PLANTS

For Stormwater Design

Species Selection for the Upper Midwest

Daniel Shaw

Rusty Schmidt

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Daniel Shaw & Rusty Schmidt
Authors

Sam Brungardt
Editor

Richard Harrison
Designer

Minnesota Pollution Control Agency

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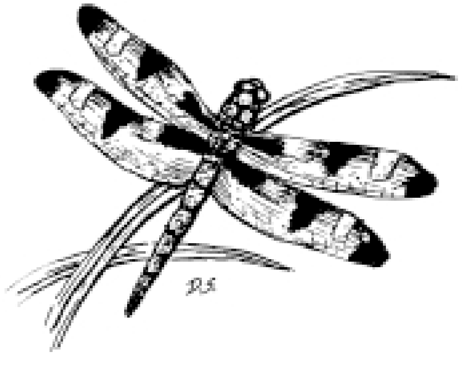
About the Authors

Dan Shaw is involved in ecological restoration, landscape and stormwater design and landscape planning at the Saint Paul-based non-profit, Great River Greening. He has worked as an ecologist and designer for several years in both the public and private sector and is author of *Native Vegetation in Restored and Created Wetlands*. He also is an adjunct assistant professor in the Landscape Architecture Department at the University of Minnesota, where he teaches plant identification and planting design classes. Shaw is also co-owner of Another Sun Nursery, a company that grows native prairie, woodland and wetland species.

Rusty Schmidt is a wildlife biologist and landscape ecologist with 10 years of natural resource experience, having spent approximately eight years with the Minnesota Department of Natural Resources and two years at URS. He conducts inventories and evaluations for game and non-game wildlife species and has conducted function and value assessments for wetlands and woodlands. Schmidt is also very involved in designing and constructing alternative methods for managing surface water runoff in an environmentally conscious way. He has created designs for restorations, rainwater gardens, bio-infiltration swales and bioretention areas. His Cedar Pond project is featured at the end of this guidebook.



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TURTLEHEAD

INTRODUCTION

In recent years interest has increased in the use of innovative methods to retain and treat stormwater. These methods, often called stormwater management practices (MPs), rely on natural processes, such as microbial activity, filtration, infiltration, denitrification, nutrient reduction and evapotranspiration, to attain water-quality goals. Although technical information is available on the design of many types of stormwater MPs, little information is currently available on plant species appropriate for these systems. This book has been developed to guide designers through the process of selecting plant species for a variety of stormwater MPs.

Photo: Dan Shaw

RAIN WATER GARDEN

Plant species included in this book have been chosen based on their availability, presence in the Upper Midwest before European settlement, aesthetic properties and functional abilities within stormwater MPs. Native plants are the focus of the book and are recommended exclusively due to their hardiness, and the wide variety of functions they provide. See page 61 for a complete list of species included in the book.

This guidebook focuses on the selection of plant species that will optimize landscape function. The beneficial functions plants perform in the landscape are varied and complex, and range from providing habitat for beneficial microbes to physically inhibiting the flow of stormwater. The ability of plants to intercept and hold rainwater and to decrease water flow with stalks, stems, branches and foliage is one of the better recognized functions of vegetation, but there are many others (MPCA 2000). In many stormwater systems, native vegetation provides habitat for amphibians, reptiles, birds and insects. Native plants also take nutrients into their tissues and their roots provide a substrate for growth of bacteria and algae, which are responsible for nutrient cycling and organic degradation. In addition, decaying plant matter supplies fixed organic carbon and food for microbes (Fassman et al. 2001). Native plants also contribute to the water cycle by returning water to the atmosphere through evapotranspiration. In stormwater MPs such as vegetated filter strips, the roots of native species increase soil strength and stability. Another function of native plants, particularly in urban areas, is to add aesthetic value to stormwater systems. The vegetation softens the appearance of structures and shoreline edges, adds interest through line, texture and contrast, and provides color and harmony with the natural environment (Fassman et al. 2001, MPCA 2000).

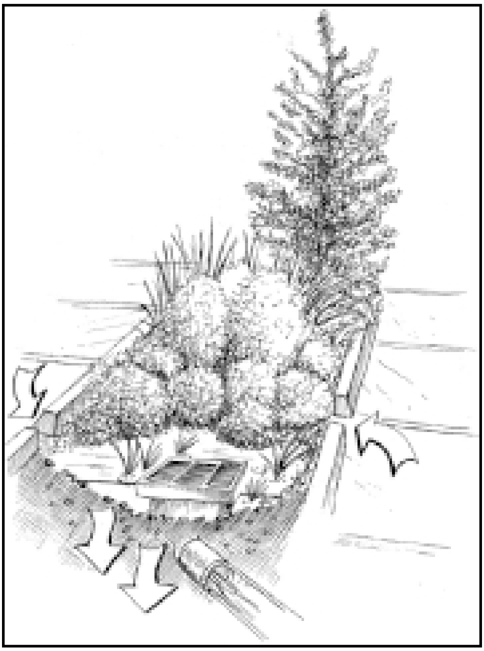
Selecting plants for stormwater MPs is not a simple process. Stormwater systems are often affected by a number of environmental conditions that are not conducive to plant growth and survival. Some of these environmental conditions include prolonged flooding, fluctuating water levels, sedimentation and pollutants. To complicate matters, invasive species are sometimes better adapted to the above-mentioned conditions and ongoing plant management may be important for project success.

Tools included in this book to aid plant selection

- Information about environmental factors that influence wetland plants
- Description of retention, detention, infiltration, wetland and filtration BMPs and species lists for individual types of BMPs
- A plant matrix to select plants appropriate for various environmental conditions
- Information and photographs of 131 plant species
- Hydrology and species information for three stormwater projects in the Twin Cities area

Using This Guidebook

This book was developed to lead designers through a plant selection process. First, **environmental factors** that influence plants in stormwater systems are presented. The potential influence of these environmental factors should be investigated during the site-analysis process and will be useful information for the selection of stormwater management practices (MPs).



INFILTRATION SWALE
(ADAPTED FROM CITY OF PORTLAND)

Next, information is presented for **common types of MPs and plant considerations are provided for each**. The information about stormwater MPs corresponds to design information in the *Minnesota Urban Small Sites BMP Manual, Stormwater Best Management Practices for Cold Climates* (Barr 2001) and the *Protecting Water Quality in Urban Areas, Best Management Practices for Dealing with Storm Water Runoff from Urban, Suburban and Developing Areas of Minnesota* manual (MPCA 2000). Only stormwater MPs that incorporate vegetation are included in this guidebook.

In addition to a discussion of planting considerations for each system, **plant lists** are provided. These lists include a large number of species for each stormwater MP. Many species were included to ensure that plant options are available to cover as many potential site conditions as possible. The plant lists are arranged by scientific name and range from mesic prairie species to emergent wetland plants. To help designers refine their plant lists for a project, **detailed information is provided for all of the 131 species that are included in the plant lists.** Page numbers are provided in the plant lists referring to the more detailed information for each plant species located in the Plant Species for Stormwater Management Practices section of this guidebook.

Information for each plant includes
• Habitat/plant community and type of system where the plant can be used • Geographic range • Plant description • Normal water level for which the species is adapted • Fluctuation tolerance • Sensitivity of other tolerances • Design considerations • Wildlife use • Nursery/plant information • Planting techniques • Indicator status

Flood tolerance charts that correlate water level and duration are presented to demonstrate how long each_species can remain inundated. These charts were developed from available research, site observations and professional judgement and review.

A **plant matrix** summarizing information for each plant starts on page 66. The plant matrix has been developed from information for each of the 131 species in the guidebook. The matrix will aid in plant selection for a number of different environmental conditions and stormwater management practices.

The authors gathered **plant composition and hydrology information for three stormwater projects** in the Twin Cities area. Plant community success and structure for each case study project is presented in appendix 2. This information should be useful to designers in making decisions about plant selection.

Environmental Influences on Plants

Many environmental factors affect plant growth and survival. These factors should be considered during project planning (particularly during plant selection). This guidebook is designed for the selection of plants after stormwater MPs have been chosen for a site. However, many site characteristics that relate to plant growth should also be considered when stormwater MPs are being selected. A thorough site analysis is necessary to compile information to aid in species selection.

General site conditions to investigate during site analysis

- Texture, organic content and pH of the soil
- Anticipated water levels or soil moisture
- Adjacent plant communities
- Slopes
- Surrounding weedy vegetation
- Amount of sun or shade
- Aspect (north-, south-, east- or west-facing slope)

Several additional environmental factors can significantly affect plant growth in stormwater projects. The following section provides detailed information about these factors. The potential influence that each of these may have on a project should be investigated thoroughly during site analysis to aid in the plant-selection process.

Environmental threats to investigate

- Flood depth and duration
- Low water levels
- Flood frequency
- Wave energy
- Sediment loads
- Pollutants and toxins
- Nutrients
- Salt
- Turbidity
- Erosion
- Invasive plants
- Herbivores

Flood Depth and Duration Flood depth and duration can significantly influence the growth and survival of vegetation. Flooding particularly influences plants in detention basins and wetland systems that receive a significant amount of water during storms.

The effect of flooding on plants includes the inhibition of seed germina- tion and vegetative reproduction, changes in plant anatomy and mortality. In plants that are not adapted to flooding, leaf and fruit formation and growth can be suppressed, premature leaf abscission and senescence can result, and shoot dieback and decreased cambial growth can occur in woody plants. Flooding can also inhibit root formation and branching as well as growth of existing roots and mycorrhizae. It may also lead to decay of the root system.


Photo: Rusty Schmidt

URBAN STREAM

Flooding can often cause many physiological changes in plants: photosynthesis and transport of carbohydrates are inhibited, absorption of macronutrients (nitrogen, phosphorus and potassium, or N, P and K) is decreased due to root mortality, mycorrhizae may be lost, stomata may close and root metabolism may be suppressed. The hormonal balance in plants can also be altered by increases in ethylene (Kozlowski 1997).

Despite the negative influences of flooding, many plant species have developed physiological and anatomical adaptations that allow them to survive in flooded conditions. These adaptations include metabolic adaptations, oxygen transport and rhizospheric oxidation, hypertrophied lenticels, aerenchyma tissue and adventitious roots.

Metabolic adaptations. Several metabolic adaptations to flooding are utilized by plants. They include control of energy metabolism, availability of abundant energy resources, provision of essential gene products and synthesis of macromolecules and protection against post-anoxic injury (Kozlowski 1997).

Oxygen transport and rhizospheric oxidation. This is the capacity of plants to absorb and transport oxygen from above-ground tissues to roots growing in oxygen-scarce environments. Oxygen transport is aided by hypertrophied lenticels, aerenchyma tissues and adventitious roots (Kozlowski 1997).

Aerenchyma tissue. This root and stem tissue is permeated with large intercellular spaces. Species that do not respond to soil anaerobiosis by enlarging their internal air spaces typically undergo anoxia in their roots (Kozlowski 1997).

Adventitious roots. Adventitious roots are specialized roots growing at or just above the water or ground surface that increase the flood tolerance of plants. Adventitious roots increase water absorption, assist with oxygen absorption, transform some toxins to less harmful compounds and increase the supply of root-synthesized gibberellins and cytokinins to the leaves (Kozlowski 1997). Adventitious roots may allow species such as buttonbush and black willow to persist in early succes- sional environments characterized by fluctuating water levels and sedi- ment levels (Donovan et al. 1988).

Seedlings and plants that are totally submerged are the most susceptible to flood-related mortality. Photosynthesis is limited or nonexistent in times of complete submergence except for plants that are adapted to submerged conditions. Seedlings are particularly susceptible to flood stress because they generally have fewer reserves to draw upon during stressful conditions. Seedlings are also susceptible to sediment deposition and scouring. Kennedy and Krinard (1974) found that tree seedlings were killed in a flood whereas trees at least one year old survived.

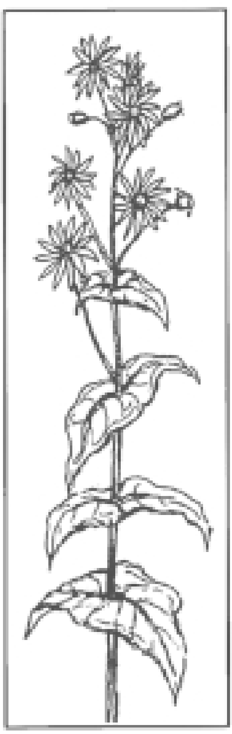
Other factors that can influence a plant’s resistance to flooding and saturated soil include its age and condition and the timing and duration of the flood (Yeager 1949, Kozlowski 1997). Generally plants are less affected by flooding in the spring than during summer months when they are actively growing. Soil conditions can also have a significant effect on plant survival. Flooding can affect soils by altering soil structure, depleting oxygen, accumulating CO^2, inducing anaerobic decomposition of organic matter and reducing iron and magnesium (Kozlowski 1997).

Harris and Marshall (1963) studied the drawdown and reflooding of wetlands in the Agassiz National Wildlife Refuge in northwestern Minnesota. After reflooding a wetland, they found that spike-rush (*Eleocharus palustris*) and soft-stem bulrush (*Scirpus validus*) were destroyed by flooding with over 15 inches of water. Common cattail (*Typha latifolia*) and sedges (*Carex* spp.) disappeared from continuously flooded areas in four to five years. Hybrid cattail (*Typha glauca*) survived in 24 inches of water through five years of flooding.

In another study investigating species' tolerance to flooding, Squires and Van der Valk (1992) found that awned sedge (*Carex atherodes*), white top-grass (*Scholochloa festucacea*), common reed grass (*Phragmites australis*), hybrid cattail (*Typha glauca*), hard-stem bulrush (*Scirpus acutus*), soft-stem bulrush (*Scirpus validus*) and alkali bulrush (*Scirpus maritimus*) survived for only one or two years in the flooded areas. They also found that some *Scirpus* species survived as tubers in the flooded areas.

Casanova and Brock (2000) investigated how depth, duration and frequency of flooding influence the establishment of wetland plant communities. The study was conducted by exposing seed bank samples to various water level treatments of depth, duration and frequency of inundation and comparing germination success. They found that depth was least important in influencing plant community composition while duration of individual flooding events was important in segregating plant communities. The highest biomass and species richness was found in pots that were never flooded and pots with short, frequent floods.

Prolonged flooding will most likely lead to plant mortality and a draw-down is generally necessary for revegetation. Most aquatic emergents need low water levels or complete removal of water from a basin for seeds to germinate. The physiological processes necessary for germination require oxygen. Since flooding restricts oxygen availability, it also prevents germination from occurring (Kozlowski 1997). Linde (University of Michigan 1974) found that cattail (*Typha* spp.), sweet flag (*Acorus calamus*), burreed (*Sparganium* spp.), bulrush (*Scirpus* spp.), Walter's millet (*Echinochloa walteri*), smartweed (*Polygonum* spp.), willow (*Salix* spp.) and flatsedge (*Cyperus* spp.) germinated most successfully when mud flats were exposed by drawdowns. Harris and Marshall (1963) determined that it is desirable to induce drawdowns in wetlands with continuous standing water every five or six years to maintain emergent cover.



CUP PLANT

Photo: Rusty Schmidt

CARDINAL FLOWER

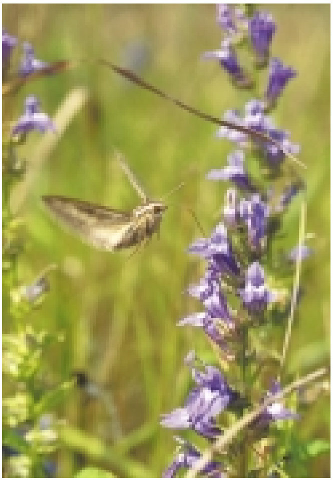


Photo: Paul Jackson

BLUE LOBELIA

Low Water Levels Prolonged low water levels can also stress plants within wetlands and stormwater systems. Most wetland plants are not well adapted to retaining moisture during dry conditions. In areas of open water that become dry, submergent species are generally replaced by emergent species. Emergent species have root systems such as large rhizomes and tubers that make them resistant to erosion by waves and ice as well as changes in water level. Submergents, however, devote most of their biomass to above-ground structures and cannot survive prolonged periods of drying (Wetzel 1983). In a study of aquatic vegetation of the St. Lawrence River, Hudon (1997) found that emergent vegetation was not affected by a one-year drop in water levels whereas submerged plants did not survive.

Photo: Rusty Schmidt

DRY POND

A variety of short-lived, early successional species are also well adapted to low water levels. Species that germinate quickly on exposed mud flats and are common in seasonally flooded basins include smartweed (*Polygonum* spp.), flatsedge (*Cyperus* spp.), spikerush (*Eleocharis* spp.) and beggartick (*Bidens cernua*). If water levels remain low, these species are generally replaced with perennial grasses and forbs.

Flood Frequency The effect of flood frequency and accompanying water fluctuations on plants has not been studied as thoroughly as that of flooding depth and duration, but it is believed to be a major plant stressor. Galatowitsch et al. (1997) found that hydrologic alterations by stormwater could reduce native perennial cover to the same extent as cultivation in wet meadows. They discovered that less than 25 percent of the relative abundance of species in stormwater-impacted wetlands is comprised of species that are characteristic of unimpacted sites. Examples of species not found in impacted wetlands included slender sedge (*Carex lasiocarpa*), Canada blue-joint grass (*Calamagrostis canadensis*) and prairie cord grass (*Spartina pectinata*). It is not known whether altered water chemistry, water fluctuations or both are responsible for the plant community changes observed. Reed canary grass (*Phalaris arundinacea*), an invasive species found in many impacted sites, may have an advantage because it can grow in flooded conditions as well as in relatively dry soils. Husveth (1999) found that sedge meadow species were more prevalent in low-fluctuation wetlands than in high-fluctuation wetlands while mudflat annual species were more common to high-fluctuation wetlands than low-fluctuation wetlands.

Photo: Rusty Schmidt

WETLAND EDGE

In Montgomery County, Maryland, Shenot (1993) conducted a study to investigate the persistence of wetland species planted along the aquatic bench (a plateau, 3-18 inches deep, designed to optimize area for emergent species) of three stormwater ponds two to three years after planting. The ponds were planted with six to eight species of plants in single-species clusters with an average density of four plants per square meter. Two ponds were extended detention ponds with periodic inundation of 3-6 feet. Eighty-two percent of the planted species persisted in the ponds after two to three years. Factors believed to contribute to plant death included frequency and depth of inundation, nutrient-poor inorganic soils, steep bench slopes and predation by ducks. Thirty-five to 80 wetland plant species established as volunteers in each of the ponds (Shenot 1993, Schueler 2000).

Relative Persistence of Eight Species of Wetland Plants on the Aquatic Bench (Shenot, 1993)		
	Persistence	*Spread*
Sweet flag (*Acorus calamus*)	Good	Limited
Arrow arum (*Peltandria virginia*)	Poor	None
Pickerelweed (*Pontederia cordata*)	Good	Moderate
Arrowhead (*Saggitaria latifolia*)	Excellent	Excellent
Lizard's tail (*Saururus cernus*)	Poor	None
Common three square (*Scirpus americanus*)	Good	Excellent
Soft-stem bulrush (*Scirpus validus*)	Excellent	Good
Wild Rice (*Zizania aquatica*)	Excellent	Limited

(Adapted from Schueler 2000)

Top 10 Volunteer Species Recorded at the Three Ponds (Shenot 1993)	
Various exotic grasses (*Graminea*)	75%
Common rush (*Juncus effusus*)	55%
Fox sedge (*Carex vulpinoidea*)	33%
Other sedges (*Carex* spp.)	33%
Smartweeds (*Polygonum* spp.)	33%
Mostly many-flowered aster (*Aster* spp.)	30%
False nettle (*Boehmeria cylindrica*)	30%
Rice cutgrass (*Leersia oryzoides*)	30%
Bugleweed (*Lycopus virginicus*)	30%
Spike rush (*Eleocharis* sp.)	22%
Defined as percentage of stations where the species was recorded as one of the five most numerically dominated species at the station. N=40	

(Adapted from Schueler 2000)

As was discussed earlier, flooding tends to limit root growth, and in some cases specialized water roots are developed. It is likely that as plants dryquickly after flooding, their root systems may not be able to supply sufficient water. A study on the effects of water fluctuation on trees, including black gum (*Nyssa sylvatica*), common baldcypress (*Taxodium distichum*) and water tupelo (*Nyssa aquatica*), in a swamp in the southeastern United States showed that weekly changes in the growth of the three species were significantly affected by changes in water levels. It is believed that the reduced growth resulted from frequent restructuring of root systems in response to alternately flooded and drained conditions. In sites that were permanently flooded or saturated, limits of tree growth was not observed (Keeland and Sharitz 1997).

SMARTWEED

Kozlowski (1997) states that "Because root growth typically is reduced more than stem growth, the root/shoot ratio is decreased. When the flood water drains away, the previously flooded plants may be less tolerant of drought because absorption of water by their small root systems cannot adequately replenish losses due to transpiration."

Although water fluctuations can have detrimental effects on plants, it is also important to recognize that the fluctuation of water levels is a natural phenomenon in many basins, particularly where there are steep slopes surrounding wetlands. In some cases, water fluctuations can help certain community types, such as floodplain forests, that are adapted to such conditions. The fluctuations may decrease weed competition and aid in seed dispersal.

Flooding frequency has been shown to influence plant diversity in some situations. Pollock et al. (1998) studied 16 wetland sites in Alaska and found that "species-rich sites had low to intermediate levels of productivity and intermediate flood frequencies, and species-poor sites had very low or high flood frequency and low productivity." This corresponds with Huston's (1979) dynamic-equilibrium model of species diversity, which predicts that the highest diversity will be found where there are intermediate levels of disturbance and low diversity will be found where there are high or low levels of disturbance.

A study in northern Minnesota (Wilcox and Meeker 1990) also demonstrated that high diversity can be found with intermediate levels of disturbance. Two regulated lakes and one unregulated lake were studied to determine the effects of water fluctuations on aquatic macrophytes. It was found that the unregulated lake, which fluctuated about 1.6 m annually, had structurally diverse plant communities at all depths. In Rainy Lake, which had reduced water fluctuations (1.1 m annually), few species were present along transects that were never dewatered. In Namakan Lake, which had increased water fluctuations (2.7 m annually), rosette and mat-forming species dominated transects where drawdown occurred in early winter and disturbance resulted from ice formation in the sediments.

Stormwater MPs, such as wet and dry swales, filter strips and rain water gardens, can be important for treating and slowing water flow before it reaches ponds and wetlands. Appropriate design is important to ensure that flooding and water fluctuation will not be severe. The outlets should be designed so as to endure natural fluctuations during storm events. Multiple wetland cells and gentle side slopes can add to species diversity by dispersing water, decreasing water fluctuations and providing a wide range of available habitat for wetland species. A Vermont study (Occoquan Watershed Monitoring Lab et al. 1990) demonstrated that multiple pond systems can promote diversity (18 species) in wetland BMPs. Common rush (*Juncus effusus*), spikerush (*Eleocharis obtusa*) and rice-cut grass (*Leersia oryzoides*) dominated the 0-to-6-inch zone; spikerush (*Eleocharis* spp.) and rice-cut grass dominated the 6-to-12-inch zone; water purslane (*Ludwigia palustrus*) and duckweed (*Lemna* spp.) dominated the 12-to-18-inch zone; and cattail (*Typha* spp.), spikerush (*Eleocharis* spp.), yellow water lily (*Nuphar adventa*) and white water lily (*Nymphea odorata*) dominated the 18-to-30-inch zone.

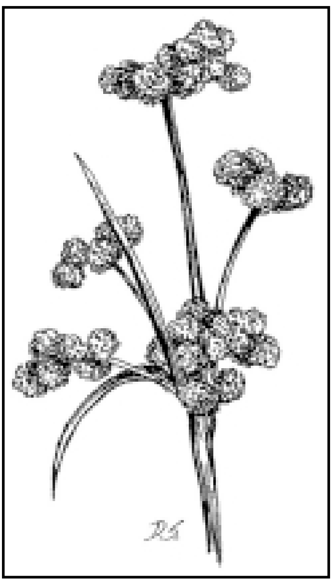
For more information on the effect of hydrology on vegetation, see appendix 2 for an investigation of three stormwater projects in the Twin Cities area.

Wave Energy On large water bodies, waves can have a significant influence on plant growth. In a study of the effects of wave action at Axe Lake in Ontario, Keddy (1983) found that "waves may have direct effects on vegetation; for example, through removing biomass, uprooting seedlings, and transporting propagules." He observed that "waves may also have many indirect effects through the erosion, transport and deposition of sediment." At Axe Lake, Keddy found that "Large leafy species on sheltered shores tended to be replaced by small creeping or rosette species on exposed shores." Of the emersed species, bulrushes (*Scirpus* spp.) tend to do best in exposed situations. If emersed plants can become established, their presence may reduce wave and current action and permit a greater variety of plants to establish (University of Michigan 1974). Stormwater MPs, such as wet ponds, generally are not large enough to be significantly affected by wave action, but waves may contribute to plant stress. Wave break structures are often necessary on large water bodies to ensure planting success.

Sediment Loads Wetlands often receive sediment and nutrients from runoff (Brown 1985) and this is the case in stormwater detention basins and other types of stormwater systems. A study of beaked sedge (*Carex rostrata*) and common fox sedge (*Carex stipata*) in Washington State (Ewing 1995) investigated the effect of sedimentation and showed that sediment deposition can depress plant productivity. Other studies have shown similar results. Van der Valk et al. (1981) found that with 15 cm of sediment, root density decreased by 37 and 49 percent in subsequent years in freshwater lowland wetlands in Alaska.

It has also been demonstrated that the accumulation of sediment negatively affects seed germination. Jurik et al. (1994) found that sediment loads as low as 0.25 cm significantly decreased the number of species that germinated from seedbank samples. The addition of sediment had the least effect on species with large seeds.

Pollutants and Toxins Plants vary greatly in their ability to assimilate toxins and pollutants into their stems and roots. With recent interest in phytoremediation and wastewater cleansing, an increasing number of species are being investigated to determine their ability to assimilate pollutants and toxins. A study by the City of Seattle (1993) investigated the ability of five wetland species to take up zinc, lead and total petroleum hydrocarbons (TPH) into plant tissue. The species chosen for the study were common cattail (*Typha latifolia*), water flag (*Iris pseudacorus*), burreed (*Sparganium* spp.), blunt-spikerush (*Eleocharis ovata*) and hardstem bulrush (*Scirpus acutus*). Of the five species, cattail was the most efficient at taking up pollutants, but concentrations of lead, zinc and TPH were highest in burreed tissue. Cattail was more vigorous and therefore had a higher pollutant uptake per area of cover. Spike rush also had high pollution concentrations within plant tissue. There is concern that wetland species that assimilate pollutants may pose a risk to wildlife that use them as a food source. This study found that concentrations of TPH, zinc and lead were higher in the roots than in the shoots, which may help decrease the risk to most wildlife species.



GREEN BULRUSH

Just as plant species vary in their ability to assimilate toxins and pollutants, they also vary in their tolerance to these materials (Stockdale 1991). Snowden and Wheeler (1993) examined 44 fen species in solution culture to determine their tolerance to iron. The plants varied greatly in their tolerance, with species such as common rush (*Juncus effusus*) and water-flag (*Iris pseudacorus*) being very tolerant, marsh marigold (*Caltha palustris*) and reed canary grass (*Phalaris arundinacea*) being semi-tolerant, and green sorrel (*Rumex acetosa*) and queen of the meadow (*Filipendula ulmaria*) being very sensitive.

Individual species can be affected by some chemicals and unaffected by others. Dushenko et al. (1995) investigated the effect of arsenic bioaccumulation and toxicity in aquatic macrophytes exposed to gold mine effluent and found that broad-leaved cattail (*Typha latifolia*) responded with decreased stand height, necrosis of leaf tips and reduced micronutrient concentrations of copper, manganese and zinc in root tissues. A study in China (Ye et al. 1998) investigating the tolerance of broad-leaved cattail to zinc (1.0 µg/ml), lead (10.0 µg/ml) and cadmium (0.2 µg/ml) accumulation found that this species was able to tolerate these metals for 48 to 72 days.

MARSH MILKWEED

Nutrients As nutrient inputs to wetlands increase, nutrients can be stored in surface litter, plants or soils. However, the capacity of a wetland to retain a nutrient such as phosphorus can become saturated over time and release of the nutrient can result. Nutrient inputs can have a direct effect on vegetation. Species like reed canary grass (*Phalaris arundinacea*) that thrive in nutrient-rich conditions can displace species that are adapted to conditions of lower nutrient availability (Horner et al. 1988). A study of a wastewater-treatment wetland showed that plants near the discharge point had greater biomass, were taller and had higher concentrations of phosphorus in their tissues (Tilton et al. 1979). Athanas and Stevenson (1991) compared two stormwater wetlands in Maryland. They found that the system that received higher amounts of sediment and nutrients had higher diversity (cattails, rushes, sedges and boneset) than the other system (cattails and common reeds), which received less sediment and nutrients. A study in Vermont (Schwartz 1985) investigated the effect of sewage on wetland vegetation. Nitrate levels of 0.328 mg/L and phosphate levels of 2.53 mg/L from raw sewage resulted in unchanged growth of cattail (*Typha* spp.). Rushes (*Scirpus* spp.), giant burreed (*Sparganium eurycarpum*), lesser duckweed (*Lemna minor*) and coontail (*Ceratophyllum demersum*) were positively affected by the nutrients, while elodea (*Elodea canadensis*) and pondweeds (*Potomogeton* spp.) were negatively affected.

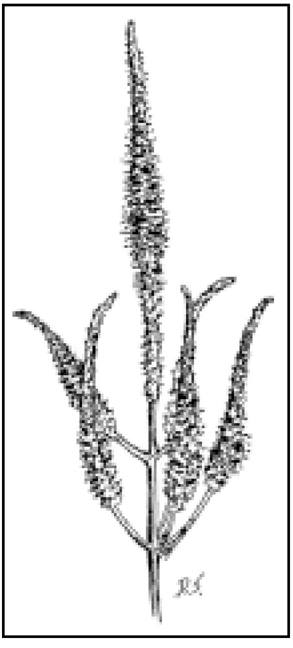

FOX SEDGE

There is concern that wetland treatment systems in northern climates will not function effectively during the winter months due to inactivity of bacteria and plant material. Research being conducted at Montana State University by Stein and Hook is showing that systems containing plants can function effectively in cold climates. The researchers are finding that wetland systems with water temperatures of 36 degrees F can effectively remove nitrogen and organic carbon from water. Plant debris and snow cover helps keep water temperatures around 36 degrees. In addition, water treatment in cold temperatures improves significantly when plants are a part of the system. This differs from research conducted in southern climates that shows that bacteria play the largest role in cleaning water and plants play a less important role. Plants that the Montana State researchers are finding most effective are sedges and bulrushes. These species are much more effective at treating water during the winter than cattails, which are relatively inactive (Flaherty 2002).

Mowing and removing above-ground growth of cattails, grasses and other species used in stormwater MPs is one method of removing nutrients. The removed biomass can be composted or possibly incinerated.

Salt Roadways and parking lots in the Midwest are salted heavily during winter months. During melting and rainfall events, salt can be washed into a stormwater system. Biesboer and Jacobson (1994) studied the role of road salt in limiting germination of warm-season grasses. They found that salt concentrations were highest within the first 3 feet from the road and then rapidly declined within 30 feet. They found that most warm- and cool-season grasses could germinate and grow beyond 10 feet from a road without experiencing stress. They state that warm-season grasses, such as blue grama (*Bouteloua gracilis*) and buffalo grass (*Buchloe dactyloides*), can handle high salinities. Warm-season grasses also have advantages over cool-season grasses because they germinate later in the season, after spring rains reduce concentrations of sodium chloride in the soil (Ohrel 2000).

Another study (Isabelle et al. 1987) demonstrated that salt in roadside snowmelt can affect species composition and biomass of wetland vegetation. In the study, seed of five wetland species was planted in greenhouse plots and exposed to snowmelt/tapwater mixtures containing 0, 20 and 100 percent snowmelt each day. After a month the seedlings were harvested, and it was found that the number of germinating seeds was inversely proportional to snowmelt salt concentration. Two species, purple loosestrife (*Lythrum salicaria*) and common cattail (*Typha latifolia*), germinated when exposed to undiluted snowmelt while other species (*Aster umbellatus, Dulichium arundinaceum* and *Scirpus cyperinus*) did not. Both purple loosestrife and cattails dominate many urban wetland and stormwater systems and their ability to germinate under high-salt conditions may contribute to their dominance.


CULVER'S ROOT

Wilcox (1986) observed that a bog in Indiana that was adjacent to an uncovered salt storage pile for 10 years was prone to invasion by non-bog species such as narrow-leaf cattail (*Typha angustifolia*). Many tamarack (*Larix laricina*) and many species of sphagnum moss (*Sphagnum* spp.) were killed by the salt. The author noted that it is probable that red maple

(*Acer rubrum*), eastern white pine (*Pinus strobus*), leather-leaf (*Chamaedaphne calyculata*), holly (*Ilex* spp.) and highbush blueberry (*Vaccinium corymbosum*) were also affected by the salt. Other than cattails, species that did not appear to be affected by salt included duckweed (*Lemna* spp.), arrowhead (*Sagittaria* spp.) and bladderwort (*Utricularia* spp.).

Turbidity While flooding is a stress to many plant species, turbid water can compound the problem. Turbidity tends to reduce the amount of photosynthesis that can be conducted by a plant by limiting sunlight. Shaw (2002) observed that in nursery beds, Tussock sedge (*Carex stricta*) fully submerged in turbid water declined quickly while plants that still had some leaves above the surface of the water continued to increase their above-ground growth. It was believed to be the combination of flooding and turbid water that caused the plants to decline.

Loading of sediments can directly increase turbidity. Street cleaning and erosion control can effectively decrease the amount of sediment entering stormwater systems.

Erosion Erosive action around roots is another potential stress to plants in stormwater systems. Erosion naturally occurs in floodplains but may also occur in stormwater systems that are not adequately vegetated. Deep-rooted, native, prairie species and wetland shrubs do a good job of stabilizing buffer areas around ponds and wetlands. Aggressive grasses, such as prairie cord grass, big bluestem, Indian grass and switch grass, as well as many native shrub species are particularly well suited for this use. Cover crops such as oats, winter wheat and annual ryegrass are also useful in controlling erosion. Cover crops germinate quickly and hold the soil while the slower-developing native grasses become established. Since cover crops germinate quickly, they are good indicators of the overall success of plantings. If cover crops do not germinate in an area, there is a good chance that native species that were planted will need to be re-seeded.

Invasive species Flooding can influence plant competition by physically or physiologically damaging plants and by changing the physical and chemical environment of soils (Pollock et al. 1998). Some invasive species seem to thrive under conditions of flooding and fluctuating water levels. Cooke et al. (1989) found that invasive species such as reed canary grass (*Phalaris arundinacea*) and purple loosestrife (*Lythrum salicaria*) can come to dominate wetlands that receive urban stormwater. Salt tolerance also gives an advantage to some invasive species, and the combination of these factors may explain why so many urban wetlands and stormwater systems are dominated by invasive plants.

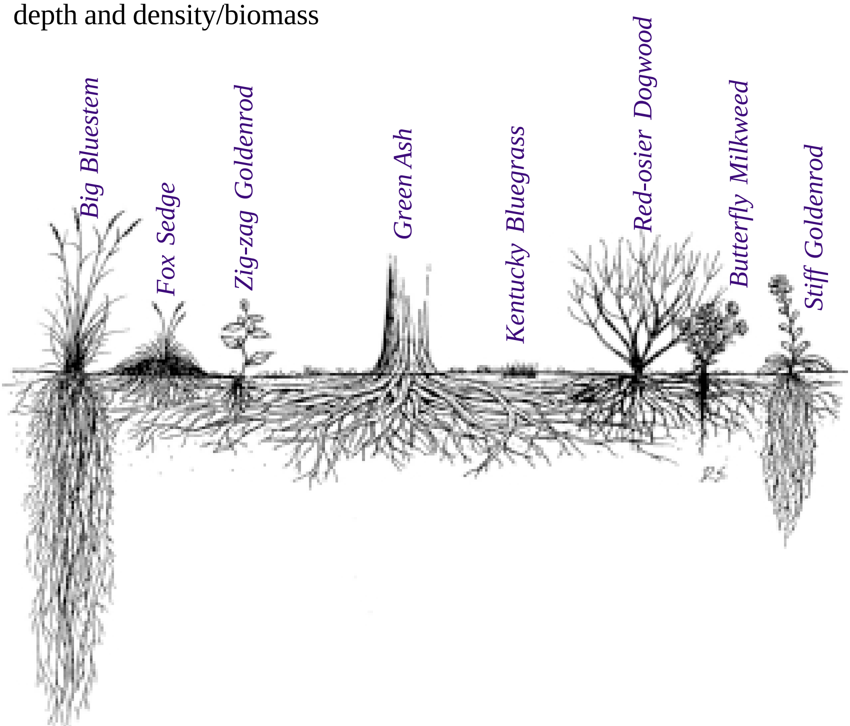
While few native plants can compete with these invasive species, some aggressive native species can live amongst them. For example, cup plant (*Silphium perfoliatum*), blue vervain (*Verbena hastata*) and green bulrush (*Schoenoplectus atrovirens*) can be found in ditches among reed canary grass (*Phalaris arundinacea*). Seed of fast-establishing natives can be used also to stabilize and compete in areas where reed canary grass is a significant threat. Ultimately, management of native plantings is important to limit the growth of invasive plants.

PURPLE LOOSESTRIFE

Herbivores Wild geese and other herbivores, such as deer, rabbits, muskrat, beavers, mice and carp, are a significant threat to new plantings. Geese are particularly attracted to seedling plants and have been know to completely destroy projects. Animal exclosures are often necessary to stop herbivores. Exclosures constructed to prevent geese from grazing newly planted areas should also help to prevent grazing by deer, rabbits, muskrat, beavers and carp. It is difficult to select plants that herbivores will not eat, so exclosures are generally the best option.

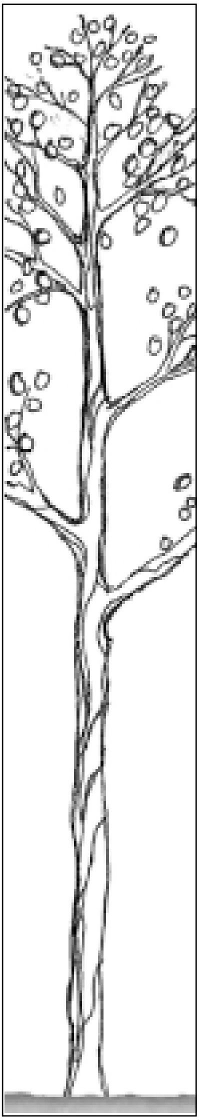
Plant Considerations and Species for Stormwater Management Practices

Root systems of species covered in this guidebook vary greatly in their depth and density/biomass



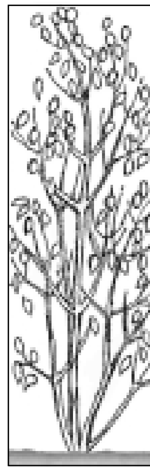
Vegetation is often grouped into the categories of trees and shrubs, grasses/sedges/rushes and forbs/ferns. Each of these categories of vegetation has its own benefits and limitations for stormwater projects.

Trees and Shrubs



Benefits

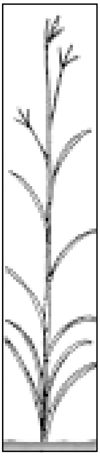
- Trees and shrubs, particularly willow species, have a significant influence on evapotranspiration and a capacity for nutrient uptake.
- Roots aid infiltration by acting as pathways for water flow.
- Fibrous roots absorb large amounts of water.
- Trees and shrubs are useful for bank stabilization and can often be planted as cuttings. Deep-rooted species are particularly useful for anchoring soil to steep slopes.
- Trees provide vertical structure in the landscape.
- Trees provide important habitat for many wildlife species.
- Trees provide important habitat for many wildlife species.



Limitations

- Debris from trees may block outlets.
- Trees cannot be used in stormwater MPs where sediment will be excavated.
- Trees can inhibit the growth of prairie species.

Grasses, Sedges and Rushes

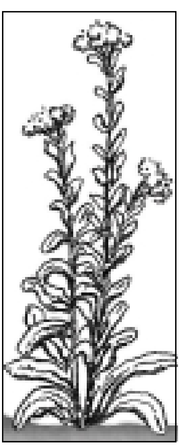


Benefits

- Roots of prairie grasses can extend deep into the ground and aid in infiltration and evapotranspiration.
- Dense root networks stabilize soil and minimize erosion.
- Wetland species, particularly broad-leaved sedges and bulrushes, generally have shallow roots but aid in evapotranspiration.
- Grasses generally have many stems and produce thatch that slows water flow and facilitates filtration, making them well suited for filter strips.
- Many grasses, sedges and rushes are efficient at nutrient uptake.
- Native grasses, sedges and rushes add winter interest to the landscape and have high wildlife value.

Limitations

- In projects with high flow rates, grasses must be mowed often to most efficiently decrease stormwater velocity. Mown clump grasses will not produce seed.



Forbs and Ferns

Benefits

- Roots of prairie forbs can extend deep into the ground and aid in infiltration and evapotranspiration.
- Wetland forbs, particularly broad-leaved species, generally have shallow roots but aid in evapo transpiration.
- Native forbs add aesthetic appeal to the land scape and have high wildlife value.

Limitations

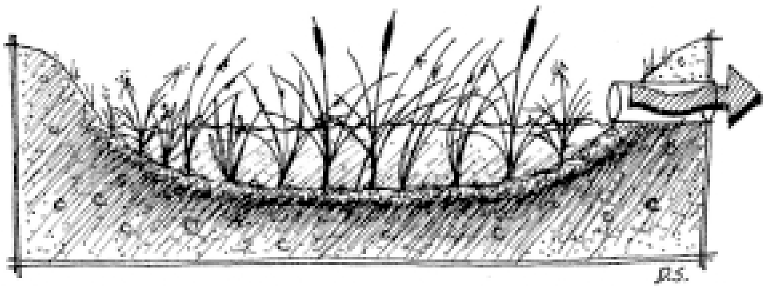
- Forbs generally have fewer basal stems than grasses and may not filter stormwater as efficiently.


Photo: Beth Kunkel

Stormwater Management Practices

The types of stormwater management practices (MPs) are grouped into the categories of retention, detention, infiltration, wetlands and filtration. The following information provides a brief description of the types of stormwater MPs and planting considerations for each.

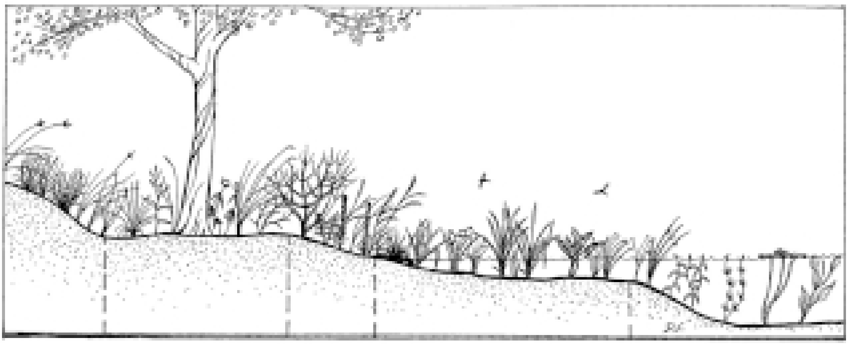
Retention



Retention (extended detention) systems are designed to utilize the retention of water to improve water quality. Retention systems covered in this guidebook include wet ponds and extended storage ponds.

Wet Ponds and Extended Storage Ponds. Wet ponds are designed to retain a permanent pool of water. The primary function of wet ponds is sedimentation, which removes metals, nutrients, sediment and organics from stormwater. Wet ponds are suitable for sites with high nutrient loads. Benches are often incorporated into wet ponds to add areas for plant growth which aid in sedimentation, evapotranspiration and providing wildlife habitat. Vegetation also acts as a barrier to keep children away from open water areas (MPCA 2000). Extended storage ponds are similar to wet ponds but are generally designed to provide temporary storage of stormwater. As a result, extended storage ponds are designed to fill quickly and then slowly decrease in water level (Barr 2001). Since both wet and extended storage ponds may experience significant water fluctuations after storms, plants must be chosen that can handle these conditions. Many urban wetlands and lakes that receive stormwater experience environmental conditions similar to wet ponds and many of the species in the following tables would be suitable for their planting.

Floodplain species may be well suited for extended storage ponds that flood and then become dry. Plant species suitable for ponds can be grouped according to zones that change with elevation. These zones are often referred to as “plant communities.” It is useful to think about plantings in terms of plant communities because plant communities are composed of species adapted to growing together.



ZONE	PLANT COMMUNITY	HYDROLOGY
1	Submergent zone	1.5-6 feet of water
2	Emergent zone	0-18 inches of water
3	Wet meadow zone	Permanent moisture
4	Floodplain zone	Flooded during snowmelt and large storms
5	Upland zone	Seldom or never inundated (the upland zone includes prairie and forest plant communities)

Zone 1 (Submergent zone) – The submergent zone is found in areas of 3-6 feet of water in wet ponds. Submergent vegetation makes up this zone because emergent vegetation generally does not grow deeper than 3 feet. Submergent species may float free in the water column or may root in the pool bottom and have stems and leaves that generally stay under water. Submergent species are important for wildlife habitat and

pollutant removal, especially nitrates and phosphorus. Submergent species are not readily available from native plant nurseries and can be difficult to plant. Many submergent species establish on their own (Ogle and Hoag 2000).

Zone 2 (Emergent zone) – The emergent zone of a wet pond is generally 0 to 18 inches deep. It is often designed as benches within ponds to optimize the area for emergent plants. Emergent plants are important for wildlife and evapotranspiration. They also provide habitat for phytoplankton, which play an important role in nutrient removal (Ogle and Hoag 2000). A wide variety of wetland species are adapted to the emergent zone. However, large fluctuations in water level and pollutants within wet ponds may limit the number of species.

Zone 3 (Wet meadow zone) – The wet meadow zone is a constantly moist area that can become inundated. The transition area between open water and the shoreline is prone to erosion. Therefore, it is an important area for plant establishment. In addition to wet-meadow grasses, sedges, flowers and shrubs, such as dogwoods, willows, buttonbush and chokeberry, are well suited to this zone.

Zone 4 (Floodplain zone) – The floodplain zone is normally dry but may flood during snowmelt and after large storms. Floodplain zones are generally flat terraces and are common along rivers and streams. If a wet pond has a steep side slope, it may go directly from zone 3 (wet meadow zone) to zone 5 (upland zone) without having a floodplain zone. Floodplain species must be adapted to extremes in hydrology; they may be inundated for long periods in the spring and be dry during the summer. The ability of floodplain species to handle extremes in hydrology make them well suited to the edges of wet ponds and detention ponds.

Zone 5 (Upland zone) – The upland zone is seldom or never inundated. A wide variety of species are well adapted to the upland zone and their selection will depend on the site conditions.

Zone 1 Submergent zone	3-6 feet of water
Note: Submergent species are not covered in depth in this guidebook, but desirable species include the following:	
Scientific Name	**Common Name**
Forbs and Ferns	
Brasenia schreberi	Water shield
Ceratophyllum demersum	Coontail
Elodea canadensis	Elodea
Lemna trisulca	Lesser duckweed
Myriophyllum exalbesieus	Water milfoil
Nelumbo lutea	Lotus
Nuphar lutea	Yellow water-lily
Nymphaea odorata	White water-lily
Potamogeton illinoensis	Illinois pondweed
Potamogeton natans	Floating-leaved pondweed
Potamogeton pectinatus	Sago pondweed
Ranunculus flabellaris	Yellow water crowfoot
Spirodela polyrrhiza	Giant duckweed
Urticularia vulgaris	Bladderwort
Vallisneria americana	Wild celery
Woffia columbiana	Watermeal

Zone 2 Emergent zone	0-18 inches of water	
Scientific Name	**Common Name**	**See Page**
Trees and Shrubs		
Cephalanthus occidentalis	Buttonbush	160
Forbs and Ferns		
Acorus calamus	Sweet flag	78
Alisma trivale	Water plantain	82
Caltha palustris	Marsh marigold	132
Polygonum amphibium	Water smartweed	250
Pontederia cordata	Pickerelweed	252
Sagittaria latifolia	Broadleaved arrowhead	270
Sparganium eurycarpum	Giant burreed	310
Typha latifolia	Broadleaved cattail	322
Grasses, Sedges and Rushes		
Carex aquatilis	Water sedge	134
Carex lacustris	Lake sedge	144
Carex stricta	Tussock sedge	154
Juncus balticus	Baltic rush	210
Juncus effusus	Soft rush	212
Scirpus acutus	Hardstem bulrush	282
Scirpus fluviatilis	River bulrush	288

Scirpus pungens	Three-square bulrush	290
Scirpus validus	Soft-stem bulrush	292

Zone 3 Wet meadow zone	**permanent moisture**	
Scientific Name	**Common Name**	**See Page**
Trees and Shrubs		
Amorpha fruticosa	Indigo bush	88
Salix nigra	Black willow	276
Sambucus pubens	Red-berried elder	278
Forbs and Ferns		
Agastache foeniculum	Giant hyssop	80
Anemone canadensis	Canada anemone	92
Angelica atropurpurea	Angelica	94
Asclepias incarnata	Marsh milkweed	102
Aster lanceolatus (simplex)	Panicle aster	108
Aster lucidulus	Swamp aster	110
Aster novae-angliae	New England aster	114
Aster puniceus	Red-stemmed aster	118
Bidens cernua	Beggarsticks	124
Boltonia asteroides	Boltonia	126
Chelone glabra	Turtlehead	162
Eryngium yuccifolium	Rattlesnake master	178
Eupatorium maculatum	Joe-pye-weed	180
Eupatorium perfoliatum	Boneset	182
Euthanmia graminifolia	Grass-leaved goldenrod	184
Gentiana andrewsii	Bottle gentian	192
Helenium autumnale	Sneezeweed	198
Impatiens capensis	Jewelweed	206
Iris versicolor	Blueflag	208
Liatris ligulistylis	Meadow blazingstar	220
Liatris pychnostachya	Prairie blazingstar	222
Lilium superbum	Turk's-cap lily	224
Lobelia cardinalis	Cardinal flower	226
Lobelia siphilitica	Blue lobelia	228
Lysimachia thrysiflora	Tufted loosestrife	230
Monarda fistulosa	Wild bergamot	236
Onoclea sensibilis	Sensitive fern	238
Osmunda regalis	Royal fern	240
Physostegia virginiana	Obedient plant	248
Potentilla palustris	Marsh cinquefoil	258
Pycnanthemum virginianum	Mountain mint	262
Scutterlaria lateriflora	Mad-dog skullcap	294
Silphium perfoliatum	Cup plant	298
Spiraea alba	Meadowsweet	314

Zone 3 Wet meadow zone *Cont.* permanent moisture

Scientific Name	Common Name	See Page
Thalictrum dasycarpum	Tall meadowrue	318
Verbena hastata	Blue vervain	326
Vernonia fasciculata	Ironweed	328
Veronicastrum virginicum	Culver's root	330
Grasses, Sedges and Rushes		
Andropogon gerardii	Big bluestem	90
Bromus ciliatus	Fringed brome	128
Calamagrostis canadensis	Canada blue-joint grass	130
Carex bebbii	Bebb's sedge	136
Carex comosa	Bottlebrush sedge	138
Carex crinita	Caterpillar sedge	140
Carex hystericina	Porcupine sedge	142
Carex languinosa	Wooly sedge	146
Carex lasiocarpa	Wooly needle sedge	148
Carex retrorsa	Retrorse sedge	150
Carex stipata	Awl-fruited sedge	152
Carex vulpinoidea	Fox sedge	156
Eleocharis obtusa	Blunt spikerush	170
Equisetum fluviatile	Horsetail	176
Glyceria grandis	Giant manna grass	194
Glyceria striata	Fowl manna grass	196
Juncus balticus	Baltic rush	210
Juncus effusus	Soft rush	212
Juncus torreyi	Torrey rush	214
Leersia oryzoides	Rice-cut grass	218
Panicum virgatum	Switchgrass	242
Scirpus atrovirens	Green bulrush	284
Scirpus cyperinus	Woolgrass	286
Scirpus fluviatilis	River bulrush	288
Scirpus pungens	Three-square bulrush	290
Scirpus validus	Soft-stem bulrush	292
Spartina pectinata	Prairie cord grass	312

Zone 4 **Floodplain zone**	**Flooded during snowmelt and large storms**	
Scientific Name	**Common Name**	**See Page**
Trees and Shrubs		
Acer saccharinum	Silver maple	76
Alnus incana	Speckled alder	86
Amorpha fruticosa	Indigo bush	88
Aronia melanocarpa	Black chokeberry	98
Betula nigra	River birch	122
Celtis occidentalis	Hackberry	158
Cephalanthus occidentalis	Buttonbush	160
Cornus amomum	Silky dogwood	164
Cornus sericea	Red-osier dogwood	168
Fraxinus nigra	Black ash	186
Fraxinus pennsylvanica	Green ash	188
Physocarpus opulifolius	Ninebark	246
Populus deltoides	Eastern cottonwood	254
Quercus bicolor	Swamp white oak	264
Salix discolor	Pussy willow	272
Salix exigua	Sandbar willow	274
Salix nigra	Black willow	276
Sambucus pubens	Red-berried elder	278
Spiraea alba	Meadowsweet	314
Viburnum lentago	Nannyberry	332
Viburnum trilobum	High bush cranberry	334
Forbs and Ferns		
Anemone canadensis	Canada anemone	92
Aster lucidulus	Swamp aster	110
Aster puniceus	Red-stemmed aster	118
Boltonia asteroides	Boltonia	126
Impatiens capensis	Jewelweed	206
Lobelia cardinalis	Cardinal flower	226
Lobelia siphilitica	Blue lobelia	228
Lysimachia thrysiflora	Tufted loosestrife	230
Physostegia virginiana	Obedient plant	248
Potentilla palustris	Marsh cinquefoil	258
Scutterlaria lateriflora	Mad-dog skullcap	294
Silphium perfoliatum	Cup plant	298
Symplocarpus foetidus	Skunk cabbage	316
Vernonia fasciculata	Ironweed	328
Grasses, Sedges and Rushes		
Carex comosa	Bottlebrush sedge	138
Elymus virginicus	Virginia wild rye	172
Leersia oryzoides	Rice-cut grass	218
Panicum virgatum	Switchgrass	242

Zone 4 **Floodplain zone *Cont.***	**Flooded during snowmelt and large storms**	
Scientific Name	**Common Name**	**See Page**
Scirpus atrovirens	Green bulrush	284
Spartina pectinata	Prairie cord grass	312

Zone 5 Upland zone	**Seldom or never inundated**	
Scientific Name	**Common Name**	**See Page**
Trees and Shrubs		
Cornus racemosa	Gray dogwood	166
Populus tremuloides	Quaking aspen	256
Quercus bicolor	Swamp white oak	264
Viburnum lentago	Nannyberry	332
Viburnum trilobum	High bush cranberry	334
Forbs and Ferns		
Agastache foeniculum	Giant hyssop	80
Allium stellatum	Prairie wild onion	84
Arisaema triphyllum	Jack-in-the-pulpit	96
Artemisia ludoviciana	Prairie sage	100
Asclepias tuberosa	Butterfly milkweed	104
Aster laevis	Smooth aster	106
Aster lanceolatus (simplex)	Panicled aster	108
Aster macrophyllus	Bigleaf aster	112
Aster pilosus	Frost aster	116
Athyrium filix-femina	Lady fern	120
Boltonia asteroides	Boltonia	126
Epilobium angustifolium	Fireweed	174
Galium boreale	Northern bedstraw	190
Helianthus grosseserratus	Sawtooth sunflower	200
Heuchera richardsonii	Prairie alumroot	202
Monarda fistulosa	Wild bergamot	236
Onoclea sensibilis	Sensitive fern	238
Potentilla palustris	Marsh cinquefoil	258
Pteridium aquilinum	Bracken fern	260
Pycnanthemum virginianum	Mountain mint	262
Ratibida pinnata	Yellow coneflower	266
Rudbeckia subtomentosa	Brown-eyed Susan	268
Smilacina racemosa	False Solomon’s seal	300
Solidago flexicaulis	Zig-zag goldenrod	302
Solidago riddellii	Riddell’s goldenrod	304
Solidago rigida	Stiff goldenrod	306
Tradescantia ohiensis	Ohio spiderwort	320
Veronicastrum virginicum	Culver’s root	330

Zizia aurea	Golden alexanders	336
Grasses, Sedges and Rushes		
Andropogon gerardii	Big bluestem	90
Panicum virgatum	Switchgrass	242
Schizachyrium scoparium	Little bluestem	280
Sorghastrum nutans	Indian grass	308

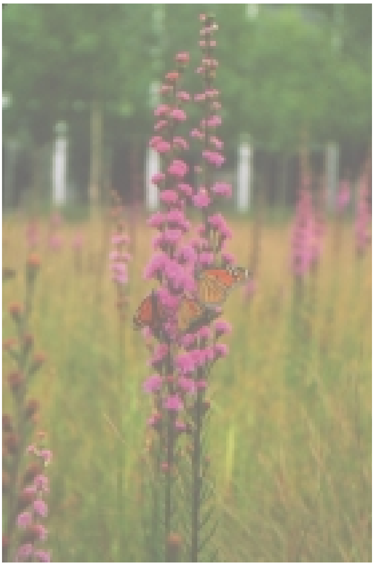
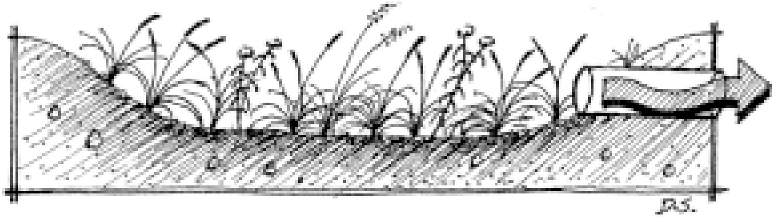


Photo: Paul Jackson

MEADOW BLAZINGSTAR

Detention



Detention systems are designed to filter and slow stormwater. Detention systems covered in this guide included dry ponds and dry swales/ditches.

Dry Pond. Dry ponds are generally at the end of storm sewer systems and are designed to reduce stormwater velocity. Dry ponds typically empty completely between storms so they provide limited pollution removal (Barr 2001). Plants in dry ponds must be able to handle flooding and subsequent dry conditions. Only a few species are well suited to dry ponds. However, several floodplain-forest and wet-prairie species are adapted to these conditions.

Dry Pond		
Scientific Name	**Common Name**	**See Page**
Trees and Shrubs		
Amorpha fruticosa	Indigo bush	88
Aronia melanocarpa	Black chokeberry	98
Betula nigra	River birch	122
Cephalanthus occidentalis	Buttonbush	160
Cornus racemosa	Gray dogwood	166
Cornus sericea	Red-osier dogwood	168
Quercus bicolor	Swamp white oak	264
Salix discolor	Pussy willow	272
Salix exigua	Sandbar willow	274
Spiraea alba	Meadowsweet	314
Forbs and Ferns		
Aster lanceolatum (simplex)	Panicle aster	108
Aster lucidulus	Swamp aster	110
Aster puniceus	Red-stemmed aster	118
Equisetum fluviatile	Horsetail	176
Euthanmia graminifolia	Grass-leaved goldenrod	184
Helenium autumnale	Sneezeweed	198
Liatris pychnostachya	Prairie blazingstar	222
Lobelia siphilitica	Blue lobelia	228

Monarda fistulosa	Wild bergamot	236
Pycnanthemum virginianum	Mountain mint	262
Vernonia fasciculata	Ironweed	328
Veronicastrum virginicum	Culver's root	330
Grasses, Sedges and Rushes		
Andropogon gerardii	Big bluestem	90
Bromus ciliatus	Fringed brome	128
Carex bebbii	Bebb's sedge	136
Carex vulpinoidea	Fox sedge	156
Elymus virginicus	Virginia wild rye	172
Panicum virgatum	Switchgrass	242
Spartina pectinata	Prairie cord grass	312

Dry Swales/Ditches. Dry swales are open, vegetated channels that are designed to filter and slow stormwater. Check dams or berms are often used to hold water and settle pollutants. Dry swales are used along easements between properties or along roadways. Sandy soils may be added to the base of dry swales if existing soils are impermeable. Under-drain systems may also be installed to direct water to a storm sewer (Barr 2001).

Grasses are generally chosen for dry swales because they have many stems to slow water flow and can be repeatedly mown during the growing season. Dry swales may be maintained as lawn, but are most effective at slowing and treating water when they are planted with dry or mesic prairie species. Grass swales should be mowed at least annually to prevent trees and shrubs from inhibiting grass growth (King County 1996). Mowing height for grass swales should be 4 to 9 inches. A common Minnesota Department of Transportation (MnDOT) seed mix used for swales is Mixture 28B.

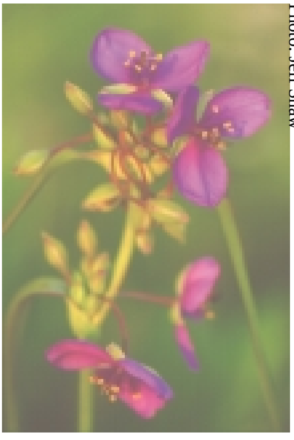


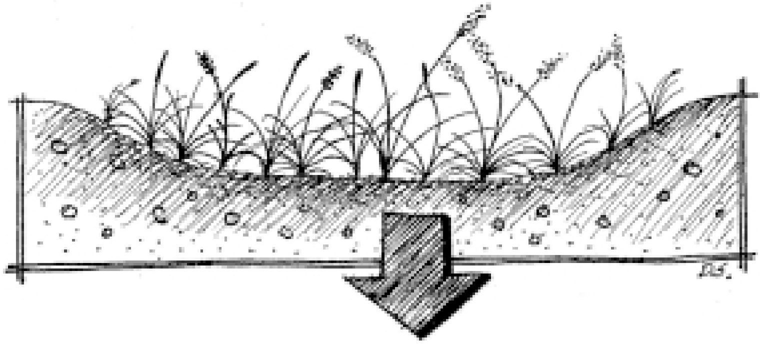
Photo: Jeff Shaw

SPIDERWORT

Dry swales

Scientific Name	Common Name	See Page
Forbs and Ferns		
Anemone canadensis	Canada anemone	92
Artemisia ludoviciana	Prairie sage	100
Asclepias incarnata	Marsh milkweed	102
Aster puniceus	Red-stemmed aster	118
Euthanmia graminifolia	Flat-top goldenrod	184
Lobelia siphilitica	Blue lobelia	228
Pycnanthemum virginianum	Mountain mint	262
Verbena hastata	Blue vervain	326
Grasses, Sedges and Rushes		
Andropogon gerardii	Big bluestem	90
Bromus ciliatus	Fringed brome	128
Calamagrostis canadensis	Canada blue-joint grass	130
Carex bebbii	Bebb's sedge	136
Carex vulpinoidea	Fox sedge	156
Elymus virginicus	Virginia wild rye	172
Glyceria striata	Fowl manna grass	196
Juncus effusus	Soft rush	212
Panicum virgatum	Switchgrass	242
Scirpus atrovirens	Green bulrush	284
Spartina pectinata	Prairie cord grass	312
Useful sod-forming grasses not covered in this guidebook		
Agrostis palustris	Creeping bentgrass	---
Elymus sp.	Wheat-grass	---
Poa palustris	Fowl bluegrass	---

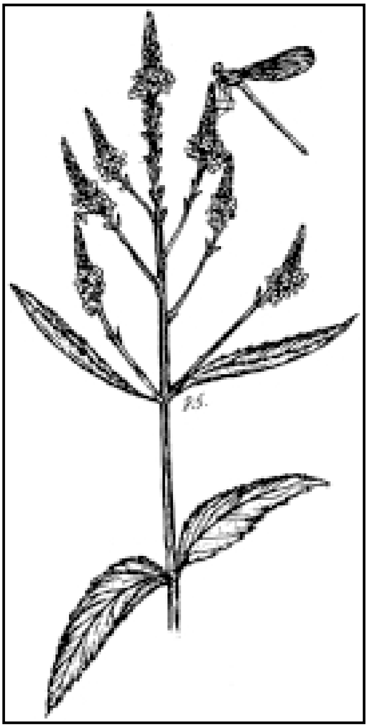
Infiltration



Infiltration systems are designed to infiltrate stormwater into the soil and often utilize plants to provide filtration and evapotranspiration. Infiltration systems covered in this guidebook include rain water gardens, infiltration basins, dry swales and infiltration trenches.

Rain Water Gardens (on-lot infiltration)

Rain water gardens are small depressions that are ideal for residential and small commercial sites. They are most effective in areas where soils have good infiltration capacity. Since these systems are designed to drain relatively quickly, a large variety of shrubs, perennial grasses and flowers can be planted. Dry- and mesic-prairie species are well suited to the side slopes of rain water gardens while wet meadow species are well suited to the lower portions.



BLUE VERVAIN

Rainwater Garden Side Slopes		
Scientific Name	**Common Name**	**See Page**
Trees and Shrubs		
Aronia melanocarpa	Black chokeberry	98
Cornus racemosa	Gray dogwood	166
Viburnum trilobum	High bush cranberry	334
Forbs and Ferns		
Allium stellatum	Prairie wild onion	84
Anemone canadensis	Canada anemone	92
Arisaema triphyllum	Jack-in-the-pulpit	96
Artemisia ludoviciana	Prairie sage	100
Asclepias tuberosa	Butterfly milkweed	104
Aster laevis	Smooth aster	106
Aster macrophyllus	Bigleaf aster	112
Aster pilosus	Frost aster	116
Epilobium angustifolium	Fireweed	174
Eryngium yuccifolium	Rattlesnake master	178
Galium boreale	Northern bedstraw	190
Heuchera richardsonii	Prairie alumroot	202
Liatris ligulistylis	Meadow blazingstar	220
Liatris pychnostachya	Prairie blazingstar	222
Lilium superbum	Turk's-cap lily	224
Matteuccia struthiopteris var. *pennsylvanica*	Ostrich fern	234
Monarda fistulosa	Wild bergamot	236
Osmunda regalis	Royal fern	240
Pteridium aquilinum	Bracken fern	260
Pycnanthemum virginianum	Mountain mint	262
Ratibida pinnata	Yellow coneflower	266
Rudbeckia subtomentosa	Brown-eyed Susan	268
Smilacina racemosa	False Solomon's seal	300
Solidago flexicaulis	Zig-zag goldenrod	302
Solidago riddellii	Riddell's goldenrod	304
Solidago rigida	Stiff goldenrod	306
Tradescantia ohiensis	Ohio spiderwort	320
Zizia aurea	Golden alexanders	336
Grasses, Sedges and Rushes		
Andropogon gerardii	Big bluestem	90
Bromus ciliatus	Fringed brome	128
Panicum virgatum	Switchgrass	242
Schizachyrium scoparium	Little bluestem	280
Sorghastrum nutans	Indian grass	308

Rainwater Garden Base

Scientific Name	Common Name	See Page
Trees and Shrubs		
Aronia melanocarpa	Black chokeberry	98
Cephalanthus occidentalis	Buttonbush	160
Cornus sericea	Red-osier dogwood	168
Ilex verticillata	Winterberry	204
Viburnum trilobum	High bush cranberry	334
Forbs and Ferns		
Agastache foeniculum	Giant hyssop	80
Anemone canadensis	Canada anemone	92
Angelica atropurpurea	Angelica	94
Asclepias incarnata	Marsh milkweed	102
Aster novae-angliae	New England aster	114
Aster puniceus	Red-stemmed aster	118
Boltonia asteroides	Boltonia	126
Chelone glabra	Turtlehead	162
Equisetum fluviatile	Horsetail	176
Eupatorium maculatum	Joe-pye weed	180
Eupatorium perfoliatum	Boneset	182
Gentiana andrewsii	Bottle gentian	192
Helenium autumnale	Sneezeweed	198
Iris versicolor	Blueflag	208
Liatris ligulistylis	Meadow blazingstar	220
Liatris pychnostachya	Prairie blazingstar	222
Lilium superbum	Turk’s-cap lily	224
Lobelia cardinalis	Cardinal flower	226
Lobelia siphilitica	Blue lobelia	228
Lysimachia thrysiflora	Tufted loosestrife	230
Onoclea sensibilis	Sensitive fern	238
Osmunda regalis	Royal fern	240
Physostegia virginiana	Obedient plant	248
Pteridium aquilinum	Bracken fern	260
Pycnanthemum virginianum	Mountain mint	262
Rudbeckia subtomentosa	Brown-eyed Susan	268
Scutterlaria lateriflora	Mad-dog skullcap	294
Silphium perfoliatum	Cup plant	298
Solidago rigida	Stiff goldenrod	306
Thalictrum dasycarpum	Tall meadowrue	318
Vernonia fasciculata	Ironweed	328
Veronicastrum virginicum	Culver’s root	330

Rainwater Garden Base *Cont.*		
Scientific Name	**Common Name**	**See Page**
Grasses, Sedges and Rushes		
Bromus ciliatus	Fringed brome	128
Carex comosa	Bottlebrush sedge	138
Carex crinita	Caterpillar sedge	140
Carex hystericina	Porcupine sedge	142
Carex vulpinoidea	Fox sedge	156
Glyceria striata	Fowl manna grass	196
Juncus effusus	Soft rush	212
Panicum virgatum	Switchgrass	242
Scirpus cyperinus	Woolgrass	286
Spartina pectinata	Prairie cord grass	312

Infiltration Basin. Infiltration basins, like rain water gardens, are designed to infiltrate stormwater relatively quickly, but they are larger in size and receive stormwater from wider areas via pipes or swales. Deep-rooted plants are most effective in these systems as they increase the rate of infiltration and prevent erosion. If sod is chosen to vegetate an infiltration basin, the sod should be grown in permeable soils; sod grown in clay may restrict infiltration. If sod is used for infiltration basins, mowing height should be 4 to 9 inches. Trees can be incorporated along the side slopes of infiltration basins but should be planted at least 15 feet away from perforated pipes and 25 feet from riser structures (Ogle and Hoag 2000).


Photo: Dan Shaw

WILD BERGAMOT

Infiltration Basin Side Slopes		
Scientific Name	**Common Name**	**See Page**
Trees and Shrubs		
Acer saccharinum	Silver maple	76
Amorpha fruticosa	Indigo bush	88
Aronia melanocarpa	Black chokeberry	98
Betula nigra	River birch	122
Celtis occidentalis	Hackberry	158
Cornus racemosa	Gray dogwood	166
Fraxinus nigra	Black ash	186
Fraxinus pennsylvanica	Green ash	188

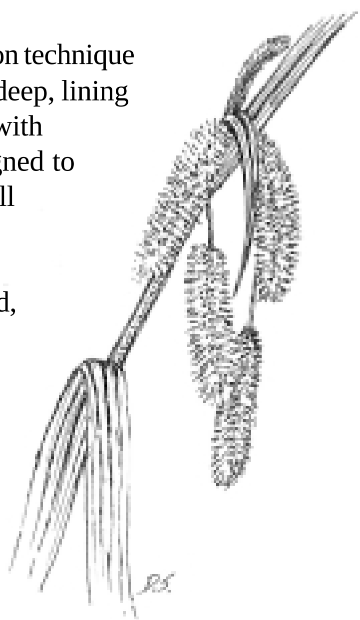
Ilex verticillata	Winterberry	204
Larix laricina	Tamarack	216
Physocarpus opulifolius	Ninebark	246
Populus deltoides	Eastern cottonwood	254
Populus tremuloides	Quaking aspen	256
Quercus bicolor	Swamp white oak	264
Salix nigra	Black willow	276
Sambucus pubens	Red-berried elder	278
Spiraea alba	Meadowsweet	314
Viburnum lentago	Nannyberry	332
Viburnum trilobum	High bush cranberry	334
Forbs and Ferns		
Agastache foeniculum	Giant hyssop	80
Allium stellatum	Prairie wild onion	84
Anemone canadensis	Canada anemone	92
Angelica atropurpurea	Angelica	94
Artemisia ludoviciana	Prairie sage	100
Asclepias tuberosa	Butterfly milkweed	104
Aster laevis	Smooth aster	106
Aster lanceolatus (simplex)	Panicle aster	108
Aster macrophyllus	Bigleaf aster	112
Aster novae-angliae	New England aster	114
Aster pilosus	Frost aster	116
Athyrium filix-femina	Lady fern	120
Boltonia asteroides	Boltonia	126
Equisetum fluviatile	Horsetail	176
Eryngium yuccifolium	Rattlesnake master	178
Euthanmia graminifolia	Grass-leaved goldenrod	184
Galium boreale	Northern bedstraw	190
Helianthus grosseserratus	Sawtooth sunflower	200
Heuchera richardsonii	Prairie alumroot	202
Liatris ligulistylis	Meadow blazingstar	220
Liatris pychnostachya	Prairie blazingstar	222
Lilium superbum	Turk’s-cap lily	224
Matteuccia struthiopteris var. *pennsylvanica*	Ostrich fern	234
Monarda fistulosa	Wild bergamot	236
Osmunda regalis	Royal fern	240
Pteridium aquilinum	Bracken fern	260
Pycnanthemum virginianum	Mountain mint	262
Smilacina racemosum	False Solomon’s seal	300
Solidago flexicaulis	Zig-zag goldenrod	302
Solidago riddellii	Riddell’s goldenrod	304
Solidago rigida	Stiff goldenrod	306
Tradescantia ohiensis	Ohio spiderwort	320

Infiltration Basin Side Slopes *Cont.*		
Scientific Name	**Common Name**	**See Page**
Zizia aurea	Golden alexanders	336
Grasses, Sedges and Rushes		
Andropogon gerardii	Big bluestem	90
Bromus ciliatus	Fringed brome	128
Carex vulpinoidea	Fox sedge	156
Panicum virgatum	Switchgrass	242
Schizachyrium scoparium	Little bluestem	280
Sorghastrum nutans	Indian grass	308

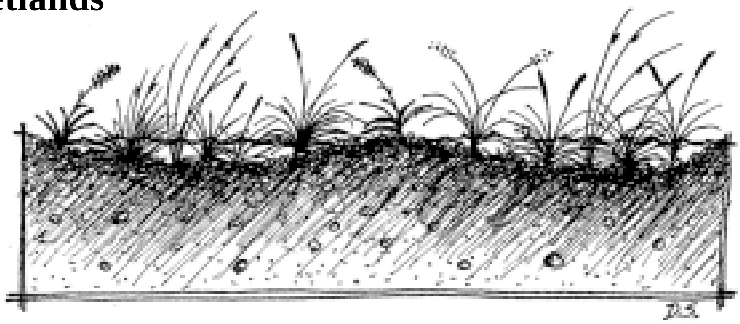
Infiltration Basin Base		
Scientific Name	**Common Name**	**See Page**
Trees and Shrubs		
Aronia melanocarpa	Black chokeberry	98
Cephalanthus occidentalis	Buttonbush	160
Cornus sericea	Red-osier dogwood	168
Ilex verticillata	Winterberry	204
Viburnum trilobum	High bush cranberry	334
Forbs and Ferns		
Agastache foeniculum	Giant hyssop	80
Anemone canadensis	Canada anemone	92
Angelica atropurpurea	Angelica	94
Asclepias incarnata	Marsh milkweed	102
Aster novae-angliae	New England aster	114
Aster puniceus	Red-stemmed aster	118
Boltonia asteroides	Boltonia	126
Chelone glabra	Turtlehead	162
Equisetum fluviatile	Horsetail	176
Eupatorium maculatum	Joe-pye-weed	180
Eupatorium perfoliatum	Boneset	182
Gentiana andrewsii	Bottle gentian	192
Helenium autumnale	Sneezeweed	198
Iris versicolor	Blueflag	208
Liatris ligulistylis	Meadow blazingstar	220
Liatris pychnostachya	Prairie blazingstar	222
Lilium superbum	Turk’s-cap lily	224
Lobelia cardinalis	Cardinal flower	226
Lobelia siphilitica	Blue lobelia	228
Lysimachia thrysiflora	Tufted loosestrife	230
Onoclea sensibilis	Sensitive fern	238

Osmunda regalis	Royal fern	240
Physostegia virginiana	Obedient plant	248
Pteridium aquilinum	Bracken fern	260
Pycnanthemum virginianum	Mountain mint	262
Rudbeckia subtomentosa	Brown-eyed Susan	268
Scutterlaria lateriflora	Mad-dog skullcap	294
Silphium perfoliatum	Cup plant	298
Solidago rigida	Stiff goldenrod	306
Thalictrum dasycarpum	Tall meadowrue	318
Vernonia fasciculata	Ironweed	328
Veronicastrum virginicum	Culver's root	330
Grasses, Sedges and Rushes		
Bromus ciliatus	Fringed brome	128
Carex comosa	Bottlebrush sedge	138
Carex crinita	Caterpillar sedge	140
Carex hystericina	Porcupine sedge	142
Carex vulpinoidea	Fox sedge	156
Glyceria striata	Fowl manna grass	196
Juncus effusus	Soft rush	212
Panicum virgatum	Switchgrass	242
Scirpus cyperinus	Woolgrass	286
Spartina pectinata	Prairie cord grass	312

Infiltration Trench. This infiltration technique involves digging a trench 3 to 8 feet deep, lining it with filter fabric and then filling it with stone. Infiltration trenches are designed to receive clean sheet flow from a small area, such as a few residences or rooftops (Barr 2001). Although infiltration trenches are not vegetated, it is important that suspended solids be removed before they enter the trench. Grassed filter strips are often an effective tool for pretreatment (Barr 2001). Grass filter strips are discussed under filtration.



Wetlands



Wetland systems are designed for flood control and the removal of pollutants from stormwater. Wetland systems covered in this guidebook include stormwater wetlands and wet swales.

Stormwater Wetland. Like natural wetlands, stormwater wetlands have the capacity to improve water quality through microbial breakdown of pollutants, plant uptake, retention of stormwater, settling and adsorption. Sediment forebays and micropools are often designed as part of stormwater wetlands to prevent sediment from filling the wetland. Stormwater from large areas can be diverted into these wetlands. If soils drain too quickly, liners can be used to hold water (Barr 2001). Stormwater wetlands will have zones and plants similar to wet ponds. They may have less fluctuation, though, and can maintain higher diversity. (For species list, see Wet Ponds and Extended Storage Ponds.)

Wet Swale. Wet swales consist of broad, open channels, used to temporarily store water. Wet swales are constructed on existing soils and are often at or slightly above the water table (Barr 2001). As a result, they can incorporate a wide variety of wetland and wet-meadow shrub, grass and flower species. The primary purpose of wet swales is to improve water quality and to slow runoff velocity. Check dams and berms are often used to slow and retain water.

Photo: Dan Shaw

Wet Swale		
Scientific Name	**Common Name**	**See Page**
Trees and Shrubs		
Alnus incana	Speckled alder	86
Amorpha fruticosa	Indigo bush	88
Aronia melanocarpa	Black chokeberry	98
Betula nigra	River birch	122
Cephalanthus occidentalis	Buttonbush	160
Cornus amomum	Silky dogwood	164
Cornus racemosa	Gray dogwood	166
Cornus sericea	Red-osier dogwood	168
Ilex verticillata	Winterberry	204
Larix laricina	Tamarack	216
Physocarpus opulifolius	Ninebark	246
Salix discolor	Pussy willow	272
Salix exigua	Sandbar willow	274
Sambucus pubens	Red-berried elder	278
Spiraea alba	Meadowsweet	314
Viburnum lentago	Nannyberry	332
Viburnum trilobum	High bush cranberry	334
Forbs and Ferns		
Agastache foeniculum	Giant hyssop	80
Alisma trivale	Water plantain	82
Anemone canadensis	Canada anemone	92
Angelica atropurpurea	Angelica	94
Artemisia ludoviciana	Prairie sage	100
Asclepias incarnata	Marsh milkweed	102
Aster lanceolatus (simplex)	Panicle aster	108
Aster lucidulus	Swamp aster	110
Aster novae-angliae	New England aster	114
Aster puniceus	Red-stemmed aster	118
Boltonia asteroides	Boltonia	126
Caltha palustris	Marsh marigold	132
Chelone glabra	Turtlehead	162
Equisetum fluviatile	Horsetail	176
Eryngium yuccifolium	Rattlesnake master	178
Eupatorium maculatum	Joe-pye-weed	180
Eupatorium perfoliatum	Boneset	182
Euthanmia graminifolia	Grass-leaved goldenrod	184
Gentiana andrewsii	Bottle gentian	192
Helenium autumnale	Sneezeweed	198
Helianthus grosseserratus	Sawtooth sunflower	200
Impatiens capensis	Jewelweed	206

Wet Swale *Cont.*

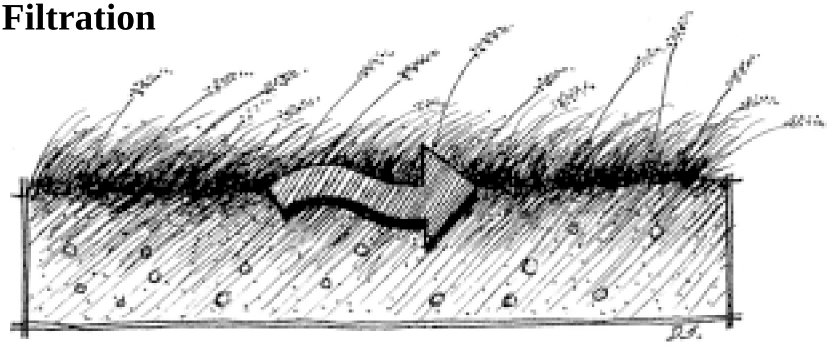
Scientific Name	Common Name	See Page
Iris versicolor	Blueflag	208
Liatris ligulistylis	Meadow blazingstar	220
Liatris pychnostachya	Prairie blazingstar	222
Lilium superbum	Turk's-cap lily	224
Lobelia cardinalis	Cardinal flower	226
Lobelia siphilitica	Blue lobelia	228
Lysimachia thrysiflora	Tufted loosestrife	230
Monarda fistulosa	Wild bergamot	236
Onoclea sensibilis	Sensitive fern	238
Osmunda regalis	Royal fern	240
Physostegia virginiana	Obedient plant	248
Polygonum amphibium	Water smartweed	250
Pontederia cordata	Pickerelweed	252
Potentilla palustris	Marsh cinquefoil	258
Pycnanthemum virginianum	Mountain mint	262
Rudbeckia subtomentosa	Brown-eyed Susan	268
Sagittaria latifolia	Broadleaved arrowhead	270
Scutterlaria lateriflora	Mad-dog skullcap	294
Silphium perfoliatum	Cup plant	298
Solidago rigida	Stiff goldenrod	306
Sparganium eurycarpum	Giant burreed	310
Symplocarpus foetidus	Skunk cabbage	316
Thalictrum dasycarpum	Tall meadowrue	318
Tradescantia ohiensis	Ohio spiderwort	320
Verbena hastata	Blue vervain	326
Vernonia fasciculata	Ironweed	328
Veronicastrum virginicum	Culver's root	330
Zizia aurea	Golden alexanders	336
Grasses, Sedges and Rushes		
Andropogon gerardii	Big bluestem	90
Bromus ciliatus	Fringed brome	128
Calamagrostis canadensis	Canada blue-joint grass	130
Carex aquatilis	Water sedge	134
Carex bebbii	Bebb's sedge	136
Carex comosa	Bottlebrush sedge	138
Carex crinita	Caterpillar sedge	140
Carex hystericina	Porcupine sedge	142
Carex lacustris	Lake sedge	144
Carex languinosa	Wooly sedge	146
Carex lasiocarpa	Wooly needle sedge	148
Carex retrorsa	Retrorse sedge	150

Carex stipata	Awl-fruited sedge	152
Carex stricta	Tussock sedge	154
Carex vulpinoidea	Fox sedge	156
Eleocharis obtusa	Blunt spikerush	170
Elymus virginicus	Virginia wild rye	172
Glyceria grandis	Giant manna grass	194
Glyceria striata	Fowl manna grass	196
Juncus balticus	Baltic rush	210
Juncus effusus	Soft rush	212
Juncus torreyi	Torrey rush	214
Leersia oryzoides	Rice-cut grass	218
Panicum virgatum	Switchgrass	242
Scirpus acutus	Hardstem bulrush	282
Scirpus atrovirens	Green bulrush	284
Scirpus cyperinus	Woolgrass	286
Scirpus fluviatilis	River bulrush	288
Scirpus pungens	Three-square bulrush	290
Scirpus validus	Soft-stem bulrush	292
Spartina pectinata	Prairie cord grass	312
Typha latifolia	Broadleaved cattail	322

Photo: Dan Shaw

OBEDIENT PLANT

Filtration



Filtration systems remain dry between storm events and are designed to remove pollutants from stormwater. Filtration MPs covered in this guidebook include bioretention systems and filter strips.

Bioretention Basins. Like rainwater gardens and infiltration basins, bioretention basins rely on plants to function effectively. Bioretention basins can be designed for infiltration but often have longer detention times and are often built with soils that have less infiltration capacity (Barr 2001). Generally the same species used for rain water gardens and infiltration basins can be used for bioretention areas (for species list, see Rain Water Gardens and Infiltration Basins).

Filter Strips. Filter strips are densely graded and uniformly vegetated areas designed to treat sheet flow (Barr 2001). Filter strips differ from natural buffers in that they are generally designed specifically for pollutant removal (MPCA 2000). In filter strips, native vegetation slows runoff, collects sediment and allows some infiltration. Dry- and mesic-prairie species, especially deep-rooted grasses, are well suited for filter strips. They produce many stems that slow water flow and have deep roots that increase infiltration and absorption. Tree and shrub species can be planted among the prairie species also, but they will inhibit growth of the prairie species if the shade they produce is dense. Dense stands of vegetation are required for filter strips to function effectively. As a result, monitoring is important to ensure the establishment and persistence of desirable vegetation. Excessive accumulation of sediment can affect plant growth and should be removed (MPCA 2000).

Filtration Strips

Scientific Name	Common Name	See Page
Trees and Shrubs		
Acer saccharinum	Silver maple	76
Aronia melanocarpa	Black Chokeberry	98
Betula nigra	River birch	122
Celtis occidentalis	Hackberry	158
Cornus racemosa	Gray dogwood	166
Fraxinus pennsylvanica	Green ash	188
Larix laricina	Tamarack	216
Physocarpus opulifolius	Ninebark	246
Populus deltoides	Eastern cottonwood	254
Populus tremuloides	Quaking aspen	256
Quercus bicolor	Swamp white oak	264
Salix nigra	Black willow	276
Spiraea alba	Meadowsweet	314
Viburnum lentago	Nannyberry	332
Viburnum trilobum	High bush cranberry	334
Forbs and Ferns		
Agastache foeniculum	Giant hyssop	80
Allium stellatum	Prairie wild onion	84
Anemone canadensis	Canada anemone	92
Angelica atropurpurea	Angelica	94
Artemisia ludoviciana	Prairie sage	100
Asclepias tuberosa	Butterfly milkweed	104
Aster laevis	Smooth aster	106
Aster lanceolatus (simplex)	Panicle aster	108
Aster macrophyllus	Bigleaf aster	112
Aster novae-angliae	New England aster	114
Aster pilosus	Frost aster	116
Athyrium filix-femina	Lady fern	120
Boltonia asteroides	Boltonia	126
Equisetum fluviatile	Horsetail	176
Eryngium yuccifolium	Rattlesnake master	178
Euthanmia graminifolia	Grass-leaved goldenrod	184
Galium boreale	Northern bedstraw	190
Helianthus grosseserratus	Sawtooth sunflower	200
Heuchera richardsonii	Prairie alumroot	202
Liatris ligulistylis	Meadow blazingstar	220
Liatris pychnostachya	Prairie blazingstar	222
Lilium superbum	Turk's-cap lily	224
Matteuccia struthiopteris var. *pennsylvanica*	Ostrich fern	234
Monarda fistulosa	Wild bergamot	236

Filtration Strips ***Cont.***		
Scientific Name	**Common Name**	**See Page**
Osmunda regalis	Royal fern	240
Pteridium aquilinum	Bracken fern	260
Pycnanthemum virginianum	Mountain mint	262
Smilacina racemosa	False Solomon's seal	300
Solidago flexicaulis	Zig-zag goldenrod	302
Solidago riddellii	Riddell's goldenrod	304
Solidago rigida	Stiff goldenrod	306
Tradescantia ohiensis	Ohio spiderwort	320
Zizia aurea	Golden alexanders	336
Grasses, Sedges and Rushes		
Andropogon gerardii	Big bluestem	90
Bromus ciliatus	Fringed brome	128
Carex vulpinoidea	Fox sedge	156
Panicum virgatum	Switchgrass	242
Schizachyrium scoparium	Little bluestem	280
Sorghastrum nutans	Indian grass	308
Other appropriate grasses not covered in this guidebook		
Bouteloua curtipendula	Side-oats grama	---
Bouteloua hirsuta	Hairy grama	---
Bromus kalmii	Prairie brome	---
Elymus canadensis	Canada wild rye	---
Koeleria cristata	June grass	---
Sporobolis heterolepis	Prairie dropseed	---
Stipa spartea	Porcupine grass	---


Photo: Paul Jackson

MOUNTAIN MINT

LITERATURE CITED

(A separate Plant Pages Bibliography is provided for the Plant Information section of this guidebook.)

Athas, C., and C. Stevenson, 1991. *The use of artificial wetlands in treating stormwater runoff.* Maryland Sediment and Stormwater Administration. 66 pp.

Azous, A. L., and R. R. Horner, 2001. *Wetlands and Urbanization: Implications for the Future*. Lewis Publishers. 238 pp.

Barr Engineering Company, 2001. *Minnesota Urban Small Sites BMP Manual, Stormwater Best Management Practices for Cold Climates*. Prepared for the Metropolitan Council.

Bedford, B., and O. Loucks, 1984. *Response of* Carex-*Dominated Wetlands to Altered Temperature and Flooding Patterns.* Environmental Research Laboratory, U.S. Environmental Protection Agency.

Biesboer, D. D., and R. Jacobson, 1994. *Screening and Selection of Salt Tolerance in Native Warm Season Grasses*. Minnesota Dept. of Transportation, Report 94-11. 33pp.

Brown, R. G., 1984. Effects of an urban wetland on sediment and nutrient loads in runoff. *Wetlands* 4:147-158.

Casanova, M. T., and M. A. Brock, 2000. How do depth, duration and frequency of flooding influence the establishment of wetland plant communities? *Plant Ecology* 147:237-250.

Claytor, R. A., and T. R. Schueler, 1996. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection.

Cooke, S. S., R. R. Horner, C. Conolly, O. Edwards, M. Wilkinson and M. Emers, 1989. *Effects of Urban Stormwater Runoff on Paustrine Weland Vegetation Communities – Baseline Investigation (1988)*. Report to U.S. Environmental Protection Agency, Region 10, by King County Resource Planning Section, Seattle, Wash.

Donovan, L. A., K. W. McLeod, K. C. Sherrod, Jr. and N. J. Stumpff, 1988. Response of woody swamp seedlings to flooding and increased water temperature, growth, biomass, survivorship. *American Journal of Botany* 36(2):131-146.

Dushenko W. T., D. A. Bright and K. J. Reimer, 1995. Arsenic bioaccumulation and toxicity in aquatic macrophytes exposed to gold mine effluent: relationships with environmental partitioning metal uptake and nutrients. *Aquatic Botany* 50:141-158.

Ewing, K., 1996. Tolerance of Four Wetland Plant Species to Flooding and Sediment Deposition. *Environmental and Experimental Botany* 36(2):131-146.

Fassman, E. A., S. L. Yu and A. L. Riscassi, 2001. *Planting Strategies for Constructed Wetlands for Stormwater Treatment*. Dept. of Civil Engineering, Univ. of Virginia, Charlottesville.

Flaherty, 2002. Using a Wetland to Clean Our Water. www.montana.edu/wwwpb/ag/bullrush.html. MSU Communication Services, Montana State Univ., Bozeman.

Galatowitsch, S. M., D. C. Whited, R. Lehtinen, J. Husveth and K. Schik, 1997. *The Vegetation of Wet Meadows in Relation to Their Land Use*. Dept. of Horticultural Science and Landscape Architecture, Univ. of Minnesota.

Harris, S. W., and W. H. Marshall, 1963. Ecology of Water-Level Manipulation on a Northern Marsh. *Ecology* 44(2):331-343.

Horner, R. R., F. B. Gutermuth, L.L. Conquest, and A. W. Johnson, 1988. Urban Stormwater and Puget Trough Wetlands. In *Proceedings of the first Annual Meeting for Puget Sound Research, 18-19 March 1988, Seattle, WA*. Puget Sound Water Quality Authority, Seattle, Wash.

Hudon, Christiane, 1997. Impact of Water Level Fluctuations on St. Lawrence River Aquatic Vegetation. *Canadian Journal of Fisheries and Aquatic Sciences* 54:2853-2865.

Huston, M. A., 1979. A general hypothesis of species diversity. *American Naturalist* 113:81-101.

Husveth, J. J., 1999. *Stormwater Impacts to the Plant Communities of Glacial Marshes in the Minneapolis/St. Paul Metropolitan Area, Minnesota, USA.* A Thesis Submitted to the Faculty of the Graduate School of the University of Minnesota.

Isabelle, P. S., L. J. Fooks and P. A. Keddy, 1987. Effects of Roadside Snowmelt on Wetland Vegetation: An Experimental Study. *J. Environ. Mgmt*. 25:57-60.

Jacobson, Robert, 2000. *Mn/DOT Seeding Manual.* Minnesota Dept. of Transportation, St. Paul.

Jurik, T. W., S. C. Wang, and, A. G. van der Valk, 1994. Effects of sediment load on seedling emergence from *Wetland* seed banks. *Wetlands* 14(3):159-165.

Keddy, P. A., 1983. Shoreline Vegetation in Axe Lake, Ontario: Effects of Exposure on Zonation Patterns. *Ecology* 64(2):331-344.

Keeland, B. D., and R. R. Sharitz, 1997. The Effects of Water-Level Fluctuations on Weekly Tree Growth in a Southeastern USA Swamp. *American Journal. of Botany* 84(1):131-139.

Kennedy, H. E. Jr., and R. M. Krinard, 1974. *1973 Mississippi River Flood's Impact on Natural Hardwood Forests and Plantations*. U.S. Forest Service Research Note. Southern Forest Experiment Station, U.S. Dept. of Agriculture.

King County. 1996. *Surface Water Design Manual* (Draft of February 1996). Surface Water Management Division, King County Dept. of Public Works, Seattle, Wash.

Kozlowski, T. T., 1997. *Responses of Woody Plants to Flooding and Salinity*. Dept. of Environmental Science, Policy and Management, College of Natural Resources, Univ. of California-Berkeley.

Minnesota Pollution Control Agency, 2000. *Protecting Water Quality in Urban Areas, Best Management Practices for Dealing with Storm Water Runoff from Urban, Suburban and Developing Areas of Minnesota.* Minnesota Pollution Control Agency, St. Paul.

Ohrel, R., 2000. Choosing Appropriate Vegetation for Salt-impacted Roadways. In *The Practice of Watershed Protection* (Article 38). Editors Thomas R. Schueler and Heather K. Holland, Center for Watershed Protection, Ellicott City, Md.

Ogle, D. G., and J. C., Hoag, (USDA-Natural Resources Conservation Service), 2000. *Stormwater Plant Management, A Resource Guide, Detailed information on appropriate plant materials for Best Management Practices.* Prepared for Boise Public Works.

Minnesota Department of Natural Resources, *www.dnr.state.mn.us*

Occoquan Watershed Monitoring Lab and George Mason University, 1990. *Final Project Report: The Evaluation of a Created Wetland as an Urban Best Management Practice*. Northern Virginia Soil and Water Conservation District. 170 pp.

Pollock, M. M., R. J. Naiman and T. A. Hanley, 1998. Plant species richness in riparian wetlanda – A test of biodiversity theory. *Ecology* 79(1): 94-105.

Rice, J. S., and B. W. Pinkerton, 1993. Reed canarygrass survival under cyclic inundation, *Journal of Soil and Water Conservation* 48(2):132-135.

Seattle Metro, 1993. *South Base Pond Report: The Response of Wetland Plants to Stormwater Runoff From a Transit Base.* Pub. No. 775, August 1993.

Schueler, T., 2000. Persistence of Wetland Plantings Along the Aquatic Bench of Stormwater Ponds. In *The Practice of Watershed Protection* (Article 87). Editors Thomas R. Schueler and Heather K. Holland. Center for Watershed Protection, Ellicott City, Md.

Schwartz, L. N., 1985. The effects of sewage on a Lake Champlain wetland. *Journal of Freshwater Ecology* 3(1):35-46.

Shaw, Daniel B., 2000. *Native Vegetation in Restored and Created Wetlands: Its Establishment and Management in Minnesota and the Upper Midwest.* Minnesota Board of Water and Soil Resources. 93 pp.

Shaw, Daniel B., 2002. Personal observation.

Shenot, J., 1993. *An Analysis of Wetland Planting Success at Three Stormwater Management Ponds in Montgomery Co., MD*. M.S. Thesis. Univ. of Maryland. 114 pp.

Snowden (nee Cook), R. E. D., and B. D. Wheeler, 1993. Iron toxicity to fen plant species. *Journal of Ecology* 81:35-46.

Squires, L., and A. G. van der Valk, 1992. Water depth tolerance of the dominant emergent macrophytes of the delta marsh, Manitoba. *Canadian Journal of Botany* 70:1860-1867.

Stockdale, E. C., 1991. *Freshwater Wetlands, Urban Stormwater, and Nonpoint Pollution Control: A Literature Review and Annotated Bibliography.* Washington Dept. of Ecology, Olympia.

Tilton, D. L. and R. H. Kadlec, 1979. The Utilization of Freshwater Wetland for Nutrient Removal from Secondarily Treated Wastewater Effluent. *Journal of Environmental Quality* 8:328-334

University of Michigan Wetlands Ecosystem Research Group, 1974. *State of the Art Survey and Evaluation of Marsh Plant Establishment Techniques, Induced and Natural*. School of Natural Resources, College of Engineering, Univ. of Michigan.

Van der Valk, A. G., S. D. Swanson and R. F., Nuss, 1981. The response of plant species to burial in three types of Alaskan wetlands. *Canadian Journal of Botany* 61:1150-1164.

Wetzel, R. G., 1983. *Limnology*. 2nd ed. Saunders College Publishing. Fort Worth, Tex.

Wienhold, C. E., and A. G. van der Valk, 1988. The impact of duration of drainage on the seed banks of northern prairie wetlands. *Canadian Journal of Botany* 67:1878-1884.

Wilcox, D.A., and J. E. Meeker, 1996. Disturbance effects on aquatic vegetation in regulated and unregulated lakes in northern Minnesota. *Canadian Journal of Botany* 69:1542-1551.

Ye, Z., A. J. M. Baker, M. Wong and A. J. Willis, 1998. Zinc, lead and cadmium accumulation and tolerance in *Typha latifolia* as affected by iron plaque on the root surface. *Aquatic Botany* 61:55-67.

Yeager, L. E., 1949. Effect of permanent flooding in a river-bottom timber area. *Illinois Natural History Survey* 25(2):65.

Yetka, L.A., 1998. Effects of planting season and hydrology on establishment and growth of sedge rhizomes in a restored wetland. Univ. of Minnesota (Master’s Thesis).

Zhang, J. and M. A. Maun, 1990. Effects of sand burial on seed germination, seedling emergence, survival and growth of *Agryopyron psammophilum*, *Canadian Journal of Botany* 68:304.

Zwack, J. A., and W. R., Graves, 1999. Variation Among Red and Freeman Maples in Response to Drought and Flooding. *HortScience* 34(4):664-668.

YELLOW
CONEFLOWER