A REVEGETATION STUDY and GUIDE

For the Flathead River Basin

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Introduction

What now remains of the formerly rich land is like the skeleton of a sick man, with the fat and soft earth having wasted away and only the bare framework remaining. Formerly, many of the mountains were arable. The valleys that were full of rich soil are now marshes. Hills that were once covered with forests and produce abundant pasture now produce only food for bees. Once the land was enriched by yearly rains, which were not lost, as they are now, by flowing from the bare land into the sea. The soil was deep, it absorbed and kept the water in the loamy soil, and the water that soaked into the hills fed springs and running streams everywhere. Now abandoned shrines at spots where formerly there were springs attest that our description of the land is true.

- Plato (427 - 347 BC)

The Flathead River Basin is one of the fastest growing regions in Montana (Flathead Basin Commission, 2009). Flathead Lake and the rivers and tributaries that feed it are attracting a growing number of people to the area. This growth places increasing pressures on the water resources that are the backbone of the region's economic and demographic growth. Streambank erosion, nutrients and other pollutants threaten the health of Flathead's waterways, and have prompted numerous restoration and revegetation projects. While the goals of many projects have been laudable, land managers and on-the-ground practitioners have experienced disappointment with the end results of many revegetation projects.

In a time when our watersheds continue to display symptoms associated with a loss of ecological and physical integrity, and budgets for ecological restoration are strained, it is imperative that we learn from our collective experience and move forward with greater success. Greater and longer term success in our revegetation efforts implies three things: 1) projects occur in the right places at the right times; 2) projects work with and not against natural processes; and 3) land owners and managers become better equipped to understand their ecosystem's needs.

In the context of increasing population growth and pressure, the Flathead is the ideal setting to evaluate past work and move forward into the future with improved understanding of ecological restoration. Long-standing relationships between conservation organizations (Flathead Lakers, Trout Unlimited), the University of Montana (Yellow Bay Research Station), Bonneville Power, Tribal and agency personnel and concerned citizens nurture a human habitat ripe with direction and enthusiasm for the task at hand. By taking both a step back to look at the big picture, and a step in to examine the successes and failures of on-the-ground work, the findings of this report are designed to contribute to the good work already underway.

The primary objectives of this manual are to:

- Contribute to the collective experience of restoration professionals in restoring riparian ecosystems in the Flathead River valley.
- Increase the economic and ecologic efficacy of riparian restoration
- Provide an overview of riparian vegetative cover along a portion of the Flathead River
- Provide recommendations that will help prioritize and implement successful projects in the future.

This report is comprised of two studies: 1. A land-use study of the 19 miles of Flathead River above Flathead Lake and; 2. An assessment of riparian soils and planting success of a revegetation project at the upper end of the Study Area. These two studies are complemented by insights into key factors that play a role in restoration of the area, namely soil water, boat wake action, invasive plant management, and long-term approaches to restoration.

Chapter 1: The Setting

Study Area

The Flathead Basin encompasses the drainages of the North, Middle, and South Forks of the Flathead River, the Stillwater and Swan Rivers, Flathead Lake and the Lower Flathead drainage, located predominantly in Flathead County, an area of 5,098 square miles in Northwest Montana. The Flathead River Basin is a tributary of the Columbia River that extends from headwaters watersheds located in British Columbia, Glacier National Park, the Great Bear Wilderness, the Bob Marshall Wilderness, the Mission Mountain Wilderness and the Rattlesnake Wilderness to the semi-arid rolling intermountain valleys near its mouth . The study area for our land-use study focused on riparian areas within the first 19 miles of the Flathead River and sloughs north of Flathead Lake.

At the upper end of the study area is the Flathead Project Area, a Watershed Consulting revegetation project completed in 2008. This section of the river is significant as it lies south of the fast-growing Kalispell area and is characterized by sloughs and oxbows, wetlands and riparian corridors, which serve as the “kidneys” of the rivers. The wide valley floor, meandering wetlands, sloughs, and cottonwood and aspen communities along the river banks here all depend on resilient and healthy riparian areas and serve an important ecological role in capturing and retaining sediment, controlling high flow events, and serving as a buffer against inputs from agricultural production.

Riparian areas represent less than 1% of Montana's landscape, but are used by 70% of migrating bird species during migration (Flathead Lakers, 2009). The northern rim of Flathead Lake west of the study area receives over 200 bird species annually and is home to a U.S. Fish and Wildlife Service Waterfowl Production Area and the Lost Trail National Wildlife Refuge (Harrison, 2009). Riparian corridors in particular and their sloughs and wetlands provide excellent habitat for white-tailed deer, beaver, river otter, muskrats, bull trout and cutthroat trout (Flathead Lakers, 2005).

Critical habitat for migratory and resident fauna, particularly birds, abounds in this area. Many of these habitats have been identified already. Related to habitat is water quality, and the following attributes were found by the Lakers as essential for the health of the river:

- Functional riparian corridors
- Wetlands and sloughs
- Functional floodplain

Some of the major threats to these critical lands were identified by the same study. These non-site specific threats include:

- Residential development and land subdivision of critical lands (river frontage, sloughs, floodplain, prime farmland and shallow groundwater areas)
- Floodplain regulations that are inadequate for protecting groundwater and preventing removal of riparian vegetation
- Removal of riparian forests
- Erosion caused by watercraft (wave action)

Long ago many valley bottoms in the tributaries to the Flathead River were logged and cleared for agriculture and grazing and hay cropping. We know now that these forests were essential to the bio-physical integrity and stability of these watersheds. Current revegetation strategies rarely consider the long-term ecologic trends and the re-establishment of riparian forests. We tend to concern ourselves with the immediate issues of the day and place. Many projects we have visited in the past lacked appropriate tree species for the establishment of riparian forest, instead emphasizing quick growing stream side shrubs for relatively quick soil stabilization. While stream-side shrub plantings will certainly do no harm, they rarely develop into the type of forests necessary for true ecologic and physical integrity. Forests are much more resilient to natural disturbance than shrub lands. If we expect continued flooding and high-energy flows, we must set the stage for enhanced biological resiliency for the long run. Even now we see mature alder and other shrubs under-cut by the forces of water and sent quickly down stream. This is not so with a mature forest. A mature forest will:

- Trap sediment and other pollutants from runoff- agricultural and residential- before they enter rivers and streams. Decreased sediment in streams keep fish spawning areas clear, reduce nutrients and improves water treatment capacity;
- Capture water from floods and slowly release it back to the aquifer;
- Produce forage- in healthy systems, producing more per unit area than uplands
- Have root masses that maintain shoreline structure and hold soil together, providing a barrier to the erosive powers of water;

- Are a consistent source of large woody debris, which, when floating or beached provide shelter for fish and habitat for aquatic insects, traps sediment and creates in-stream diversity (riffles, pools and runs) which are important stream characteristics to maintain aquatic life;
- Provide shade, which helps regulate stream temperatures and improves fish habitat;
- Reduce stream velocity during high-flow events, which, in the absence of vegetation, can rapidly erode streambanks which can lead to a lowering of the water table.

(Flathead Lakers, 2009, Agriculture and Agri-Food Canada, 2009)

Disturbance – The Setting of Interest

Human caused or human exacerbated disturbance is the focus of our investigations and the object of our management recommendations. Though human presence and growth in the Flathead Basin causes a necessary disturbance to natural ecosystems, the response of these ecosystems to disturbance is little known and less studied. Understanding how we as inhabitants of the Flathead's watersheds influence natural processes and physical elements is vital to the success of our overall ecological restoration efforts.

Some activities that had and continue to have a significant influence on the ecosystem include:

- Logging
- Dams- artificial lake/river levels
- Roading
- Boat wake effects
- Clearing for agriculture
- River and stream dredging and straightening
- Grazing
- Clearing for aesthetics
- Utility corridor clearing

Each of these activities influences the biological and physical resiliency of river ecosystems and their susceptibility to further disturbance. In many places in the Flathead basin, the cycle continues as human made disturbance intensifies the influence of natural disturbance, directing ecologic trends towards an unfortunate end. When these river systems become sufficiently degraded that agricultural land and personal property are threatened, people are quickly compelled to armor the river, effectively negating natural ecologic processes. Our Project Area is a case in point.

Note that each of the above listed activities supports an essential element that allows us to live and work in the area. Often, it is not what we do that causes long-term shifts in ecologic trends, but how we do it. In the past several decades, Montanans have learned to pursue the necessities while conserving and protecting those elements most essential to the health of the land. The Flathead is a case in point, where the lake remains one of the cleanest in the world due in part to the protected status of 80% of its headwaters areas (Woesnner et al., 2004; Flathead Basin

Commission, 2009). Despite these protections, critical riparian habitats throughout the study area are lacking. Cottonwood trees, of particular importance to riparian communities, have suffered from reduced regeneration potential due in part to dam-altered river levels, and are thus seen as ever more critical components of healthy riparian ecosystems.

The "disturbance setting" is evidenced on the landscape where we see:

- Aggressive, invasive grass or weeds that can out-compete native shrubs and trees. These species do not have the deep-binding root mass of native vegetation and thus do not provide the ecological function desired in a healthy riparian community;
- A lack of shade-providing trees which can lead to warmer stream temperatures, increased algae growth and decreases in dissolved oxygen;
- A lack of large woody debris recruitment potential (except in grassland stream systems);
- A lack of native shrub and tree seeds to restock disturbed areas;
- A lack of appropriate seed germination substrate (silt deposits un-encumbered with grass);
- Drought issues caused by changes in soil characteristics, hydrology and cobble deposits;
- Sites desertified by tree removal or over-grazing;
- Browser habitat enhanced on a landscape scale; and
- Mass wasting of riverbanks due to vegetation removal, trampling of vegetation, limited riparian buffer zones and boat wake action

The water quality of Flathead Lake, the barometer of health for the watershed, has been declining since the 1970s, as demonstrated by increased algal blooms, the increased ability of the lake to grow algae, reduced oxygen in deep waters and decreased water clarity. Flathead Lake received a 303d listing by the Montana Department of Environmental Quality (DEQ) in 1996 and 2000. Causes of impairment were nutrients, siltation, organic enrichment or low dissolved oxygen, algal growth, PCBs, metals and mercury. Nitrogen and phosphorous levels in the lake have risen 10-20% since the 1970s (Flathead Basin Commission, 2009). The TMDL for Flathead Lake prescribes a 15 percent reduction in nutrient loading (MDEQ, 2001; Flathead Lakers, 2005).

Climate of the Flathead Basin and Tributaries

Kalispell, located on the Flathead Valley floor at 2,954 ft, is approximately 9.5 miles from the northern end of Flathead Lake and receives an average of 17.2 inches of rainfall per year. The wettest months of the year are May and June, with most other moisture occurring in the form of snowfall during the winter months between November and January. The riparian areas surrounding the Flathead River in the area of concern for this report roughly share this trend of precipitation. With its headwaters in 37 glaciers in Glacier National Park and other protected areas such as the Mission Mountains, the Flathead River is snow-melt dominated, underpinned by groundwater baseflow. It is important to note that local geography will obviously play a significant role in determining more accurate estimates of precipitation patterns, which vary dramatically over the 2,339m topographic gradient of the Flathead basin (Woessner et al., 2004).

The growing season of the region likewise will vary with elevation and specific geographic location. More generally, frost-free conditions persist for between 120-130 days for the valley areas south of Kalispell, with 10 additional growing days along the eastern edge of Flathead Lake. The months including and between May and September constitute that portion of the year when frost-free temperatures have the greatest possibility to occur and where the average minimum monthly temperature exceeds freezing. Higher elevations will yield much different conditions with areas above 6,000 feet usually having less than 50 days of frost-free weather, although riparian areas exceeding this elevation will likely not be as degraded or in as great a need for restoration as riparian zones at lower elevations.

Figures 1 and 2 below contain more detailed information on climate in the Kalispell area. Data was collected at the Kalispell Glacier PK AP Weather station, 7.45 miles from Kalispell. Data sources include the National Weather Service, National Oceanic and Atmospheric Administration, and National Climatic Data Center.

Figure 1. Kalispell yearly temperatures

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Max °F	28.9	35.2	44.9	56.0	64.7	71.9	80.2	80.5	69.0	55.3	38.6	30.1	54.6
Mean °F	21.4	26.8	34.9	43.4	51.3	57.7	63.5	63.2	53.1	41.9	30.9	23.1	42.6
Min °F	13.8	18.4	24.8	30.8	37.9	43.5	46.7	45.8	37.1	28.4	23.2	16.1	30.5

Figure 2. Kalispell average yearly precipitation

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Inch	1.47	1.15	1.11	1.22	2.04	2.30	1.41	1.25	1.20	0.96	1.45	1.65	17.21

Geology of Flathead River and Tributaries

The exposed bedrock of the Flathead River Basin is all Belt rock, Precambrian sedimentary rock formed through compressional deformation about 80 million years ago (Alt and Hyndman, 1986; Woessner et al., 2004). The Flathead River Basin lies within the Rocky Mountain Trench, a straight trough with steep valley walls on both sides which extends into the southern Yukon of Canada. This trench, formed 60 million years ago along with the Rocky Mountains, filled with ice during glacial periods and moved slowly southward, carving out the valley. During the

Pinedale ice age 15,000 years ago, the Cordilleran Ice Sheet filling this trench stopped at Polson, where the glacier's terminal moraine was formed. As the meltwater drained over the top of the moraine in the channel now filled by the south and west-flowing Flathead River, it easily carved away at the glacial sediment deposits forming the moraine (Alt, 1984).

The entirety of Flathead Lake should have been drained except that the river hit bedrock within the moraine and continued carving its way through the Rockies until its confluence with the Clark Fork River west of Perma. As the glacier receded, a variable range of alluvial (gravel, sand, silt and clay) and outwash (boulder, gravel and sand mixture) deposits were left throughout the valley. The lakes and ponds throughout the valley and in the moraines near Polson were created from large blocks of ice that remained after the glaciers receded (Alt, 1984).

The Community/Culture Context

Arguably one of the most important and most overlooked aspects of stream health is the involvement of landowners with riparian property in the conservation and restoration of their stream banks. In the context of increasing growth pressures, critical streamside lands will have more, rather than fewer landowners. These lands typically have the highest development values and smallest agricultural potential (Flathead Lakers, 2004). The first question is who are these landowners? According to the U.S. Census Bureau, 47.4 percent (about 35,000 people) of the population in Flathead County lives in urban centers and 52.6 percent in rural areas. The entire population of our Study Area is considered rural. More interesting, however, is that only 3.7 percent of the people living in rural areas include households concerned with growing crops or raising livestock and 96.3 percent are non-farm residences (Flathead Lakers, 2004).

Equally important is the community of scientists, recreationalists, and state institutions involved in protecting the waters. The more these different actors can converge on the mutual importance of maintaining healthy riparian buffers and floodplain forests, the closer we will come to a sustainable form of restoration and stream conservation.

Conservation easements have been used increasingly in the area, and can be effective for conserving critical lands. To date, 3,324 acres of land are in easements along the river south of Kalispell (Flathead Basin Commission, 2009). These agreements need to be accompanied by effective compliance monitoring. Otherwise, easements can become a quick money-maker for landowners who can, without oversight, maintain their current practices.

This said, there are strong cultural traditions in the area. Agriculture has long been the main occupation in the basin. Agricultural producers are arguably in the most direct contact with their environments and thus see the changes in hydrology, bank stability and wildlife habits on and around their land. Though the most troublesome signs of stream health of the Study Area were found on agricultural lands (see Chapter 2), these land owners should be seen as key allies since they have a vested interest in protecting and maintaining prime agricultural soil.

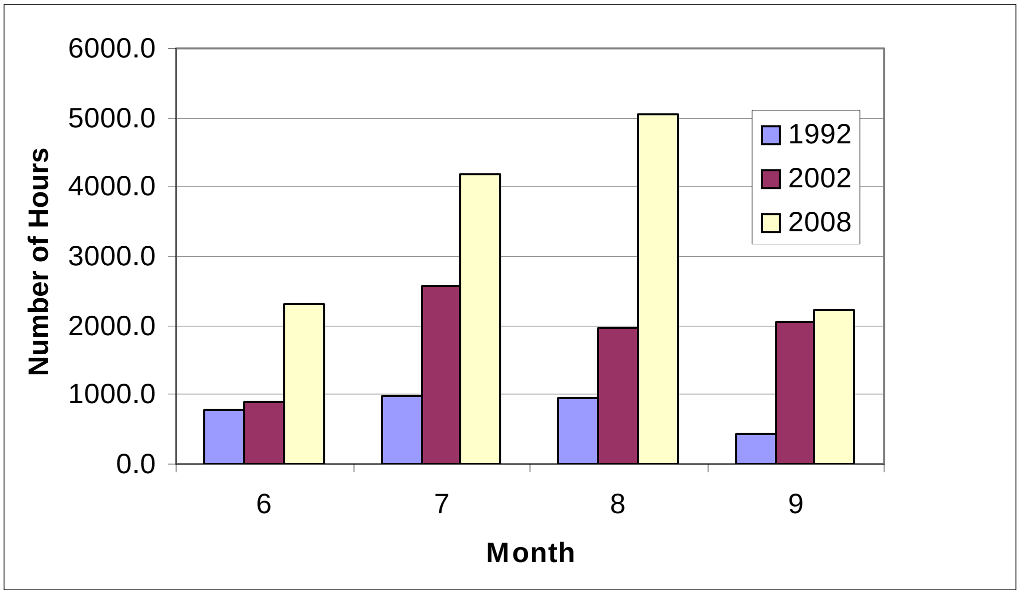
Boating on the River

Another culture of the region, albeit much more recent, is that of boating. Motorized watercraft have open access to the Flathead River from the lake as far up as where the South Fork of the

Flathead River joins the main stem. With the completion of Kerr Dam in 1938, the water level of Flathead Lake is held at full pool all summer and into the fall. The increased elevation of the lake surface backs up water in the Flathead River approximately 22 miles and affects our entire study area. The deeper depths and reduced current speed has improved motor boating opportunities in these river miles (Deleray and Cavigli, 2008).

Boating use in 2008, consequently, increased in both the river and sloughs by two to three times since 2002 and four to five times since levels in 1992 (Deleray and Cavigli, 2008), as shown in Figure 3. As boat usage increases, so have issues related to their use, including noise pollution and, of interest to this report, the eroding power of boat wakes on stream banks. A detailed discussion of the erosive forces from boat wakes can be found in Appendix D.

Figure 3. The estimated total number of boating hours per month on the lower reach of the Flathead River and sloughs.



Our assessment of the area begins with these observations in mind.

Chapter 2: Current Riparian Issues, Conditions and Trends

Riparian clearing is the biggest problem in the valley as far as bank stabilization and water quality.

Larry Van Rinsum
Flathead Conservation District
(Flathead Basin Commission, 2009)

Individual revegetation efforts in the Flathead region offer us the opportunity to recognize and learn from the factors that lead to success or failure. In a basic sense, success can be defined as plants surviving with enough vigor to significantly enhance soil stability and/or provide habitat for fish and wildlife. Piecemeal projects with differing success rates may not be enough to maintain the ecologic integrity required of ecosystems facing immediate threats. Stepping back, we must also examine ecologic trends at a larger scale to determine the size and scope of restoration needs and to help prioritize actions. It is important to note that much work has already been done in this regard. This report reaffirms earlier work by the Flathead Lakers, among others, and provides some statistical analysis in the hopes of boosting the argument for more and better stream-side restoration in this area.

Riparian Vegetation Assessment

With the aid of digital maps, we assessed and analyzed the relative vegetation of streambanks along the first 19 miles of the Flathead River north of the Lake, and their associated land uses. We conducted this exercise in order to provide a bigger-picture assessment of riparian conditions in the study area, potentially providing land managers with a broader set of targets.

Methods and Assumptions

The survey is based on digital map images from May of 2004 and was designed to provide a snapshot of this segment of the region. Both left and right riverbanks were measured from Flathead Lake to the Project Area. The length and width of streambank vegetation was tallied using digital mapping applications. Our break-points for measurements corresponded to obvious changes in land uses. The four land uses identified were forest, wetland, residential and agriculture.

Mature vegetation are trees or shrubs with deep-binding root mass, which most accurately resemble the pre-development riparian community of the basin. The exact character of riparian vegetation along banks is difficult to determine from the vantage point used. However, a mature tree-lined bank (Figure 4) is easily discernible from a bare bank or one with sparse vegetation (Figure 5).

Figure 4. Streambank with thin strip of mature vegetation.

For the purposes of this study, there is no distinguishing between mature shrubs or tree species. Due to the limitations of our digital images, banks covered in grasses, sedges or rushes, or those which are above the water line during most of the year, were considered lacking vegetation. Data from wetlands, for example, shows bank lengths often lacking mature vegetation. These ecosystems, however, often offer a significant buffer to streambanks from the effects of boat wakes or high-flow events. In some cases, depositional areas that looked to be underwater in May but are dry beaches most of the year could have been classified as wetlands.

Figure 5. Streambank with no vegetation and road.

Given the valley's historically tree-filled character, we assume that mature tree species are historically the most naturally occurring and thus most resilient riparian vegetation, and thus, what should be strived for in revegetation efforts.

Results

Main Channel

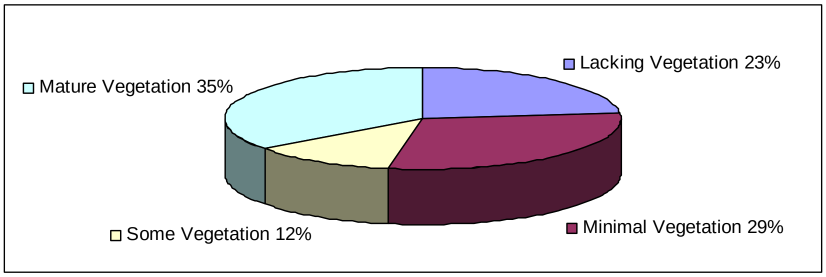
As discussed in Chapter 1, the amount and width of the riparian buffer along stream banks is one of the key determinants of a streams ability to carry out its ecological functions. Table 1 explains the riparian stability index used in this survey.

With development pressures increasing in the period between 2004- 2008, some changes in land use could have occurred within the project area, but it is assumed that most agricultural land remains in agriculture and most wetlands and forests remain intact. We also assume, because of vegetative growth rates in this climate that areas with no or sparse vegetation (including sedge and grass-dominant riparian areas) would not, in 4 years, come to have mature riparian areas. Ownership of wetland and forested areas is not known nor was it in the scope of this survey to determine the amount of these lands that could be converted to other land uses.

Table 1. Bank vegetation stability index

% Vegetation	Stability Index
0-25%	Lacking Vegetation
26%-50%	Minimal Vegetation
51%-75%	Some Vegetation
76%-100%	Mature Vegetation

Figure 6. Riparian vegetation types and frequency



Over the course of the study area, all four types of bank stability were present to varying degrees, as shown in Figure 6.

Of concern to ecologic trends is the 52% of stream banks that have zero to minimal vegetative cover. These vegetative cover regimes were distributed among differing land use types.

Examples of these four land use types are given in Figures 7 thru 10. Agriculture is the dominant land use in the study area, occurring on 60% of the Flathead's stream banks.

Figure 7. Example of residential land use type

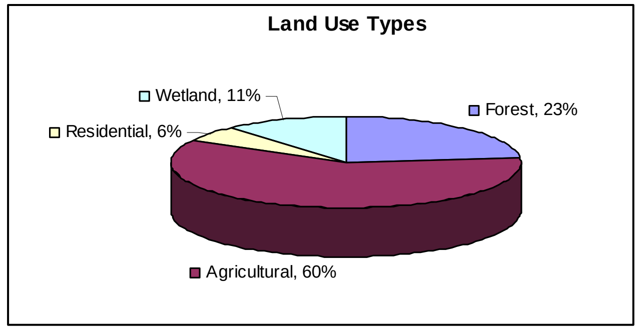
Figure 8. Example of wetland land use type

Figure 9. Example of forest land use type

Figure 10. Example of agricultural land use type

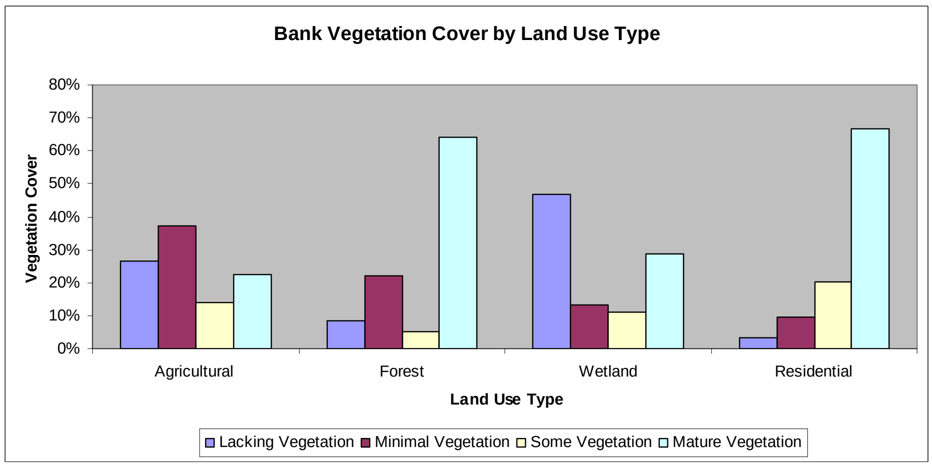
Residential land use was primarily located near Flathead Lake and occupies 6% of stream banks. Figure 11 shows the distribution of land use types, calculated by the length of stream bank bordered by that associated land use type.

Figure 11. Land use types and frequency



With a general understanding of the types of riparian cover and the types of land use in the study area, further analysis was done to correlate riparian cover to land uses. Not surprisingly, forested lands had the highest percentage of mature vegetation. Residential land use types also had a high percentage of banks with mature vegetation, which reflects the values held by people who buy property in this area. Agriculture, on the other hand, showed most of its land as either lacking or having minimal vegetation. These results are summarized in Figure 12.

Figure 12. Bank vegetation by land use type



The width of a riparian vegetation buffer is another critical determinant of ecologic resiliency. Table 2 shows the average width of vegetative buffers by land use type. Riparian buffers on agricultural lands are one-third those of forested lands. The maximum width measured to was 200 feet. Putting together estimates of riparian width and length, we were able to calculate the vegetated area per foot of stream bank for the different land use types. The results, shown in Table 3 demonstrate a larger gap between forest land use types and agricultural ones. The latter have only 39 square feet of riparian vegetation per foot of

Table 2. Width of riparian vegetation by land use type

Land use type	Average width of vegetation (ft.)*
Forest	185
Agricultural	62
Residential	74.74
Wetland	91

**200 ft. max width*

Table 3. Mature vegetation per bank length

Land Use Type	Mature vegetation per bank length (square feet)
Forest	146
Agricultural	39
Residential	63
Wetland	48

stream bank. Roads within 100 feet of streambanks are one reason for a lack of vegetation. Feet of road near streambanks is summarized in Table 4.

Table 4. Length of Road within 100 ft. of river

	Road length within 100 ft. of stream (ft.)
River Left	5300
River Right	5700

A lack of mature riparian vegetation can be more or less problematic depending on the part of the river lacking vegetation. Of specific concern to this study are poorly vegetated banks on outside bends of rivers, where bank stress is higher during high flow events, and where significant erosion can occur. Table 5 shows a breakdown of vegetation stability index in relation to outside bends. Of the sediment contributions from the Flathead River to Flathead Lake, it can be assumed that a fair portion of this sediment comes from outside bends on un-vegetated lands.

Table 5. Total bank length, cover and bank stress

Total Bank Length and Vegetation Cover				
Stability Index	Total Bank Length	% of total	Outside Bends	% of Total Bank
Lacking Vegetation	47968	23%	14590	7%
Minimal Vegetation	60737	29%	10695	5%
Some Vegetation	24621	12%	4688	2%
Mature Vegetation	73064	35%	9104	4%
	206390	**100%**	**39077**	**19%**

Interestingly, a 2004 report by the Flathead Lakers on critical lands in the area identified approximately 50,000 feet of streambank lengths where erosion is occurring, and many of these sites were located on un-vegetated outside bends, shown in Figure 13 (Flathead Lakers, 2004). It is evident that agricultural lands with minimal to no vegetation are the source of much of the erosion occurring in this section of Flathead River.

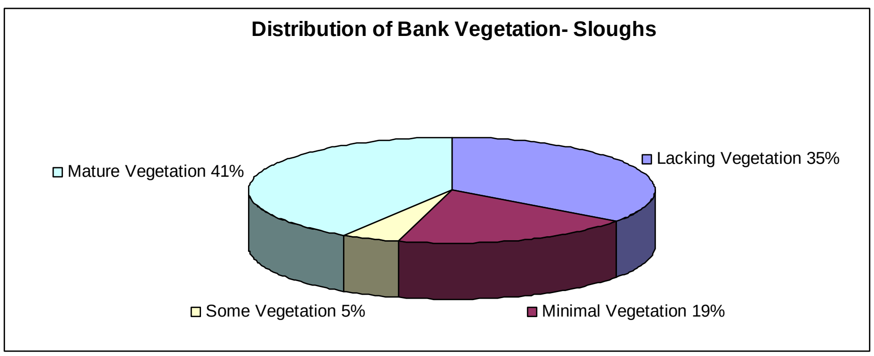
Figure 13. Erosional areas within study area

Sloughs

There can be no doubt that the sloughs and wetlands of the study area, to borrow a phrase from the Flathead Lakers, are "critical lands." Foy's Bend, Fennon Slough, Egan Slough, Church Slough and Weaver Slough were identified as critical lands (Flathead Lakers, 2004), primarily due to the wetland ecological services they provide and their high level of use by migratory waterfowl and songbirds, and the habitat they provide for brooding and nesting geese and herons. Because the sloughs have very slow moving or no current and warm summer temperatures, they resemble lakes more than river habitats, making them attractive to boaters. We analyzed the riparian condition of these areas, and summarized them in Tables 6-8.

Bank vegetation in sloughs is generally either very well established or mostly lacking (Figure 14). Though attributing causes to these statistics is beyond the scope of this report, the dichotomy between forested and non-forested lands in sloughs may be related to the conservation easements that have been targeted to these areas.

Figure 14. Distribution of bank vegetation in sloughs



As with the main stem of the river, Agriculture dominates the land uses of the sloughs (Figure 15).

Figure 15. Land use type in sloughs

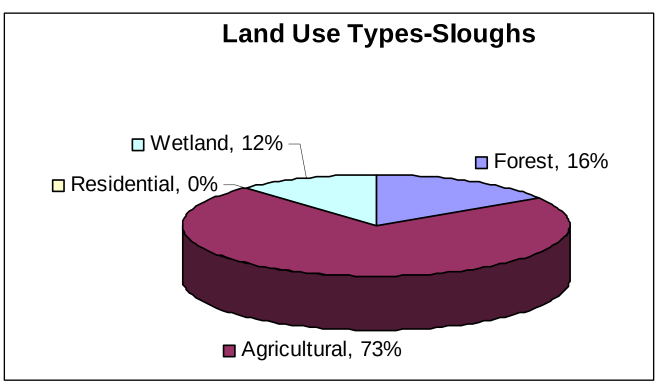


Table 6. Average width of mature riparian vegetation in sloughs

Land Use	Average Width of vegetation (200 ft. max)
Forest	178
Agricultural	70
Residential	0
Wetland	90

Table 7. Eroding bank in sloughs (From Flathead Lakers, 2004)

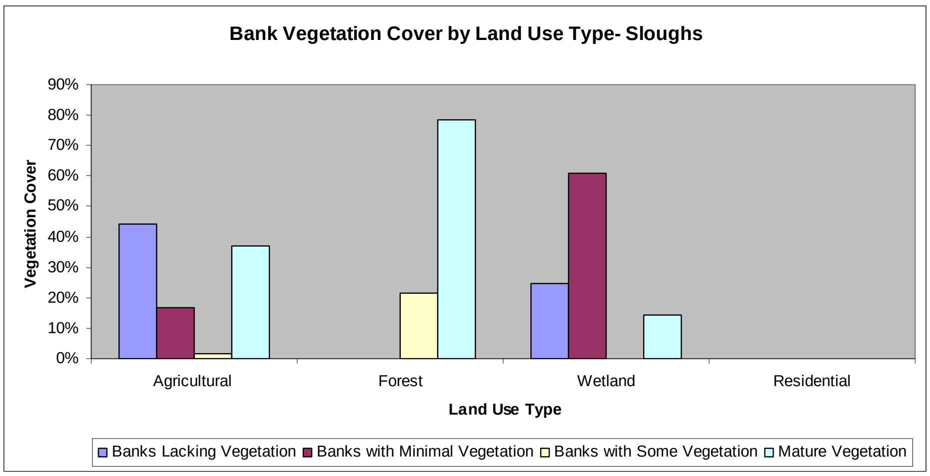
Slough	Eroding bank (ft.)
Church Slough	6352
Egans Slough	6352
Half Moon Slough	1500
Fennon Slough	0

Table 8. Road length within 100ft. of sloughs

Slough	Road length within 100 ft. of stream (ft.)
Church Slough	5000
Half Moon Slough	777
Fennon Slough	1100

Compiling our data sets provides a snapshot of relative riparian vegetative cover in the sloughs (Figure 16). As with the main stem, agricultural lands with no or minimal vegetation are of the most concern. Wetland areas also show a high percentage of un-forested or minimally forested banks. These areas are of less concern, because wetlands serve as natural buffers and in many cases could be dominated by sedges and other non-"mature" vegetation as categorized in this report.

Figure 16. Bank vegetation by land use type in sloughs



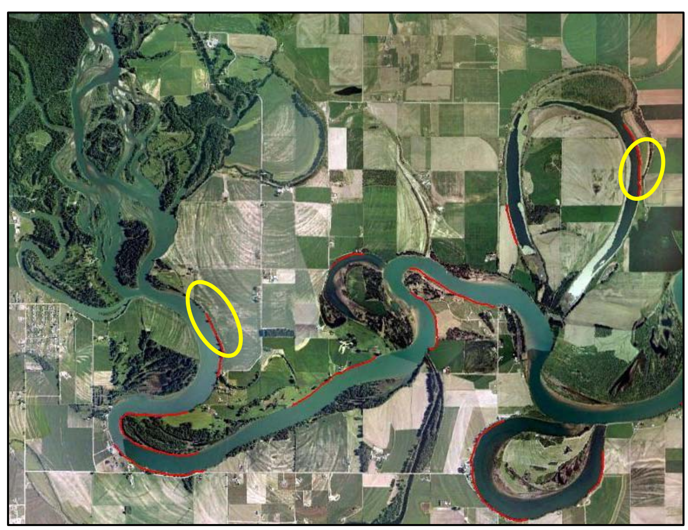
Riparian Vegetation Assessment Summary

Digital mapping applications can be useful tools for collecting coarse data on land-use and riparian area relationships. For on-the-ground work, site visits and site-specificity are essential to any restoration activity. This brief survey provides land managers a big-picture look at relative proportions of mature, well-vegetated riparian areas within the lake-affected segment of the Flathead River. Residential development, though of increasing concern in the politics and economics of the region, does not have a strong correlation with riparian areas lacking vegetation. Agriculture in the Study Area, in contrast, is where we find most high-stress banks lacking adequate vegetative cover. These lands and these landowners should be prioritized for restoration in this area.

Revegetation Site Assessment

In 2007 and 2008, Watershed Consulting implemented a streamside revegetation project in two areas of the Flathead River, along the left bank (facing downstream) of the north-westernmost section of the Study Area and in the south-easternmost section of Egan's Slough. We returned to monitor plant establishment in each of the three subsequent years in an attempt to explore a few of the factors that influence revegetation success specific to the Flathead River ecosystem. Figure 17 shows the locations of the projects (in yellow).

Figure 17. Revegetation Site Assessment Project Areas



Flathead River Site

This project site is along the outside bend of a relatively un-protected streambank on the Siderius ownership and surrounded by agricultural land use. We planted 1350 trees and shrubs, mostly in 1 gallon pots, along a ½-mile stretch of river in the spring of 2008. The area is typical of the land-use type concluded to be of highest priority in our land-use study: agricultural on an outside bank. The area is characterized by high vertical banks, agricultural activities in the riparian (haying) and, despite some patches of mature trees, a lack of necessary riparian shrub and tree cover. We planted a suite of Cottonwood, Aspen, Chokecherry, Red-Osier Dogwood, Rose, Serviceberry, Alder, River Birch and Hawthorn at a density of approximately 1 plant/1 ¼ square yard.

Due to the instability of these banks, a large volume of rip-rap was placed along the banks prior to our planting (See figure 18). As will be discussed, construction activities associated with the rip-rap had a large impact on revegetation success and was an unanticipated factor in this project. During our 2010 visit to the site, new areas were seen where large chunks of streambank had collapsed into the river. It may be that this area was not rip-rapped (Figure 19).

Figure 18. Rip-rap on banks along Flathead Site

Figure 19. Blown-out section of bank

The driving questions for our work at the Flathead River Restoration site were:
(1) Where in the soil profile is water most available to plants based on slope position and soil horizon exposure?
(2) Will plants provide bank stabilization at this site?
(3) When planting on high banks on the Flathead River, is it worth the extra effort and investment to use "tall ones" containerized plants?
(4) What types of soils are present at this particular site and how does soil type, soil moisture and soil texture influence revegetation and restoration?

Study Design and Methods

Each of the above questions was addressed with different methods. Site assessments and monitoring were conducted in October, 2008 and May, 2010.

(1) Planting on a high dry bank is risky. We often plant horizontally into the exposed bank face. When the soil profile is exposed by a river bank, and appropriate for planting, which soil deposits will give the best results? For example do soil horizons with gravel supply more water than other soil horizons? In order to determine where water was most available to plants, we dug 18 total soil pits (6 from locations directly adjacent to the current farm field (U), 6 from locations between the edge of the crops and the Flathead River (M), and 6 from locations nearest the river on the lowest part of the slope (L). Samples were taken from 5 different depths within each pit: 0-6 inches; 6-12 inches; 12-18 inches; 18-24 inches; and 24-30 inches. Gravimetric soil moisture content was performed on each sample and particle size analysis to determine soil texture was performed on a subset of these samples. Percent plant available water was determined using soil texture and percent soil moisture. This analysis was used to compare pits on site at the particular time when samples were collected. Full Results are shown in Appendix B.

(2) A primary reason for planting on a high dry bank is to produce a "hinge effect" years into the future. We wanted to track if our revegetation effort produce the hinge effect? In order to examine this, we established 5 permanent photo points in July of 2009 (See photos in Appendix A). These points are marked by a yellow-capped rebar stake on site.

(3) "Tall Ones" are native plant stock 4 x 4 inches on the open end and 14 inches deep. They are typically about $1.50 more expensive than a regular one-gallon containerized plant and require a deeper hole. In May of 2008 we planted 40 of each cottonwood, dogwood, and rose in groups of 4 (2 tall and 2 regular of the same species within each group) as shown in Figure 20.

Figure 20. Container Size and Watering Study

NW		NE
Tall, Watered Rose	← 1 meter →	Regular, Watered Rose
↑ 1 meter ↓		↑ 1 meter ↓
Tall, un-watered Rose	← 1 meter →	Regular, Un-watered Rose
SW		SE

We returned in July, 2008 and May, 2010 to assess survivability of tall ones versus one-gallon pots.

(4) We examined this question by digging and describing a soil pit in a section where native vegetation was well established on this site. We also examined soil texture and moisture content in 20 pits throughout the site. Soil samples were collected and textures were measured for

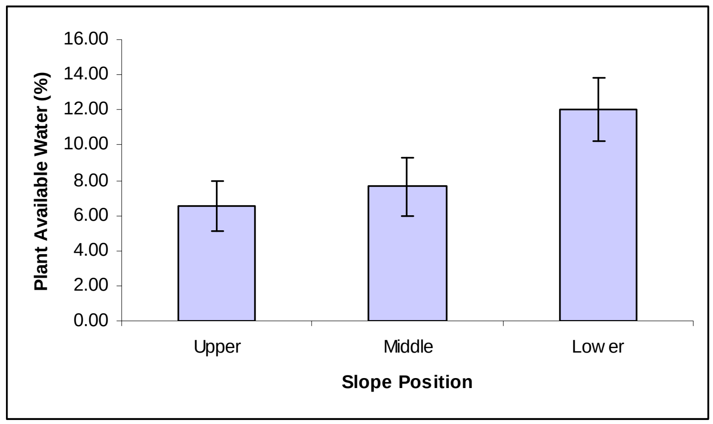
different soil layers in the laboratory by the gravimetric particle size analysis method also known as the hydrometer method.

Results and Discussion

(1) Where is the soil water located throughout the soil profile?

We found that soil moisture varied greatly between slope positions but also between horizons within the same pit on this particular site. As would be expected, the pits nearest to the field had the least plant available water and the pits nearest to the river overall had the most plant available water (Figure 21).

Figure 21. Percent plant available water by slope position at the Flathead River Re-vegetation Site.

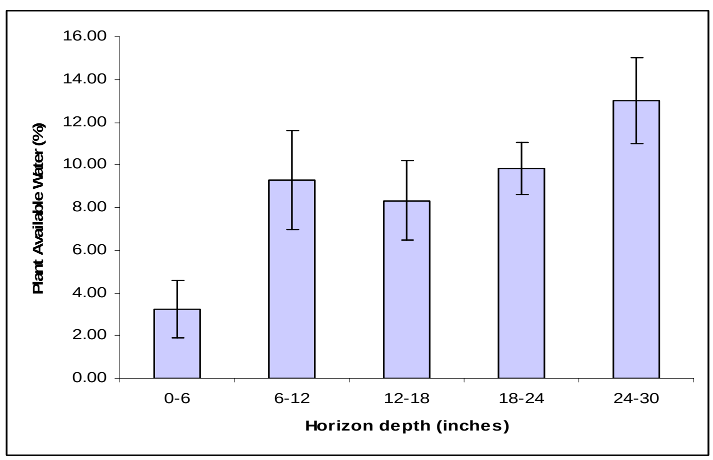


We also found that the top soil horizon has minimal plant available water versus even the second soil horizon (6-12 inches). Moving lower in the profile, percent available water increases (Figure 22).

That there are a large range of soil textures in this alluvium is well known. We can make a few generalizations at this particular site: the area nearest the current farm field is more compact than closer to the river and this area also has the least amount of plant available water.

(2) Will plants provide bank stabilization?

Figure 22. Percent plant available water by horizon depth at the Flathead River Re-vegetation Site.



In May of this year we could determine that the ecological trends of the site are heading in the appropriate direction. In the future (5-10 years), these plants will likely provide all the bank stabilization this site requires. Approximately 85% of planted trees and shrubs have survived, though plant vigor is low. In October, 2008 plant mortality was determined to be 11%. Upon closer investigation, we have concluded that three primary limiting factors affected plant establishment: wildlife browse, machine-compacted soils and competition from invasive species. These factors are discussed further in the Discussion section below.

Aspen, which are particularly sensitive species, suffered the greatest mortality of all species planted. Approximately 90% of them did not survive.

(3) When planting on high banks on the Flathead River, is it worth the extra effort and investment to use "tall ones" containerized plants?

We found no difference in survivability between regular sized potted plants and tall potted plants. Our test of watering was also unable to provide consistent results as the Project Area was watered after our initial test. The other limiting factors on site proved to be more relevant than watering or not watering.

Heavy browse in the first 6 months of the planting certainly caused plant mortality and the other limiting factors mentioned above impacted plant survival much more than the size of the planted container. At this site it is probably not worth the extra cost and the extra effort of planting "tall ones." In some cases, if the water table is a bit deeper, or you find that the water is more readily available in a lower soil horizon, "tall ones" may be able to utilize more soil water and may survive better than regular one-gallon pots. Locating where soil water is available and where the water table may be located is tricky in these systems and is addressed in Chapter 3.

(4) What types of soils are present at this particular site and how does soil type, soil moisture and soil texture influence revegetation and restoration?

At the end of July 2008, we dug a soil pit in a well-vegetated site to assess soil conditions. Soil textures within the pit ranged from a silt loam to a sandy loam in the lower horizon, as shown in Table 9. Generally the soils are calcareous and from an alluvial parent material.

Table 9. Soil profile taken in July, 2008

Horizon	Depth (inches)	Description
O	2-0	Forest litter and duff.
A	0-4	Very dark grayish brown (10 YR 3/2) silt loam; fine granular structure; friable; common fine and medium roots; few coarse fragments; mildly alkaline (pH 8.0); calcareous (mild reaction); gradual smooth boundary.
Bk	4-16	Brown (10 YR 5/3) silt loam; medium to coarse angular blocky; friable to very friable; few coarse roots; few coarse fragments; mildly alkaline (pH 8.0) calcareous (strong reaction); gradual smooth boundary.
BCk	16-30+	Pale brown (10 YR 6/3) sandy loam; fine subangular blocky to granular; very friable/loose; no roots; mildly alkaline (pH 8.0); calcareous (very strong reaction).

Soil textures varied greatly between pits in this area. We found loam, silt loam, sandy loam, and silty clay loam. Textures varied dramatically within pits, though the profile we saw matches the typical profile for this soil type, the Swims silt loam 3-7% slopes:

0 to 1 inches: Slightly decomposed plant material
1 to 5 inches: Silt loam
5 to 12 inches: Silty clay loam
12 to 26 inches: Silt loam
26 to 55 inches: Stratified very fine sandy loam to silty clay loam
55 to 60 inches: Loamy fine sand

The most significant effect of these different soils is that when we encountered a sandier soil, mortality was generally higher. Sandy soil has a very low water holding capacity, increasing drought-induced mortality. In our experience, deep-rooted cottonwoods are one of the few species that can root effectively in these conditions. Cottonwood roots typically get to depth quickly, increasing survival.

Conclusions

Though we were able to determine the important soil properties and soil moisture characteristics important for planting success, other limiting factors played a more important role in this project, namely wildlife browse, mechanical compaction and weeds. Our goal in this discussion is to glean some lessons from what we observed.

Figure 23. Browse after first year on Red osier dogwood

Wildlife Browse:

Browse on plantings was significant in the first year after planting (Figure 23). Our 2008 site evaluation showed the heaviest browse was on aspen, red osier, rose, and cottonwood, while browse on chokecherry, alder and hawthorn were lower. These observations held true in 2010. Alder plugs, all planted lower down on the slope and without cages, were among the most vigorous plants.

Plant vigor in the second year was low, due in part to plants being stunted from a first summer of heavy browse. Horsetail (*Equisetum arvense*) was seen growing out of the weed mats with our plantings in the lower and mid-slope positions. As Horsetail only grows in the presence of water, it is an interesting indicator of available soil moisture and demonstrates that lack of water is not the factor preventing plant establishment.

The method that we used for browse protection was chemical application. These applications displayed little effect. This is especially true after animals get desperate for browse and learn to ignore the bitter taste. Combined with the fact that these chemicals must be applied several times annually, we are not impressed with this technique and will probably not use it in the future.

In April 2009, we returned to the site and installed individual nets around each plant. These protections saved a majority of the species planted and allowed for some modest growth in 2009. With one year of truncated growth behind them and now with adequate protection, we anticipate a good growth year for the plants this year.

Figure 24. Cottonwood regeneration emerging through rip-rap.

Another browse-protection option that could have worked in this context and should be considered for similar projects is a single continuous fence 15 ft. back from the bank to protect large areas. An added benefit of this approach is that it protects natural regeneration from browse. In several instances chokecherry and cottonwood shoots from existing mature vegetation was outperforming our plantings by 3 or 4 times (Figure 24). This is always the preferred and least expensive restoration alternative.

<u>Mechanical Compaction</u>

Before the start of the revegetation portion of the project a large amount of rip-rap was piled into the water to prevent loss of streambank. This work was done by a large excavator that made multiple passes along the top of the bank and whose shovel likely patted the streambank soils down after re-grading. The compaction caused by this equipment dramatically affected plant growth (Figure 25). The ground was so compact during planting that picks were used instead of hodads.

Figure 25. Some areas were devoid of plants, even weeds. Mechanical compaction is the likely cause.

Figure 26. Platy soils in upper planting area.

Using a soil penetrometer we tested for soil compaction everywhere we came to a patch of dead plants. The correlation between plant mortality and compaction was 1 to 1. Where compaction was most severe, the upper soil horizons became platy, shown in Figure 26.

These platy, compacted soils affect plants in 3 ways:

- They destroy soil pore spaces and thereby their ability to hold water
- They limit the access of roots to deeper soil horizons
- They drastically reduce soil gas exchange and a plant roots' ability to respire.

Pockets of more and less compact earth are typical of areas where machinery was present on a streambank, moving back and forth in some areas and less-so in others. Roots require oxygen to grow. In the absence of this element their growth often appears stunted. This is what we witnessed throughout the Project Area. Where compaction was less significant, plant growth was close to where we would expect it, as in the southernmost planting area shown in Figure 27.

Excavator operators unfamiliar with the factors necessary for plant growth often compact the soils on purpose, using the machine bucket to tamp the soil into place. These sites display poor survivorship and growth despite adequate precipitation. Compaction can be assessed with a compaction probe, platy soil structure or a soil infiltrometer.

Figure 27. Plant growth in southernmost section beginning to poke through netting

There are three primary approaches used to de-compact damaged soils:

- Freeze-thaw events (natural)
- Appropriate construction techniques and mechanical ripping
- Enhanced biologic activity through addition of organic matter, for example, mulch.

Soil compaction is an unseen and difficult to detect issue often disregarded by land managers. We have studied the influence of soil compaction in many ecosystems and soil types, always with similar results – soil compaction is a primary factor that influences plant vigor. This site demonstrates this same effect.

Weeds

When planting took place, the soil had recently been worked and was mostly bare. In order to protect the new plants, they were planted through a 2 foot square of black weed mat. This small square was not enough to hold back the brome grass (See Figure 28), thistle, curled dock (*Rumex crispus*) and an aggressive Eurasian weed in the mustard family.

Figure 28. Weed mat suppressing brome grass around plant, but it comes up through planting hole

The mustard variety of weed, taking advantage of plants weakened by browse, were able to spread from areas between weed mats to light perforations in the Weed mats- in planting hole, stake holes, etc. In all, about 6% of the plants are being outcompeted by weeds growing up through the planting hole (See Figure 29).

Hand weeding and some spot spraying of weeds at this point would provide a boost to plant survival. Applying herbicide in close proximity to these plantings must be done with great care.

Egans Slough Site

Figure 29. Aggressive weed in mustard family taking over a planting

This site is approximately 3000 ft. long and 15-ft. wide, along a low-lying swath of riparian area. Vegetation, including cattails, rushes and other wetland species in submerged areas, was dominated by Reed canary grass away from the water's edge. The natural biologic resiliency of the site is extremely high, but ecologic trends at the time of planting were poor, as riparian shrubs and trees succumbed easily to thick swards of reed canary grass.

Our approach at this site was to contain the canary grass first and establish a safe area for native transplants. We conducted an experiment to assess the efficacy of weed mats. Our driving questions were: What propagules remain after a year of weed fabric and associated decomposition? Are native sedge seeds viable and will they germinate when exposed to sunlight?

Study Design and Methods

A total of 1600 feet of weed mat was placed over reed canary grass in 12 plots in the spring of 2007 and allowed to sit for one year. In May of 2008 we established 12 planting plots on the weed mats and protected them with deer fencing. Species planted were similar to those used in the Flathead River Project Area.

In a few areas in each plot we cut a 1 m^2 of fabric and removed it. We were hoping to examine how viable the native seed populations would be after the weed mat was in place for 1 year. We also noted the condition of the roots, thickness of the grass mat, live plants present, and bare mineral soil exposed in the openings. In July of 2008 we examined the openings again.

Results and Discussion

Figure 30. Vigorous growth in Egans Slough plantings

For the most part, the weed mat has successfully contained the canary grass and allowed native plants to establish. Some cottonwoods are 8 feet tall and plant survival is over 90% (Figure 30). The primary difference between plants of this project and the Flathead River site is that plant vigor here is excellent, as browse was never a limiting factor.

In areas where we exposed the soil under the mat, weeds completely dominated native vegetation (See Figures 31). Most of the exposed areas contained a thick (5 + cm) layer of matted reed canary grass and thistles, and occasionally hounds tongue and mullein. By the end of July 2008, the majority of the openings were completely weed covered. Once established in these openings, the weeds found openings in planting holes. Ninety percent of the native plants grew enough to survive the weed infestation, but there was some mortality.

Figure 31. Weeds completely taking over opening in weed mat (Fall, 2008)

We did learn that we probably could leave the weed mat out at least 2 years before planting in order to try and eliminate more competition from reed canary grass. We also noted that weeds were growing into the revegetation area from outside the cages. Extending the weed mat two feet from the edge of the cage may eliminate this competition near cage edges. This type of close proximity competition has significant influence on plant survival and vigor.

Weeding the cages is important at this site. After one season of maintenance, weeds have a difficult time returning to the scene of the crime. So at this site, it is important to return and remove the weeds from the openings as soon as possible.

Conclusions and Recommendations

Combining the results of this study with previous work, certain sections of the study area deserve priority attention because of their existing eroding potential and also their potential to, if restored using principles outlined in this report, provide long-term ecological resiliency.

- Establish a goal of increasing the width of riparian vegetation on agricultural lands, with a prioritization of outside bends and areas already identified by the Flathead Lakers.
- Emphasize restoration efforts that are long-term oriented and leave room for natural fluctuations of the river (i.e. rip-rap is not the answer). Riparian forests should be the goal.
- Allow the appropriate time necessary for natural regenerative processes to establish. Far too often "restoration" is equated with putting native plants in the earth. This is only a part of the equation as weeds, deer and mechanical operations in a riparian area can create difficult situations for native revegetation.
- Consider the influence of construction activities on the revegetation potential of a site. Learn to use construction activities to increase the revegetation potential, for example to create a bulge in the capillary fringe by trenching fine soil to depth, or mechanically de-compacting the soil.
- Plan and budget for monitoring and maintenance into the future.

Chapter 3: Management Recommendations for Restoration

Every revegetation project is site specific and should be implemented according to on-site climatic, biological and physiological characteristics. Professionals should not rely on cookie-cutter approaches. At the same time, there are critical elements to the success of revegetation projects regardless of location. The following discussion provides a consolidated summary of our experiences with revegetation strategies.

Our investigation with this project began with concerns over available water. Many restoration projects fail because of water shortages and this is especially true in the western United States where water is a limiting factor in many ecosystems. In regards to soil water and revegetation practices, land managers can increase revegetation survivorship and vigor with:

- Proper soil water assessment
- Appropriate planning and project design features
- Construction techniques
- Project maintenance

Soil Water Assessment

Use these tools to assess soil water characteristics for proposed revegetation sites:

(1) Determine the Depth to the Water Table for each proposed revegetation site: For Western Montana find this information at the Web Soil Survey at http://www.websoilsurvey.nrcs.usda.gov

(2) Weather data for the particular site: Precipitation data is a very useful tool in determining when to water a particular site or when to plant at a particular site. This type of information can be found at: www.noaa.gov, http://www.wcc.nrcs.usda.gov/snow/, climate.ntsg.umt.edu, and nris.mt.gov/nrcs/reap.

(3) Soil survey data: This type of information can be extremely useful when assessing soils on a site. Soil survey data contains soil texture information, water table levels, precipitation data, and infiltration data. Soil survey data can be found on the web at the NRCS Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm).

(4) Soil characteristics that influence soil water:
    1) infiltration rates
    2) percolation
    3) capillarity
    4) aeration
    5) water holding capacity
    6) plant available water

All of these issues entail an in-depth investigation of on-site soil characteristics; specifically, investigators must determine soil texture and rock content in each soil horizon. We recommend land managers interested in further study of this topic organize a workshop that details site assessment techniques and examples in the field. We also recommend using a digital soil moisture probe to determine where water is most available on site or determining what soil moisture you are working with at particular times of the year. We recommend soil moisture monitoring in late August.

Appropriate planning and project design features

Once the status of the soil water has been determined, managers can take steps to avoid problems or build in design features that provide plant available water. Design features include:

- Avoid planting in deep gravels without access to the water table. Capillary rise or rooting depth will provide the access to water.
- Plant appropriate species for the on-site soil water characteristics. For example, on a high bank where the surface soils are disconnected from the capillary fringe, plant dry site conifers.
- Create a bulge in the capillary fringe by excavating down to the water table and backfilling with a fine textured soil.
- Enhance the water-holding capacity of surface soils by amending with fine textured soils or compost. There is also manufactured soil amendments produced specifically for this purpose.
- Use planting stock with rooting depths appropriate for site conditions. Four basic choices exist:
    - Small 6 inch stock
    - One gallon stock – eight inch root depth
    - Tall containers with a 14 inch root depth
    - Stinger plantings with a 30+ root depth
- Use plants that provide hydraulic lift. Hydraulic lift describes the process where some deep rooted plant species transport water from depth to the surface. These plants actually exude water from their roots into the upper soil horizons. This process can provide water to other shallow rooted species. Cottonwoods and some willows provide this service.

Construction Techniques

If there is heavy equipment available during the construction phase of a restoration project, use this machinery to enhance the revegetation potential of the site. Techniques include:

- Create micro-sites for planting
- Amend soils by burying fine textured soils in strategic locations
- Create a bulge in the capillary fringe
- Minimize or ameliorate soil compaction
- Bury large woody debris in gravel flood plains
- Use transplants when feasible.
- Use native forest litter and duff as a seed source, brush in with an excavator.

Reconnecting Hydrology

Often a construction site becomes disconnected from the natural hydrological processes, either through compaction or accidentally creating a vertically oriented capillary break between the undisturbed soils and ground water and the project area. Maintaining or reconnecting hydraulic conductivity takes time and patience. Planting trees with large roots can accelerate the process.

We recommend waiting a year between project earth moving phase and the revegetation phase. This allows large pore spaces to fill and provides time for water to find its way into the disturbed soil.

Project Maintenance

Revegetation projects cannot be installed and abandoned. Most projects need some sort of maintenance for several years after completion. This effort should be included in the planning and design phase.

Project maintenance typically means weeding and watering. Both activities are related to on-site water resources. If feasible and necessary, we recommend watering new plantings for the first growing season. Water about 3 times during the season beginning in mid July and ending in mid August.

Maintenance is strongly linked to monitoring and adaptive management. Practitioners are often surprised by unintended results such as weed infestations, pest and pathogen outbreaks, or the success of some species relative to others.

Stream-side Restoration: Critical Elements

Four primary issues mean the difference between success and failure for most revegetation projects:

- Soil Moisture & Aeration
- Animal Browse
- Plant to Plant Competition
- Long-Term Ecologic Trends

Soil Moisture and Aeration

The most common issue related to the success of revegetation projects is a lack of appropriate soil moisture throughout the growing season. Unfortunately, the areas in need of vegetation restoration are those same areas that have had some sort of severe disturbance, either natural or human-caused. In the Flathead watersheds, these disturbances often lead to the loss of plant available water.

Five elements contribute to on-site soil water and soil gas exchange:

1) infiltration rates (how water enters the soil)
2) percolation (how water moves through the soil)
3) capillarity
4) aeration (soil gas exchange)
5) water holding capacity and plant available water

A quick evaluation of previous revegetation projects in the study area would most likely reveal several issues related to soil moisture that were not addressed in the project design:

- Projects disconnected from the larger hydrologic process through placement of fill dirt or compaction.
- Plants placed in excessively well drained soils, often associated with new construction.
- Inappropriate species planted on high terraces where access to ground water is impossible for a small tree or shrub.
- A lack of maintenance for the first growing season (weeding & watering).

Other off-site examples of planting projects that made good use of on-site water resources and that could be utilized within the project area:

- Soil lifts with rooted cuttings placed on the water's edge.
- Plantings placed in sub-irrigated soils.
- Man-made terraces, either excavated or placed, near the water table.
- Man-made benches formed by installing a brush bundle and the vertical wall behind collapsing on this structure, providing an excellent germination and planting substrate.
- Appropriate species planted distant from water.
- "Stinger" plantings able to penetrate rock fill to water table.

Long-Term Ecologic Trends

Long ago the Flathead Basin was logged and cleared for agriculture, grazing and hay cropping. We know now that these forests were essential to the bio-physical integrity and stability of these watersheds. Current revegetation strategies rarely consider the long-term ecologic trends and the re-establishment of riparian conifer forests. We tend to concern ourselves with the immediate problems and issues. The result, to the detriment of an intact and naturally-flowing stream system providing ecological services, is rip-rap.

Another common situation in many projects is the lack of appropriate tree species for the establishment of riparian forests. Instead projects emphasize quick-growing stream side shrubs for relatively quick soil stabilization. While stream-side shrub plantings will certainly do no harm, they rarely develop into the type of forests necessary for true ecologic and physical integrity. Forests are much more resilient to natural disturbance than shrub lands. If we expect continued flooding and high-energy flows, we must set the stage for enhanced biological resiliency for the long run. Even now we see mature alder and other shrubs under-cut by the forces of water and sent quickly downstream. This is not so with a mature forest. A mature forest will:

- Provide appropriate bank strength.
- Shade the stream and soils for cool water and fish habitat.
- Provide woody debris necessary for appropriate stream morphology and fish habitat.
- Enable quick water infiltration.
- Dissipate high energy flood waters.
- Maintain long-term biological and physical resiliency.

Revegetate in Phases

The most successful revegetation projects are often those implemented in phases. A multi-year plan should develop a biological and physical foundation that increases the site revegetation potential for specific species or ecologic trends through time. Astute observations, patience and persistence are required for this approach. Often, the inability of funding to allow for multi-year budgets can be a stumbling block.

Phases and steps are not limited to planting and can include a variety of situations, for example:

- Conduct channel work, and then allow for a flood event, followed by planting. This allows excessively well drained soils common after construction to "settle" and some macro-soil pore space to fill with silt during a flood. Examples of channel work design features that may increase their revegetation potential through time include:
    - Root wad revetments
    - Constructed terraces or flood plains lacking soil fines or hydrologic connectivity
    - Terraces constructed by anchored brush bundles and erosion
    - Fill slopes
- Place fabric over invasive grass, wait two growing seasons to allow grass roots and rhizomes to decay, then plant or seed.
    - Plant fabric patches in phases as well, especially if cedar plantings are planned.
- Plant alder in an appropriate gravel substrate, let this grow for two seasons, and then inter-plant other shrubs and conifers. This technique is highly successful. Two year old alder:
    - Provides quick bank stabilization;
    - Enhances the revegetation potential for other species;
    - Significantly decreases phase II plantings' mortality and stimulates conifer growth; and

Monitoring, Adaptive Management and Gauging Success

Nearly every proposal or plan of action should include plans to monitor success or failure. We recommend an approach that links "adaptive management" to the lessons learned through monitoring. "Adaptive management" employed by some agencies is the process of learning by doing and taking appropriate actions when faced with problems.

Three elements lend themselves to successful monitoring, adaptive management and overall project success:

- Observation
- Adjustment
- Persistence

These are common themes in the most successful revegetation projects. These characteristics are also rare.

Observation

Observation is the on-the-ground portion of monitoring, where we look closely at our work. Two primary elements should be investigated depending on the maturity of the project: Survivorship & Function

1) Survivorship
To asses survivorship we must do more that calculate the ratio of living to dead plantings and characterize plant vigor. We should also re-assess the factors that limit plant establishment and growth. Often our initial assessment did not detect important issues, which could determine project success. The post-project assessment "monitoring" should be similar in character to the initial site assessment.

Refer back to the Assessment Portion of this guide; four primary issues often mean the difference between success and failure:

- Soil Moisture & Aeration
- Animal Browse
- Plant to Plant Competition
- Long-Term Ecologic Trends

Our task here is to decipher *why* the plants live with vigor or die where they were planted.

2) Function
Project success should also be gauged by how well the vegetation is fulfilling the bio-physical needs of the watershed. Often this characteristic cannot be judged for several years after plant establishment. Issues we consider may include:

- Enhanced bank strength
- Stream bank complexity, for example: stable undercut banks
- Stream shade and associated cooler water temperatures
- Wildlife habitat, including insect habitat for fish food
- Appropriate ecologic trends

Adjustment & Persistence

Understanding the issues, developing remedies and implementing a plan of action are key to long-term project success. Initial planning and design phases should build these elements into the project budget. Often persistence is the element that turns a project into an outstanding success. Again, the Stein ownership on the East Fork of the Bull River is a prime example. Practitioners monitored and adjusted techniques through time. Their persistence developed a riparian plant community that exceeded all expectations.

Concerns and Recommendations

The goal of this manual is to provide direction for future revegetation efforts in the Flathead Watersheds (from Flathead Lake to the braided section south of Kalispell) in order to increase the economic and ecologic efficacy of riparian restoration projects within the Flathead River Basin. In this manual we have raised several key considerations for future revegetation efforts which can be used as a roadmap for assessment and prioritization of projects.

We learned from this experience that plant connectivity to groundwater, though an important issue to address, were not the most important limiting factors to the establishment of a healthy riparian community. As demonstrated in the difference in plant vigor between the Egans Slough and Flathead River sites, compaction and animal browse were significant. These obstacles can be overcome with long-term strategies to re-establish riparian forest communities using some of the guidelines in the previous chapter.

> The goals of a specific project are often the greatest influence on the choice of a revegetation technique. In the Flathead watersheds, two basic goals drive the demand for revegetation:
>
> 1. To control erosion and mass wasting to prevent sediment delivery to sensitive streams and associated fish habitat. This includes projects intended to enhance bank strength.
> 2. To restore ecosystem function (i.e. watershed water holding capacity, bio-physical resiliency, etc).

Establishing real targets to create an average riparian vegetative buffer width of 100ft will have significant and positive impacts for wildlife, streambank stability and long-term property values (Flathead Lakers, 2005). Though residential properties in the project area do not show a high level of threatened riparian banks, subdivision is a growing concern. Subdivision proposals are expected to include a "Riparian Resource Management Plan." This recommendation for streambank width should be included in these plans.

As our soil analysis shows, riparian soils of this region are variable in nature and should be understood prior to commencing projects. We can't emphasize enough the importance of pre-project assessment and planning by qualified professionals and post-project maintenance and monitoring. These all too often neglected components can make or break a restoration project. It is these components, before and after project implementation, that can benefit the most from landowner and community input and participation. Natural resource managers who heed these guidances will be doubly rewarded by having long-term restoration plans and the essential community buy-in and participation that lead to real, long-term ecologic sustainability.

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Glossary

Aeration -The process by which air in the soil is replaced by air from the atmosphere. In a well aerated soil the soil air is very similar in composition to the atmosphere above the soil. Poorly aerated soils usually contain a much higher concentration of carbon dioxide, and lower levels of oxygen than atmospheric air. The rate of aeration depends largely on the volume and continuity of air filled pores within the soil.

Aggregate – A group of primary soil particles that adhere to each other more strongly than to other surrounding particles.

Biologic Resiliency – The ability of the land and ecosystem to respond appropriately to disturbance. Typically, biologic resiliency is decreased by removal of organic material on the soil surface. Forests may experiences a decrease in plant and animal diversity, weed incursions, soil erosion, loss of the native seed bank etc.

Cation Exchange Capacity – The ability of a soil to hold or make available to plants negatively charged nutrients. Clays and humus are negatively charged, and as a result can hold nutrients.

Clay – A soil particle less than 0.002mm in size.

Compaction – The process by which soil particles are re-arranged to decrease pore space and bring them into closer contact with one another.

Ecologic Trends – The direction an ecosystem or forest is headed in the not-so-distant future.

Effective Precipitation – The portion of the total rainfall which becomes available for plant growth.

Humus – A fairly stable component of the soil organic matter remaining after the major portions of plant & animal have decomposed.

Hydraulic Lift – The ability of many plants to transport water from depth to the surface soil, and exude water from roots to the soil.

Infiltration – The downward entry of water into the soil.

Mycorrhiza Fungi – Usually a symbiotic relationship between a fungi and a plant.

Nitrogen Fixation – The conversion of elemental nitrogen to a form usable by plants & other life.

Organic Matter – The answer to many of our problems. Accumulation should balance decomposition.

Overland Flow / Surface runoff. Precipitation that does not enter the soil, but runs over the soil. A primary cause of erosion.

Pore Space – The volume of void space in a soil. An ideal soil has 50% pore space and 50% solid material.

Root Respiration – Unlike leaves in sunlight, roots need oxygen to function. Roots take in oxygen and release carbon dioxide into the soil pore space.

Sand – A soil particle between .05 and 2.0mm in size.

Silt – A soil particle between 0.05 and 0.002 mm in size.

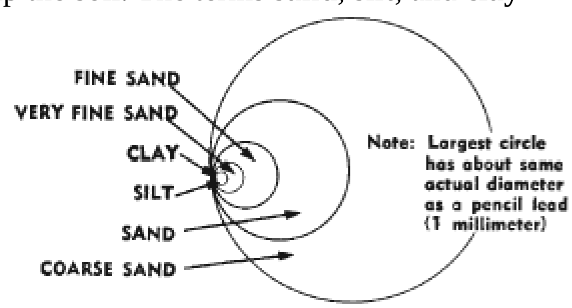
Soil Forming Factors - Climate, parent material, topography, biologic activity, and time.

Soil Structure – The arrangement of primary soil particles into secondary particles **–** peds.

Soil Texture – The relative proportion of sand, silt & clay in a soil.

Surface Sealing – Fine particles on the surface of a soil that inhibit water infiltration.

Texture- refers to the size of the particles that make up the soil. The terms **sand**, **silt**, and **clay** refer to relative sizes of the soil particles. Sand, being the larger size of particles, feels gritty. Clay, being the smaller size of particles, feels sticky. It takes about 12,000 clay particles lined up to measure one inch. Silt, being moderate in size, has a smooth or floury texture.



Comparison of clay, silt and sand particles

Water Holding Capacity – The ability of the soil to hold water.

Water Stable Aggregate – A soil aggregate that is stable in water, and resists dissolving into primary particles.

Appendix A: Permanent Photo Points (July 2009)

Photo Point #1: Section 1- Facing North

Photo Point #2: Section 1- Facing South

Photo Point #3: Section 2 – Facing North

Photo Point #4: Section 2 – Facing 250 degrees

Photo Point #5: Section 3 – Facing South

Appendix B. Soil texture at the Flathead River Re-vegetation Site

			Percent (%)			
Slope Location	Sample	Depth (inches)	Sand	Silt	Clay	Soil Texture
L	1	0-6	60	32	8	Sandy Loam
L	1	6_12	48	44	8	Loam
L	1	12_18	16	66	18	Silt Loam
L	1	18-24	8	70	22	Silt Loam
L	1	24-30	14	64	22	Silt Loam
M	1	0-6	54	38	8	Sandy Loam
M	1	6_12	78	17	5	Loamy Sand
M	1	12_18	72	22	6	Sandy Loam
M	1	18-24	54	36	10	Sandy Loam
M	1	24-30	62	30	8	Sandy Loam
U	1	0-6	44	44	12	Loam
U	1	6_12	46	44	10	Loam
U	1	12_18	60	32	8	Sandy Loam
U	1	18-24	58	34	8	Sandy Loam
U	1	24-30	58	34	8	Sandy Loam
L	2	0-6	14	62	30	Silt Loam
L	2	6_12	12	58	30	Silt Clay Loam
L	2	12_18	12	56	32	Silt Clay Loam
L	2	18-24	8	60	32	Silt Clay Loam
L	2	24-30	6	62	32	Silt Clay Loam
M	2	0-6	44	42	14	Loam
M	2	6_12	24	62	14	Silt Loam
M	2	12_18	14	66	20	Silt Loam
M	2	18-24	14	64	22	Silt Loam
M	2	24-30	18	58	24	Silt Loam
U	2	0-6	44	42	14	Loam
U	2	6_12	10	70	20	Silt Loam
U	2	12_18	10	62	28	Silt Clay Loam
U	2	18-24	6	68	26	Silt Loam
U	2	24-30	14	66	20	Silt Loam

Appendix C. Understanding Soil Water

Introduction
Water is one of the most important components of plant survival and revegetation project success (Bay and Sher 2008). Water provides plants with structure, mediates chemical reactions within the soil and plants, and transports and dissolves nutrients, metabolites and other chemicals (Liste and White 2008). Water movement and storage in soils is often overlooked and deserves more attention, especially on our revegetation projects. Understanding where water can be found in the soil profile, and how water travels from the hill slopes and thru riparian areas is essential to project success. Most land managers assume that water is generally available in riparian areas. However, many times human activities and natural occurrences can make the water unavailable to plant life. In this section we will discuss:

- Where water can be found in the soil profile
- How water travels through various soil types
- How water is stored
- How human activities, including restoration activities can damage plant / water processes
- How active management can restore soil water-holding capacity and water movement through the soil

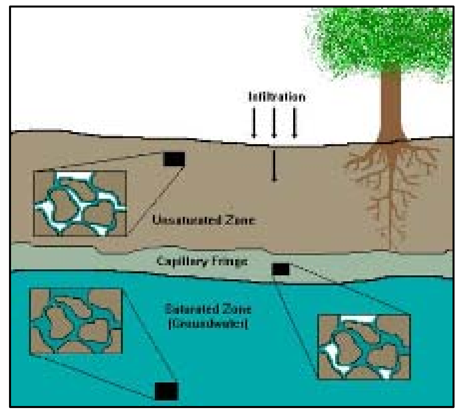
Soil Water- Where is it?
To understand how water moves through soils, we must understand three characteristics of the water that influence water movement: adhesion, cohesion and surface tension. Adhesion is the attraction of water molecules to solid surfaces such as soil or the glass sides of a graduated cylinder. Cohesion is the attraction of water molecules to each other and surface tension results from cohesion. Water molecules have such a strong attraction to each other, that the forces of cohesion keep water in soils because water has a greater affinity for itself than it does for air. Surface tension is why many insects can walk across the water without falling through.

Water will always flow from where water is to where water is not and gravity always pulls water down. So water moves from a wet soil to a dry soil and from an upper soil to a lower soil. The amount this water moves is based on energy levels. This is referred to as the soil water potential. Soil water potential has three components: 1) matric potential - the attraction of water to soil surfaces; 2) osmotic potential - the attraction of water molecules to areas with less salt; and 3) gravitational potential - the force of gravity that makes water move towards the center of the earth. The total soil water potential is the combination of these three potentials. The way water behaves in soils is more closely related to the energy status of water than to the actual water content of the soil.

Capillary rise. Water can also move in an upward direction in a process known as capillary rise. Capillarity is due to the forces of adhesion and cohesion. To demonstrate, stick a thin straw in you favorite beverage and note how the fluid seems to defy the laws of gravity and travel a short distance upward. Try this again with a large diameter straw and note the decrease in the height of the fluid column. Capillarity is inversely proportional to the tube radius: the smaller the tube radius, the greater the capillary rise.   In this way finer textured soils will have greater capillary rise than coarse textured soils. Soil texture is defined below.

When we say a pasture or forest is sub-irrigated, we often mean that the water table is close enough to the surface to allow capillary rise to transport water from the ground water table upwards to reach plant roots.

Figure 32. Capillary fringe diagram



The zone in which water rises from the water table is called the capillary fringe (Figure 32). Above the capillary fringe, soil is not fully saturated (all air space is not filled with water), but below the capillary fringe the soil is saturated; this is groundwater or water table.

Soil texture: Technically speaking, soil is earth composed of particles 2mm in size and smaller. Soil texture is the relative amount of sand, silt and clay. Sand is the largest soil particle, followed by silt and clay being the smallest. Soil scientists call rocks over 2 mm in size course fragments: for example, gravel, cobble and boulders. Soil texture influences pore space which in-turn affects:

- infiltration rates (how water enters the soil)
- percolation (how water moves through the soil)
- capillarity
- aeration, (soil gas exchange)
- water holding capacity and plant available water

These characteristics of the soil must be considered for all revegetation projects (Bhattacharjee et. al. 2008).

1) Infiltration

Infiltration refers to the movement of water into the soil from the surface. This process influences how much of the annual precipitation may be available for plant uptake. When infiltration rates are compromised (typically through soil compaction) soil moisture and soil aeration are decreased (Bhattacharjee et al 2008). Infiltration rates for different soil textures are shown in Table 10.

Table 10. Infiltration rates (mm/hr) in different textured soils (table from Hillel 1998)

Soil Texture	Steady Infiltration Rate (mm/hr)*
Sands	>20
Sandy and Silty Soils	10-20
Loams	5-10
Clayey Soils	1-5

*these rates are not constant; they are to give an order of magnitude. Actual rates could be much higher or lower.

Sandy soils will have high infiltration rates and will lose much of the soil moisture from precipitation events fairly quickly, whereas clay soils have much lower infiltration rates. After a precipitation event or flood, Bhattacharjee et al (2008) found that the rate of soil moisture decline was different for different soil textures. Sandy loam and loamy sand textured soils lost 1.3% soil moisture per day, loam/silt loam textured soils lost 1.6% soil moisture per day, silt/clay loam textured soils lost 1.65% soil moisture per day, and clay textured soils lost 1.66% soil moisture per day (Bhattacharjee et al 2008). The same study also determined that for cottonwood seedlings in sandy soils, percent soil moisture was the most important factor influencing revegetation success.

2) Percolation

Percolation is the way water moves through the soil. As common sense dictates, coarse textured soils have a higher percolation rate that finer soils. When considering revegetation projects, we are interested in maintaining the natural percolation rate and character through the construction phase. Often a completed stream restoration site is excluded from ground water and capillary rise because the soil percolation and associated hydrological processes may be compromised due to compaction or other collateral effects of restoration.

3) Capillarity

Capillary action, as previously described, is strongly associated with soil texture. As such, it can move water up or down in the soil horizon. When assessing capillary rise for revegetation it is important to note the changes in soil texture in different soil horizons above the water table. For example, we often see a fine textured soil horizon at depth, with a gravel layer on top, followed by another layer of fine textured soil on top of this. These layers of different textured soils represent sediment deposits in times of high energy runoff (coarse textured gravels) and low energy deposits (silt loams). The coarse textured soil horizon can act as a “capillary break.” This layer of coarse material, such as sandy gravel, which has a low wicking potential, prevents capillary water from moving move up or down. Practically speaking, this can either help or hinder the revegetation project depending on where the capillary break lies in relation to ground water and surface soils.

In a loamy soil horizon, if the ground water were fairly near the surface, at approximately 5 feet depth, natural capillary action can easily lift water into the rooting zone. However, if there is a gravel lens between ground water and surface soils, this coarse textured horizon acts to break the capillary action, disconnecting rise to surface soils. Conversely, in areas of high rainfall, and a water table at depth (10 feet or more), a capillary break can be a significant advantage. In this case, precipitation infiltrates into the soil and percolates through the topmost soil horizons. It moves downward via gravity and capillary action. When the water reaches the capillary break on its way down, only the “gravitational water” works its way through the gravel. The remaining water is held in the topmost soil horizons via the forces of adhesion and cohesion. Understanding the capillary forces in project areas is key to successful revegetation.

4) Aeration

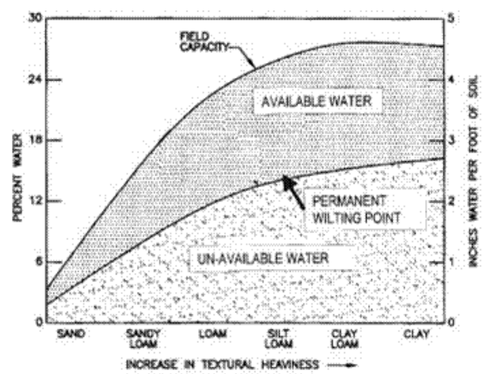
A typical soil is about 50% sand, silt and clay and 50% pore space. Of this pore space, about half is filled with water and half is air. Plant roots must have gas exchange to survive. Plant roots respire and need oxygen while off-gassing carbon dioxide. Without proper aeration, plants will do poorly. On a revegetation site, poor aeration can be caused by soils saturated with water or soils that have been compacted by construction activities. Consider soil aeration with every project by testing for infiltration or bulk density.

5) Water Holding Capacity and Plant Available Water

The water holding capacity of a soil is determined primarily by soil texture and soil organic matter. The finer the soil texture, the greater the water holding capacity. For example, a silt loam can hold more water than a sandy loam. Texture also affects plant available water - the water plants are able to pull from the soil. Plant available water is much different than *water holding capacity*, and the two concepts are easily confused. Water holding capacity of a soil is the amount of water by volume the soil can hold after all gravitational water has drained. This is also called field capacity. As a plant draws water from the soil, the extraction becomes increasingly difficult due to the forces of adhesion and cohesion. The point where plants can no longer draw moisture from the soil is termed ***the permanent wilting point***. This point differs for each plant species.

Plant available water is the measurement of soil moisture between field capacity and the permanent wilting point. A fine textured soil will have more moisture at the permanent wilting point than a coarse textured soil. This is due to stronger adhesion forces (associated with smaller pore spaces) in the fine textured soil. For example, if a sandy loam and a clay loam have exactly the same soil moisture by volume, the sandy loam will have more plant available water (Figure 33). This figure displays the amount of available water in a soil based on the general texture of the soil as well as how many inches of water would be in the soil by foot.

Figure 33. Soil water volume versus soil texture.



Appendix D: Boat Wakes and Erosion

Some studies have concluded that, “Boats have been shown to affect water clarity and can be a source of nutrients and algal growth in aquatic ecosystems” (Asplund, 2000). The use of motorized boats and personal watercraft (PWC) on Flathead Lake and the Flathead River just north of the lake has been steadily increasing in the last decade (Deleray and Cavigli, 2008). This increased activity generates substantial income for Flathead County during the summer months. These activities have also generated substantive complaints from residents regarding noise pollution and the increased frequency of waves, which some claim are increasing bank erosion. Erosion attributable to boat wakes has not been measured on the Flathead River. Other studies however, have been done. Below is a summary of current knowledge available on boat wake-generated erosion.

Shoreline erosion has been documented in river systems and is attributed to the proximity and frequency of boat traffic (Asplund, 2000). There are several key factors in determining the effect of boat wakes on stream channel stability. Two of those factors are the energy of the water hitting the shore, and the characteristic of the bank material itself (Asplund, 2000). The energy of the water hitting the shore is derived from the width and depth of the channel or lake, and the “duration and total amplitude” of short-term fluctuations (Lorang and Stanford, 1993b). In small channels wakes can account for 95% to 98% of the energy dissipated onto banks, thus proving to be a considerable factor in overall stream bank stability (Canada Coast Guard, nd).

These forces interact with the bank, whose erosive potential will be determined by its substrate, orientation, gradient and amount of riparian vegetation (GreenBlue, 2008). It follows that the amount of vegetative cover and human disturbance will affect boat-wake erosion rates at a given site. Researchers at the Flathead Biological Station documented the three main ways in which wave energy interacts with banks in an erosive manner.

Figure 34. Varying boat speeds and wakes (Canada Coast Guard, nd)

Wave height
Waves are generated by natural storm processes and winds. The magnitude of waves generated by boats is affected by several factors, including the boat’s speed, size, passenger and cargo loading, hull shape, the depth of the water, the distance of the boat to the shore and the speed at which the boat is travelling, which affects how much of the boat’s hull is in contact with, and displacing, water.

Displacement Speed- The slowest speed for most motorboats, where the bow of the boat is down in the water and results in minimal wake.

Transition Speed- When power is increased, boats use more fuel as they attempt to get the vessel onto its planing hull. As a result, the bow of the boat rises and the stern plows through the water, creating the largest wake.

Planing Speed- At this speed, the bow drops down and only a small amount of the hull is in contact with the water. Many cruisers and houseboats do not reach this speed (Canada Coast Guard, nd; Minnesota DNR, 1993).

Though boat waves can dissipate quickly, waves from several boats often combine in periods of high traffic to create larger and more persistent waves, which invariably cause more bank erosion (Asplund, 2000). Personal water craft such as wave runners generate small waves similar in size to storm-generated waves, but as they tend to navigate in circles to create waves, a high frequency of low waves are sent to shore.

Observations made by the Minnesota Department of Natural Resources have shown that a wave that is 12.5cm (5 in.) high does not cause significant shoreline damage, but that a wave 25cm (10 in) high is five times more destructive. A small motorboat produces a wave that is 25-cm high at planing speed. Cruising yachts can generate waves that can easily reach 62.5 cm or more. (Canada Coast Guard, nd; Minnesota DNR, 1993). Erosion potential was determined to be high for any vessel creating a wave over 35cm in height at the bank, medium for waves between 20-35cm and low for waves below 20cm (Wilcox, 2000). The distance from shore also affects the waves erosive potential, as shown in Table 11. Within the first 1.5 miles of where the Flathead River enters Flathead Lake, the river's width is between 500- 800 ft across.

Table 11. Vessel wave height (centimeters) (Wilcox, 2000)

Vessel Type	**Distance from Shore Line**		
	0-100 ft	100-300ft	300-500ft
Jet Skis	8	4	0
Fishing Boats	16	8	4
Pontoon	8	4	4
Medium Power	24	20	10
Large Cruisers	50	40	20
House Boats	8	4	4

In New Zealand, jet boats, outboard-powered boats and jet ski waves were measured at between .6 to 13.3 cm. These waves were 2-80 times larger than background wind-generated waves and had from 2-100 times the energy of background waves. Conditions vary and it is hard to predict the exact effect of specific boats, as many variables are at play (McConchie and Toleman, 2003).

Flathead

Due to prevailing winds from the south and easily erodible soils, the north shore of Flathead lake sees the greatest wave fetch, and hence has seen the greatest erosion. Wave fetch is the distance a wave travels and is positively correlated to wave energy. This area of the lake has been studied for wave-induced erosion, which was determined to be between .5 to 2.5m yr^{-1}. No studies have been done on wave-induced erosion on the river.

Significant storm-related wave heights ranged between 75 and 125 cm with frequencies between waves of 3.5-4.5 seconds (Lorang and Stanford, 1993). This data suggests that storm-induced waves are much higher than any waves produced by boats. One critical factor to consider, and which has not been studied, is the frequency of boat passes relative to any given area. More boat passes could generate an increased wave frequency and thus influence its erosive potential.

A major factor in the Flathead scenario is the artificially high lake and river level. As stated in the report, “distribution of wave energy at various lake levels is an important factor in understanding shoreline erosion” (Lorang and Stanford, 1993). Flathead Lake is artificially kept at its “full pool” depth for a significant part of the summer and fall season, which translates into increased wave energy hitting banks, instead of the beaches that would be present at lower lake levels. If lake levels were lowered by less than a meter before late fall storms, the study suggests, a significant reduction of wave energy from 70% to 18% could be achieved (Lorang and Stanford, 1993).

Conclusions

Due to a high number of variables on the impact of boat wakes on shorelines, boat-traffic managers do not have specific guidelines that can be followed. No-wake zones are highly recommended but only enforced with a great deal of effort. By law, boat operators are liable for any damage caused by their wakes and several places around the country have created active campaigns to educate boat owners to the detrimental effects of wakes on shores, personal safety and personal property such as docks, other watercraft, and other boaters.

Appendix E: Reed Canary Grass

Reed Canary Grass (Phalaris arundinacea L.)

Introduction: Reed Canary Grass (RCG) is a tall, cool-season, perennial, sod-forming grass of the *Poaceae* family whose mature stems reach 6-8 ft. It is the only member of the *Phalaris* genus that is circumboreal and may be the precursor to all New World taxa of the genus (Anderson, 1961). It is considered native in the lower 48 states and Canada and probably introduced in Alaska (USDA, 2009). It is considered non-native in the southern US (Lyons, 1998) but others say its centers of diversity are the Mediterranean and Southwestern US (Sahramaa, 2004).

The plant forms extensive single-species stands along margins of lakes and streams, wet open areas and poorly drained soils. Tolerant of freezing temperatures, the plant begins its growth early in the spring and can quickly out-compete other species with vigorous rhizomatous growth. It is tolerant of frequent and prolonged flooding as well as submergence and moderately tolerant of drought and saline or alkaline soils (GISD, 2009). RCG is considered a facultative wetland species for the USDA's Region 9, which includes Montana (USDA, 2009). In many natural wetlands it is considered a "problem grass" (Apfelbaum and Sams, 1987) for its suppression of soil seed banks and species diversity. Around the world it is notoriously considered a noxious weed.

History: RCG has a long agronomic history, dating back as far as 1749 when a student of Linnaeus's in Sweden researched forage crops and found RCG to be among the best (Sahramaa, 2004). The first agronomic trials of RCG in the US probably began in the 1830s in New England when farmers were looking for high yielding forage crops (Merigliano and Lesica, 1998). At the turn of the century in Washington it was used frequently as a "breaking in" plant after a forestry operation and before land was converted to agriculture. It was planted as fodder between stumps and debris until land became more easily converted to agricultural uses (USDA, 2009). In some parts of the country (e.g., Alaska, Montana, Washington) it was recommended as a silage or grass fodder for ruminant livestock and a bank stabilization species for agriculture projects (Galatowitsch, 2007). These cultivated strains of RCG were typically planted along ditches and waterways in agricultural areas.

Populations of RCG increased dramatically in abundance 40-60 years ago, likely in response to "increases in soil nitrogen enrichment, impaired hydrology, and construction impacts in wetlands" (Galatowitsch, 2007). The plant grows well in semi-open and open habitats and with increasing habitat disturbances, ranging from ditching of wetlands, channelization, deforestation, overgrazing and intentional planting (Hoffman and Kearns, 1997), has become invasive in many places.

Because of its positive response to increases in nutrient levels, RCG has more recently become widely used in wastewater management. Agro-industrial uses for RCG have gained support in Europe since the 1990s, beginning in Finland and Sweden (Sahramaa, 2004) where the crop is actively researched as a potential biofuel crop.

Taxonomy and Ecology: RCG is one of 15 species in the *Phalaris* genus, which has almost worldwide distribution except for Antarctica and Greenland (Anderson, 1961). Its ornamental variegated form (*P. arundinacea* var. *picta* L.) is commonly referred to as Ribbon grass. Over 115 genotypes have been developed worldwide (Wisonsin, 2009).

RCG is considered highly variable in its size, shape of inflorescence and overall coloration, with no correlation to geographic distribution or with each other, suggesting a high degree of inherent plasticity (Apfelbaum and Sams, 1987).

RCG can be identified by rounded stem with prominent ligule or papery membrane at the base of its leaves (Wisconsin, 2009).

Confusion with Other Species
While *P. arundinacea* may be confused with *P. aquatica* (harding grass), *Dactylis glomerata* (orchard grass), and *Calamagrostis canadensis* (bluejoint), it can be distinguished from these other species. RCG has non-bulbous culms that arise from very stout rhizomes. Its glumes are usually wingless or, if wings are present at all, they are narrow and inconspicuous. Fertile florets of RCG are narrowly lanceolate and more or less circular in cross-section. The seeds are usually less than 2 mm long (CSP, 2005).

Propagation and Growth: The management "problems" associated with RCG can be attributed to several key features of the plants growth and propagation characteristics:

- high capacity for viable seed setting
- rhizomatous spread
- affinity for disturbed areas
- plastic response to changing hydrologic conditions (shifting growth from roots to shoots depending on available water) (Galatowitsch, 2007)

Seeds
RCG seeds have a low rate of germination and germinate best immediately after ripening. They have no dormancy period and germination rates are not affected by temperature changes. Seeds can persist for 5-7 years in wetland sediments (Galatowitsch, 2007). They float in

water and attach to fur, soles of shoes and clothing (Wisconsin, 2009).

When inundated with water for extended periods of time, seeds are short-lived (Lyons, 1998). Seed growth requires high-light canopy gaps, but rhizomes can extend into low-light areas (Galatowitsch, 2007).

Rhizomes

Most emergent shoots came from rhizomes or tiller buds in the upper 5 cm of soil. Few shoots arise from buds lower than 20cm in the soil (Apfelbaum and Sams, 1987) and the rhizome network, though dense, is described as shallow (<30cm) (Galatowitsch, 2007).

For 5-7 weeks after germination, RCG grows vertically. Rhizome development in greenhouses occurred 26 days after germination. After 16 weeks, plants bloomed and had an average of 48 rhizomes per plant (Apfelbaum and Sams, 1987). Dense root mats form within 1 year (Apfelbaum and Sams, 1987; Lyons, 1998; USDA, 1999). When cut, new leaves emerge from rhizomes or exposed nodes.

The growth and productivity of RCG peak twice, in late spring (leaf and inflorescence) and then in late summer (stem and rhizome).

Disturbance and Nutrient Uptake

Invasive populations of RCG are generally thought to be descendent of non-native cultivars or ecotypes (Apfelbaum and Sams 1987; Hutchison, 1992) or the result of crosses between cultivated and native strains (Merigliano & Lesica, 1998). Species invasions into native systems usually occur as a result of human-induced disturbance, for example in the Kenai Peninsula, Alaska, where recent spread of the grass has been recorded along major roads and boat docks, which subsequently invade native habitats. Even in relatively unimpacted systems, the “disturbance” from frequent flooding and drawdown can be considered an invasion window for the spread of RCG. An effective invasion event does not require a large influx of seeds (Galatowitsch, 2007).

In the Swan River Oxbow Preserve of the Nature Conservancy in Montana, RCG cover increased 35% over nine years, coinciding with a drastic decrease in population of the federally endangered *Howellia aquatilis* (Lyons, 1998). Available literature is replete with examples of drastic declines of wetland and wet prairie species after several years of RCG growth (Apfelbaum and Sams, 1987).

RCG has inefficient uptake and use of nitrogen. Consequently, when additional nitrogen is added to a wetland area, RCG growth is stimulated more so than other wetland species. Increased nutrient levels in general, and particularly from fertilizers, have been shown to stimulate RCG growth and propagation. When cultivated for forage, yearly application of nitrogen is recommended for sustained yields.

Soil and Hydrologic Conditions

RCG requires 18 inches annual precipitation to perform well, and can withstand continuous inundation for 60-70 days. While natural populations are found primarily in marshes and other wet habitats, upland varieties are more drought tolerant. RCG can also tolerate saltier soils with frequent flooding (USDA, 2009).

Changes in hydrology and nutrient loads in streams favor RCG over other native wetland species. When RCG encroaches into a stream channel, it has been linked to accelerated siltation of rock and sand bars, reduction of the active channel-area and the alteration of fluvial dynamics. Where the grass is perched on edges of incised watercourses, it may promote further soil erosion beneath its root mass where water flows rapidly. These alterations likely contribute to the reduced habitat conditions for native wildlife and fish species, particularly salmonids and bird species (Slemmons, 2007).

Uses: There are many known and some potential uses for RCG. These are briefly summarized in this section.

Biomass: RCG's popularity as a forage plant is in part due to its biomass productivity, suggested to be up to 9 tons/acre in nutrient-rich soils (USDA, 2009). Trials under dry conditions show canary grass yielding more hay than smooth brome, timothy, tall meadow oat, red top, meadow fescue and orchard grass (Lyons, 1998). Sahramaa (2004) reports yields of 6-8 tons/ha in Nordic conditions, with best yields (10 tons/ha) occurring when left over-winter and harvested in the spring before appearance of green shoots. Below-ground biomass accounted for half of the total plant biomass.

Trials in a rich marsh found total net productivity of RCG to be 2028 g/m^2/yr, higher than Broad-leaf cattail (*Typha latifolia)* and Bulrush (*Scirpus fluviatilis).*

Distribution of biomass within the above-ground plant altered significantly among different cultivars with the averages being 59% straw, 23% leaves and sheaths, 7% nodes and 5% shoots from Finnish studies (Sahramaa, 2004).

Cultural: Okanagan-Colville Indians of British Columbia and Washington used to make fishing weirs and mats for eating and drying berries out of RCG. Though research is not abundant, one can imagine many applications for the strong-fibered grass.

Energy: RCG is currently cultivated in Finland on 2,700 ha as a potential fuel crop for solid fuels, motor fuels, pyrolysis oil and biogas. Studies there show 10% RCG can be used in a fuel mix with peat and wood chips without adjustments to fuel handling equipment at Finnish power plants (Sahramaa, 2004). The high ash content of RCG is a limiting factor in its establishment as a biofuel crop (Wrobel et al., 2009).

Erosion Control: The robust rhizomatous root system of RCG was identified early on for its erosion control (USDA, 1999). Consistent management however is required, as plants can easily out-compete other native species and create monocultural stands that eventually increase siltation in streams.

Filter Fields: RCG is a heavy user of fertilizer and its growth in wet areas make it good for filter fields to collect wastewater from food processing and livestock industries and sewage treatment plants (USDA, 2009). The Center for New Crops and Plants Products states that *P. arundinacea* is the most popular species for irrigation with pollution control sewage effluent from municipal and industrial sources (Lyons, 1998). Runoff waters from peat production areas have been filtered and evaporated by RCG in Finland (Sahramaa, 2004).

Finnish researchers have also experimented with frozen, chopped RCG as a filter which can, after specific treatment, separate oils from water to treat oil spills in shallow coastal waters (Pasilli, 2004).

Forage: RCG is described by the Center for New Crops and Plants Products as producing "nutritious, palatable, succulent herbage for pasture, silage, and hay" (Lyons, 1998). As seedheads appear, the quality of the forage decreases (Miller, 2007; USDA, 2009). RCG can be planted as a hay crop or for forage and fodder, particularly in wet sites not suitable for other forage plants. In Australia it is used primarily as sheep fodder.

High alkalinity (9 alkaloids have been found) in RCG has caused poor weight gain and diarrhea in cattle and has spurred targeted forage yield and improved palatability studies in North America (Sahramaa, 2004).

RCG will persist under close, frequent use but yield will be greatly reduced. Its persistence under heavy use makes it well suited for calving, lambing, holding areas or other special-use pastures (USDA, 2009).

Paper and Pulp: The fibers of RCG can be used in pulp and papermaking. Tests in Finland and Sweden show it could replace the use of Birch for fine paper production, with an internal rate of return almost identical to that for wood (Paavilainen and Tulppala, 1996, Finell, 2003). Two techniques which improve RCG's competitiveness relative to trees are post winter (delayed) harvesting and briquetting for transport. Low interest in the pulping industry is the only reason cited for its non-adoption in Finland (Sahramaa, 2004).

Wildlife: Some suggest areas invaded by RCG are of little use to wildlife due to its dense stands (USDA, 2009). Watershed Consulting's experience in the Flathead Valley, Montana shows canary grass as providing good cover and bedding habitat, at least for deer. The shattered seeds are also eaten by many birds (USDA, 2009)

Management:

As with most invasive species, the best and least cost management of RCG is preventative. Actions that increase abnormal flood pulses or nutrient runoff will likely increase the abundance of RCG in sites where it is already present. Kercher and Turoff (2007) explain that to accurately determine the cause of RCG invasion, natural flood and nutrient and sediment fluxes should be understood jointly with human-induced disturbances. They describe a three-step invasion process in which (1) resident native species populations decline due to accelerated nutrient and sediment loads which (2) accelerate *Phalaris a*. growth and the (3) further decline of native vegetation.

Management priorities for RCG invasions should be closing of the canopy of the affected area quickly (Galatowitsch, 2007) and replacement of RCG with a diverse native plant community. A small number of native plant species, namely pale spike rush (*Eleocharis palustris*), broad-leaf cat-tail (Typha latifolia), skullcap speedwell (*Veronica scutellata*) and Columbian sedge (*Carex aperta*) have been reported to survive within RCG infestations. One species, porcupine sedge (*Carex hystericina*) was demonstrated in Wisconsin and Minnesota to suppress the growth of RCG when nutrient levels were lowered via carbon enrichment. Management strategies that prevent sediment accumulation and maintain mosaics of microtopographies tend to favor native vegetation (Tu, 2004).

Management strategies should be site specific and can change based on the size and density of infestation, location relative to stream channels and available surrounding vegetation. RCG infestations can be small, patchy or large, occurring in uplands, wetlands, right-of-ways, or in active channels. Some areas, such as those with persistent nutrient inputs and abnormal hydrology, "should be considered poor candidates for restoration" (Galatowitsch, 2007). As the invasion of RCG has been influenced heavily by human factors, identifying the cause of stream disturbances (particularly from upstream sources) that facilitated the invasion of RCG should be part of any management plan (Wisconsin, 2009).

One key to establishing management practices is to address both above-ground and below-ground growth in parallel and at the appropriate time in the plant's life cycle (Wisconsin, 2009). Putting a management plan on hold for a growing season could lead to a zero-sum gain when management resumes (Wisconsin, 2009).

A long-term restoration and management test to establish woody species to shade out RCG was conducted by the University of Wisconsin. The 10 most successful species, planted as one to three-year bare root trees and shrubs, were able to establish in a variety of test plot conditions that included herbicide, mowing and herbicide, herbicide and plowing, and herbicide and burning. Fall herbicide and spring plowing provided the highest survival rates for a majority of species. The plots with the highest herbaceous species diversity also showed the highest tree and shrub survival (Hovick and Reinartz, 2007).

In general, where RCG is inter-mixed, mechanical or burning methods will be more effective, while non-selective herbicides are most effective for monoculture stands (Lyons, 1998). Active-channel management strategies require creativity as there is little literature available for guidance. The most used management strategies are outlined below:

Biocontrol: No biological control measures have shown to work (Lyons, 1998; Tu, 2004)

Burning: Limited applications and tests. Controlled burns around an Illinois prairie preserve kept RCG from invading native grasses. In some British wetlands managed for reed thatch (*Phragmites communis*), a combination of burning and spring flooding improved germination and competitive advantage of reed thatch where RCG was present, but results were related to reed thatch (Abfelbaum and Sams, 1987). Spring burning is advised to reduce seedbanks but is not an effective method for killing rhizome networks (Galatowitsch, 2007).

Fire is an effective control for RCG in highly productive wetlands. Fire should be reserved for sites with a healthy native seed bank of fire-adapted species (Lyons, 1998).

Timing of burns is important. Late spring burns were found by Henderson (1991) to be more successful than early spring burns, but may harm other species (Lyons, 1998).

Cutting, Spraying, Covering: Discing or mowing followed by herbicide application over several seasons is part of the typical prescription for RCG reduction in the United States (Galatowitsch, 2007). Wilkins and Hughs (1932) experimented with a field of equal mixtures RCG, Kentucky bluegrass (Poa pratensis), timothy (Phleum sp.) and mixed clovers (Trifolium spp.). Cutting the RCG twice in a season did not eliminate it but cutting five times in a season completely eliminated it (Lyons, 1998).

Hoffman and Kearns (1997) recommend black plastic but advise not to allow any shoots to poke out from the edge of plastic as these leaves will provide nutrients to rhizomes (Lyons, 1998). This strategy was also recommended for small populations (<100 m^2) on the Kenai peninsula but not advised for unstable (river channels) or large areas (Galatowitsch, 2007). Apfelbaum clipped plots at ground level and covered areas with opaque black plastic for up to two growing seasons. This successfully reduced RCG populations, but the species persisted (Abfelbaum and Sams, 1987).

Watershed Consulting has observed in extensive field trials that mowing RCG leaves pointed stubs which more easily penetrate the plastic covering. The preferred method is to lay plastic over the full plant, matting it down and using the vegetation as a mulch layer. Miller recommends scalping plants to ground level before tarping.

Some methods shown to be ineffective are clipping seed heads or simply covering RCG with a mulch layer (Lyons, 1998). One experience on the Puget Sound, however, showed positive results mulching with cardboard covered by 4-6” of wood mulch.

Grazing: Grazing may be an unreliable single-action management strategy for *P. arundinacea.* RCG can cause indigestion or illness in livestock, and grazing can often be inappropriate in wetland environments where natural RCG stands persist. Haslam (1973) suggested producing "marsh hay" in waterlogged soils and grazing with ponies versus cattle or sheep (Lyons, 1998). There is evidence (Agrawal, 1998) that grazing induces RCG's chemical defenses, making it less palatable over time, while cutting does not (Lyons, 1998).

Revegetation: As the primary limiting factor of RCG seed germination is light availability, the ideal endpoint of revegetation efforts should be the establishment of a "complex, multi-species herbaceous canopy that is vertically and phenologically layered. The best way to ensure this is to plant a diverse species mixture of different shapes and forms (e.g., sedges, rushes, cool- and warm-season grasses, and forbs)" (Wisconsin, 2009).

RCG is susceptible to shade at 41% or higher, affecting the below-ground biomass more than the leaves (Stannard and Crowder, 2001). Generally, planting in late fall/winter favors the establishment of most forbs, sedges and cool-season grasses, while spring seeding will favor warm-season grasses. Plugs of any species should be planted in spring. In riparian areas, tarping is more difficult and seeding native vegetation is not recommended. Instead, Miller suggests spot-treating RCG with herbicide and using native tree saplings (Willow, alder, cottonwood). One study suggested willow, chokecherry and redosier dogwood were suitable light competitors to RCG (Stannard and Crowder, 2001).

In a comparison of nutrient-deprivation versus shading, Iannone et al. concluded that, "rapidly establishing a perennial plant community may be more important than reducing initial resource availability when trying to limit invasions of resource-rich restorations (Iannone et al., 2008). Applying sawdust to soil limits the availability of nitrogen to RCG while allowing native plants time to compete.

A suggested frost-seeding method is to burn the site after the first hard frost and broadcast seed (Wisconsin, 2009). Hutchison (1992) advises competitive crop management is most effective when used in combination with prescribed burning.

A list of suggested species to outcompete RCG is available at http://www.appliedeco.com/Projects/ReedCanaryBrochure.pdf.

Water Level Controls: RCG seeds are generally short-lived when inundated, but the time period of inundation is not clear. Some studies show germination rates decreased after 3 months of inundation, while others say as long as 12 months. After 48 months of inundation, seed germination is completely controlled (Lyons, 1998).

The whole plant is tolerant of periodic flooding but intolerant of continual ponding, particularly in warmer weather (Stannard and Crowder, 2001). In the

Smith and Bybee Wetlands Natural Area north of Portland, OR, a water control structure was installed to mimic natural flood events, specifically spring flooding (freshet) and summer drying, to control RCG which had invaded native riparian willow stands. Water was retained in the wetland until late May, and then allowed to draw down from late spring to August or September. The control was closed again in November to collect the next year's rain. Where inundation was greater than 0.85m, RCG was reduced by 6.1 percent; where willow forest was regenerating, RCG decreased by 10.8 percent. Late-germinating emergent wetland species responded positively to the new hydrologic regime. Though reports are equivocal, reductions in biomass have been measured at flood depths of 15 and 30cm. Some important native taxa, such as smartweed (Polyconum spp.), water-purslane (Ludwigia spp.), willows (Salix spp.), thrive under flood conditions, though research on their relationship to RCG in flood conditions is generally lacking (Jenkins, 2005).

Chemical Control: Generally RCG is better controlled by chemicals in upland sites (Lyons, 1998). In all cases reviewed, yearly treatments with herbicides were required to completely suppress infestations. Strictly chemical application methods have provided poor long-term control (Apfelbaum and Sams, 1987).

The key to chemical control is to apply at a time for maximum transmittal from foliage to rhizomes, generally understood to be early-bolting to pre-bud stages and in the fall (Miller, 2007). Herbicides should be used before plants lose appreciable chlorophyll (otherwise, late summer). Galatowitsch (1997) recommends after first frost as the best time to apply herbicide, as nutrient flow is towards roots at the end of the growing season. Hoffman and Kearns (1997) suggest removing old leaves to ensure only new growth absorbs the herbicide.

Mowing several weeks before herbicide application allows for regrowth and the necessary foliage cover to readily transport the herbicide to the root zone. Similarly, mowing at least seven days after herbicide application (Miller, 2007) insures the chemical is fully transported to the rhizomes.

Large stands of RCG have been shown to be difficult to kill without harming desirable native plants and without adequate controls, as plants reestablish quickly after mechanical or chemical control (Apfelbaum and Sams, 1987). Spot-treatment is recommended for spotty patches, as these chemicals are non-selective and should not be applied broadly over diverse populations. Brush control mowers that apply herbicide to blade have not been tested but are suggested for investigation (Miller, 2007)

In aquatic systems, short-term effects from herbicide use often include reduced dissolved oxygen, increased carbon dioxide, reduced pH, increased bacterial populations, changes in nutrient status, and changes in vegetation and faunal communities.

Source	Chemical Treatment	Quantity	Additional Treatment	Result/Recommendation	Reported in
Paveglio and Kilbride, 1996	Glyposhpate (Rodeo)	0.5% solution @ 2.25 quarts/acre	Herbicide plus LI-700 surfactant; Discing three times post herbicide. Herbicide pre-discing suppresses seedling emergence.	99% control in first year	Lyons, 1998
William et al., 1997	Glyposhpate (Rodeo and Roundup)	1.2-2.25 lb/ai/acre	Early heading or in late fall.		
Miller, 2007	Glyposhpate (Rodeo or Aquamaster)	0.75% solution @ 1.5-2.3 quarts/acre	Followed by sapling revegetation	Recommended, not tried for riparian areas. Apply when juvenile salmonids not in stream	Slemmons, 2007
Miller, 2007	Glyposhpate (Roundup)	2-3 quarts/acre (3lbs/gal)	Mowing 2 weeks prior and 1 week after herbicide (to allow plant to regrow and uptake chemical)	For right of ways	Slemmons, 2007
Miller, 2007	Imazapyr (Arsenal)	3-4 pints/acre (2lbs/gal)	+ adjuvant (nonionic surfactant, crop oil concentrate, etc. as shown on label)	For right of ways. Recommended, not tried: use brush control mowers that stream herbicide onto blade	Slemmons, 2007
Miller, 2007;	Sulfometuron (Oust)	3-5 ounces/acre (at 75%)	+ 0.25% nonionic surfactant.	For right of ways. Not recommended for crop-land;	Slemmons, 2007

				Recommended, not tried: use brush control mowers that stream herbicide onto blade	
Galatowitsch, 2007	Dalapon	12 lbs/acre		Apply at flowering time. Also effective as late fall application	Slemmons, 2007
Galatowitsch, 2007	Glyphosphate	1.5 lbs/acre		Apply at flowering time	Slemmons, 2007
Galatowitsch, 2007	fluazifop butyl (grass-specific)	3% solution		For larger populations of RCG. Best when dominant native vegetation is sedge or other non-grass	Slemmons, 2007
William et al., 1997	Fluazifop-D (Fusilade, Horizon)	0.25-0.38 lb/ai/acre (1-1.5 pint/acre)	+1% v/v crop oil concentrate or 0.25% v/v nonionic surfactant	Do not apply to stressed grasses. Do not apply if rainfall expected within an hour	Lyons, 1998
Apfelbaum and Sams, 1987	Boron	300 ppm		Complete tissue necrosis 3 weeks after application	Apfelbaum and Sams, 1987

Reed Canary Grass Management Practices (Adapted from Wisconsin, 2009)						
Treatment	**Effect**	**Should use**	**Could use**	**Should not use**	**Timing**	**Comments**
Burning	Removes biomass and litter; may kill seed in soils. Reduces Available nitrogen over multiple burns Releases seed bank of desirable/undesirable species Stimulates dormant buds of RCG, rhizomes re-sprout Can jumpstart growing season by warming soil	To reduce RCG in late spring after RCG is active but before natives break dormancy To force RCG to re-sprout and use reserves from rhizomes Use in combination with other practices	To remove thatch prior to a planting/seeding of desirable natives To remove thatch and prompt early spring sprouting of RCG, with glyphosphate or sethoxydim	In fall to control RCG in short term; RCG benefits from high light conditions after fire In early spring in mixed vegetation sites; RCG growth is encouraged by increased light, unless you plan to combine with another treatment On organic sites if very dry	Late spring	Jumpstart occurs if burn done in fall or spring No research on critical density of RCG that can be controlled by burning alone Early burns will stimulate RCG; timing and frequency critical
Excavation	Removes rhizomes and seed bank Removes sediment and nutrients Alters hydrology	Where material can be pushed to fill drainage ditches or where it can be moved off site; where deeper water is desired During winter, to reduce soil compaction During summer when wet sites are dry	To remove alluvium over native wetland soils	If there is no soil disposal site If compaction is an issue If you don't want a deep-water marsh If there is a high-quality remnant plant community in area	Winter Summer	May cause soil compaction RCG will rapidly re-colonize disposed soil; use caution when selecting disposal site Additional treatments will be necessary on drier sites Seed with natives afterwards, except in the deepest water, or if a rich native seed bank exists May require special permits

Tree/shrub planting	When woody species overtop RCG, shade slows its growth May change plant community Adds structure to habitat	Where herbaceous vegetation cannot gain a competitive advantage	Where landscape is receiving RCG seed inputs Where inflows can't be diverted To connect existing woody patches	Where management goal is to maintain grassland habitat	Late Summer/Fall	Apply herbicide/mulch around newly planted trees/shrubs Conifers may be the most effective at shading RCG Need to control RCG for 3-5 years to allow tree establishment
Grazing	Reduces biomass in spring Causes disturbance Allows seedling establishment (good/bad) Adds nutrient to system	In highly disturbed sites to reduce RCG biomass In fall, after a presecribed burn (RCG regrowth more palatable)	To reduce biomass and height before herbicide treatment To reduce seed production Light, to sustain diversity	During wet conditions in spring where trampling and compaction can damage a site If there is a high-quality remnant plant community in area	Spring Fall	Effective at suppression only Use proper stocking rates to prevent overgrazing of desirable species and streambank impacts
Mowing and harvesting	Removes biomass and nutrients Reduces RCG height Similar to fire (promotes seed establishment, stimulates plant growth by increasing light)	To reduce biomass before herbicide treatment To remove P from site Before RCG seeds heads appear To prepare for herbicide application	As a substitute for fire (though not quite the same) To change fire behavior by reducing fuel height	Where tussocks and microtopography will be damaged When grassland bird nesting habitat will be impacted If site is too wet for equipment	Late Spring (before seed heads appear)	On high quality sites, avoid use during growing season
Mowing without harvesting	Reduces RCG height Increases light-promotes competition Depletes rhizome reserves Creates dry biomass for fire	To prepare for herbicide application To stress RCG When harvesting equipment is unavailable	To change fire behavior by reducing fuel height	Where tussocks and microtopography will be damaged When grassland bird nesting habitat will be impacted If site is too wet for mower	Late spring (before seed heads appear)	May impede establishment of natives, due to remaining mat of vegetation

Herbicide: broad spectrum (i.e. glyphosphate, imazapyr)	Reduces plant heightIncreases light-promotes competitionDepletes rhizome reservesCreates dry biomass for fire	On sites without native plants prior to reseeding. To dry out RCG in order to burnIn late summer for maximum translocation to roots	For treating clones within areas of nativesAs an initial herbicide treatment on monotypic stands of RCGIf RCG height precludes use of other herbicidesIn early spring or late fall, when RCG is live, but other plants dormantOn wet sites, with a surfactant approved for aquatic use	On sites with desirable native plants actively growingSoon after mowing/burningWhen amphibians are on site (unless using Rodeo + a surfactant approved for acquatic use, as Roundup formulation can have negative effects on amphibians)	Late summer for maximum translocation Early Spring/Late Fall during dormancy of other plants	Should be part of a continued control strategy, where natives are later introducedMultiple treatments may be necessaryMay need a permit for application on wetlandsRhizome translocation less effective if temperature >70°FOther treatments may influence herbicide effectivenessAdd ammonium sulfate to tank mix if water is hard
Herbicide: grass-specific (i.e. sethoxydim or fluazifop)	Suppresses growth of most grasses Releases native plant community (except for grasses)	On sites with desirable, native, non-grass species When active growth resumes after burning/mowing, when RCG is 6-12" tall	Following other herbicide treatments to control residual or re-emerging RCG	For immediate eradication If standing water is present On sites with desirable grasses When RCG is >12" tall	Late spring	Apply with surfactant/crop oil > one treatment required Effectiveness of sethoxydim is reduced by UV light Add a water conditioner or acidifier if water is hard
Tillage	Exposes rhizomes to light; might activate dormant buds Fragments rhizomes and may increase RCG density Can contribute to erosion	In combination with herbicide treatment (makes dormant rhizome buds respond to chemical control) On monotypic, damaged sites to prepare for crop production	To prepare a seedbed To reduce RCG seed bank	Where microtopography must be maintained Where RCG is mixed with desirable natives On wet sites, where soil could become compacted, or equipment can get stuck If offsite impacts are possible (sedimentation/erosion)	Spring/early summer	For most effective control, combine with another treatment Depth should be 4-6" to target RCG rhizomes Till in spring or early summer Repeated tillage can be effective if conducted every four weeks

Altering hydrology	Prolongs/increases water levels Prevents RCG seed germination Kills RCG rhizomes	If new water depth is >12" If high water can be maintained through the growing season	To promote the growth of emergent plants such as native cattail, burr-reed and bulrush species	If new water depth is <12" or site seasonally dries out If other invasives are nearby (Typha x glauca, Phragmites)	Spring (flood) Late summer (draw down)	High water can promote growth of other invasives (Typha x glauca, Phragmites) if present in the area May require special permits
Mulching/solarization with plastic or fabric	Non-selective treatment; shades out all plants Kills adult plants Kills RCG rhizomes	For small, isolated RCG clones For 1-3 consecutive years On patches with high edge:area ratio, to facilitate reconolozation by soil fauna	To facilitate seeding or planting of natives	Where desirable natives are mixed with RCG For abatement on large sites If native species are present In areas with microtopography		Resurgence from seedbank may occur when tarping removed May have adverse effects on soil microorganisms May alter soil chemistry Not always an effective treatment