CHAPTER 6

ROLE AND USE OF VEGETATION

As discussed in Chapter 2, riparian vegetation plays an important role in the riverine environment. This chapter focuses on the incorporation of vegetation in bank stabilization projects. While vegetation can introduce a cost-effective, self-maintaining mechanism for improving bank stability, the species used should be selected to meet the specific conditions of each site. This chapter introduces some factors influencing species selection and provides guidelines for selecting vegetation most likely to succeed in these types of projects.

6.1 EFFECT OF VEGETATION ON BANK STABILITY

Vegetation offers the best long-term protection against surficial erosion on slopes and provides some degree of protection against shallow mass-movement. Vegetation prevents surficial erosion by (adapted from Gray and Leiser 1982):

- *Interception.* Foliage and plant detritus absorb rainfall energy and prevent soil compaction from raindrops.
- *Restraint.* Root systems physically bind or restrain soil particles while the above-ground detritus filters sediment out of runoff.
- *Retardation.* Plant detritus increases surface roughness and slow velocity of runoff.
- *Infiltration.* Roots and plant detritus help maintain soil porosity and permeability.
- *Transpiration.* Depletion of soil moisture by plants delays onset of saturation and runoff.

Vegetation, primarily woody plants, also helps prevent mass-movement, particularly shallow sliding in banks. Possible ways woody vegetation affects banks include (Gray and Leiser 1982):

- *Root Reinforcement.* Roots mechanically reinforce a soil by transfer of shear stresses in the soil to tensile resistance in the roots.
- *Soil Moisture Modification.* Evapotranspiration and interception in the foliage limit buildup of soil moisture stress.
- *Buttressing and Arching.* Anchored and embedded stems can act as buttress piles or arch abutments in a slope, counteracting shear stresses.
- *Surcharge.* The weight of vegetation on a bank exerts both a downslope (destabilizing) stress and a stress component perpendicular to the bank which tends to increase resistance to sliding.
- *Windthrowing.* Destabilizing influence from turning moments exerted on a bank because of strong winds blowing through trees, i.e., the toppling of trees and upheaval of the root mass and associated soil.

The first three effects--root reinforcement, soil moisture depletion, and buttressing--enhance bank stability. The fourth, surcharge, may have either a beneficial or adverse impact depending on soil or bank conditions. The last, windthrowing, may negatively affect bank stability. In addition to Gray and Leiser, Coppin and Richards (1990) provide a thorough discussion of these effects.

Vegetation adds stability to hillslopes by providing cohesion via the root systems and by reducing soil water content through transpiration. Low clay content, non-plastic, granular soils are more susceptible to rapid mass soil movements (especially debris avalanches and flows) than more cohesive soils, because shear strength is determined primarily by soil particle interlocking. Root systems of vegetation can stabilize shallow or steep soils by anchoring the soil mass to fractures in bedrock and tying hillslopes together across zones of weakness (Sidle 1980; Ziemer 1981).

Woods (1938) studied the root structure of many Pacific Northwest native plants. He found that the best plants for soil-binding include hazel, vine maple, quaking aspen, willows, snowberry, and kinnikinnik (all rated excellent), and oceanspray, Pacific blackberry, black raspberry, and Oregon grape (all rated good). Sidle (1980) reports that root strength tests show that coastal Douglas fir roots are stronger than western hemlock roots, which are stronger that sitka spruce roots. Many non-commercial trees and brush that are often suppressed or killed by herbicides and slash burning have even stronger root systems. Ziemer (1981) reports that the live roots of shrubs are twice as strong as coniferous roots of the same size. Root biomass, however, is more important than root size in improving stability. Smith (1976; as cited in Gordon et al. 1992), for example, found that a bank with a two-inch thick root mat of 16-18 percent root volume afforded 20,000 times more protection from erosion than a bank without vegetation.

6.2 LIMITATIONS OF VEGETATIVE MEASURES

Vegetative measures should not be viewed as a panacea for all bank failures or soil erosion problems. There will usually be some delay between the introduction of the vegetation and the start of its active role. It may be weeks or months for grasses and herbaceous vegetation, and several years for shrubs and trees, before the system is fully effective.

If the banks are highly unstable, some initial safeguards against failure may be required. These include biodegradable and synthetic geotextiles, cribwalls, or rock. These safeguards, which are described in the next chapter, may provide temporary protection until the vegetation becomes established or may be incorporated as a long-term component of the project.

There are also long-term effects (e.g., weathering or changing moisture content) where bank soils may increase or decrease in strength. In these cases, the aim is to use appropriate plants in a complementary way. This could entail using rapid-growing plants to make up an early deficiency in soil strength, or slow-growing plants in situations where soil strength would otherwise become critical.

A frequently voiced concern about the use of plants in flood control and bank stabilization projects is that the roots will weaken the structure. The main danger from prying or wedging would most likely arise from species with trunks or stem sizes that exceed the diameter or size of openings in the face of levees, revetments, and other structures. It is important, therefore, not to install vegetation that will mature into large-diameter trees in the front openings of a structure such as a cribwall.

Similarly, another concern is the susceptibility of mature trees to windthrow. Some species, such as black cottonwood, red alder, or isolated, individual Douglas fir, have a potential to topple as they approach maturity. Plant form and size at maturity, longevity, and the location of larger species selected for a project should be matched with the level of protection required at the site.

Often, surface erosion controls such as grass seeding or hydro-mulching will work satisfactorily at less cost than "engineered" solutions. In some cases, a structural retaining system alone or in combination with vegetation would be the more appropriate and most effective solution. No matter which approach is applied, the selected solution must address the mode and cause of failure.

6.3 PLANT SELECTION

For vegetative streambank protection systems to be successful, plants must grow well at the site. Whether or not a plant species is appropriate at a particular site depends on several factors: purpose of planting, soil moisture (permeability and drainage), available sunlight, brush competition, potential for animal damage, and elevation among others (Baumgartner et al. 1991).

6.3.1 CHECKLIST FOR PLANT SELECTION

The questions in Table 6.1 should be answered as early in the project as possible. Some of these questions will be answered by one person from a particular discipline; others will need to be answered by an interdisciplinary team. This team should consist of technical experts from the project agency staff, staff from other agencies (e.g., Depts. of Ecology or Fisheries), private consultants, and/or other individuals with appropriate expertise.

The answers to these questions, used in conjunction with the tables included in this chapter, will provide the basis for selecting the most appropriate vegetation for a bank stabilization project. Common species suitable for the King County area are listed in Table 6.2 along with information about size, habitat value, root form and depth, and propagation. Table 6.2 should be considered a partial list of appropriate woody species for riparian planting. This table also includes some non-native but highly useful species. This list should be carefully reviewed for any projects strictly limited to the use of native species. Table 6.3 provides additional information on wildlife utilization (shelter, feeding, etc.) for some plant species recommended for riparian areas.

None of the plant lists should be construed as definitive or absolute, but rather as suggested species, some of which are frequently overlooked in traditional landscape architecture. Plant inventory lists from nearby locations can also provide valuable information on native plants best suited to the project. There are no substitutes for on-site analyses and site-specific recommendations. These lists, however, are a starting point for gathering information and making preliminary decisions when few or no other data are available.

Table 6.1 A checklist for selecting the most appropriate vegetation for a bank stabilization project.

1	What are the specific goals and objectives of the project? Re-establishment or enhancement of existing plant community? Restoration of a previous plant community? If so, what time frame (e.g., 1-, 10-, 50-, 100-years ago)?
2	What are the geographic characteristics of the project site (elevation, slope aspect, and topography)?
3	What are the climatic characteristics of the project site (types, amount, and timing of precipitation; length of growing season; average temperature; velocity and direction of prevailing winds; available light)? Will the light requirements of the plant assemblage (full light, partial shade, or shade tolerant) be met under the existing and/or anticipated site conditions?
4	What soil types exist in the project site and adjacent areas? What are the specific characteristics of these soils (permeability; drainage; available water capacity; fertility; texture)?
5	What is the hydrology of the project site? Is the site periodically covered with water? If so, how frequently and for what length of time? Is the site covered by standing water or flowing water? If flowing water, what is the estimated depth and velocity?
6	What is the condition of the existing plant community? Is it a natural plant assemblage? Has it been recently altered or disturbed? If altered or disturbed, to what extent? What was the cause of the alteration (a single event versus ongoing disturbance)?
7	Are there existing or planned access roads or pathways in and near the project site? What form of vegetation (herbs, shrubs, trees) is appropriate for the intended function of the bank (such as recreation or maintenance access, if any)?
8	Do site conditions require special design considerations such as vegetation height or shape, type of root structure for erosion control and bank stability (e.g., are velocity control or windthrow a concern); soil type and depth (e.g., are shallow soils or till present)?

Table 6.1 A checklist for selecting the most appropriate vegetation for a bank stabilization project, continued.

9	Do present or potential hazards to the integrity of the plant community exist on-site (e.g. grazing, recreational use, dredging or maintenance activities, encroachment by development activities, changes to site hydrology and soil moisture, sediment deposition)?
10	What will be the secondary function (after stabilization) of the project area: aesthetics; recreation (active or passive); fish and wildlife habitat; sound or visual barrier; water quality protection or treatment?
11	What fish and wildlife needs are or could be provided by the plant community (e.g., food; shelter; nesting sites; migration corridors)? Is there an opportunity to restore or enhance existing fish and wildlife habitat (e.g., shading for control of water temperatures)?
12	What plant communities are reasonable and practical given the real constraints of the project site, budget, and regulatory requirements?
13	What is the availability and cost of the desired plant species? What density of cover is desired, and in what time frame? How much of the plant installation can be lost (e.g., mortality or vandals) and still meet project goals? What is the budget for plant materials?
14	What are the short- and long-term maintenance requirements of the project site (disease and pest control; fire control; weed/competitive species control; irrigation; frequency of mowing or brushing)?
15	Will the recommended vegetation require special site preparation or equipment for installation (e.g. control of invasive species such as reed canary grass; tree spades for larger stock)?
16	Will the prescribed vegetation require supplemental irrigation, fertilization, or fencing to become established? Are these measures available?
17	Given local climatic and hydrologic conditions and site constraints, when is the best time of year for planting? Does planting need to be staged over time (weeks, months, or years)? If there is no choice in planting times, what is the best form of plant material to use (live stakes, rooted cuttings, nursery stock).
18	What are the skills of the planting crew? Will training be required? How large a crew is available? How large is the area to be planted/how long will it take with the available crew? Are adequate plant storage facilities available if material cannot be planted in one day?

Table 6.2 Characteristics of some native western Washington trees and shrubs with high utility for bank stabilization projects.

SPECIES Scientific and common names	METHOD OF PROPAGATION[1]	EXPECTED ROOTING SUCCESS[2,3]	HABITAT VALUE	FORM & SIZE	ROOTING CHARACTER	LONGEVITY[4]	MOISTURE & LIGHT	COMMENTS[5]
Abies grandis grand fir	seed	low	--	tree to 200+'	deep taproot[6,7]; many lateral branches	long	well-drained; sun	the best conifer for soil binding roots[6]
Acer macrophyllum big-leaf maple	seed	no[8]	fair as food	tree to 100'	shallow	medium	moist-dry, sun-part shade	low elev.; usu. good soil
Acer circinatum vine maple	2nd year wood placed horizontally[9]; seed	fair[8]	good cover, food, browse	shrub or small tree to 35'	moderately deep, spreading	short-medium	moist-dry; sun-shade	low to mid elev.; sprouts from roots
Alnus rubra red alder	seed, cuttings, suckers	fair[3,9]	good as food	tree to 80'	shallow, strong, lateral	medium	moist-dry; sun-shade	fast grower; high survival from "pull-ups"[10]; may prevent laminated root rot[11]
Alnus sinuata Sitka alder, slide alder	seed, cuttings, suckers	no	good as food	shrub to 25'	--	medium	moist; sun	low to high elev.
Amelanchier alnifolia serviceberry, shadbush	suckers, seed	--	good as food, browse	shrub or small tree to 30'	deep, spreading	short-medium	well drained-dry; sun	low to high elev.
Arctostaphylos uva-ursi bearberry, kinnikinnik	seed, cuttings	poor	high	mat forming shrub to 1' high, 15' wide	shallow, dense, extensive, highly branched	short	well drained-dry; sun-shade	slow grower; branches set roots; good above ground cover; evergreen
Berberis aquifolium tall Oregon grape	cuttings, layers	good[12]	high	shrub to 7'	deep, rhizomatous; spreads by rootstocks	short	well-drained; sun-shade	Secondary host of blackstem rust of grains; slow grower; evergreen
Berberis nervosa low Oregon grape	cuttings, layers	good[12]	high	shrub to 4'	rhizomatous; spreads by rootstocks	short	well-drained-dry; sun-shade	slow grower; thicket forming; good on slopes; evergreen

Table 6.2 Characteristics of some native western Washington trees and shrubs with high utility for bank stabilization projects, continued.

SPECIES Scientific and common names	METHOD OF PROPAGATION[1]	EXPECTED ROOTING SUCCESS[2,3]	HABITAT VALUE	FORM & SIZE	ROOTING CHARACTER	LONGEVITY[4]	MOISTURE & LIGHT	COMMENTS[5]
Cornus stolonifera red-osier dogwood	cuttings, layers	good[8]	high	shrub to 20'	shallow, strong, lateral, fibrous; spreads by rootstocks	short	wet-well drained; sun-shade	susceptible to twig blight; fast grower; holds soil well; branches root; winter color
Corylus cornuta hazelnut	seed, suckers	no[8]	good food and cover	shrub to 15'	extensive, branching	short	moist-dry	low elev.
Holodiscus discolor oceanspray, creambush	seed	poor	browse	shrub to 10'	shallow, spreading	short	moist-dry; sun-part shade	resprouts readily when cut or grazed; good on dry, steep slopes
Lonicera involucrata black twinberry	cuttings	good[9]	high as food	spreading shrub to 10'	shallow, spreading	short	wet-moist; shade	low to mid elev.
Malus fusca western crabapple	seed	poor[12]	fair as food, good cover	shrub to 20'	shallow, spreading	short-medium	moist-well drained; sun	low elev.; forms dense thickets; "may prove of value in streambank control"[13]
Oemleria cerasiformis Indian plum	seed, cuttings	fair[14]	high	sparse shrub to 15'	shallow, spreading	short	moist-dry; sun-shade	low to mid elev.
Philadelphus lewisii mock orange	cuttings, layers	good[15]	good browse	shrub to 10'	fibrous	short	moist-dry; sun-shade	no pests; low to high elev.; fast vigorous grower
Physocarpus capitatus Pacific ninebark	cuttings	fair-good[9]	fair	sparse shrub to 20'	shallow, lateral	short	moist-well drained; sun-shade	low to mid elev.
Pinus contorta lodgepole pine	seed	low[3]	fair food and cover	tree 30-100'	shallow, well branched	medium	moist-dry; sun	excellent above ground cover

Table 6.2 Characteristics of some native western Washington trees and shrubs with high utility for bank stabilization projects, continued.

SPECIES Scientific and common names	METHOD OF PROPAGATION[1]	EXPECTED ROOTING SUCCESS[2,3]	HABITAT VALUE	FORM & SIZE	ROOTING CHARACTER	LONGEVITY[4]	MOISTURE & LIGHT	COMMENTS[5]
Populus tremula quaking aspen	cuttings, seed, suckers[14]	good[14]	high	medium tree to 40'	shallow, extensive, invasive	short-medium	moist-dry; sun	insects and disease in monoculture; root rot; low to mid elev.; forms dense groves
Populus balsamifera black cottonwood, balsam poplar	cuttings	good[8]	good cover, forage	tree to 80'	shallow, fibrous	medium	wet-moist	susceptible to root rot, windthrow; low to mid elev.; fast grower
Pseudotsuga menziesii Douglas fir	seed	--	fair as food, cover	tree to 200+'	shallow	long	well drained-dry; sun	good soil binding roots; low to mid elev.
Rhamnus purshiana cascara, chittam bark	cuttings	--	good	large shrub or small tree to 30'	--	medium	moist-dry; sun-shade	susceptible to crown rust of oats; low to mid elev.; coppices freely
***Ribes* spp.** currant, gooseberry	seed, cuttings in fall[14], layers	fair in fall with rooting hormone	high	dense shrubs to 7'	fibrous	short	wet-dry; sun-shade	Secondary host of white pine blister rust: DO NOT plant within 900' of 5-needle pines; low to high elev.
***Rosa* spp..** rose	stem cuttings, root cuttings, layers	fair	high, good forage	sparse to dense shrubs to 4'	poor for erosion control	short	dry-moist; sun-partial shade	low to mid elev.
***Rubus* spp.** blackberry, raspberry, salmonberry	divisions, cuttings, root cuttings	fair	high	ground cover and shrubs to 10'	shallow, fibrous, trailing branches set roots	short	wet-dry; sun-shade	excellent erosion control by dense above-ground portion
***Salix* spp.** willow	cuttings	good[8]	high as cover	shrubs, trees to 40'	shallow, extensive	short-medium	moist-wet; sun	short lived but sucker freely; susceptible to aphids, borers, tent caterpillars, spider mites

Table 6.2 Characteristics of some native western Washington trees and shrubs with high utility for bank stabilization projects, continued.

SPECIES Scientific and common names	METHOD OF PROPAGATION[1]	EXPECTED ROOTING SUCCESS[2,3]	HABITAT VALUE	FORM & SIZE	ROOTING CHARACTER	LONGEVITY[4]	MOISTURE & LIGHT	COMMENTS[5]
Sambucus racemosa red elderberry	cuttings from 2nd year wood[9], root cuttings, seed	good[8,12]	high as food and cover	shrub to 20'	fibrous; strong adventitious roots[16]	short	moist-dry; sun-shade	coppice freely; may grow 13' in one season[13]
Sorbus sitchensis Sitka mountain ash	seed	unknown	good	shrub to 20'	--	short-medium	moist-dry; sun-part shade	"with promise for erosion control"[13]; may be susceptible to fireblight
***Spiraea* spp.** spirea, hardhack	divisions, suckers, cuttings, root cuttings	good[12]	fair as cover	dense shrub to 7'	extensive, fibrous	short	wet-well drained; sun-shade	no pests; dense thickets; sucker profusely
Symphoricarpos albus, S. mollis snowberry	suckers, cuttings	good[8,12]	high as food and cover	dense shrub to 3', *mollis* about 1'	extensive, branching, fibrous; spread by rootstocks	short	moist-well drained; sun-shade	susceptible to anthracnose, powdery mildew; dense thickets, sucker readily
Thuja plicata western red cedar	seed	no	fair	tree 150'-200'	shallow	long	moist-wet; shade	low elev.
Tsuga heterophylla western hemlock	seed	no	fair	tree 100'-160'	shallow	medium-long	moist; shade	low elev.
Viburnum opulus guelder rose, high-bush cranberry	cuttings, seed	good[15]	--	shrub to 20'	strong adventitious roots[16]	short	well drained-moist; sun-shade	susceptible to aphids; showy fruit

Table 6.2 Characteristics of some native western Washington trees and shrubs with high utility for bank stabilization projects, continued.

1 From Apgar (1910) except as noted.

2 Rooting success from cuttings: Good = >75 percent; Fair = 50 to 75 percent; Poor = <50 percent; No = poor success, even in nursery.

3 Larson and Guse 1981.

4 Longevity: short is less than 50 years, medium 50 to 200 years, long greater than 200 years.

5 Elevation: low is less than about 2000 feet, mid from 2000 to about 5000, high above 5000.

6 Woods 1938.

7 Van M. Bobbit, Washington State University, and James R. Clark, University of Washington, state that tap roots in mature trees are rare in the Pacific Northwest.

8 Dan McCain, Stormlake Growers, Snohomish, Washington.

9 Ron Vanbianchi, Pacific Wetland Nursery, Kingston, Washington.

10 Scott Lambert, Soil Conservation Service; Streambank Rehabilitation in Western Washington and Oregon using Willow species, Douglas Spirea, and Red-Osier Dogwood. Unpublished.

11 Mathews 1988.

12 Marchant and Sherlock 1984

13 Van Dersal 1938.

14 Kruckeberg 1982.

15 Dirr 1975.

16 Schiechtl 1980.

Table 6.3 Wildlife use of selected species. (From Hanley 1984, Washington Department of Wildlife [no date], Snohomish County 1990.)

COMMON NAME	BOTANICAL NAME	VALUE
maple	Acer spp.	moderate
alder	Alnus spp.	moderate
serviceberry	Amelanchier alnifolia	moderate
bearberry	Arctostaphylos spp.	moderate
Oregon grape	Berberis nervosa	moderate
paper birch	Betula papyrifera	moderate
red-osier dogwood	Cornus stolonifera	high
hazelnut	Corylus cornuta	high
salal	Gaultheria shallon	moderate
oceanspray	Holodiscus discolor	*
trumpet honeysuckle	Lonicera ciliosa	moderate
black twinberry	Lonicera involucrata	moderate
crabapple	Malus fusca	moderate
Indian plum	Oemleria cerasiformis	moderate
mock orange	Philadelphus lewisii	*
Pacific ninebark	Physocarpus capitatus	*
Sitka spruce	Picea sitchensis	moderate
lodgepole pine	Pinus contorta	high
western white pine	Pinus monticola	high
black cottonwood	Populus balsamifera	high
quaking aspen	Populus tremuloides	low
bitter cherry	Prunus emarginata	high
chokecherry	Prunus virginiana	high
Douglas fir	Pseudotsuga menziesii	moderate
ferns	Pterophyta	low
cascara	Rhamnus purshiana	moderate
currant	Ribes spp.	moderate
rose	Rosa spp.	moderate
salmonberry	Rubus spectabilis	high
blackberry	Rubus spp.	high
thimbleberry	Rubus parviflorus	high
willow	Salix spp.	high
elderberry	Sambucus spp.	high
Sitka mountain ash	Sorbus sitchensis	high
hardhack	Spiraea spp.	moderate
snowberry	Symphoricarpos albus	moderate
creeping snowberry	Symphoricarpos mollis	moderate
western red cedar	Thuja plicata	moderate
western hemlock	Tsuga heterophylla	moderate
mountain hemlock	Tsuga mertensiana	moderate
huckleberry	Vaccinium spp.	moderate
highbush cranberry	Viburnum opulus	moderate

** Not all species were rated for value, only noted that they were of value. Values include nesting, resting and feding for birds, mammals, game, and other animals.*

6.3.2 PLANT COMMUNITIES

Schiechtl (1980) says that the use of unsuitable plant species has been a major reason for failure in vegetative bank stabilization systems. Only plants from sites with ecological conditions similar to the project site should be used. Locally obtained plants are generally better adapted than plants obtained from distance sources. Identification of the local plant communities is therefore the first step in planning large-scale bank stabilization projects.

Ecologists recognize specific plant communities or associations based on dominant tree, shrub, and forb species. In King County and lower Puget Sound, the plant communities are typically mesic communities (i.e., those found in moderate moisture conditions) dominated by conifers.

Year-round soil moisture is a major factor in defining what species and therefore what communities will characterize a given area. Therefore, the process of compiling recommended species lists for planting along streams and rivers depends on soil moisture conditions that are expected to be present in the area. This information can be obtained from a variety of sources. The U.S. Soil Conservation Service soil survey, for example, contains information on drainage, permeability, depth to water table, and other characteristics of local soil series. The U.S. Fish and Wildlife Service National Wetlands Inventory maps provide information on depth, duration, and frequency of soil saturation and/or inundation. Consideration of this information is important in selecting appropriate plant species for a given site. Although not a substitute for information collected from on-site evaluations, these sources provide initial baseline data.

Plant species should be selected for particular areas based on their moisture requirements and tolerance levels. Table 6.4 lists five generalized plant associations (very droughty, droughty, moderate, wet and very wet) for revegetating riparian corridors. These associations are defined by matching local-native species with anticipated soil moisture conditions. In Table 6.4, plants that require greater or lesser wet soil conditions were placed in groups specified for wetter or drier sites, respectively. While some plants in this list are not always readily available from nurseries, they can be found in nurseries specializing in native plants. If adequate lead time is available, many nurseries will grow plants, under contract agreements, at lower costs than they can be obtained otherwise. As more nurseries are now offering native species, the cost of native species should become comparable to more traditional non-native plants.

A few woody plants are adapted to frequent or prolonged flooding or to poorly drained soils (see Whitlow and Harris 1979 for information about flood tolerance). Most woody vegetation, however, grows better with free drainage and usually does not tolerate continuous waterlogged soil conditions. Sites with poorly drained soils may require special treatment such as adding soil amendments.

Plants that grow in riparian and wetland areas are often well suited to bank stabilization projects. Riparian vegetation is similar to wetland vegetation and yet distinct. Wetland vegetation is defined as plant species that are found in wetlands with some range of frequency (Reed 1988). Called hydrophytes ("water loving"), these plants often have physical or physiological adaptations that enable them to compete more effectively in saturated, oxygen-poor soils. In contrast, riparian vegetation is vegetation growing in close proximity to streams or rivers to influence or be influenced by those waterbodies. These plants may or may not be hydrophytic. It is important to realize that many species selected for wetland projects may not be appropriate for riparian projects, due to different tolerance levels of drought, inundation, flooding, or moving water. Simultaneously, there are many species commonly used in wetlands with very wide tolerance ranges, and many of these are highly suited to riparian habitats as well. In riparian planting schemes, some plants with the ability to withstand extended periods of drought, especially for areas high on the bank, will likely be needed.

Another goal is to select species that can compete with and eventually shade out reed canary grass or other undesirable species. Prior to planting, preliminary mechanical control (tilling or cutting) should be used to reduce initial competition and allow easier placement and planting of species. It will also be necessary to select a midstory of small trees and shrubs that are shade tolerant.

Certain species are well suited for planting in areas which may be designated as access corridors or where maintenance activities occur. These areas require plants communities that recover well from trampling and other disturbances. Species in Table 6.4 marked with a dagger (†) have rapid regrowth and high tolerance to disturbances such as pruning to ground level and disruption by heavy equipment.

Table 6.4 Species recommended for proposed plant associations for revegetation of riparian corridors.

Common Name	Scientific Name	Indic. Stat.	Max. Ht.	Elev. Range	Plant Associations A	B	C	D	E
vine maple	Acer circinatum	FACU†	25	l-m	*	*	*		
big-leaf maple	Acer macrophyllum	FACU†	100	l	*	*	*		
serviceberry	Amelanchier alnifolia	FACU	30	l-h	*	*	*		
tall Oregon grape	Berberis aquifolium	UPL	7	l-	*	*			
low Oregon grape	Berberis nervosa	UPL†	2	l-m	*	*			
paper birch	Betula papyrifera	FACU	65		*	*	*		
Pacific dogwood	Cornus nuttallii	FACU	65	l-	*	*	*		
salal	Gaultheria shallon	UPL†	7	l-m	*	*			
ocean spray	Holodiscus discolor	UPL†	10	l-	*	*			
trumpet honeysuckle	Lonicera ciliosa	UPL	3	l-	*	*			
mock azalea	Menziesia ferruginea	FACU	7	m-	*	*	*		
Indian plum	Oemleria cerasiformis	UPL†	15	l-	*	*			
Oregon boxwood	Pachystima myrsinites	UPL	3	m-	*	*			
choke cherry	Prunus virginiana	FACU	20	l-	*	*	*		
bitter cherry	Prunus emarginata	FACU	50	l-	*	*	*		
Douglas fir	Pseudotsuga menziesii	UPL	300	l-h	*	*			
red-flowering currant	Ribes sanguineum	UPL†	7	l-	*	*			
clustered rose	Rosa pisocarpa	FACU†			*	*	*		
thimbleberry	Rubus parviflorus	FACU†	10	l-h	*	*	*		
black raspberry	Rubus leucodermis	UPL†	10	l-	*	*			
red elderberry	Sambucus racemosa	FACU†	20	l-m	*	*	*		
Cascade mountain ash	Sorbus scopulina	UPL	20		*	*			
creeping snowberry	Symphoricarpos mollis	UPL†	1.5	l-m	*	*			
snowberry	Symphoricarpos albus	FACU†	7	l-m	*	*	*		
Pacific yew	Taxus brevifolia	FACU	80	l-	*	*	*		
western hemlock	Tsuga heterophylla	FACU	200	l-m	*	*	*		
red huckleberry	Vaccinium parvifolium	UPL	13	l-	*	*			
oval-leaf huckleberry	Vaccinium ovalifolium	UPL	3		*	*			
Oregon viburnum	Viburnum ellipticum	UPL			*	*			
red alder	Alnus rubra	FAC†	80	l-m		*	*	*	
hazelnut	Corylus cornuta	FAC†	15	l		*	*	*	
black hawthorn	Crataegus douglasii	FAC†	20	l-		*	*	*	
black twinberry	Lonicera involucrata	FAC†	10	l-		*	*	*	
western crabapple	Malus fusca	FAC†	20	l-		*	*	*	
mock orange	Philadelphus lewisii	FAC	10	l-		*	*	*	
Pacific ninebark	Physocarpus capitatus	FAC†	20	l-m		*	*	*	

Table 6.4 Species recommended for proposed plant associations for revegetation of riparian corridors, continued.

Common Name	Scientific Name	Indic. Stat.	Max. Ht.	Elev. Range	Plant Associations A	B	C	D	E
Sitka spruce	Picea sitchensis	FAC	230	l		*	*	*	
black cottonwood	Populus balsamifera	FAC†	120	l-m		*	*	*	
cascara	Rhamnus purshiana	FAC	30	l-		*	*	*	
prickly currant	Ribes lacustre	FAC†	7	l-h		*	*	*	
Nootka rose	Rosa nutkana	FAC†	7			*	*	*	
salmonberry	Rubus spectabilis	FAC†	15	l-m		*	*	*	
Scouler willow	Salix scouleriana	FAC†	40			*	*	*	
western red cedar	Thuja plicata	FAC	230	l-		*	*	*	
wild guelder rose	Viburnum opulus	FAC	10			*	*	*	
red-osier dogwood	Cornus stolonifera	FACW†	20	l-			*	*	*
Oregon ash	Fraxinus latifolia	FACW	65	l-			*	*	*
Pacific willow	Salix lasiandra	FACW†	40	l-			*	*	*
Hooker's willow	Salix hookeriana	FACW†	40				*	*	*
Geyer willow	Salix geyeriana	FACW†	15	l-h			*	*	*
Douglas spirea	Spiraea douglasii	FACW†	7	l-h			*	*	*
highbush cranberry	Viburnum edule	FACW					*	*	*
bog rosemary	Andromeda polifolia	OBL	2.5					*	*
bog birch	Betula glandulosa	OBL	15	l				*	*
alpine laurel	Kalmia microphylla	OBL	2	m-h				*	*
bog labrador-tea	Ledum groenlandicum	OBL						*	*
sweetgale	Myrica gale	OBL	7					*	*
under-green willow	Salix commutata	OBL†	8					*	*
heart-leaf willow	Salix rigida	OBL†						*	*
bog willow	Salix pedicellaris	OBL†	3					*	*
diamond-leaf willow	Salix phylicifolia	OBL†	12					*	*
wild cranberry	Vaccinium oxycoccos	OBL						*	*

Indic. Stat. = *plant indicator status (UPL, FAC, etc) from USFWS (Reed 1988), or adapted from Hitchcock and Cronquist (1973). Species marked (†) indicate trees and shrubs tolerant of severe pruning: these either stump sprout readily or sucker from roots.*

UPL Obligate upland: occurring almost exclusively in non-wetland environments.

FACU Facultative upland: occurring primarily in non-wetland environments, but also frequently in certain types of wetlands.

FAC Facultative: occurring with approximately equal frequencies in wetlands and non-wetlands.

FACW Facultative wetland: occurring primarily in wetlandenvironments, but also frequently in non-wetlands.

OBL Obligate wetland: occurring almost exclusively in wetland environments.

Table 6.4 Species recommended for proposed plant associations for revegetation of riparian corridors, continued.

Max. Ht. = *the approximate height (feet) to which plants will grow under natural conditions with sufficient time. Mature height, or the size at which plants begin to flower and produce seeds, is substantially less in many species.*

Elev. Range = *the elevations where the species commonly occurs. l=low, sea level to 2500 feet, m=mid, 2500 to 4500 feet, h=high, above 4500 feet. All elevations are variable depending on microclimates.*

Plant Associations = *planting suggestions for different soil moisture regimes based on soil information from the King County soil survey (SCS 1973) and indicator status (Reed 1988). Nomenclature follows Flora of the Pacific Northwest (Hitchcock and Cronquist 1976) and National List of Plant Species that Occur in Wetlands (Reed 1988). Plant associations recommended for various soil moisture levels:*

A. Very droughty soils: use UPL and FACU species. These conditions may be expected in porous or well-drained (sandy) soils or high on the bank, especially on south or west facing banks with little shade.

B. Droughty soils: use mostly UPL and FACU species; FAC species may be used occasionally if site conditions are somewhat moist. These soils occur in areas similar to very droughty soil, but where moisture retention is better (e.g. less sandy soils, shade, and north or east facing banks).

C. Moderate soils: use FACU, FAC, and FACW species. Most of King County has these soils. They are loamy soils with some clay, on level areas to steep slopes. They may be shallow soils over hardpan, or areas where seeps are common. Plant selection should consider microclimatic conditions including seeps, slope, aspect, etc. Steeper slopes, for example, will be drier than level soils because of water run off.

D. Wet soils: use mostly FAC and FACW species; OBL species can be used in particularly wet areas as long as the soil is not compacted. In King County, most of these soils consist of nearly level silt loams. They retain water rather than allowing it to run off after rain, and are moist to wet for most or all of the year. Because these areas have minimal slope and typically slow-moving streams, erosion is seldom a problem.

E. Very wet soils: use FACW and OBL species. These soils may be found along meandering rivers and streams with low banks. There is typically a high water table that allows the development of organic soils (peats and mucks). They are not well suited to large woody vegetation, as trees tend to blow over. Dense thickets of shrubs and small trees are common. Because these areas have minimal slope and typically slow-moving streams, erosion is seldom a problem.

6.3.3 SOILS

A basic understanding of soil is essential for anyone designing or installing landscape plans, regardless of whether the landscape is a formal garden or an ecological restoration project. While soils are responsible for the poor performance of landscape plants more often than any other single factor, they are often given little consideration (Harris 1992). Landscape plants probably suffer more from moisture-related problems (either too much or too little) than from any other cause.

Significant soil characteristics include drainage, compaction, texture, structure, strength, nutrients, and pH. Texture and structure are important for root penetration and soil moisture. While gravelly and sandy soils drain freely and allow good root penetration, they are easily eroded and droughty. Plants selected for such sites should be species that grow well under these conditions. Soils with high clay content resist erosion and hold water well but may restrict root development. Finely textured soils also are more prone to soil compaction than are coarse or sandy soils. Compacted soils require additional preparation (discussed further in Chapter 7). Soil conditioners can be applied during construction to modify physical soil conditions.

Plants vary in their tolerances to pH conditions. If soils are unusually acid or alkaline, it may be possible to select plants suitable for that condition. Most plants do well with soil pH between 6.5 and 8.3. Acid-loving plants grow well between pH 4.0 and 6.5.

The soils at each site, or every one hundred (100) feet on large sites, may be checked for nutrients, pH, and toxins. Nutrient tests, however, are of limited value for woody landscape plants, especially trees (Harris 1992, citing other authors). Soil fertilizers and conditioners may be required for poor-quality soils to produce optimum growth conditions for the species selected. Soils may need to be treated to alter pH on sites with severe problems. If soils at a site contain substances toxic to plants, the soils may have to be removed and replaced.

Soil samples should be taken of all fill materials that are brought to the site prior to use if their ability to support plants is questionable. Soils from deep excavations, several feet below the topsoil layer for example, may lack the nutrients or microorganisms necessary for plant growth. Testing by an approved laboratory may include analyses for a range of nutrients including nitrogen, phosphorous, and potassium, as well as pH. The laboratory reports should also include recommended fertilizer and lime amendments for woody plant materials. Basic soil analyses typically cost less than $30 per sample; tests for pesticides and other contaminants have additional costs.

Soils in King County (more than 30 different soil series) range in moisture content from very poorly drained to excessively drained (SCS 1973). The SCS specifies seven natural drainage classes that are defined by the frequency and duration of saturation or partial saturation that existed during the development of the soil since the last glaciation. The SCS soil survey for King County, which mapped the soil types for much of the county (excluding Seattle and the forest production zone in the eastern half of the King County), is an excellent source of information about what general types of soils can be expected to occur in any given area. Most, if not all, series occurring in King County are traversed by streams and rivers.

Disturbed soils needing revegetation may be atypical of naturally occurring soil series. Such soils lack the usual physical structure found in undisturbed soils, and drainage and permeability may differ substantially from nearby areas. Disturbed areas nonetheless have certain characteristics, such as texture, water and air content, density, pH, and organic content, that influence plant performance and selection. A summary of the characteristics of King County soils is provided in Table 6.5. Evaluation of soils on the project site, plus information presented in Tables 6.4 and 6.5, along with professional judgment of horticulturists and ecologists, should be used together to identify plants suited to the soil moisture conditions at each project site. Thus, appropriate plants may be selected from the plant association list (Table 6.4) corresponding to the on-site soil type(s) (Table 6.5).

Table 6.5 Moisture content, plant associations, erosion potential of King County soils, and percent of mapped King County area covered by various soil types. (Adapted from SCS 1973.)

MOISTURE CONTENT (DRAINAGE CLASS)	PLANT ASSOCIATION	SOIL SERIES	EROSION POTENTIAL	PERCENT OF KING COUNTY AREA
very droughty (excessively drained)	A	Neilton	slight to moderate	1.4
		Pilchuck	moderate to severe	
droughty (well and somewhat excessively drained)	B	Beausite	moderate to very severe	19.5
		Edgewick	slight	
		Newberg	slight	
		Nooksack	slight	
		Ovall	slight to severe	
		Puyallup	slight	
		Ragnar	moderate to severe	
		Salal	slight	
		Everett	slight to severe	
		Indianola	slight to severe	
		Klaus	slight	
moderate (moderately well drained)	C	Alderwood	slight to severe	58.9
		Kitsap	slight to severe	
		Si	slight	
		Sultan	slight	
wet (poorly and somewhat poorly drained)	D	Bellingham, Buckley, Norma, Oridia, Puget, Renton, Snohomish, Woodinville, Briscott, Earlmont, Sammamish	all have slight erosion potential	11.6
very wet (very poorly drained, organic)	E	Orcas	none	2.8
		Seattle	none to slight	
		Shalcar	none	
		Tukwila	slight	
			Total	94.2*

**   The remaining area consists of either 1) soils so disturbed that they cannot be classified as soil series or 2) such small areas that they could not be mapped individually at the survey scale.*

6.3.4 MULCHES

Control of surface erosion and maintenance of soil moisture levels can both be attained by using mulches. Mulching not only reduces future maintenance requirements, it also increases plant survival. Mulches may be inorganic or organic, with or without erosion control seed mixtures. Selection of a particular mulch depends on site characteristics, product availability, costs associated with acquisition and installation, effectiveness (Kay 1984), and the purpose of the mulch (Table 6.6). Most organic mulches will require additional nitrogen to compensate for the tie-up of nitrogen in the decomposition process. Mulches may be used to prevent establishment of competitive weeds on new slope stabilization projects or to introduce selected species as surface cover or around plants. The use of mulches results in increased germination of applied seed mixes (Sears and Mason 1973). Mulches also increase soil moisture retention and decrease the need for frequent irrigation. Mulches improve soil structure and, other than an initial nitrogen deficit, reduce the need for fertilizers. Chamberlain (1986), describing plant installations in late summer, stated that "without the (straw) mulch, it is doubtful that the plants could have survived without constant watering."

Mulches provide immediate protection from surface erosion and help retain soil moisture essential for rooting. Lack of soil moisture, caused by evaporation from the surface from wind or sun, and surface erosion both contribute to planting and live staking failures. Many authors (USFS 1989) describe the use and benefits of various mulches for erosion control and vegetation establishment.

Some mulches may be detrimental to established or establishing woody vegetation. If an organic mulch is used, especially wood chips or sawdust, the decomposition process requires a large volume of nitrogen. This creates a nitrogen deficiency in the soil, which can be remedied by

Table 6.6 Benefits and limitations of various types of mulches.

TYPE OF MULCH	BENEFITS	LIMITATIONS
chipped wood	readily available; aesthetically accepted; inexpensive	may prevent establishment volunteer seedlings if too deep; creates nitrogen deficit
rock	usually available on-site; inexpensive	can create blanket that inhibits plant growth
straw or hay	immediate cover followed by grasses from seeds (unless specified "weed free"); very cost effective	may need to be anchored; may contain undesirable species
hydraulic mulch and seed mixes	grass-legume mixes bind and improve soil; low labor costs	may compete with woody vegetation for water and nutrients during establishment
organic or inorganic fabric or mats	very durable to readily biodegradable depending on type; effective on steep slopes	nylon or plastic nets may be harmful to wildlife; may have high labor and material costs
commercially produced compost	can be nitrogen stabilized and of predictable quality; improves soil quality	can be expensive for large areas

the addition of nitrogen fertilizer. Fresh redwood and cedar sawdust and Douglas fir, larch, and spruce bark have been demonstrated to be toxic to young plants (Harris 1992, citing studies by several others). Toxicity can usually be eliminated by composting or leaching the material before using. Hydroseeded grasses, though commonly applied around new plantings, can compete for water and nutrients. Grasses are very competitive and grow rapidly, taking up high proportions of nutrients. Some may also release chemicals that harm other species directly, although extensive research in this field is lacking.

6.4 ENVIRONMENTAL CONCERNS IN PLANT SELECTION

Because shade is so important in maintaining fish habitat, fast growing trees that attain a great height and produce dense canopies are desirable. The best local examples are cottonwood, big-leaf maple, Douglas fir, and alder. The required height of vegetation can be determined by the angle of the sun (in King County, about 66° in summer) and the setback distance from the water's edge. Sometimes deciduous species are preferred because they allow more light to the understory early in the spring when minimal impacts to the water temperatures are expected from increased light. Conifers are appropriate in mixed stands with deciduous species if greater shading is desired. Conifers, such as cedar, while slower growing, are also desirable because of their larger size at maturity, longer lifespan, and their contribution of durable woody debris. Woody debris is important in forming and maintaining fish habitat.

Vegetation that spreads laterally or that can be oriented to project over the water will have the greatest benefits in the shortest period. Further, vegetation that can tolerate periodic inundation and can be placed close to the ordinary high water mark (or below) will provide the most usable area. Willows are an excellent choice for most applications next to streams because of the many available varieties, their flood tolerance, and their compatibility with vegetative designs. Slightly upslope from the willows, alder and cottonwood are valuable in providing shade. Shading downslope willows sufficiently may cause them to grow over the stream. Conifers should be included where appropriate for a long-term source of large woody debris.

Species selection for riparian plantings should consider the naturally occurring associations in the project area. These species are most likely to survive; native species also provide habitat best suited for local wildlife populations. Natural plant associations are best identified by direct observation of undisturbed, natural reaches up- or downstream of the project site. If undisturbed reaches do not exist near the site, other streams with similar characteristics, preferably within the same watershed, may be used to determine native plant communities. Specific information is available for some areas from public and private organizations such as the Department of Natural Resources Natural Heritage Program, the Washington Native Plant Society, and the University of Washington School of Forestry. Franklin et al. (1988) provide excellent general information about Pacific Northwest plant communities at various elevations. In King County, common trees and shrubs in lowland riparian areas include red alder, cottonwood, Pacific and other willows, western red cedar, bigleaf and vine maples, and salmonberry. At higher elevations (i.e. above 2000 feet), Alaska cedar, Englemann spruce, slide alder, Rocky Mountain maple, and other species replace or add to those of the lowlands (Franklin et al. 1988, Hitchcock and Cronquist 1973).

When considering the effect of vegetation on flood conveyance, several options exist. First, low growing shrubs such as black twinberry, currant, or snowberry can be used. These plants are flexible when mature, bending with currents or debris, so that little or no maintenance is required unless sites are invaded by species with larger form. Second, taller shrubs like willows or red-osier dogwood could be used with a regular maintenance program to prevent growth to full form. Third, select fast growing trees such as cotton or red alder that form a closed canopy. These trees have a long-term beneficial effect on flood conveyance by inhibiting the growth of shade intolerant species such as reed canary grass. Trees with low branches, and spaced at wider intervals, have limited impact on flow resistance.

Individual plant species vary in their tolerance to shade. Some plants grow best in shade or filtered light. While many shrubs are shade tolerant once established, they may require ample sunlight during establishment. If existing vegetation deeply shades a site, some crown thinning might be required at the time of construction. Only enough vegetation should be removed to allow adequate sunlight for plant growth. Because pruning cuts of any kind can introduce disease organisms into an otherwise healthy plant, an arborist or horticulturist should be consulted before crown thinning.

Competition for water, nutrients, and light caused by overplanting will result in plant stress. Stressed plants are more susceptible to pests and diseases, and may have higher mortality rates. Over the course of years, some plants will die of natural causes and provide more room for others. The canopy of natural communities is often interwoven, without distinct boundaries between plants. Plants for surface cover should be spaced at 70 to 80 percent of the area they cover *at maturity*. This provides ample room for early growth and denser immediate cover than 100 percent spacing. If high plant mortality occurs, an assessment of the reason for failure should be made, and the area replanted if necessary with appropriate species.

From an aesthetic perspective, plants may be selected for a variety of reasons. Where the ability to see the river is of high value, options such as low growing forms, regular maintenance to restrict growth, or large trees without understory should be considered. If vegetation is expected to play a significant part of the visual experience, the plant's appearance is important. Items such as leaf and stem color, the type, color, and season of flowering, and other visual components should be considered.

6.5 PROTECTING RIPARIAN VEGETATION

Serious erosion problems can result from removal of vegetation and subsequent exposure of streambank soils to wind, rain and foot traffic. Bank failures can sometimes be averted by simple measures such as preventing damage to existing vegetation, allowing damaged plant communities to recover naturally, and re-establishing vegetation where it has been removed. Fences provide bank protection by reducing impacts from livestock and humans and by protecting bank vegetation from disturbances. Fences are used where existing vegetation or slope stabilization projects need protection or where bank degradation can be prevented by restricting access. If restricted access is necessary, fences should border the entire project area. The type of fence depends on the amount of protection needed and from what (e.g., erosion from nearby construction, livestock), adjacent land use, and aesthetic considerations. Fences may be built from manufactured components or material existing on site such as poles and rocks. Although fences can prevent further deterioration of the bank, they will not repair bank failures, and they may require on-going maintenance.

RECOMMENDED SOURCES FOR ADDITIONAL INFORMATION

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