and society.

A bibliography on the relationships of riparian areas and streambank protection was compiled by Ott (2000) for the Alaska Board of Forestry, which included a few studies from Alaska. A study on the Tanana River found “no useful relationships” between bank characteristics (vegetation, soil, or permafrost) and bank erosion rates, perhaps due to the large size of the Tanana which makes vegetation of minor importance in influencing bank erosion (Gatto 1984 in Ott 2000). A study of soil freeze-thaw effects on bank stability concluded that immediately after streambank soils thaw they are especially vulnerable to erosion (Gatto 1995 in Ott 2000).

Ott (2000) noted concern that timber harvest in Alaska could lead to increased bank erosion, as documented in studies in lower latitudes (see next section). No research on timber harvest and bank erosion in the Interior of Alaska was encountered, perhaps because of the limited size of the timber industry in Interior Alaska.

OTHER STUDIES

Plant species have differing abilities to stabilize streambanks based on different structural and ecological characteristics. Many riparian plants have strong deep and dense roots that help bind sediment and stabilize streambanks. Obligate wetland rhizomatous grasses, sedges and rushes have been shown to have greater root abundance, and grow to greater depths than upland species (Manning et al. 1989; Toledo and Kauffman 2001). Numerous observational field studies have documented increased bank stability associated with greater abundance of riparian vegetation (Beeson and Doyle 1995; Burckhardt and Todd 1998; Toledo and Kauffman 2001; Micheli and Kirchner 2002). Field tests have documented how riparian plants increase bank stability (Smith 1976; Simon and Collison 2002). Theoretical papers have described the positive influence of riparian vegetation on bank stability and channel form (Hicken 1984; Millar 2000). Lab studies have shown the benefit of plant roots in binding sediment and preventing erosion (Kleinfelder et al. 1992; Dunaway et al. 1994; Gran and Paola 2001).

A study in Virginia observed increased erosion in soils that had experienced freezing during the previous winter, which is consistent with Gatto (1995) reported in Ott (2000) described above for Alaska.

FLOODWATER STORAGE

Riparian areas act as a sponge, particularly during high flows and floods, by absorbing and storing water that overflows the banks of a river. During and after high flows water is temporarily stored in the soil, the banks and in the hyporheic zone (shallow groundwater closely connected to the river), which decreases the magnitude of downstream flooding (see pages 64-68 of (National Research Council 2002). Over time some of the water is released back to the stream, which for small or dryland streams can help maintain perennial flows.

The abundant moisture in riparian soils supports distinct vegetation – plants that require more water than is typically available in upland settings. The availability of water also tends to support greater abundance of vegetation in riparian areas. The unique and abundant vegetation of riparian areas is valuable to many animal species and maintains many of the important functions of riparian areas.

ALASKA STUDIES

No research on the value of riparian areas for floodwater storage in Alaska was found.

OTHER STUDIES

Vegetation helps increase infiltration because roots break soil particles, create pathways for infiltration, and root turnover in the soil increases organic matter which increases porosity (Mitsch and Gosselink 2000). When riparian soils are compacted (by vehicles, animals or humans) the soil is not able to absorb and store as much water (Blackburn 1984). Soil compaction and decreased infiltration can occur due to agricultural activities. Riparian buffers with multiple species had infiltration rates five times greater than for cultivated field or pasture (Bharati et al. 2002). The removal of livestock was correlated to three-fold to 11-fold increases in infiltration and water storage in riparian areas (Kauffman et al. 2004).

In urban areas impervious surfaces, such as pavement and buildings, decrease infiltration (Groffman et al. 2003). The percent of a watershed with impervious surfaces has been reported to be negatively correlated to stream health (Booth 2005).

Riparian vegetation is supported by water from flood flows and groundwater. Alteration of flow can cause losses of riparian vegetation and a shift from wetland to upland species or hydrologic drought (Groffman et al. 2003).

CONTAMINANT FILTERING AND STORAGE

Functioning riparian areas can delay or prevent sediment and pollutants from moving into streams and rivers. Therefore riparian areas can help maintain good water quality for fish, wildlife and human needs. The functions of riparian buffers in filtering sediment and nutrients, and purifying water is reviewed by Barling and Moore (1994). Numerous reviews have focused on nitrogen removal by riparian buffers (Straughan Environmental Services 2003; Mayer et al. 2006).

ALASKA STUDIES

No studies addressing contaminant filtration within riparian areas in Alaska were encountered.

OTHER STUDIES

Numerous studies have documented degradation of water quality after forests were converted to agriculture (Hickey and Doran 2004). That review noted that not all buffer strips will perform the same because of various site-specific factors. Riparian forest buffers that were 33 ft. (10-m) wide significantly reduced incoming contaminants in surface runoff and even 22 ft. (6.6-m) of buffer significantly reduced some contaminants (Schoonover et al. 2005).

HABITAT FOR FISH AND WILDLIFE

The functions maintained by riparian areas are important for maintaining fish and wildlife habitat (Kauffman and Krueger 1984; Fitch and Adams 1998; Naiman et al. 2000). Fish habitat in particular is enhanced by numerous functions provided by riparian vegetation (Armour et al. 1991; Platts 1991). A thorough review of salmonid habitat relationships to riparian areas is provided by Spence et al. (1996).

ALASKA STUDIES

Riparian areas provide valuable habitat for numerous animals in Alaska. A review of wildlife use of floodplain forests of the Tanana Basin is presented by Magoun and Dean (2000) who note that these riparian areas support water dependent animals such as beaver, mink, otter, and water shrew as well as other mammals that depend on early successional vegetation of riparian areas for food include such as moose (Figure 4), snowshoe hare, and yellow-cheeked voles. Bird species, such as

FIGURE 4.
Moose browsing riparian shrubs along Chena River, near Nordale Road bridge.

peregrine falcons, bald eagles, waterfowl and shorebirds utilize the floodplains of the Tanana Basin for foraging and or nesting (Magoun and Dean 2000).

The Alaska Forest Resources and Practices Act (ADNR 2007) seeks to protect fish habitat and water quality through protection of the following ten components:

1. channel morphology
2. clean spawning gravels
3. food sources
4. large woody debris
5. nutrient cycling
6. streambank stability
7. stream flow
8. sunlight
9. water quality
10. water temperature

The importance of riparian areas for fish habitat is reviewed in a bibliography related to Alaska forestry by Durst and Ferguson (2000a). Large woody debris can play an important role in providing fish habitat, particularly in smaller streams, as described in a different bibliography by Durst and Ferguson (2000b).

Studies in southeast Alaska have documented the negative impacts of fine sediment and decreased permeability of streambed substrate on productivity of fish spawning (McNeil and Ahnell 1964). Another study in Alaska documented lower fish productivity associated with turbidity, as caused by suspended sediment resulting from mining or other human activities (Lloyd et al. 1987). A summary of studies on the impacts of increased sediment on fish spawning and rearing success is presented by Waters (1995).

The nearshore area of rivers provides important habitat for fish. Most of the mainstem rearing habitat for Chinook salmon in the Kenai River occurs in a very narrow (6-foot wide) strip along the river bank which is where 80 percent of all juvenile Chinook were found (according to ADF&G surveys cited in Liepitz 1994). Nearshore areas provide habitat for rearing salmon because of: (1) slower moving water; (2) cover provided by emergent or overhanging vegetation; and (3) suitably sized river bottom material, from gravel to large cobble (Liepitz 1994). The value of nearshore areas for fish is enhanced by riparian vegetation which dissipates stream energy, provides shade, and stabilizes streambanks.

Salmon carcasses provide a subsidy of nutrients to streams and riparian areas, which is beneficial for fish (including subsequent generations of salmon) and aquatic insects (Wipfli et al. 2003) and for riparian plants and insects when the carcasses are transported onto the floodplain by water or animals (Gende et al. 2002). Furthermore there are feedback loops between aquatic and terrestrial ecosystems, such that increased fish productivity supports greater riparian productivity and increased riparian productivity supports greater fish productivity.

It is unclear how important stream shading is for fish habitat in Alaska, since the streams are already relatively cold. One negative result of warmer stream temperatures as a result of removal of streamside vegetation could be increases in certain species such as pike that do better in warmer water, which could harm other fish like salmon and whitefish, according to Mark Wipfli, fisheries biologist at the University of Alaska Fairbanks (personal communication, September 2008). Pike and other large fish eat young salmon, thereby reducing their population sizes.

OTHER STUDIES

Many studies have documented negative impacts to fish or fish habitat as a result of removing riparian vegetation (such as from grazing or timber harvest) or other negative impacts to riparian areas.

Removal of vegetation can decrease stream shading and cause increases in stream temperature (Jackson et al. 2001; Hickey and Doran 2004), which can have negative consequences for fish. NRC (National Research Council 2002) (p. 103) has review of thermal regulation.

Removal of vegetation and physical disturbance of streambanks often leads to bank erosion which increases the amount of fine sediment inputs to the stream (Meehan 1991). Sediment can have negative effects on fish habitat, particularly spawning of salmonids (Everest et al. 1987 cited in (Waters 1995). Removal of vegetation can also lead to channel widening which can result in wider shallower channels, which has negative consequences for fish (discussed below in "Disturbance to riparian Area Functions" section).

In urban areas there are typically both localized and watershed-scale impacts from human activities that are harmful to fish populations. Protection of riparian areas, at least for low intensity urbanization, can help mitigate some of the impacts of urbanization on fish populations, by shading streams, stabilizing streambanks, providing organic inputs, supporting invertebrate and trapping and/or storing sediment and contaminants. However, high intensity urbanization overwhelms the ability of riparian buffers to perform those functions (Roy et al. 2007).

Beaver are dependent upon stream and riparian ecosystems, where they build dams and construct lodges and caches of branches for winter food (Collen and Gibson 2000). Beaver generally have positive effects on aquatic and riparian ecosystems, such as providing fish habitat, storing water, and trapping sediment. There could also be some negative effects to certain wildlife resulting from beaver such as: impediments to upstream fish migration, increased water temperature, and inundation of habitat (Collen and Gibson 2000).

Birds utilize riparian areas for habitat and migration routes. A number of studies have documented relationships between riparian habitat features and bird diversity (Heath and Ballard 2003) or greater bird diversity in areas with less disturbance from livestock (Dobkin et al. 1998; Krueper et al. 2003). A review of impacts on riparian birds from livestock grazing was done by Saab et al. (1995).

Functioning riparian areas help protect the hyporheic zone, as reviewed by National Research Council (2002) (see p.68). A bibliography by Correll (2003) lists many articles about hyporheic interactions with streams, but no summary of the articles is presented. One of the few studies on the relationship of riparian areas and the hyporheic zone is by Boulton et al. (1997) who found that streams in watersheds with native forest had more diverse invertebrate fauna and cooler water temperatures in the hyporheic zone compared to similar streams in watershed with pasture.

PROPERTY VALUE

Protection of riparian areas may increase the value of nearby properties, because of the aesthetic values of healthy rivers and riparian areas. Wenger and Fowler (2000) cite studies that found higher property values for houses closer to rivers and in "conservation subdivisions." Other studies found that floodplain protection, riparian buffers or stream restoration projects had a neutral or positive correlation to higher property values (Center for Watershed Protection; South Carolina Department of Health and Environmental Control). However, a study in Oregon found that planting trees to enhance riparian buffers would reduce the value of those properties (Mooney and Eisgruber 2001).

DISTURBANCE TO RIPARIAN AREA FUNCTIONS

Some damage or destruction of riparian vegetation is natural, due to flows that break plants or erode soil where they are growing, browse by animals (such as moose), fire, or cutting and flooding by beaver. Many riparian plants have mechanisms to withstand or even take advantage of disturbances such as flooding, sedimentation, fire, and the physical force of water (Naiman and Decamps 1997; Kozlowski 2002). For example, many willow and alders have the ability to sprout vegetatively which allows a new plant to grow from a branch that has been broken by the stream or an animal. Vegetative regrowth allows for a rapid recovery after disturbances that are short-lived or localized, as documented by Gecy and Wilson (1990).

When there is excessive alteration or destruction of riparian vegetation (and the accompanying disturbance to soil) the functions described above are diminished. Removal of riparian vegetation decreases bank stability which can lead to numerous negative impacts, such as bank erosion, excessive sediment in the stream, channel widening (Millar 2000), and loss of pools and other features of stream complexity. Channel narrowing after removal of livestock has been consistently observed in a number of studies (Hubert et al. 1985; Platts and Nelson 1985; Myers and Swanson 1995; Magilligan and McDowell 1997; Clary 1999; Coles-Ritchie et al. 2007).

A list of activities that can damage the vegetation and soils of riparian areas is presented below:

- Vehicles driven on riparian areas (including cars, trucks, off-highway vehicles, snowmobiles, and motorcycles)
- Roads and bridges in riparian areas
- Building in riparian areas (homes, buildings, etc.)
- Timber harvested in riparian areas
- Vegetation cut or otherwise destroyed in riparian areas
- Mining activities along rivers
- Heavy recreation in riparian areas
- Dams and diversions removing water that supports riparian areas
- Livestock grazing and trampling riparian plants and soil
- Bank hardening with rock or cement (includes channelization of rivers)
- Removal of wood

The activities listed above can negatively impact riparian functions and lead to undesirable results, such as:

1. Contamination from:
    a. Sewage
    b. Waste-water and warm effluent
    c. Sedimentation
    d. Nutrient overload
    e. Organic contamination
    f. Toxic waste
2. Erosion of soil from riparian area or streambanks, causing loss of property
3. Sedimentation in the stream
4. Loss of organic inputs—including large wood
5. Thermal alteration (warmer in summer and colder in winter)
6. Declines in fish habitat and populations
7. Impacts to terrestrial habitat
8. Flow alteration

Fortunately Alaska is dominated by natural and functioning stream and riparian ecosystems. However, there are some impaired waterways, in terms of water quality, in the Fairbanks North Star Borough, including the Chena River, Chena Slough, Noyes Slough, and Goldstream Creek, which are all listed as category 5 waters and have an impaired status for a variety of parameters (ADEC 2008). These waterways could benefit from improved management of riparian areas to minimize the contamination of the waterways.

SECTION 3. Protective Systems

Efforts to protect and restore riparian areas are becoming more common, in part because of increasing recognition of the importance of riparian areas and because of a decline in their abundance and quality. Protection and restoration efforts seek to maintain or restore some or all of the functions of riparian areas.

Some riparian areas across North America are in good condition and efforts should be made to conserve these areas, particularly because they are becoming less abundant on the landscape. Ideally, measures to conserve functioning riparian areas will occur at the watershed-level to maintain the physical, biological and hydrological processes that are essential to functioning riparian ecosystems. At this larger scale, measures can be taken to set aside "natural" areas (wild and scenic rivers, preserves, parks, municipal water supply protection areas, wilderness, etc.) or to establish buffers, to maintain the processes and functions of riparian areas. Conserving wetlands and riparian areas in the upper region of a watershed has greater ability to influence water quality and flood water abatement than conserving reaches lower in the watershed (Brinson 1993). Conservation should be the first step in any effort to achieve functioning riparian systems.

While much of Alaska's rivers and riparian areas are in their natural condition, even in Alaska some riparian areas have been severely impacted by activities such as mining and urban development. These impacts can have negative consequences for ecosystems and society, and the impacts can be cumulative moving downstream, where there are important fisheries among other natural resources. A dramatic example of this in Alaska is the Kenai River at Kenai, where major bank erosion has occurred causing extensive financial losses (US Department of the Army 2006).

The Fairbanks North Star Borough has experienced construction of homes and buildings along some waterways, particularly the Chena and Tanana Rivers and in localized areas of other rivers (Figure 5). In many cases the natural vegetation has been removed, leading to increased bank erosion and loss of property. As a result, there are various efforts to protect riverbanks and riparian areas in the Fairbanks North Star Borough. Many homeowners and businesses along the Chena and Tanana Rivers have undertaken costly measures (bioengineering, riprap, retaining walls, etc.) with uncertain long-term benefits, to stabilize riverbanks to protect their property. Examples of properties with varying amounts of intact riparian vegetation along the river are presented below in Figure 5.

Ice-jam flooding on the Tanana River in the spring of 2003 caused an estimated $2 million in damage in the Salcha area (Lake 2003) and in response $800,000 has been spent on buyouts of properties vulnerable to flooding (see Box 2).

FIGURE 5.

Examples of properties along the Chena River showing different levels of impact to the riparian area. In the top photos the riparian vegetation has been removed and replaced with rock riprap, grass and other landscaping plants, which allows unrestricted views of the river but causes a loss of habitat for wildlife and fish and likely increased bank erosion. In the middle photos some of the riparian vegetation remains, which still allows a view of the river while providing some bank protection and fish and wildlife habitat. The lower photos have much of the natural riparian vegetation, which provides a more natural view and the greatest natural bank protection and fish and wildlife habitat.

BOX 2

Salcha River Buyouts:

Homeowners along the Salcha River (east of Fairbanks) were experiencing major bank erosion and flooding, and in some cases made expensive ($30,000 by one homeowner account), and largely unsuccessful, efforts to protect their homes. The situation was so severe that the Natural Resources Conservation Service (of the USDA) decided it was more cost effective to buy the properties, and remove the homes, rather than using an engineered solution to protect the homes from the river. With money from the US Congress, the Fairbanks North Star Borough used $800,000 to purchase 5 properties that were among the most vulnerable to flooding, and then removed structures to restore natural floodplain functions in perpetuity. Only a small portion of the properties that are chronically affected by floods were bought out. (This information is based on personal communication with Rod Everett, of the NRCS in April 2008.)

The Fairbanks North Star Borough has also purchased private lands along the Chena River to convert them to parkland and to maintain or improve the riparian functions of that land according to Dan Chagnon, FNSB Parks Superintendent (personal communication, April 2008). Presumably these areas will benefit from a certain level of riparian restoration.

PASSIVE RESTORATION

Passive restoration involves cessation of activities that cause negative impacts or prevent recovery of riparian systems (Kauffman et al. 1997). Passive restoration is the simplest way to restore riparian areas, if site conditions are favorable for natural recovery, so it should be the first attempt at restoration (Wissmar and Beschta 1998). Two common examples of passive restoration in the western US include “rewatering” of streams (which had water diversions) and cessation of livestock grazing (Kauffman et al. 1997). Often the removal of negative impacts is all that is needed to restore riparian areas because of their resiliency, which is a product of the abundance of water and the mechanisms that many riparian plants have to recover from disturbance (such as sprouting from broken stems; germination on bare, moist soil; and rhizomatous growth form).

ACTIVE RESTORATION

"Active restoration" may be needed in cases where the disturbance has been such that passive restoration is insufficient to restore the riparian area. Examples of disturbance that may require active restoration include major soil erosion, changes in geomorphology, and construction of structures or roads too close to the river. In such cases, active restoration may be needed to help in the process of recovery to a natural or at least a stable state. With active restoration there is always the risk that the effort will be ineffective or even damaging, therefore passive restoration should be attempted first, if possible.

Planning is an essential part of any restoration effort, which should include a "thorough understanding of past natural disturbances and human-induced changes on riparian functions and attributes, obtained by a historical reconstruction of the catchment" (Wissmar and Beschta 1998).

Bioengineering is an approach that is becoming more widely accepted and used (Li and Eddleman 2002). Bioengineering involves the use of plant material (living or non-living) and mechanical elements to control erosion and to increase streambank stability (Allen and Leech 1997). These techniques have the benefit of mimicking natural systems, including the self-sustaining characteristic of riparian vegetation. Some examples of bioengineering activities include:

- Brush mattress
- Brush layering
- Wattling bundles (live shrub stems)
- Dormant willow post method
- Vegetative geogrid (fabric encapsulated soil)
- Coir rolls and mats (made from coconut or other fibers)
- Various other plant materials such as logs and root wads

Bioengineering approaches are being implemented at a few sites in the Fairbanks North Star Borough. These efforts include the use of bioengineering techniques such as bundles of willow branches (Figure 6) that are set in the bank, some of which sprout and send out roots adding to bank stability (Dan Chagnon, Fairbanks North Star Borough Department of Parks and Recreation, personal communication, April 2008). There are also bank stabilization demonstration plots along the Chena River, near the Carlson Center, which were established a number of years ago that are being observed over time to see which methods work well. Box 3 presents another effort that utilized bioengineering techniques to stabilize banks along the Chena River.

FIGURE 6.
An example of a bioengineering project to stabilize the bank along the Chena River, near the Tanana Chiefs Conference building. This project involved covering riprap with soil and then placing willow bundles in diagonal rows on the bank.

Bioengineering techniques may not always be sufficient to stabilize streambanks as suggested in a study in Alaska by Karle et al. (2003). In that study they calculated that in places where the force of flood flows is great, bioengineered structures will not always be able to maintain the banks. The authors observed some failures of bioengineered structures in Alaska and attributed the failures to flowing ice, undermining of toe protection, buoyancy effects, and failure of construction fabrics. They call for more testing of bioengineering techniques to determine how well they prevent erosion from floods in various types of Alaska rivers.

Fencing and walkways are other examples of active restoration techniques that can be used to protect riparian areas and streambanks from people (such as fishermen) or animals (such as livestock), although such efforts can be expensive.

The costs of bioengineering techniques are generally less than traditional bank hardening techniques (Donat 1995), although it is difficult to generalize about costs as explained by Allen and Leech (1997):

> Bioengineering treatments are normally much less expensive than traditional methods of streambank erosion control, e.g., riprapped revetment, bulkheads, but not always depending on the environmental setting and the project objectives. Costs can vary tremendously by availability of materials, hauling distances, prevailing labor rates for the geographic area, and a host of other factors.

BOX 3

Chena Bank stabilization:

In 2005 the Fairbanks North Star Borough spent $78,057, which were matching funds to $234,172 of federal funds from Natural Resources Conservation Service (NRCS), for river bank stabilization along the Chena River. Three organizations in downtown Fairbanks, located between the power plant and the Carlson Center, received funds to use bioengineered measures to stabilize the river banks (FNSB 2005b).

GUIDES TO RESTORATION

A review of riparian creation and restoration is presented by Manci (1989), which summarizes the literature (over 100 citations) on planting, fencing, landforming, installing instream devices and treating soil. One of the guides listed below is specifically for Alaska: "Streambank Revegetation and Protection: A Guide for Alaska" (Walter et al. 2005) and the US Corps of Engineers Nationwide Permit program in Alaska does not require agency review of streambank stabilization proposals if they are designed in accordance with that manual. A list of publications that give guidance about active restoration activities include:

- *Bioengineering for Streambank Erosion Control* (Allen and Leech 1997)
    - Review of successful bioengineering efforts to stabilize streambanks.
- *The Practical Streambank Bioengineering Guide* (Bentrup and Hoag 1998)
    - Presents a user's guide to natural streambank stabilization techniques for the arid and semi-arid Great Basin and Intermountain regions of the western US.
- *Streambank Restoration Manual for British Columbia* (Polster Environmental Services 2001)
    - Describes the steps to restore damaged sites including site preparation, vegetation establishment, bioengineering techniques, maintenance, and effectiveness monitoring.
- *Shoreline Armoring Research Program: Phase II-Conceptual Model Development for Bank Stabilization in Freshwater Systems* (Sargeant et al. 2004)
    - Discusses the ecological concepts of freshwater ecology and lists bank stabilization options and the positive and negative aspects of each.

(list continued)

- *Streambank Revegetation and Protection: A Guide for Alaska* (Walter et al. 2005)
    - Presents techniques (with diagrams and photos) to prevent erosion and revegetate streambanks in Alaska.
- *Field Guide for the Identification and Use of Common Riparian Woody Plants of the Intermountain West and Pacific Northwest Regions* (Hoag et al. 2008)
    - Provides information about species that can be used for bank stabilization.

BANK HARDENING TREATMENTS

Rock, cement, and other materials are sometimes used to “harden” river banks in order to halt or prevent erosion. These techniques, when done properly, can be effective at stabilizing the bank and protecting property. Bank hardening deflects the stream and its erosive force, which is beneficial for the owner of that piece of land. However, the landowner downstream of hardened banks can experience greater stream velocities and possibly greater erosion from the deflected flow.

Bank hardening techniques that eliminate vegetation eliminate the ecological benefits of that vegetation such as stream shading, organic inputs, habitat for animals, sediment trapping and dissipation of stream energy. When riprap, a common form of bank hardening, is used many important features are lost such as overhanging banks, shade, and organic inputs (Schmetterling et al. 2001; Sargeant et al. 2004). Other problems with riprap include increased near shore water velocities and loss of cover for fish and wildlife (Walter et al. 2005). “Studies that quantitatively investigate the effects of riprap on fish densities largely suggest a preponderance of evidence against the continued use of riprap along rivers and streams” (Schmetterling et al. 2001). Revegetation and restoration with natural materials (bio-technical approaches) more closely mimic natural processes that protect streambanks, provide habitat, and incorporate water into the soil.

URBAN AREAS

Urban areas present unique challenges in balancing ecological and social objectives. For many people it is desirable to live adjacent to rivers and streams, but that creates potential damage to property from flooding and bank erosion. Schmetterling et al. (2001) recommend avoiding building in floodplains:

> Preventing floodplain development through public education and governmental regulations will reduce the need for further bank stabilization. Discouraging floodplain property development is a sound goal to follow … lateral streambank erosion is a natural process that must be allowed to occur in many stream types.

Because of the risks associated with structures in the floodplain, insurance rates for houses in floodplains are much higher (Box 4).

In many urban settings there are already structures in the floodplain, very close to rivers and in these settings it is often desirable to maintain or increase the stability of the river bank. Ideally, any bank stabilization effort will include native riparian vegetation because those plants typically are excellent at binding the soil and stabilizing the banks, in addition to providing wildlife habitat. Bioengineering (described above) involves the use of plants and natural materials to reinforce river bank stability.

In some places parks, greenbelts or other semi-natural areas can be established along urban rivers, which provides the following benefits:

- **Floodwater detention.** When the river floods there is space for the water to go and to be absorbed into the ground, which decreases the magnitude of flooding downstream.
- **Minimize damage and costs.** It is cheaper to clean and repair parks than buildings.
- **Aesthetics.** People like to spend time in parks near rivers, walking, biking, picnicking, etc.

At a few sites the Fairbanks North Star Borough has established parks along the Chena River. One concern with semi-natural settings in urban parks is the potential public safety risk associated with vegetation concealing inappropriate or illegal activities according to Mike Cox, Director of the FNSB Parks and Recreation (personal communication, April 2008). One response to this concern is to remove vegetation along the rivers and plant grass. Unfortunately, turf grasses (such as Kentucky bluegrass) do not have as deep, dense, and strong roots as native riparian grasses, sedges and rushes (Manning et al. 1989). Therefore increased bank erosion often occurs after conversion of riparian vegetation to turf grass.

The preferred management of riparian areas is to leave all the vegetation, which will provide the most benefit for bank stability, floodwater storage, and wildlife habitat. If trimming vegetation cannot be avoided (for line-of-sight visibility, river views, or access to the water) it should be done so as to minimize the damage to plants, and to leave the majority of vegetation intact. Trimming plants too much reduces belowground biomass (Magoun and Dean 2000), which decreases the health of plants and decreases their ability to stabilize river banks.

Some communities across the United States have established parks or greenbelts along rivers to achieve ecological or social benefits. An example is the Gwynn Falls watershed that flows into Baltimore, MD, where riverside properties were converted from industrial and agricultural uses to a series of parks (including a 14-mile trail system) along the Gwynn Falls River (Groffman et al. 2003).

The Fairbanks North Star Borough seeks to leave vegetation near the ordinary high water mark and on steep banks next to the stream (Dan Chagnon, Fairbanks North Star Borough Department of Parks and Recreation, personal communication, April 2008). In some parks the vegetation is selectively cleared or completely removed to eliminate cover for vagrants or hiding places for stalkers.

BOX 4

Flood Risk:

Houses located in "high risk" flood areas like floodplains have a substantial risk (26%) of suffering flood damage over the term of a 30-year mortgage (www.floodsmart.gov). Homeowner insurance policies typically don't cover flood damage, and state and federal disaster assistance usually only provide low interest loans, not compensation for losses. The National Flood Insurance Program provides flood insurance policies to everyone living within participating communities, like the Fairbanks North Star Borough, but the maximum coverage is $250,000 for a residential home and $100,000 for its contents.

A house on the hill still has some risk of being flooded (therefore it is called a "preferred risk") but it is much less expensive (1/3 to 1/8th as much) to insure for flood damage compared to a "high risk" home. To obtain a preliminary estimate of the 1% annual flood risk (often called the 100-year flood), see www.floodsmart.gov or follow the tutorial to make a FIRMette map at www.msc.fema.gov. These flood risks are only estimates, so an official risk assessment should be obtained before making any financial decisions on a property. Although there is a lower annual risk for much larger floods, these floods do occur at unpredictable intervals, and should also be considered in your financial planning.

CONCLUSIONS ON PROTECTIVE SYSTEMS

"The power of passive restoration for achieving functioning riparian vegetation cannot be overstated" (National Research Council 2002). Passive restoration, which is discontinuing activities that are damaging the riparian area, is the cheapest and simplest way to restore riparian areas, and should be the first step in any restoration effort. Where passive restoration is inadequate to restore stream and riparian processes, active restoration may be needed. Where active restoration is conducted, careful planning should be used to increase the likelihood of success, and effective use of valuable restoration resources. Bioengineered techniques provide improved bank stabilization and foster many of the natural processes that are important for aquatic and terrestrial biota. Hard engineering does not maintain many of the natural processes; therefore it should be discouraged except for locations where it would be the only option. Monitoring the results of restoration efforts is a valuable and unfortunately uncommon activity that can identify corrective needs before they become a serious problem, and when results are shared (such as in publications) they provide guidance to other restoration professionals and land managers about the effectiveness of different techniques. The public can also benefit from learning about the successes (and failures) of restoration efforts.

In some urban settings it is impossible to recapture all the natural processes and functions of riparian areas, but some of the functions can and should be restored for a reasonable expense (Booth 2005):

1. Eliminate point sources of pollution
2. Reconstruct physical channel elements to resemble equivalent undisturbed channels
    a. Such as pools, substrate, wood, accessible floodplains
3. Provide habitat for self-sustaining biotic communities, even if not exactly like pre-disturbance

Care should be taken to use resources wisely in urban stream and riparian restoration, as stated by Booth (2005):

> Long-term improvement of stream conditions is not feasible under typical urban constraints, so large sums of money should not be spent on unrealistic or unreachable targets for stream rehabilitation. However, such a strategy should not be an excuse to preclude potential future gains by taking irreversible present-day development or rehabilitative actions.

SECTION 4. Riparian Buffers: Effective Widths, Establishment and Management

The previous section described actions to restore the stability of streambanks which may often be necessary to address problems such as bank erosion and property loss, but can also be costly and may fail to provide some important riparian functions. The need for such action can be prevented by protecting intact riparian areas. One way to do this is to establish "riparian buffers" along streams, which are areas where some human activities are restricted. "The establishment of riparian buffer zones is generally accepted as the most effective way of protecting aquatic and riparian habitats (Cumins et al. 1994 in Spence et al 1996)." There are two aspects to management of riparian areas with buffers: the width of the buffer and the allowable activities within the buffer (Spence et al. 1996). The scientific literature provides guidance on these two aspects of riparian buffer establishment, which are summarized in this section, based mainly on review papers (summaries of multiple studies) as well as some primary research (results from individual studies). This section also lists resources for planning and establishing riparian buffers and considerations for determining buffer width adjustments at specific locations along the river.

RECOMMENDED BUFFER WIDTHS FROM THE LITERATURE

A number of publications have reviewed the scientific literature on riparian buffers and have recommended minimum buffer widths to maintain riparian functions, which are described in Table 1 on the following pages.

TABLE I. SYNOPSIS OF ARTICLES THAT REVIEW RIPARIAN BUFFER WIDTH RECOMMENDATIONS

Citation	Type of Publication	Number of Papers Reviewed	Geographic Focus	Recommendations
US Army Corps of Engineers (1991)	Review of technical literature concerning the width of riparian buffer strips needed to protect water quality and other values.	200 citations (mix of studies, reviews and regulations)	Across USA, although report done for Vermont	"fairly narrow (i.e. < 98 ft.) buffer strips can adequately provide many riparian functions. Shade provided by trees in narrow (33-66 ft. wide) buffers generally appears to control temperature of small streams. Under most circumstances 66-98 ft. wide buffers appear adequate to remove suspended sediments from surface flows ... Narrow (66 ft.) buffers may also significantly reduce nitrogen levels in surface runnoff and groundwater ... Relatively wide buffers are probably required to provide sufficient habitat for riparian wildlife and plants."
Welsch (1991)	Recommendation for forest buffers, with a focus on agricultural settings.	19 citations (mix of studies and reviews)	Eastern USA	95 ft. buffer is recommended, comprised of three zones: the first zone is the 15 ft. closest to the stream, and is trees; the second zone is 60 ft. and includes shrubs; the third zone is 20 ft., is furthest from the stream, and is grasses. This strategy involves planting vegetation in settings where the natural riparian vegetation is no longer present, such as in agricultural settings.
Johnson and Ryba (1992)	Summary of buffer recommendations by various investigators	38 studies	Humid temperate climates, including Washington and Oregon, Eastern US coastal areas and Mid-west	Recommendations range from 10 to 656 ft. "Buffers less than 33 ft. provide little if any maintenance of various riparian functions. Buffers of 49-98 ft. provide minimal maintenance of most functions; buffers greater than 98 ft. appear adequate for most functions."
Castelle et al. (1994)	Literature search of the scientific functions of buffers.	Over 30 studes	Eastern USA	A 49 ft. buffer "was found to be necessary to protect wetlands and streams under most conditions."
Kondolf et al. (1996)	Review the status of riparian habitat in the Sierra Nevada.	Over 100 citations, but few are studies of riparian buffers	Sierra Nevada	They "Propose a more direct system for estimating a variable-width buffer system based on the community and energy area in combination with slope and other measurable risk factors." The buffer is at least as wide as one site-potential tree, 150 ft., but that value is increased based on the other factors (the distance is multiplied by the base of natural logs (e) raised to a power equal to 1+slope (in decimal form)).

Spence et al. (1996)	Review of relationships between riparian areas and fish habitat and recommended riparian buffer widths.	Approximately 40 studies	Pacific Northwest	"fully protected riparian buffers of approximately one site potential tree (98-148 ft. in most Pacific Northwest forests) are likely adequate to maintain most key functions, including shading, LWD, small organic litter inputs, nutrient regulation, and sediment control (for surface erosion in the riparian zone only)."
Wenger (1999)	Summary of findings from the scientific literature to provide a foundation for riparian buffer ordinances in Georgia.	140 studies	Georgia in particular, and other parts of USA	30 ft. buffer is absolute minimum width. 100 ft. fixed-width riparian buffer is recommended for local governments that find it impractical to administer a variable-width buffer. At least 300 ft. will be necessary for some wildlife species. “Whenever feasible, the riparian buffer should be extended to the edge of the 100-year floodplain.” Buffers should be native vegetation and all major sources of contamination should be excluded from the buffer (such as construction, septic tank drain fields, and agriculture).
Christensen (2000)	Review of the current "Best Available Science" (BAS) regarding the requirements for riparian buffers to maintain fisheries and wildlife habitat.	Approximately 40 (mix of studies and reviews)	Pacific Northwest, and Washington in particular	Summary of minimum buffers: Shade: 100 ft.; LWD: 150 ft.; Organic matter: 100 ft.; Streambank stability: 100 ft.; Control sediments: 100 ft.; Nutrient and pollutants: 100 ft. “Overall, most studies have recommended buffers between 100 ft. to 180 ft.”
Fischer and Fischenich (2000)	Description of riparian functions and buffer recommendations for each function.	Over 30 studies and some reviews as well	Across USA and Canada	Water Quality Protection: 16–98 ft.; Flood Attenuation: 65–490 ft.; Input of Organic Materials: 10–33 ft.; Riparian Habitat: 98–1,640+ ft.; Stream Stabilization: 33–65 ft.
Straughan Environmental Services (2003)	Identified the effects of riparian buffers on nitrogen removal.	Over 30 (mix of studies and reviews)	Mid-Atlantic coastal plain was target, but general resources also included	Buffers to remove nitrogen should be no less than 75 ft.
Hickey and Doran (2004)	Review of articles related to buffers for agriculture and forestry.	Over 100 studies	Agricultural settings	"Wide buffer strips (98-328 ft.) provide the best protection from non-point source pollution." Authors feel that there is a need to study the efficacy of narrower, such as 3-33 ft., buffers for agricultural settings because of the cost of taking land out of production for wider buffers.

Parkyn (2004)	Review of “published research on the efficiency and management of riparian buffer zones (RBZ) with respect to the attenuation of sediment and nutrients, and biodiversity enhancement.” The focus is on agricultural land.	Over 50 studies	New Zealand, Australia and USA	Recommend 33 ft. to 66 ft. buffer widths “as the minimum necessary for the development of sustainable indigenous vegetation with minimal weed control, and to achieve many aquatic functions.”
Polyakov et al. (2005)	Review of effectiveness of riparian buffers in removing sediment, pathogens, and nutrient loads into surface and groundwater in agricultural watersheds.	Over 50 studies	USA and other countries (such as New Zealand)	They note the benefits of riparian buffers for sediment retention and pollutant removal. But they argue that fixed-with riparian buffers remove too much land from agricultural production. They advocate variable-width buffers, or precision riparian buffer delineation, to “take into account the spatial and temporal variability across the landscape” and to maximize the combined ecological and economic benefits.
Sheldon et al. (2005)	Review of wetland ecology and management, riparian functions and buffer widths.	Approximately 40 studies	USA, with emphasis on Washington State	25 to 75 ft. for wetlands with minimal habitat functions and low-intensity land uses adjacent to the wetland; 75 to 150 ft. for wetlands with moderate habitat functions and moderate or high-intensity land uses adjacent to the wetland; 150 to 300+ ft. for wetlands with high habitat functions, regardless of the intensity of the land uses adjacent to the wetland
Mayer et al. (2006)	Review of relationship between buffer width and nitrogen removal capacity; also summarizes riparian regulations.	14 review papers and over 50 studies	USA	Buffers greater than 164 ft. “more consistently removed significant portions of nitrogen entering a riparian zone.” "Finally, riparian buffers are often protected to achieve multiple goals (e.g. sediment trapping, aesthetics, wildlife habitat), some of which may require wider buffers..."

One way to summarize the potential riparian buffer widths is to consider the range of widths that are recommended in the literature for different riparian functions, as presented in Figure 7.

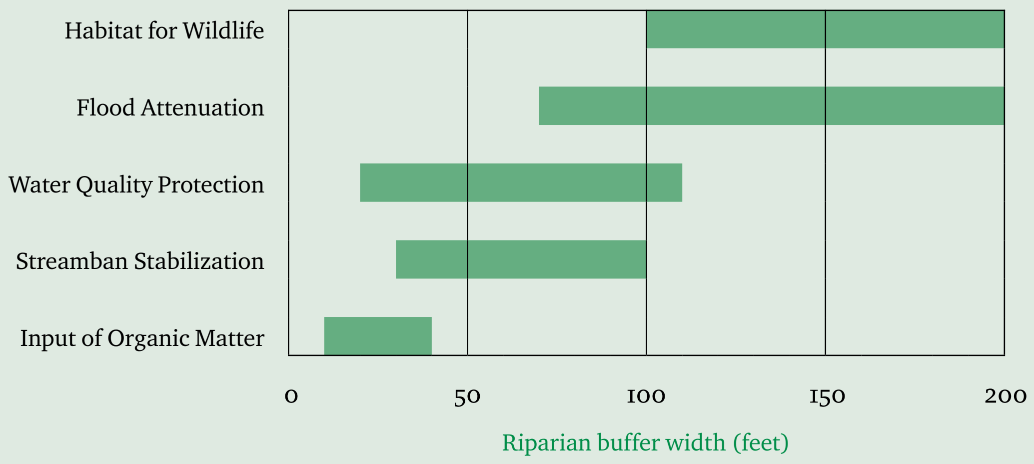

FIGURE 7.
The range of recommended riparian buffer widths encountered by Fischer and Fischenich (2000) in their review of riparian buffer literature. The widths for "habitat for wildlife" and "flood attenuation" were truncated before the very large values of 1600 ft. and 490 ft. respectively.

Recommendations for riparian buffer widths, by feature, were compiled from the scientific literature and are presented in Table 2. These data are consistent with those of Fischer and Fischenich (2000) that are presented in Figure 7.

TABLE 2. RANGE OF RECOMMENDED BUFFER WIDTHS, BASED ON REVIEW PAPERS. MINIMUM, AVERAGE AND MAXIMUM WIDTHS ARE FROM SUMMARY PAPERS, WHICH REVIEWED MANY INDIVIDUAL STUDIES. A DASH INDICATES NO INFORMATION FOUND.

Riparian Feature or Process to Protect	**Recommended Riparian Widths (feet) from Review papers**			**Citations**
	Minimum	**Average**	**Maximum**	
Streambanks	30	54	100	Wenger (1999), Fischer and Fischenich (2000), Christensen (2000)
Floodwater Storage	65	—	entire floodplain	Fischer and Fischenich (2000), Wenger (1999)
Contaminant Filtering and Storage	13	70	164	Johnson et al. (1992), Straughan Environmental Services (2003), Mayer et al. (2006)
Habitat for Fish and Wildlife	33	393	1,000	Johnson et al. (1992), Fischer and Fischenich (2000) Wenger (1999)

When establishing riparian buffer guidelines or regulations, some activities could be limited or restricted within riparian buffers in order to protect the riparian and aquatic ecosystems (Table 3).

TABLE 3. ACTIVITIES IN RIPARIAN AREAS THAT OTHERS RECOMMEND AS PERMISSIBLE, CONDITIONAL OR RESTRICTED.

Riparian management activity	Where or when permissible or conditional in buffer zone	Citation
Bank stabilization	bioengineering techniques to reduce the potential for bank erosion are permissible	Allen and Leech (1997); Li and Eddleman (2002); Chagrin River Watershed Partners Inc. (2006)
	bank hardening is discouraged because of loss of ecological benefits	Li and Eddleman (2002); Donat (1995); Schmetterling et al. (2001)
Removing, trimming, or replacing vegetation	vegetation removal is restricted	University of Virginia (2002)
	clearing of trees is prohibited	University of Virginia (2002)
	trim no more than 25% of tree canopy and no more than 33% of height	Iowa State University (2002)
Fertilizer and pesticide application	not in riparian area	Spence et al. (1996); Wenger (1999)
	ideal is not to apply fertilizer to lawns in or adjacent to riparian areas	Schueler et al. (2004)
Contaminant storage	not in riparian area	Wenger (1999)
	not in riparian buffer	Broadmeadow and Nisbet (2004)
Waste disposal	not in riparian buffers	Wenger (1999)
Transportation (e.g. foot, road, boat) infrastructure	keep impervious surfaces in urban areas below 10%	Spence, et al. (1996)
Structures (houses and other buildings)	no new development	Spence et al. (1996)
	no construction or soil disturbance	Schmetterling et al. (2001); Chagrin River Watershed Partners Inc. (2006)

GUIDES TO PLAN AND ESTABLISH RIPARIAN BUFFERS

Decision-makers who are involved in planning, establishing and regulating riparian buffers should consult with biologists and certified engineers, and they could use the following publications (sorted by year published):

- *Riparian Forest Buffers: Function and Design for Protection and Enhancement of Water Resources* (Welsch 1991)
- *Protecting floodplain resources: A Guidebook For Communities* (Smardon and Felleman 1996)
- *Protecting Stream and River Corridors Creating Effective Local Riparian Buffer Ordinances* (Wenger and Fowler 2000)
    - See "Summary of Recommendations" with key steps to developing an effective riparian buffer ordinance.
- *A Stream Corridor Protection Strategy for Local Governments* by the University of Virginia (2002)
    - Explains how to establish buffers, and case studies from Maryland, Virginia and Pennsylvania
- *Precision riparian buffers for the control of nonpoint source pollutant loading into surface water: A review* (Polyakov et al. 2005)
    - Recommends precision design of buffers based on spatial and temporal variability, primarily for agricultural settings.
- *Riparian Setbacks: Technical Information for Decision Makers* (Chagrin River Watershed Partners Inc. 2006)
    - Riparian buffers for Ohio
    - CRWP's riparian setback model recommends minimum setback widths of 25, 75, 120, or 300 feet on either side of a river or stream
    - Reviews buffers for other locations
- *Planner's Guide to Wetland Buffers for Local Governments* (Environmental Law Institute 2008)
- *Riparian Buffer Design Guidelines For Water Quality and Wildlife Habitat Functions on Agricultural Landscapes in the Intermountain West* (Johnson and Buffler 2008)
    - For agricultural settings
- *The Riparian Toolbox: Model Regulations and Legal Issues* (online document at http://www.hydroqual.com/projects/riparian/legal.htm)
    - Lists websites with ordinances for regulations from various states

Homeowners and others who own or manage property along rivers could benefit from the following websites about riparian area management:

- *Benefits of Riparian Zones: Using native plants to protect streambanks and shorelines*
    - http://www.tva.gov/river/landandshore/stabilization/benefits.htm
- *Riparian Buffers: Rationale, Strategies, and Resources for Restoring and Protecting Streamside Corridors*
    - http://www.riverkeepers.org/pdf/riparian_buffers_fact_sheet.pdf
- *Focus: Riparian Areas*
    - http://www.ecy.wa.gov/pubs/0010023.pdf
- *Backyard Buffers*
    - http://www.cofc.edu/~uses/assets/papers/backyard.pdf

OTHER FACTORS FOR SELECTING BUFFER WIDTHS

There are a number of reasons why it might be useful to increase or decrease the recommended width of a riparian buffer.

REASONS FOR RECOMMENDING WIDER BUFFER WIDTHS

- Larger and dynamic rivers that:
    - migrate within valley bottom and even can cut into hillsides
    - experience major flooding from high flows, ice dams or debris dams
- Steep stream slope — as in Island County's draft ordinance from November 2007 quoted in Environmental Law Institute (2008)
- Steep hillsides adjacent to stream (Kondolf et al. 1996)
- Adjacent wetlands that need protection (Wenger 1999)
- Fish populations of importance (ADF&G USFWS and ADNR 2002)
- Critical Wildlife areas
- Intensive land use — as in Island County's draft ordinance from November 2007 quoted in Environmental Law Institute (2008)
- Impervious surface coverage is high within the watershed
- Potential for blowdown of trees that would decrease the size of buffer (Durst and Ferguson 2000a); this is referred to as "windfirmness" by the Tongass NF (USDA Forest Service 2008)
- Outside of river bends (where stream power is greatest and where bank erosion can be dramatic)

REASONS FOR RECOMMENDING NARROWER BUFFER WIDTHS

- Existing structures or development make it impractical to implement the recommended buffer width
- Low priority stream (because of lack of fish or other reasons)
- Small peak (flood) flows
- Minimal flow in stream

SECTION 5. Regulatory Agency Buffer Widths

This section presents summaries of existing regulations for protecting riparian areas and associated stream characteristics. First is a summary of government (other than Alaska) regulations and recommendations (Table 4), followed by a summary of regulations or guidelines for Alaska government entities (Table 5).

The merits of a single-width buffer versus a variable-width buffer (tailored to each site) are discussed in the literature (Johnson and Ryba 1992; Fischer and Fischenich 2000; County Of Santa Clara 2003). A single buffer width (fixed-width) will not be perfect for all waterways and adjacent land uses but it is much easier to administer than a variable-width buffer. Where there is time, money, and expertise "precision riparian buffers" can be identified in order to obtain maximum conservation with minimum removal of land from human activities as described by Polyakov et al. (2005). An approach for "delineating channel migration zones" is presented by Rapp and Abbe (2003) as a way "to predict areas at risk for future channel erosion due to fluvial processes" and to guide development away from such areas. Calculating this channel migration zone requires significant information (using a 35-page protocol to collect the data for a site) including data on the channel valley, channel dimensions, channel bed material, bank soils, bank vegetation, and bank erosion. This kind of information can be collected at a site, for a price, but it is not practical to collect this much data over a large area, such as a municipality or a watershed. A fixed-width buffer is the most practical for large areas, which is why it is what is used by most regulatory agencies, as presented below.

TABLE 4. RIPARIAN BUFFER REGULATIONS FROM LOCATIONS ACROSS THE CONTINENTAL US.

Location	Entity	Objective	Buffer	Citation
Northwestern USA	USDA Forest Service and USDI BLM PACFISH strategy	Protect fish habitat on federal land in anadromous watersheds of Northwestern USA	A 300-foot "riparian habitat conservation area" or buffer on fish bearing streams in forested ecosystems and a 150-foot buffer on permanently flowing non-fish bearing streams. In non-forested rangeland ecosystems the entire 100-year floodplain should be the "riparian habitat conservation area."	USDA Forest Service (1995)
Northwestern USA	USDA Forest Service and six other federal agencies, which developed the Northwest Forest Plan	Protect riparian areas in relation to timber harvest	Perennial streams: buffer is twice as wide as the height of a mature tree that could grow at the site (two site potential tree heights) which is about 340-400 ft. Ephemeral streams: buffer is as wide as the height of a mature tree that could grow at the site (one site potential tree height) which is about 170-200 ft. There is no cutting of trees in the buffer.	FEMAT (1993)
USA and Canada	Provinces, territories and states	Protection of riparian areas in relation to timber harvest	Mean buffer width regulations ranged between 49 ft. and 98 ft. for treed riparian buffers after timber harvest among states, territories and provinces. Mean boreal zone regulations ranged between 46 ft. and 131 ft.	Lee et al. (2004)
USA	States	Manage timber harvest in riparian areas	A 50-foot minimum width for riparian management zones was the average in a survey of states. Minimum recommended widths ranged from 25 ft. to 200 ft.	Blinn and Kilgore (2001)
East Coast of USA	Chesapeake Bay Agreement (multiple states)	Restore / protect Chesapeake Bay (prevent contamination, etc.)	A 35-foot buffer is minimum, and some states require 100 ft.	University of Virginia (2002)
California	Counties (10)	Various	Median setback distance of 75 ft. with a range from 20 – 200 ft. for the 10 counties in the survey.	County Of Santa Clara (2003)

TABLE 5. RIPARIAN BUFFER REGULATIONS IN ALASKA.

Location	Entity	Objective	Buffer	Citation
Statewide	US Army Corps of Engineers	Mitigation projects	Required 25 to 50-foot buffer.	Federal Register (2007)
Statewide (state, private and municipal land)	Alaska Department of Natural Resources	Manage timber harvest in riparian areas to preserve fish habitat.	ADNR has a complex set of criteria to determine the width of riparian buffer for Region III (Interior of Alaska), but a simplified summary is that for most water bodies with anadromous or high value resident fish there is a minimum riparian buffer of 33 ft. and various levels of protection within 100 ft. of the water body.	Forest Resources and Practices (ADNR 2007);
Statewide	Alaska Dept. of Environmental Conservation, Water Quality Standards, Antidegradation policy (18 aac 70.015)	Maintain and protect water quality.	Existing water uses and the level of water quality necessary to protect existing uses must be maintained and protected. If the quality of a water exceeds levels necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water, that quality must be maintained and protected (some exceptions can be granted).	ADEC (2006)
Interior Alaska	General Recommendations for Riparian Management Zones		Primary zone (closest to channel—maintain natural vegetation; minor vegetation management allowed, but no construction, and at least 26-foot width (100 ft. for some settings). Secondary zone—maintain at least 50% natural vegetation and at least 26-foot width and 100 ft. for some settings (buffer diagrams are at www.habitat.adfg.alaska.gov/images2/rmzbuffer.jpg). Building setback of at least 50 ft. At least some buffer widths of 328 ft. needed for wildlife habitat.	ADF&G USFWS and ADNR (2002)

Tongass National Forest (Alaska panhandle)	US Forest Service	Manage timber harvest and other activities.	"No commercial timber harvest is allowed within 100-foot horizontal distance either side of Class I streams (with anadromous fish) and Class II streams that flow directly into a Class I stream." There is not a fixed buffer requirement for other activities (recreation, roads, etc.) but there are general suggestions for minimizing impacts to riparian areas.	USDA Forest Service (2008)
Chugach National Forest (Southeast Alaska)	US Forest Service	Manage timber harvest and other activities.	Various categories of "Riparian Management Areas" are presented, many of which have buffer requirements of at least 100 ft., one site potential tree height (130 ft.), or the active portion of the floodplain.	USDA Forest Service (2002)
Regional	Alaska regional plans are described in subsequent table			

TABLE 6. RIPARIAN BUFFER POLICIES FROM "AREA PLANS" PREPARED BY THE ALASKA DEPARTMENT OF NATURAL RESOURCES FOR MANAGEMENT OF STATE LANDS (SEE www.dnr.state.ak.us/mlw/planning/areaplans).

Area Plan	Applicability	Buffer (ft.)
Northwest: 2005	Standard Stream Corridor (if retained as public land)	>200
	Public Access along All Navigable/Public Waters	50
	Building Setback from Non-Anadromous Waters	75
	Building Setback from Anadromous/High-Value Resident Fish Waters	100
Upper Yukon: 2003	Standard Stream Corridor (if retained as public land)	100-300
	Public Access along All Navigable/Public Waters	50
	Building Setback from Non-Anadromous Waters	50
	Building Setback from Anadromous/High-Value Resident Fish Waters	100
Tanana Basin: 1991	Standard Stream Corridor (if retained as public land)	100-200
	State Recreation Rivers	1/4 mile
	Public Access along All Navigable/Public Waters	50
	Building Setback from Streams/Lakes	100
	Agriculture (fencing for livestock may be required)	100
Copper River Basin: 1986	Standard Stream Corridor (if retained as public land)	100-200
	State Recreation Rivers	1/4 mile
	Public Access along All Navigable/Public Waters	50
	Building Setback from Streams/Lakes	100
	Agriculture (fencing for livestock may be required)	100
Kuskokwim: 1988	Standard Stream Corridor (if retained as public land)	100
	State Recreation Rivers	1/4 mile
	Public Access along All Navigable/Public Waters	50
	Building Setback from Streams/Lakes / Remote Cabins	100/50

A 50 ft. riparian buffer is the typical policy for the municipalities and boroughs of Alaska that have riparian buffer policies (Table 7).

TABLE 7. RIPARIAN BUFFERS POLICIES FOR SOME MUNICIPALITIES IN ALASKA, BASED ON THE "GENERAL RECOMMENDATIONS FOR RIPARIAN MANAGEMENT ZONES IN INTERIOR ALASKA" (ADF&G USFWS AND ADNR 2002). (MANY OF THESE BUFFERS CAN BE ADJUSTED DEPENDING ON VARIOUS FACTORS ON A CASE-BY-CASE BASIS.)

Municipality Ordinances	Applicability	Buffer (ft.)
City of Anchorage 21.40.115 R10 F 3.0	Development/Disturbance adjacent to designated streams	100
	Building Setback (with conditions and exemptions)	25
City of Homer 21.59.110	Development/Disturbance adjacent to designated streams	50
	Building Setback (with conditions and exemptions)	60
City & Borough Juneau 49.70.310/950	Development/Disturbance adjacent to designated streams	50/25
	Building Setback (with conditions and exemptions)	50
Kenai Peninsula Borough 21.18.025-070	Development/Disturbance adjacent to designated streams	50
Kodiak Island Borough 17.13 & 14.080	Development/Disturbance adjacent to designated streams	50
	Building Setback (with conditions and exemptions)	50
Matanuska-Susitna Borough 17.52.070	Building Setback (with conditions and exemptions)	75

The text of the plans and ordinances listed above provide specific guidelines and policies to protect riparian areas and streams, with one of the primary considerations being whether the streams are fish-bearing. The plans allow a number of exceptions, such as:

- bridges
- transportation and utility corridors
- culverts
- water supply intakes
- docks
- open space and parks
- public structures whose purpose is to access the waterbody
- fish culturing
- recreational and subsistence activities
- certain research activities
- structures for which there is no feasible alternative.

Because of the many exceptions, the objectives of these riparian buffer and stream setback ordinances might not always be achieved.

The Fairbanks North Star Borough currently has a "Waterways Setback overlay zoning designation" (zoning section 18.48.090 WS) that is intended to restrict most structural development within a minimum of 25 feet from the ordinary high water mark (except for permitted structures, similar to those listed above). In addition, the zoning code provides for a "Waterway Protection overlay zoning designation" (zoning section 18.48.100 WP) that is intended to promote riparian habitat, prevent erosion, minimize natural hazards and promote waterway ambiance and aesthetics. These overlays only exist in places where the Planning Commission has approved them as part of another rezone request. The setback has not been applied generally and it currently exists only along a very short length of the Chena River and its tributaries, according to Doug Braddock of the FNSB Department of Community Planning (personal communication, October 2008).

An example of an effort to improve riparian management in Alaska is the proposal to "Establish a Stream Conservation Corridor with a single land use designation extending 500 feet from either bank of Montana Creek" in the City and Borough of Juneau to protect fish habitat, prevent water contamination, and to avoid damage from flooding and erosion (Trout Unlimited 2006). The Juneau Assembly recently (Oct. 20, 2008) decided to implement the 500 ft. stream conservation corridor for lands belonging to the City and Borough of Juneau. The 500 ft. corridor does not apply to private lands, which are still subject to the existing 50 ft. setback (Table 7).

SECTION 6. Conclusions

Riparian areas perform a number of functions that are important ecologically and for society. Since people like to live, work and play along rivers they inevitably impact the riparian area and the river. Even in Alaska, where there is a tremendous amount of natural landscapes, there is increasing pressure on riparian and stream ecosystems, particularly in the more populated Greater Fairbanks area and in the Fairbanks North Star Borough in general. Increasing development of property along the Chena River and use of the river is increasing the impacts to riparian areas including bank erosion, decreased ability to capture and store flood water, loss of wildlife habitat, and decreased ability to trap and filter sediment and chemicals. Management of riparian areas in the Fairbanks North Star Borough is becoming increasingly important in order to maintain these natural systems and avoid the mistakes of other developed areas, such as in the contiguous United States.

Some general principles that should be understood in managing activities in riparian areas and adjacent to rivers include:

- Rivers repeatedly flood and deposit sediment adjacent to the river, creating flat features called floodplains. Floodplains are indicators that flooding has occurred there in the past, suggesting that flooding will occur there in the future. Flood frequency (flood return interval) can only be estimated (such as 25-year or 100-year floodplain) but not predicted.
- Bank erosion and channel migration are natural processes (although relatively slow or episodic).
- Riparian vegetation stabilizes soil and decreases (but does not eliminate) bank erosion.
    - Allowing natural riparian vegetation to flourish decreases the likelihood of erosion (but does not prevent it).
    - Planting riparian vegetation can improve streambank stability and decrease the likelihood of erosion (but cannot prevent it). Planted vegetation needs time to gain a good foothold along the river, so there will be a lag in the improvement of bank stability after planting.
- Removal of riparian vegetation increases vulnerability to streambank erosion.
    - Bioengineering can be used to improve streambank stability and decrease the likelihood of erosion (but cannot totally prevent it).
    - Bank hardening decreases the likelihood of erosion (but cannot totally prevent it). Bank hardening also eliminates many ecological benefits of riparian vegetation. In addition, bank hardening may increase the likelihood of erosion downstream if the hardening results in increased water velocity downstream.
- Erosion typically is greatest on the outside of a bend in the river, because that is where the water velocity and stream power are the greatest.

(list continued)

- Riparian vegetation traps and stores sediment and contaminants: “Riparian management can be viewed as a last line of defence for attenuating contaminants before entering the stream” (Parkyn 2004).
- Leaving a natural area along the river allows for infiltration of floodwater which can decrease the intensity of flooding downstream.
- The river connects us all through:
  - Flowing water
    - What we put in the river flows downstream to other people and communities.
  - Recreation
    - We like to use the river for various activities, such as: boating (motorized and non-motorized), fishing, wildlife viewing, etc.
  - Fish
    - Fish use the river and swim up and down the river. Salmon begin life in the river, then swim out to the ocean and return back upriver a few years later.
  - Wildlife
    - Many animals use the river and the riparian area for food, cover and travel.
  - Pollution
    - Pollution in the river can harm others and compromise many of the benefits of rivers.

In developed areas it is important to maintain natural riparian vegetation next to the stream to stabilize the bank when water flows against it, from high flows or wave action caused by boats. Natural vegetation (such as willows, alders, and wetland grasses and sedges) typically has dense, deep and strong roots which bind the soil and resist erosion. Branches and stems in the water also help to protect the bank from flowing water, wave action, and ice gouging. Removal of this vegetation can compromise the bank stability and can accelerate the rate of bank erosion and loss of property.

There is a tendency for landowners along streams to cut riparian vegetation for views of the river or other reasons. Some of the benefits to landowners of leaving a natural riparian buffers (as described by the Tennessee Valley Authority) include:

- Reduce property loss from excessive erosion
- Protect water quality
- Maintain wildlife habitat
- Increase property value (maybe)
- Contribute to the natural beauty of the land
- Dissipate noise from river traffic, roads, and nearby properties

(list continued)

- Reduce maintenance time and related costs
- Provide privacy
- Screen unsightly views
- Enhance scenic views

In cases where structures are already very close to the river it is impossible to restore the natural riparian conditions. In such settings it is still useful to leave as much natural vegetation as possible or to revegetate with native species. If erosion is actively taking place, then bioengineering approaches can be used to halt erosion, and to mimic the natural processes that repair damaged areas and that can recover after disturbance unlike bank hardening techniques which require significant maintenance. If the structure is at risk then bank hardening, such as riprap (rocks) and retaining walls, may be necessary to increase the stability of the bank but many of the benefits of natural vegetation will be eliminated, such as dissipation of stream energy, wildlife habitat, and shade.

Impervious surfaces, such as pavement and buildings, in the floodplain tend to increase the magnitude of flooding. The best way to minimize floodwater damage is to preserve the entire 100-year floodplain in its natural state (Wenger 1999). Where that is not possible, whatever vegetation is left within the floodplain will be beneficial in slowing flood flows and enhancing infiltration and storage of water within the soil, which decreases downstream flooding (Poff et al. 1997; Polyakov et al. 2005). A landowner who maintains their riparian area in good condition will only slightly decrease their vulnerability to flooding, but the cumulative benefits of many landowners protecting riparian areas could be substantial for the community.

In summary, as riparian areas are protected the stability of streambanks will be enhanced which will improve protection of property. Riparian areas also will enhance dissipation of stream energy and storage of floodwaters. Riparian areas will intercept and store contaminants, which maintains water quality and fish habitat. Riparian areas will help provide fish habitat in other ways, such as through preventing fine sediment from covering spawning gravel, shading the stream, and providing organic inputs. Riparian areas will also provide valuable habitat for birds and other terrestrial animals.

It is hoped that this document will be helpful to the Fairbanks North Star Borough in their effort to maintain the functions of riparian areas and the benefits that they provide for the community. There are a variety of options for managing riparian areas, which have varying degrees of benefit to the community and impact to the landowner, as listed below (in increasing degree of intensity):

- Education (schools, community, etc.)
- Recommendations to landowners
- Streamside buffer ordinances (primarily for new development)
  - Fixed-width buffer
  - Variable-width buffer
- Restriction of certain activities along rivers
- Prohibition of development in floodplain
- Buyout and removal of structures in floodplain

Waterways link us all within the Tanana Watershed. As individuals, businesses, and government protect riparian areas we all benefit. On the other hand, as individuals, businesses and government cause or allow the loss of riparian functions along our streams we are all negatively impacted because streambanks erode, water quality is compromised, recreational opportunities are diminished and fish and wildlife habitat is lost. In a community with a river running through it, as with the Fairbanks North Star Borough, and other communities in the Tanana Watershed, we must decide how to balance development and protection of riparian areas. This document is intended to increase understanding about riparian functions in the Tanana Watershed, so that as a community, we can decide how to maintain the quality of life that healthy riparian areas and waterways provide.

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