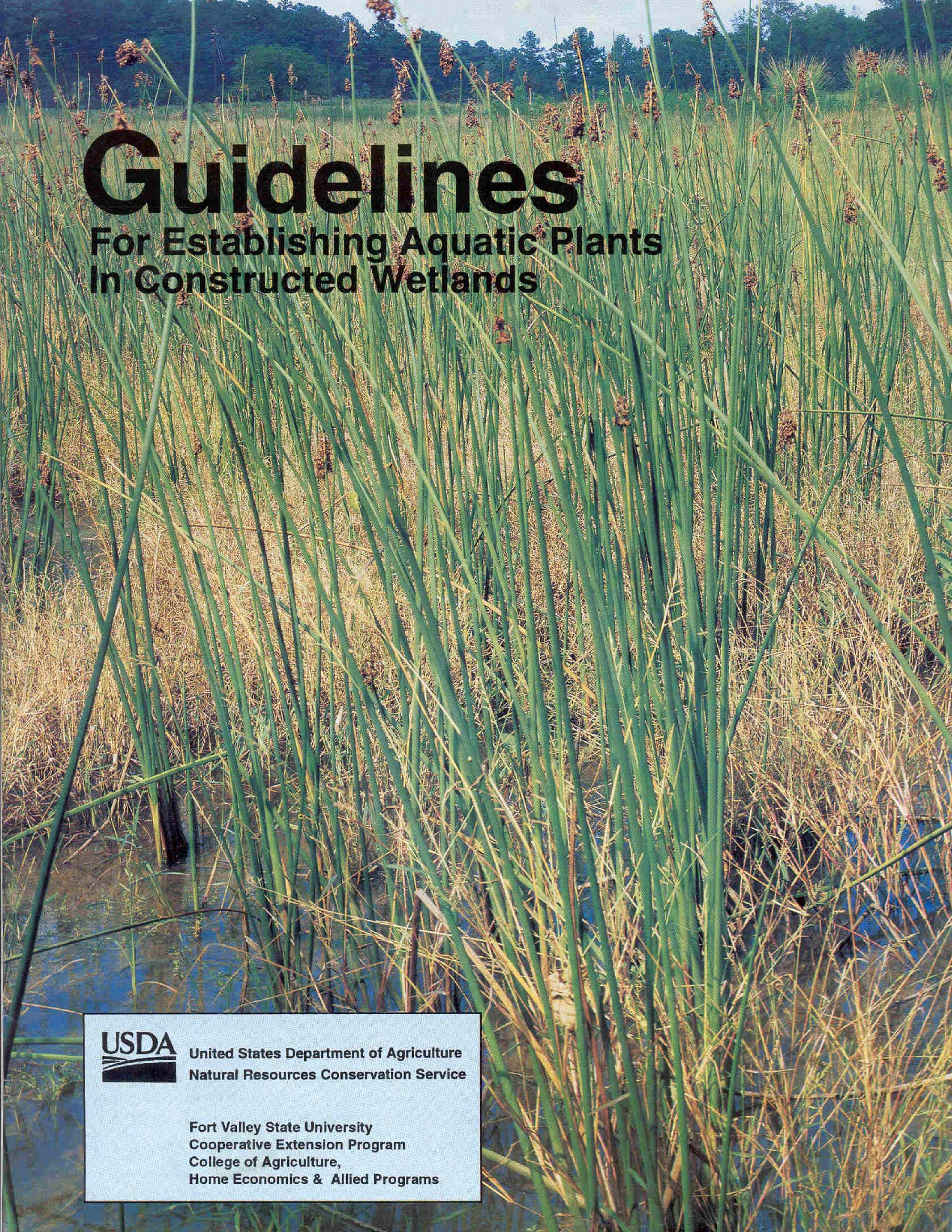

Guidelines

For Establishing Aquatic Plants In Constructed Wetlands

USDA
United States Department of Agriculture
Natural Resources Conservation Service

Fort Valley State University
Cooperative Extension Program
College of Agriculture,
Home Economics & Allied Programs

Guidelines for Establishing Aquatic Plants in Constructed Wetlands

INTRODUCTION

The use of constructed wetlands to treat agricultural and municipal nonpoint sources of pollution and their potential for treating animal wastes is a rapidly emerging biotechnology. The vegetative component is a major factor in the function of constructed wetlands, yet there is limited technical information available on the selection of plants adapted for systems to treat agricultural wastes.

Recent evaluations reflect a growing concern over non-point source (NPS) pollution, especially agricultural wastewater, agricultural cropland runoff, and urban stormwater runoff. These principal contributors to NPS pollution problems have been difficult to remedy with conventional wastewater treatment and soil and water conservation methods.

NPS pollution from agricultural and urban areas, failed home septic tank drain fields, and mining and other land disturbing activities detrimentally impact 30-50 percent of our nations' waterways. Constructed wetlands have recently received considerable attention as low-cost, efficient means to clean up many types of waste-water. Contaminated waters flowing through constructed wetlands are cleansed by a combination of physical, chemical, and biological activities and emerge as clean water (Hammer, 1990).

The vegetative component is a major factor in the waste treatment processes that occur in constructed wetlands. The principal function of vegetation in constructed wetland systems is to create additional environments for microbial population (Pullen and Hammer, 1989). The stems and leaves in the water column obstruct flow and facilitate sedimentation, and provide substantial quantities of surface area for attachment of microbes and constitute thin-film reactive surfaces. Plants increase the amount of aerobic microbial environment in the substrate.

***Figure 1**—(From left) Leverette Blankenship, of the Alabama Department of Public Health, and Donald Surrency, Georgia NRCS Plant Materials Specialist, examine a residential constructed wetland (rock reed filter) for a failed septic system in Alabama. In urban areas, Iris' are used to provide treatment as well for beautification.*

Wetland vegetation also increases the amount of aerobic environment available for microbial populations, both above and below the surface. Wetland plants transport oxygen from the leaves through the stem to the roots. Radial oxygen loss from the roots creates an oxidized zone in the soil immediately surrounding them. Wetland vegetation also traps sediment and removes nutrients and pollutants from the water column and soil. Wetland plants produce more biomass per acre than any other species group and export huge quantities of detritus to aquatic systems, providing direct benefits to the food chain.

Microbes play a major role in the transformation of substances critical to all life on earth. In wetlands, the population of microbes in the substrate shifts from aerobic species near the surface to anaerobic species as depth increases. Aerobic microbes also continue to function in the thin, oxygen-rich zone called the rhizosphere surrounding the roots of wetlands vegetation and at the water surface. Mycorrhizial fungi are beneficial microbes that facilitate nutrient uptake, reduce stress, enhance salt and contaminant tolerance, and enhance the initial survival and growth of wetland plants.

In 1989, the Americus Georgia Plant Materials Center of the Natural Resources Conservation Service, formerly the Soil Conservation Service, evaluated an assembly of aquatic plant species for potential use in constructed wetlands and to expand constructed wetlands technology.

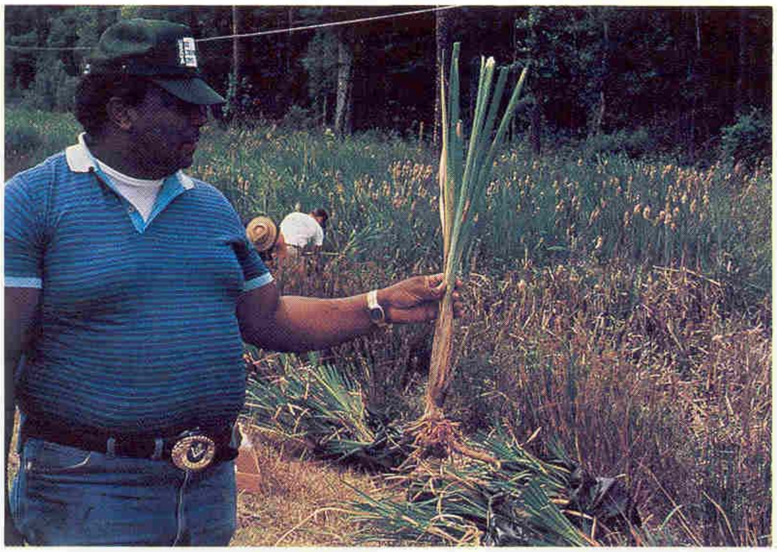

Figure 2—Harvest wetland plants near the site when commercial plant materials are unavailable.

Plants were assembled and evaluated in constructed wetland projects treating wastewater from a swine operation, a dairy operation, catfish production ponds, and a small municipality in southwest Georgia. These projects focused on obtaining information about plants which would grow under different hydrological and substrate conditions in the southeast. In addition, these projects were designed to determine which plants possess the most appropriate attributes for wastewater treatment. The following characteristics were noted and tested: planting methods, depth of planting, spacing by species, tolerance to ammonia, physical and chemical parameters of the effluent, vegetative techniques, site preparation, selection of species, sources of plant materials, planting techniques and equipment, water level management, and operations and maintenance requirements of aquatic species.

Based on these field evaluations, this publication offers guidelines for establishing aquatic plants in constructed wetlands in the southeast.

SELECTING WETLAND PLANT MATERIALS

Constructed wetlands should be planted with emergent vegetation. Selection of species appropriate to project goals is important since the plants in wetland systems provide the basis for animal life, as well as conduct important hydrologic buffering and water purification functions.

Hydrologic Consideration

Water depth, duration, seasonality, and frequency or periodicity of flooding are important in determining plant species appropriate for use in a constructed wetlands system. Water depth causes different vegetation zones in a wetland because deeper water may restrict oxygen from reaching the substrate. Water depth may also influence the degree of light penetration and photosynthesis.

Nutrient Tolerance

Physical and chemical parameters of animal waste lagoon wastewater can affect the survival and growth of wetland plant species. Therefore, constructed wetlands must be a planned component of the total animal waste treatment system. Knowledge of the nutrient concentrations of animal waste lagoons is important for selection of the most tolerant plant species for constructed wetlands that will be used to treat dairy, swine, and poultry waste water. It is essential to collect samples of the lagoon effluent and determine the water chemistry for Biological Oxygen Demand (BOD), pH, ammonia, and suspended solids in older lagoons as part of the planning process. A multi-cell system of three or four cells in a series provides the best reduction of effluent from the animal lagoon. Based on four years of field evaluations in Alabama and Georgia, appropriate plant selection for multi-cell constructed wetlands with high ammonia concentrations consists of the following:

Cell 1	Cell 2
Bulrush	Bulrush
Giant Cutgrass	Giant Cutgrass
	Cattail

Cell 3	
Bulrush	Giant Cutgrass
Cattail	Maidencane
Canna Lily	Pickerelweed
Prairie Cordgrass	Blue Flag Iris
Arrowhead	Common Reed

Failed Septic Systems

The species listed below can be selected as the primary plants for establishment in the center of the residential constructed wetland.

1. 'Halifax' maidencane (*Panicum hemitomon*)
2. 'Flageo' marshhay cordgrass (*Spartina patens*)
3. Dwarf cattail (*Typha laxmanni*)
4. Green taro (elephant ear) (*Colocasia esculenta*)
5. Arrowhead (*Sagittaria latifolia*)
6. Arrowhead (*Sagittaria lancifolia*)
7. Softrush (*Juncus effusus*)
8. Cattail (*Typha latifolia*)
9. American bulrush (*Scirpus americanus*)
10. 'Restorer' giant bulrush (*Scirpus californicus*)
11. Smooth cordgrass (*Spartina alternifolia*)
12. Soft rush (*Juncus coriaceous*)

Decorative Species

The following is a list of flowering and decorative species that can add aesthetic value to the landscape, especially around the perimeter of the cells:

1. Canna lily *(Canna spp)*
   - orange canna
   - red canna
   - yellow canna
2. Iris:
   - purple (*Iris tridentata*)
   - blue water iris (*Iris versicolor*)
   - yellow water iris (*Iris pseudacorus*)
3. 'Sumter Orange' Daylily (*Hemerocallis fulva)*
4. Sweetflag (*Acorus calamus*)
5. Dwarf Japanese rush (*Acorus gramineus*)
6. Spider lily/swamp lily (*Crinum americanus*)
7. Cardinal flower (*Lobelia cardinalis*)
8. Red root (*Lachnanthes caroliniana*)
9. Swamp rose mallow (*Hibiscus moscheutos*)
10. Halberd leaved marshmallow (*Hibiscus militaris*)
11. Marshmallow (*Hibiscus coccineus*)
12. Spider lily (*Hymenocallis spp.*)

In constructed wetland studies at Eatonton, Georgia, Restorer Giant Bulrush (*Scirpus californicus*), a newly released plant variety, survived ammonia concentrations greater than 200 mg/l for extended periods. Ammonia tolerance is one of the main characteristics for selecting plants to treat swine and dairy waste water in constructed wetland systems.

Soils

A detailed soil survey report should be prepared for the site. Soils at the site of the proposed wetland must be assessed for overall suitability. Water-holding capabilities are influenced by soil texture, which will determine length of inundation. Organic matter and pore size distribution are also important. Clays and loams generally retain moisture longer than sands and sandy loams. The coarse textured soils may result in having "drier" plant communities, depending on water level. The soil's general ability to support biological functions should be considered, as well as the limitations of the soils for establishing the desired plants. The soil survey or soils information located in Section II of the Field Office Technical Guide (FOTG) provide interpretations for wetland vegetation.

Excessive seepage losses in constructed wetlands usually result from selecting a site where the soils are too permeable to retain enough water for the planned function. This may be the result of inadequate site investigations in the planning stage. Plans for reducing seepage losses by sealing should be part of the design. The problem of reducing seepage losses is one of reducing the permeability of the soils to a point where the losses become tolerable. Losses may be reduced by methods such as compacting of onsite soil materials, clay blankets, bentonite, chemical additives, and flexible membranes.

Substrate

Many substrates are suitable for wetland establishment. Loamy soils are especially good because they are soft and friable, allowing for easy rhizome and root penetration. But fine-textured soils such as clay may limit root and rhizome penetration.

Site excavation for wetland establishment is likely to expose a subsoil that may not be as conducive to plant growth as the topsoil. Clays and gravels frequently underlying more favorable soils may be sufficiently dense or hard to inhibit root penetration, may lack nutrients found in topsoil, or may be impermeable to water needed by roots.

The substrate compaction will greatly affect herbaceous plant survival. It will also affect the development and rate of spreading of the root system. Substrates that are compacted should be deconsolidated by plowing, disking, rototilling, or ripping as part of the construction plans and specification. Substrates to be planted to herbaceous plants should be deconsolidated to depths of 4 to 6 inches.

Topsoil Stockpiling/Soil Amendments

It is strongly recommended that the original topsoil excavated from the constructed wetland be stockpiled for later use as a soil amendment in

Figure 3—Commercial nurseries in the region are gearing up to meet the demand for wetland plants. (Refer to Table 1 for a list of commercial sources.)

Figure 4—A mechanical pine tree planter is used to plant wetland plants—such as, bulrush, maidencane, cutgrass, and cattail—for large constructed wetland systems.

the buffer area. A 3-inch or 6-inch amendment of topsoil over the buffer will provide the necessary nutrients and organic matter.

SOURCES OF WETLAND PLANT MATERIALS

Wetland plants can be purchased from commercial nurseries, collected in the wild, or grown for a specific project. Each method has distinct advantages and disadvantages regarding quality of material, availability of plants, and cost for acquisition and planting.

The primary advantage of commercially supplied plants is quantity availability and site delivery in a suitable planting condition. This reduces logistical problems in procuring plants, but the buyer of large quantities should arrange to have material supplied in several smaller shipments coordinated with planting activities. Reducing storage time at the planting time will reduce plant mortality.

Commercial suppliers carry only a limited number of species, and there is a natural tendency to plan wetland plantings around that supply. Nursery supplied plants are also genetically and physiologically adapted to their growing site and may be difficult to establish and maintain at locations with different edaphic and climatic characteristics. When selecting a nursery, avoid large latitudinal distances between plant source and destination; longitudinal variation is more acceptable. Finally, plants that have been packaged, shipped, and stored before planting may be stressed at time of planting. Post-nursery care of wetland plants is very important during the interval between delivery of the plants and subsequent planting. These plants are prone to desiccation and should be frequently watered and shaded while on site. Commercial nurseries that produce wetland plant materials for constructed wetlands are listed in **Table 1**.

Planting considerations include not only the specifics of actual wetland planting, such as equipment, planting depth, and plant spacing, but also pre-planting concerns, such as time of planting and site preparation.

Time of Planting

Time of planting is regionally specific, but is critical to the initial survival of the new wetland. Regional planting times are well known by local specialists. Losses from heat stress and drought will occur when bareroot stock is planted in the hot summer months.

The transplanting window for Alabama and Georgia extends from early April to mid-June. Planting after these dates is quite chancy, as emergent wetland plants need a full growing season to build the root reserves needed to get through the winter. The plants should be ordered at least six months in advance to ensure the availability of desired species.

Site Preparation

Once the wetland area has been shaped and graded, the site should also be disked, harrowed, and otherwise prepared for planting root stock or seedlings. Depending on the planned species and water level management, it is often a good idea to release water onto a site to facilitate soil setting prior to planting, especially where slopes are critical. This can aid in the prevention of high spots and possible vegetation loss.

Wetland Planting

Seedbed preparation and planting in wetlands generally do not require specialized equipment. In most cases, standard farming equipment (tractors, disks, harrows, etc.) can be used in a wetland, depending upon the firmness of the substrate and on whether or not the water source is fully applied to the site at the time of planting.

Modified tree planters can be used for bareroot wetland tree and shrub species. In wetlands where the soil is saturated at the time of planting, the commercially available tracked or light equipment is suitable for planting such sites. In soft substrates where transplanting of plant materials is required, hand planting with dibbles has been found to work quite well.

Wetlands are generally planted with whole plants or dormant rhizomes and tubers. Establishment from seed typically has not been successful because of stratification requirements of wetland seed.

Constructed wetland cells in Putnam County, Georgia, were planted with regular tree dribbles manually and with a one row tractor-drawn tree planter. Tree planters can be used on large sites to transplant giant cutgrass, giant bulrush, cattail, maidencane, pickerelweed and canna lily. Plant materials should be planted deep enough to prevent propagules from floating out of the planting hole. Planting densities vary with target operating dates and species used. In the southeast, a 3-4-foot spacing for most herbaceous plants provides a good stand in about four to six weeks, with excellent coverage in eight to ten weeks. Giant cutgrass is a vigorous spreader and propagates easily from the nodes on 6-8- foot centers and should obtain a dense stand in a relatively short period.

Table 3, the recommended plant spacing by species for constructed wetlands, is based on four years of data that was obtained by evaluating the plant growth and rate of spread in actual constructed wetland con-ditions in Alabama and Georgia[6].

POST-PLANTING WATER LEVEL MANAGEMENT

Proper water depth and its careful regulation are the most critical factors for plant survival during the first year of planting. New plantings can fail because of mistaken concepts that wetland plants need or can survive in deep water. Small, new plants lack extensive root, stem, and leaf systems with aerenchyema channels to transport oxygen to the roots. Consequently, flooding can cause more problems for wetland plants during the first growing season than too little water, especially if the wastewater has low dissolved oxygen content. After the constructed wetland cells are planted, the subtrate should be saturated with pond water to about 1-inch for four to five weeks. After the sixth week, or when the submergent plants show new and vigorous growth, water levels should be slowly and gradually increased to support erect, upright growth forms. The plants should be allowed to become established before wastewater effluent from the animal waste lagoon is discharged into the constructed wetlands. The lagoon effluent can be applied to the existing water in cells to acclimate the plants to the increased nutrient load. It is absolutely essential that the stems and leaves of desirable species are above the water surface to avoid drowning new or even older established plants, but water levels should never be lowered to expose plant roots. Dry cell conditions, or not enough water, will result in poor survival.

It is important to the survival of the vegetation to design the system with little or no slope on the substrate and with easily maintained water control structures that precisely regulate elevations. Water level management must create very similar water depths and duration of flooding throughout the newly planted area, and must precisely maintain the level despite fluctuating inflows. Many new plantings have been lost because stormwater inflows could not be discharged rapidly enough to avoid overtopping and drowning small plants. The inability to drain the entire area on schedule due to undersized control structures or uneven substrates will cause spotty areas of poor growth and mortality.

Water levels can be manipulated to control prolific growth and spread of weedy plants. For example, cattail may be controlled by deep flooding for several weeks during the growing season after the stems have been cut. Flooding may also inhibit establishment of undesirable opportunistic species.

Figure 5*—Post planting water level management is critical for wetland plant survival during the first year of establishment.*

Figure 6—Hand planting with a tree dibble can be successful for planting residential systems and small municipal systems.

OPERATION AND MAINTENANCE

Since system hydrology is the most important and most easily manipulated factor, maintaining control and monitoring system inflows, outflows, and water levels is essential to managing the new wetland. Insuring integrity of dikes, berms, spillways, and water control structures should be a regularly scheduled activity. Each of these components should be inspected at least weekly and immediately following any unusual storm event. Any damage, erosion, or blockage, should be corrected as soon as possible to prevent the need for expensive repairs.

During start-up of the constructed wetland system it is important to determine and record the flooding frequency, duration, and extent of coverage. This is basically the frequency and time periods that the water surface elevation is above the elevation of the wetlands substrate in any part of the system. Surface water elevations, determined from a staff gauge or recording graph, are related to substrate elevations on the "as built" topographic map to calculate flooding depth, frequency, and duration of flooding in each area and the volume of the water in the wetland. The latter is useful in predicting the time needed to flood the system to a certain elevation with a given rate of inflow or to water it with available discharge rates.

Vegetative cover on dikes and spillways should be maintained by mowing and fertilizing as needed. Frequent mowing encourages grasses to develop good ground cover.

Regardless of the care taken during the initial planting of the wetland and buffer it is possible that some areas may remain unvegetated and some species may not survive. Poor survival can result from many unforeseen factors, such as predation, poor plant stock, changes in water levels, drought, and many other unpredictable factors. Thus, it is advisable to plan and budget for an additional round of reinforcement plantings after one or two growing seasons. The records on wetland plant species distribution, collected during routine inspections, is invaluable to guide plant selection for the reinforcement planting.

Muskrats and other burrowing animals can damage dikes and spillways, and unrepaired burrows may lead to dike failure. If wire screening was not installed in the dikes, a thick layer of gravel or rock over trouble spots may inhibit burrowing. However, if damage continues, trapping and shooting may be needed for temporary relief until wire screen can be installed. Burrows are most easily eliminated by setting explosive charge from the top of the dike to collapse the network of tunnels and then filling the subsequent crater with compacted clay. Fences, pathways, roadways, and visitor facilities should be inspected concurrent with the weekly dike inspections and repaired as necessary. Pesticide or other chemicals should not be used unless extreme circumstances warrant use, in which case care is necessary to avoid damaging the system. This also applies to insecticides, since heavy applications of insecticides have damaged emergent vegetation in some wetlands.

Livestock grazing may cause serious damage to wetland vegetation, especially during the early years when plants are becoming established. Rubbing and loafing beneath shrubs and trees often damage new growth and accelerates erosion, exposing roots and causing mortality. Perimeter fencing may be required if livestock are anticipated to be a problem.

The maintenance area around the aquatic site should be mowed twice a year to prevent woody growth. All remaining areas can be managed as a wet meadow or forest.

REFERENCES

1. Hammer, Donald A. 1992. *Creating Freshwater Wetlands.* Ann Arbor: Lewis Publishers.

2. Surrency, Donald, "Selection and Evaluation of Plants for Constructed Wetlands." *Proceedings of Constructed Wetland Symposium, Ohio State University.*[12]

Plants for Tomorrow, Inc.
16361 Norris Road
Loxahatchee, Florida 33470
Phone: (407) 790-1422

Woodland Farms
Rt. 1, Box 221
Bod Godfrey Road
Arnoldsville, Georgia 30619
Phone: (706) 742-7538
Fax: (706) 742-7538

Okefenokee Growers
Post Office Box 4488
Jacksonville, Florida 32201-4488
Phone: (904) 356-4881
Fax: (904) 356-4884

Suncoast Native Plants
Post Office Box 248
Palmetto, Florida 33561
Phone: (813) 729-5015

Horticultural Systems, Inc.
c/o Otto Bundy, Sr.
Post Office Box 70
Parrish, Florida 34219
Phone: (813) 771-4114/4115

Environmental Concern
210 West Chew Avenue
Post Office Box P
St. Michaels, Maryland 21663
Phone: (301) 745-9620

Note: *This vendor list is not exhaustive nor does it imply an endorsement of any particular nursery.*

AQUA-Tech Farms
462 Juniper Street
Neeses, South Carolina 29107
Phone: (803) 247-5697
Fax: (803) 247-5697

Flowerwood Nursery, Inc.
Post Office Box 665
Loxley, Alabama 36551
Phone: (205) 964-5122
Toll Free: 1-800-356-9368
in Alabama
1-800-858-3521 Outside

Spandle Nurseries
Highway 301 South
RFD 2, Box 125
Claxton, Georgia 30417
Phone: (912) 739-1598
or 1-800-553-5771
Fax: (912) 739-2701

TABLE 2. Maximum Water Depths For Emergent Wetland Plant Species

Emergent Wetland Species	Maximum Depth
A. Primary Species	
Giant bulrush *(Scirpus californicus)*	12 inches
Softstem bulrush *(Scirpus validus)*	12 inches
Giant cutgrass *(Zizaniopsis miliacea)*	12 inches
B. Secondary Species	
Halifax maidencane *(Panicum hemitomon)*	12-18 inches
Cattail *(Typha latifolia)*	12 inches
Arrowhead *(Sagittaria lancifolia)*	6-8 inches
Common reed *(Phragmites australis)*	6-10 inches
Water chestnut *(Eleocharis dulcis)*	6 inches
Juncus effusus	6 inches
Smooth cordgrass *(Spartina alterniflora)*	6 inches
Prairie cordgrass *(Spartina pectinata)*	6 inches
C. Exotic Species Aesthetics and Beautification	
Canna lily *(Canna flaccida)*	6 inches
Pickerelweed *(Pontederia cordata)*	6 inches
Blue flag iris *(Iris virginica)*	3 inches

Note: *These depths can be tolerated, but plant growth and survival may decline under permanent inundation at these depths. Primary species are rapid colonizers; secondary species do not spread as rapidly.*

TABLE 3. Recommended Spacing For CWS

Plant Materials	Spacing
Maidencane	3' x 3'
Giant cutgrass	6' x 6'
Prairie cordgrass	3' x 3'
Common reed	3' x 3'
Water chestnut	3' x 3'
Giant bulrush	4' x 4'
Cattail	3' x 3'
Elephant ear	3' x 3'
Blueflag iris	3' x 3'
Canna lily	3' x 3'
Arrowhead	3' x 3'
Smooth cordgrass	3' x 3'

Figure 7*—In 1989, an assembly of emergent wetland plants was evaluated for constructed wetlands to treat swine waste at the Sand Mountain Experiment Station in Alabama. This was the first time emergent wetland plants were tested for constructed wetland use in the Southeast. Selected plants from this study were also recommended for municipal constructed wetlands.*

Figure 8—Restorer giant bulrush, Wetlander giant cutgrass, and Halifax maidencane were planted in constructed wetlands for treating nitrates in catfish production ponds in the Blackbelt Area of Alabama.

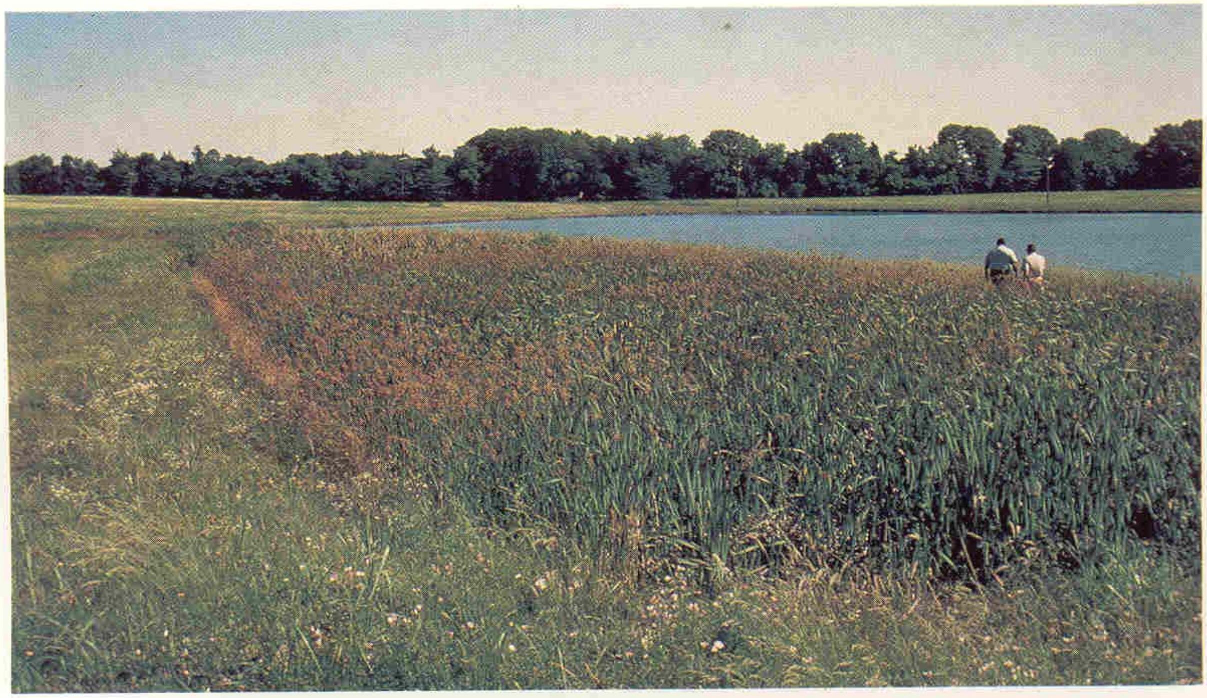

Figure 9—Restorer giant bulrush, (blue flag iris, canna lily along water level) planted in a municipal constructed wetland located in Lakeland, Georgia.

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