Southern University Educational Urban Forest

[Report Appendices]

March, 2014

Report prepared for Southern University's Urban Forestry Program

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March 2014

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[Report Appendices]

A - State of Louisiana Related Information

Conservation, Protection and Utilization of Louisiana's Coastal Wetland Forests

Final Report to the Governor of Louisiana from the

Coastal Wetland Forest Conservation and Use Science Working Group

April 30, 2005

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CONSERVATION, PROTECTION AND UTILIZATION OF LOUISIANA'S COASTAL WETLAND FORESTS

EXECUTIVE SUMMARY

Louisiana's coastal wetland forests are of tremendous economic, ecological, cultural, and recreational value to residents of Louisiana, the people of the United States, and the world. Although some two million acres of forested wetland occur throughout Louisiana, over half are in the coastal parishes. Large-scale and localized alterations of processes affecting coastal wetlands have caused the complete loss of some coastal wetland forests and reduced the productivity and vigor of remaining areas. This loss and degradation threatens ecosystem functions and the services they provide.

In response to the continuing loss and adverse impacts to Louisiana's coastal wetland forests, the Governor commissioned the formation of the Coastal Wetland Forest Conservation and Use Science Working Group (hereafter referred to as SWG). The mission of the SWG was to provide information and guidelines for the long-term utilization, conservation, and protection of Louisiana's coastal wetland forest ecosystem, from both environmental and economic perspectives. To accomplish this mission the following objectives were developed:

1) Gather and synthesize scientific information available on regeneration, growth, and potential harvesting effects on coastal wetland forests.

2) Gather and summarize field information on general characteristics of previously harvested baldcypress and tupelo forest stands to evaluate their potential to regenerate, become established, and remain vigorous.

3) Review existing laws, regulations, policy, and guidelines affecting coastal forestry activities (and current forest conditions).

4) Develop science-based, interim guidelines for the conservation and utilization of coastal wetland forests.

5) Identify critical areas of priority research needed to refine these interim guidelines.

The SWG developed this report to address these objectives. To emphasize the most important points of the report, the SWG developed a set of Findings and Recommendations. These are presented here with a summary of supporting information from the body of the report.

Findings

1) Louisiana's coastal wetland forests are of tremendous economic, ecological, cultural, and recreational value to residents of Louisiana and the people of the United States and the world; and include:

- **wildlife habitat (including migratory songbirds/waterfowl, threatened and endangered species),**
- **flood protection, water quality improvement (including nitrate removal), and storm protection,**
- **carbon storage and soil stabilization,**
- **economic benefits of fishing, crawfishing, hunting, timber production, and ecotourism**

The importance of these forests is derived in part from the unusual deltaic landscape they occupy. Most coastal wetland forests in Louisiana are a product of the Mississippi River and therefore experience natural development and degradation cycles as do most coastal marshes. The delta cycle can be seen as a balance between the forces that lead to formation and maintenance of wetlands (mainly riverine input) and the forces that lead to loss (subsidence and saltwater intrusion). This contributes to their global significance and adds to the impetus to develop appropriate management strategies.

Wetland functions are the physical, chemical, and biological processes that sustain the wetland ecosystem, irrespective of any interaction with humans, and can be broadly grouped into biotic, hydrologic, and biogeochemical functions. The most important functions of coastal wetland forests are biogeochemical nutrient transformations (wetlands are uniquely suited to mitigate the negative impacts of nonpoint source pollution), flood storage, and maintenance of characteristic plant communities for wildlife habitat and timber production. The important fish and wildlife habitat functions include habitat for threatened species (e.g., Louisiana black bear, bald eagle) and economically important species (e.g., crawfish and waterfowl). Millions of landbirds, including virtually all of the eastern neotropical migrant landbird species in the United States and numerous species from the western United States, migrate through the coastal forests of Louisiana during spring and fall migration. Dozens of wading bird rookeries and over one hundred bald eagle nests are located in Louisiana's coastal forests. In addition, two of three subpopulations of the Louisiana black bear use these forests. It is generally understood that the actual value of any particular tract is dependent upon the animal species of interest and numerous forest characteristics, including geographic location and size of the forest stand, connectivity to the adjacent forest stands and habitats, landscape composition, hydroperiod, vertical structure, tree sizes and species composition. Direct forest loss as a result of conversion of forest to open water or marsh would obviously be highly detrimental to species dependent upon coastal wetland forests. More subtle habitat changes, such as alterations in forest structure and composition and increased flood depth and duration, are also significant threats to many wildlife species.

The landscape position and biogeochemical properties of coastal wetland forests give them both the opportunity and mechanisms to alter pollutant loadings to aquatic ecosystems. While nutrient loading can have detrimental effects on natural wetlands, Louisiana's coastal wetland forests are sediment and nutrient deprived as a result of the Mississippi River levee system and are experiencing significant habitat loss. Under these conditions, the addition of nutrients and sediments is the only way for these ecosystems to maintain their surface elevation relative to sea-level rise.

Ecosystem services are the benefits that humans and society derive from the functions of an ecosystem and the value of these services can be quantified. There are few data on the value of the specific ecosystem services provided by coastal wetland forests and it is beyond the scope of this effort to develop accurate estimates specifically for these wetlands. We can derive a rough estimate from the scientific literature of $7,927 per acre per year for swamps and floodplains multiplied by the estimated 845,692 acre of swamp forest area for a total value of $6.7 billion per year. Based on current stumpage volume and price, the value of the standing cypress-tupelo timber in the area delineated by the SWG has been estimated by the Louisiana Department of Agriculture and Forestry to be $3.3 billion.

2) The functions and ecosystem services of Louisiana's coastal wetland forests are threatened by both large- and small-scale hydrologic and geomorphic alterations and by conversion of these forests to other uses.

- **Subsidence, sea-level rise, and levee construction are the large-scale hydrologic and geomorphic alterations responsible for the loss of Louisiana's coastal wetland ecosystems including coastal wetland forests. Since Louisiana's coastal wetland forests are nutrient deprived as a result of the Mississippi River levee system, addition of nutrients and sediments is the only way for these ecosystems to maintain their surface elevation relative to sea-level rise.**
- **The cumulative effects of small-scale or local factors can be of equal or greater importance in coastal wetland forest loss and degradation than large-scale alterations. These factors include increased depth and duration of flooding, saltwater intrusion, nutrient and sediment deprivation, herbivory, invasive species, and direct loss due to conversion. Causal agents include highways, railroads, channelization, navigation canals, oil and gas exploration canals, flood control structures, conversion of forests to urban and agricultural land, and non-sustainable forest practices.**
- **Under less severe impacts, many of the important functions and ecosystem services are lost or degraded even though the trees may be intact and the forest may appear unaffected.**
- **Without appropriate human intervention to alleviate the factors causing degradation, most of coastal Louisiana will inevitably experience the loss of coastal wetland forest functions and ecosystem services through conversion to open water, marsh, or other land uses.**

A number of factors have led to the massive loss of coastal wetlands in Louisiana. Foremost among these are flood-control levees along the Mississippi River that resulted in the elimination of riverine input to most of the delta and contributed to wetland loss. Hydrological disruption via control of rivers has reduced freshwater and sediment inputs, while canal construction has led to much greater saltwater intrusion into coastal wetlands. Increasing water levels resulting from eustatic sea-level rise and subsidence are also major degradation factors. Without the annual flood of new sediments, subsidence exceeds sedimentation in many areas, and most of coastal Louisiana is presently experiencing an apparent water level rise of about 3.3 feet per century. These detrimental, large-scale processes have been seriously increased by management practices and societal infrastructure that have also altered and degraded ecosystems.

As water levels continue to rise, the coastal forests will be subjected to more prolonged and deeper flood events. Even though many of the forest species growing in these areas are adapted to prolonged inundation, extended flooding during the growing season can cause mortality of these tree species. Already many of the trees in these areas are showing evidence of severe stress. Even baldcypress and water tupelo, two of the dominant species in Louisiana's coastal forests, slowly die when exposed to prolonged, deep flooding of longer than normal duration and regeneration of new trees cannot occur under flooded conditions. Together, these impacts are so substantial that total loss of wetland forests is nearly assured in most of coastal Louisiana without active measures to ameliorate problems.

The Barataria, Lake Verret, and Lake Pontchartrain basins, located in south central and southeastern Louisiana, contain extensive freshwater wetland forests. There are approximately 242,000 acres of seasonally (mostly permanently) flooded forests and wooded swamps in the Barataria Basin, 101,000 acres in the Verret Basin, and 213,000 acres in the Pontchartrain Basin. All of these watersheds were once overflow basins of the Mississippi or Atchafalaya rivers. With the construction of the flood protection levees along these rivers in the 1920-1940s, the only source of freshwater presently is rainfall or backwater flooding. When these areas received riverine input, sediment deposition served to offset apparent water level rise due to land subsidence. With the cessation of sediment input, regional subsidence is leading to increased flooding of these areas. Water levels in the Barataria, Lake Verret, and Pontchartrain basins historically followed a seasonal pattern of flooding and drying with the extent of flooding depending on the elevation of the site and seasonal water budget. Barataria and Verret basins have experienced significant increases in the total number of days flooded per year. In Barataria Basin, the swamps have always been flooded to some extent, but forests are now flooded almost year round. Even during dry periods such as 1981 and 1985-1986, these forests were rarely free of standing water. Since the 1950s, flood water levels in the swamps of the Pontchartrain Basin have doubled. If water levels continue to rise, coastal forested areas will eventually be replaced by scrub-shrub stands, marsh, or open water.

3) Regeneration is a critical process of specific concern in maintaining coastal wetland forest resources. Successful natural regeneration of this resource in the 1920s was due to fortuitous conditions existing at that time. Currently, there is a lack of regeneration in coastal cypress-tupelo forests that is a direct result of factors identified above and their interactions with regeneration processes.

Baldcypress and water tupelo are the primary tree species in the coastal swamp forests of Louisiana. Consistent mast crops do not occur in either species until trees are about 30 years old. Baldcypress trees will generally produce seed every year, but larger seed crops occur every three to five years. However, baldcypress seeds cannot germinate in standing water, and seedlings must grow tall enough during short drawdown periods for their crowns to extend above the water surface to survive flooding during the growing season. Baldcypress seedlings can withstand complete inundation for up to 45 days, but long-term flooding above the foliage results in high mortality. Baldcypress is exacting in its needs, but regenerates well in swamps where there is ample sunlight and the seedbed is moist but not flooded during the time period of seed germination and seedling establishment.

Changes in hydrology have reduced regeneration in many stands even though overstory trees may still be thriving. Ultimately, the lack of regeneration will eliminate forest cover. When favorable conditions for germination and seedling growth do not immediately precede or follow a regeneration harvest, stand regeneration can only occur through artificial regeneration. In places where flooding is sufficiently persistent and deep, even artificial regeneration is not possible. For example, natural regeneration of baldcypress was poor to non-existent in south Louisiana swamps following logging operations in the 1980s, mainly because the land remained flooded for much of the year.

Herbivory is another problem that has long existed in Louisiana's swamps, and directly affects regeneration. One of the most important agents of this problem is the nutria, which has become firmly established throughout the coast since the 1950s. Nutria often clip or uproot newly planted baldcypress seedlings before the root systems are fully established, thus destroying the whole seedling. Several alternatives have been proposed to prevent nutria from eating newly planted baldcypress seedlings. Reducing nutria is one alternative to the problem, but this method is expensive.

The strict requirement for seedling establishment and pervasive seedling herbivory together dictate that management of coastal wetland forests hinges in large part on ensuring regeneration. Managing forested wetlands for timber production is generally difficult because of the periodic to continuously flooded nature of these sites. Although there is some knowledge regarding silvicultural practices for the drier end of the forested wetlands continuum (e.g., wet pine flats and moderately well drained to poorly drained bottomland hardwoods), there has been little research into optimum silvicultural practices for wet sites. It has been suggested that baldcypress and tupelo stands should be managed on an even-aged basis because of the characteristics of the species, the nature of the existing stands, and the sites they inhabit. The most common regeneration method used for this purpose with other species is clearcutting when stems reach the desired size. Residual stems should be removed or deadened to limit competition on natural or planted seedlings.

4) In those areas where flooding prevents or limits the natural regeneration of the cypress-tupelo forest, artificial regeneration through tree planting is the only

currently viable mechanism to regenerate the forest. Some swamps are altered to such a significant extent that even artificial regeneration is not possible. Coppice or stump sprouting does not provide sufficient numbers of viable trees to reliably regenerate the forest, even under optimum conditions.

Because of the exacting requirements for germination and establishment and the variable success of stump sprouting, planting of baldcypress and water tupelo is likely necessary in many areas to ensure adequate stocking of future stands. Innovative planting methods are often required for forested wetland sites because of standing water, unconsolidated or organic substrates, and herbivory. Habitats planted have ranged from standing, stagnant water to flowing water in coastal to inland sites of Louisiana and South Carolina. Bareroot seedlings of baldcypress and water tupelo have been successfully planted under flooded conditions.

5) Conditions affecting the potential for forest regeneration and establishment are recognizable based upon existing biological and physical factors. The SWG has developed a set of condition classes for the dominant wetland forest type, in Louisiana's coastal cypress-tupelo forests. All references to flooding depths or durations assume average rainfall conditions, not extreme or unusual events. Sediment input is generally beneficial, but in localized situations, excessive levels can prevent or prohibit natural or artificial regeneration under SWG Condition Classes I and II. The SWG Cypress-Tupelo Coastal Wetland Forest Regeneration Condition Classes are:

<u>SWG Condition Class I:</u> Sites with Potential for Natural Regeneration

These sites are generally connected to a source of fresh surface or ground water and are flooded or ponded periodically on an annual basis (pulsing). They must have seasonal flooding and dry cycles (regular flushing with freshwater), usually have both sediment and nutrient inputs, and sites in the best condition are not subsiding. These sites have some level of positive tree growth, thereby providing increasing or stable biomass production, organic input, and experience re-charge of water table after drought periods. Sites in this category that are subject to increasing flood frequency, increased flood duration, or increasing flood water depths may eventually move into the next lower category unless action is taken to remedy these detrimental conditions.

<u>SWG Condition Class II:</u> Sites with Potential for Artificial Regeneration Only

These sites may have overstory trees with full crowns and few signs of canopy deterioration, but are either permanently flooded (which prevents seed germination and seedling establishment in the case of baldcypress and tupelo) or are flooded deeply enough that when natural regeneration does occur during low water, seedlings cannot

grow tall enough between flood events for at least 50% of their crown to remain above the high water level during the growing season. These conditions require artificial regeneration, (i.e., planting of tree seedlings). Water depth for sites in this category is restricted to a maximum of two feet for practical reasons related to planting of tree seedlings. Planted seedlings should have at least 12 inches of crown (length of main stem with branches and foliage present) and must be tall enough for at least 50% of the crown to remain above the high water level during the growing season. Sites with a negative trajectory (increasing average annual water depth) may eventually move into SWG Condition Class III unless action is taken to remedy this detrimental condition.

<u>SWG Condition Class III:</u> Sites with No Potential for either Natural or Artificial Regeneration

These sites are either flooded for periods long enough to prevent natural regeneration and practical artificial regeneration, or are subject to saltwater intrusion with salinity levels that are toxic to cypress-tupelo forests. Two trajectories are possible for these two conditions: 1) freshwater forests transitioning to either floating marsh or open fresh water, or 2) forested areas with saltwater intrusion that are transitioning to open brackish or saltwater (marsh may be an intermediate condition). SWG Category III sites are placed in specific subcategories relative to stress conditions as listed below. They may differ in the types of recommendations made or actions that should be taken relative to the particular stressing agent.

A. Forests with saltwater intrusion or high soil salinity:

1. Chronic (semi-permanent) saltwater intrusion (e.g., coastal areas with high rates of subsidence). These are sites where saltwater intrusion is of a long-term nature and requires correction.
    a. For baldcypress, chronic levels of soil salinity of four ppt or greater increases mortality of seedlings and makes the likelihood of regeneration unreliable.
    b. For tupelo, chronic levels of salinity greater than two ppt increases mortality.
2. Acute (temporary) flooding with saline waters such as from storm surges. These conditions are temporary and tolerance can be much higher.

B. Forests with water levels exceeding two feet at time of planting makes artificial regeneration impractical.

6) Physical and biological processes link coastal forests and coastal marshes. The current Louisiana Coastal Zone Boundary does not accurately reflect the full extent of Louisiana's coastal wetland forests. The lack of focus on large scale restoration and

protection activities outside the Louisiana Coastal Zone Boundary makes them more vulnerable to loss and degradation from detrimental impacts.

Louisiana's coastal wetland forests have been shaped by the sediments, water, and energy of the Mississippi River as natural deltas have been formed and abandoned over the last 5,000 years. During the regressive or constructional phase of the delta cycle, the system is dominated by freshwater riverine inputs with the formation of corresponding freshwater marshes and swamps, which then deteriorate during the marine-dominated transgressive phase. The largest areas of Louisiana's coastal wetland forests are swamps in the deteriorating transgressive phase of the Deltaic Plain. Deterioration of the delta in areas currently occupied by forested wetlands will result in hydrological conditions unsuitable for forest cover and result in conversion to marsh or open water. As in coastal marshes, where local deterioration is accelerated by neighboring marsh conversion to open water, the condition of forested wetlands depends in part on neighboring forests and marshes. In particular, saltwater intrusion into forested wetlands is often increased when neighboring marshes deteriorate.

7) Spatially explicit data of coastal wetland forest conditions necessary to guide restoration, regulatory, and management efforts are scarce. USDA Forest Service Forest Inventory and Analysis (FIA) data are inadequate for these purposes.

The condition of coastal wetland forests and the stressing factors are known to vary across the coastal zone; however, existing data are insufficient to guide restoration, regulatory, and management efforts in most areas.

The most complete data available on the area of forest types in Louisiana come from FIA, currently collected by the Louisiana Department of Agriculture and Forestry in cooperation with the USDA Forest Service. Cypress-tupelo forests of the region in 1974 were dominated by relatively small trees, but 29 years of growth has seen the size structure change to be dominated by larger trees. However, FIA data and other scientific information suggest coastal cypress-tupelo forests are not currently growing vigorously, if at all, and suggest environmental stresses may be playing a part in stand development. Systematically collected field-based and remotely-sensed data are needed but are currently lacking.

Recommendations

Based on these findings, the SWG recommends that the Louisiana Governor's Office:

1. Adopt the following statement of mission and intent regarding coastal wetland forest ecosystem policy: The State of Louisiana will place priority on conserving, restoring, and managing coastal wetland forests, including collaborative efforts among public and private entities, to ensure that their

functions and ecosystem services will be available to present and future citizens of Louisiana and the United States.

2. Recognize the regeneration condition classes (Finding 5) for cypress-tupelo forests developed by the Science Working Group (SWG) and use them to classify existing coastal forest site conditions for management, restoration, protection, and use purposes.

3. Place priority on maintaining hydrologic conditions on SWG Regeneration Condition Class I lands.

4. Delay timber harvesting on Condition Class III lands because these lands will not regenerate to forests. The goal is to allow time for hydrologic restoration and improvement of stand conditions to Class I or Class II lands. Place an interim moratorium on harvesting on state-owned Condition Class III lands. Develop mechanisms to delay timber harvesting on privately owned Condition Class III lands.

5. Before harvesting SWG Condition Class I and II sites, a written forest management plan with specific plans for regeneration must be reviewed by a state-approved entity so appropriate practices can be suggested based on local site conditions. The intent is to ensure that cypress-tupelo regeneration and long-term establishment take place and that species or wetland type conversion does not occur.

6. Develop spatially explicit data regarding SWG Condition Classes, existing hydrologic and geomorphic conditions, and current and future threats to coastal wetland forests. These data should be collected, evaluated, and updated by a consortium of state, local and federal agencies, universities and non-governmental organizations and made available to all entities. Adding remotely-sensed data to this data set should be aggressively pursued. Such data are critical to wisely manage and care for the coastal forest wetland ecosystem of Louisiana.

7. Establish and maintain a system of long-term monitoring of coastal wetland forest conditions, supplemental to FIA and Coastal Reference Monitoring System (CRMS) datasets, expanded to include the entire SWG coastal wetland forest area (see Figure 1). Additionally, monitoring of restoration should occur, and include measures to evaluate success. This may entail some long-term efforts because forests may take 25 years to establish functioning stands.

8. Coastal forests extend beyond the current Coastal Zone Boundary. Therefore, the target area for large scale restoration should be expanded to include coastal wetland forests as defined by the SWG (Figure 1), especially those in major river bottoms draining to the coast (e.g., Atchafalaya and

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INTRODUCTION

Wetland forest regeneration and sustainability may not be receiving adequate consideration in coastal Louisiana. Although coastal Louisiana forests are addressed to some extent in the Louisiana Coastal Area (LCA) Restoration Study (November 2004), their loss and rapidly deteriorating condition, interest in managing and restoring this natural resource, and the paucity of information available to accomplish these goals all point to a need to place increased emphasis on their conservation, protection, and study. Wetland forests influencing and protecting coastal areas also exist outside the Louisiana Coastal Zone, as defined by the State, and these forests are not addressed in that document. Despite the extensive evidence of the important role wetland forests play in providing critical habitat for many wildlife species and in maintaining water quality and coastal integrity, coastal forested wetland systems are rapidly disappearing.

In 1989, the Louisiana Legislature passed the Louisiana Coastal Wetlands Conservation, Restoration and Management Act (Act 6) providing an administrative structure for coastal restoration. Among other things, the Act established the Wetlands Conservation and Restoration Authority that develops an annual "Wetlands Conservation and Restoration Plan." Act 6 also established the Governor's Office of Coastal Activities and the Office of Coastal Restoration Management within the Department of Natural Resources to coordinate and manage components of Louisiana's coastal restoration program.

The 1998 Coast 2050 report entitled "Toward a Sustainable Coastal Louisiana" was a foundation for the May 1999 LCA section 905(b) Reconnaissance Report. The report recommended the implementation of feasibility studies. In the spring of 2002, the U.S. Army Corps of Engineers held public scoping hearings, soliciting input from interested parties. This set the stage for seeking programmatic authorization for funding under WRDA to implement strategies from the Coast 2050 Plan through the Louisiana Coastal Area (LCA) Feasibility Study designed to foster restoration and protection of Louisiana's coastal ecosystem. In November 2004, the LCA Ecosystem Restoration Study was published providing priorities and a framework for near-term restoration of selected coastal wetlands in Louisiana.

Renewed interest in the forested wetland resource, especially baldcypress, by the forest industry and private loggers now target the second-growth cypress in areas logged 80-100 years ago where natural regeneration was able to establish new forests. This renewed interest in harvesting coastal forests has raised questions about environmental issues and the ability of some of these forests to regenerate.

A comprehensive assessment of current scientific knowledge and condition of Louisiana's coastal wetland forests is therefore critical. Therefore, the Governor's Office initiated the formation of a Science Working Group (SWG) on Coastal Wetland Forest Conservation and Use. An Advisory Panel was also established by the Governor's Office to advise and assist the SWG. The mission of the SWG is to provide information and guidelines for the long-term utilization, conservation, and protection of Louisiana's coastal wetland forest ecosystem, from both environmental and economic perspectives. The following objectives were developed:

1) Gather and synthesize scientific information available on regeneration, growth, and potential harvesting effects on coastal wetland forests.

2) Gather and summarize field information on general characteristics of previously harvested baldcypress and tupelo forest stands to evaluate their potential to regenerate, become established, and remain vigorous.

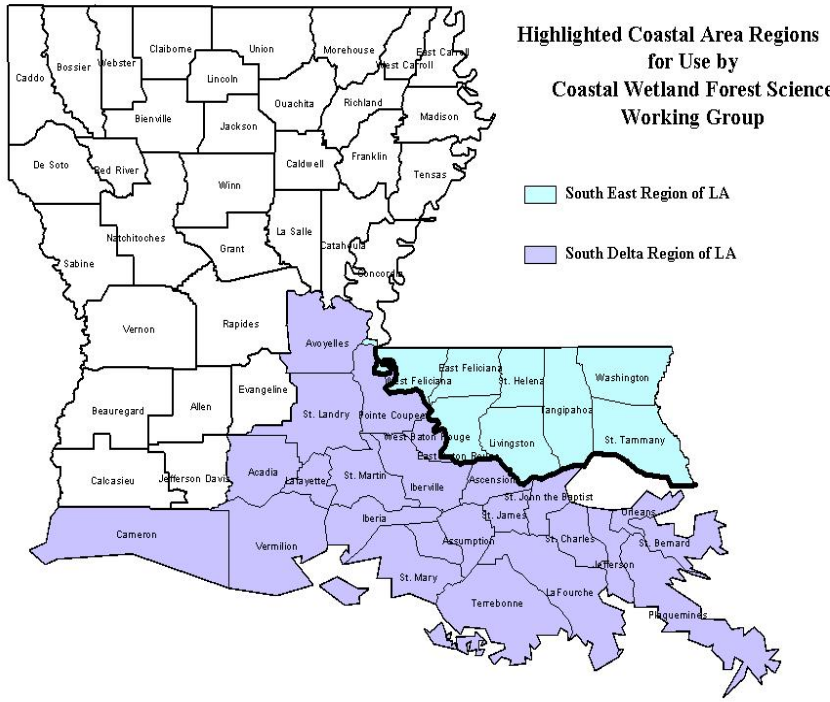
3) Review existing laws, regulations, policy, and guidelines affecting coastal forestry activities (and current forest conditions).

4) Develop science-based, interim guidelines for the conservation and utilization of coastal wetland forests.

5) Identify critical areas of priority research needed to refine these interim guidelines.

The SWG developed the following report to address these objectives. To emphasize the most important points of the report, the SWG developed a set of Findings and Recommendations to the Governor's office as to appropriate actions that should be taken to ensure the long-term utilization, conservation, and protection of Louisiana's coastal wetland forest ecosystem.

With the SWG's mission in mind and to meet the objectives stated above, the forest area to be considered needed to be defined. Large areas of coastal wetland forests extend beyond the Louisiana Coastal Zone Boundary, especially in major river bottoms draining to the coast (e.g., Atchafalaya and Pearl River Basins) and those with extensive areas of coastal wetland forests (e.g., Lake Maurepas). One useful boundary that does encompass these areas is defined by two USDA Forest Service inventory regions that together comprise 31 parishes of southern Louisiana (Figure 1). For these reasons, the SWG adopted these combined regions as the area of interest for assessing coastal wetland forests. Although there are extensive areas that are not coastal wetland forest in this area, it does encompass all areas of interest.



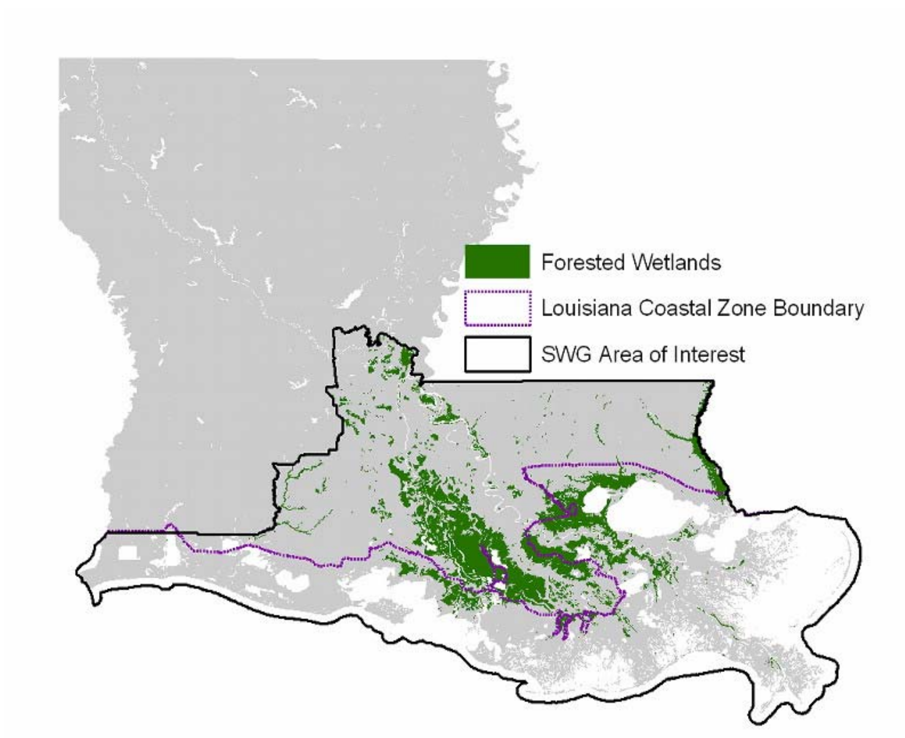


Figure 1. Louisiana Coastal Wetland Forest Area established by the Governor's Science Working Group on Coastal Wetland Forest Conservation and Use; (upper) USDA Forest Service forest inventory regions composing the SWG Coastal Wetland Forest Area; (lower) forested wetlands within the SWG Coastal Wetland Forest Area compared to Louisiana Coastal Zone Boundary.

LOUISIANA COASTAL WETLAND FORESTS: STRUCTURE, FUNCTIONS, AND ECOSYSTEM SERVICES

Forested wetlands are freshwater ecosystems dominated by trees or shrubs and can be divided into two general categories in Louisiana: swamps or bottomland hardwood forests. While both wetland types are formally classified as palustrine wetlands in the Cowardin classification of the National Wetlands Inventory (Cowardin *et al.*, 1979), swamps are flooded for most if not all of the growing season and dominated by baldcypress, pondcypress and water tupelo (Penfound, 1952; Mitsch and Gosselink, 2000a). Bottomland hardwoods are seasonally inundated for varying lengths of time with as many as 70 commercial tree species depending on the hydroperiod (Putnam *et al.*, 1960; Hodges, 1997).

The natural ecosystems of coastal Louisiana are dominated by the underlying geomorphic processes responsible for their formation. The majority of Louisiana's wetland forests are found in the Lower Mississippi River Alluvial Valley (LMV) and the Deltaic Plain. The southern extent of the LMV and the beginning of the Deltaic Plain is geographically defined by the Donaldsonville-Franklin line; however, the true geologic boundary extends to the head of the Atchafalaya River (Saucier, 1994). This geologic boundary better correlates with the geographic boundaries of the South Delta Forest covered in this report.

Coastal wetland forests in the Deltaic Plain have been shaped by the sediments, water, and energy of the Mississippi River as natural deltas have been formed and abandoned over the last 5,000 years (Coleman *et al.*, 1998). During the regressive or constructional phase of the delta cycle, the system is dominated by freshwater riverine inputs with the formation of corresponding freshwater marshes and swamps, which then deteriorate during the marine-dominated transgressive phase (Roberts, 1997). The largest areas of Louisiana's coastal wetland forests are swamps in the deteriorating transgressive phase of the Deltaic Plain.

Historically, wetland forests in both the LMV and the Deltaic Plain were intimately connected to the Mississippi River and its tributaries and distributaries. Annual pulses of freshwater, sediments, and nutrients collected from the 1.2 million square mile Mississippi River drainage basin were dispersed during flood events creating a mosaic of soil types and plant communities throughout the LMV and the Deltaic Plain. The fine-grained alluvial deposits in the LMV are not prone to compaction and, thus, subsidence is not a factor in this area. However, the cumulative effects of eustatic (actual) sea-level rise, crustal sinking, tectonic activity, and sediment consolidation result in high rates of subsidence that dominate the surface elevation and geomorphology of the Deltaic Plain (Saucier, 1994; DeLaune *et al.*, 2004). Subsidence rates for large areas of the Deltaic Plain range from 1.0 to 3.5 feet per century (Figure 2). Relative (eustatic + subsidence) sea-level rise in the Deltaic Plain is predicted to range from 20 to 40 inches over the next 100 years (Twilley *et al.*, 2001). Titus and Narayanan (1995) predict a one foot rise along the Gulf Coast by 2050.

While coastal wetlands can maintain their surface elevation despite sea-level rise with sediment inputs and organic accumulation from high primary productivity (Baumann *et al.*, 1984; DeLaune *et al.*, 2004), the construction and maintenance of flood-protection levees has isolated south Louisiana from Mississippi River sediments, nutrients, and freshwater, which are critical to the long-term survival of coastal wetland forests (Kesel, 1989; Boesch *et al.*, 1994; Day *et al.*, 2000). The area of swamps in the Deltaic Plain is projected to decrease by 231,890 acres by the year 2050 even with current restoration efforts (Table 1). This represents 42% of the existing wetland forest and three of the nine basins will lose between 30% to 55% of their remaining swamps. Adding sediments and nutrients to these degraded coastal wetland forests through river diversions (Day *et al.*, 2003), municipal wastewater (Day *et al.*, 1999), or stormwater diversions (Woods, 2004) is an essential component of sustaining this ecosystem.

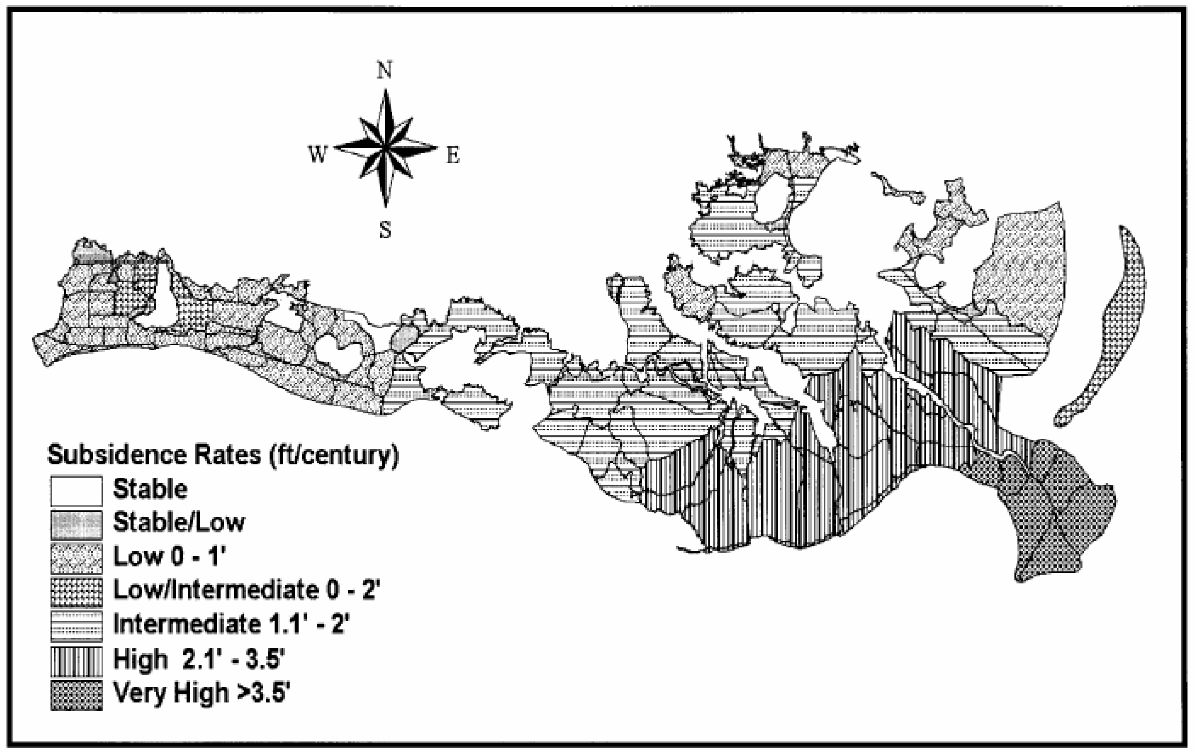


Figure 2. Estimated subsidence rates in Louisiana's Deltaic Plain (Gagliano, 1998).

Table 1. Projections of marsh and swamp forest losses in the Louisiana Deltaic Plain (Louisiana Coastal Wetlands Conservation and Restoration Task Force, 1998).

Region	Basin	Acres of marsh in 1990	Acres of marsh lost by 2050 without restoration	Acres of marsh preserved by the Breaux Act and diversions	Net acres of marsh lost by 2050 at current restoration levels	Acres of swamp in 1990	Acres of swamp lost by 2050 at current restoration levels
1	Pontchartrain	253,000	50,330	4,720	45,610	213,570	105,100
2	Breton Sound	171,100	44,480	17,900	26,580	0	0
2	Mississippi Delta	64,100	24,730	18,340	6,390	0	0
2	Barataria	423,500	134,990	42,420	92,570	146,360	80,090
3	Terrebonne	488,800	145,250	5,170	140,080	152,400	46,700
3	Atchafalaya	48,800	(30,030)*	8,080	(38,110)*	12,600	0
3	Teche/Vermilion	234,300	32,160	3,360	28,800	18,390	0
4	Mermentau	441,000	61,710	2,600	59,110	370	0
4	Calcasieu/ Sabine	317,100	50,840	12,440	38,400	170	0
	Total	2,441,700	514,460	115,030	399,430	543,860	231,890

*Due to delta building, acres will be gained in the Atchafalaya Basin

Wetland Functions

Wetland functions are the physical, chemical, and biological processes that sustain the wetland ecosystem, irrespective of any interaction with humans, and can be broadly grouped into biotic, hydrologic, and biogeochemical functions (Brinson, 1993; Smith *et al.*, 1995). Examples of generalized wetland functions include surface water storage (hydrologic), maintaining plant and animal communities (biotic), and nutrient cycling (biogeochemical) (Table 2). The fish and wildlife functions (biotic) are covered in detail later in this chapter. Like other wetlands nationwide, any specific coastal wetland forest in Louisiana may or may not perform all of the functions listed in Table 2. Functions of a specific wetland will vary in terms of functional capacity or the degree to which they are performed depending on the health of the wetland and the landscape setting (Mitsch and Gosselink, 2000a). Among the most important functions of coastal wetland forests are biogeochemical nutrient transformations, flood storage, and maintenance of characteristic plant communities.

Biogeochemical Nutrient Transformations

Wetlands are uniquely suited to mitigate the negative impacts of nonpoint source pollution. Their landscape position and biogeochemical properties give them both the opportunity and mechanisms to alter pollutant loadings to aquatic ecosystems (Johnston, 1991). However, quantifying these capabilities for a specific wetland or class of wetlands requires a more detailed understanding of both the wetland and the chemistry of the pollutant. For example, nitrogen and phosphorus have different chemical characteristics and different controls of their fate and transport. The reduction of inorganic nitrate to nitrogen or nitrous oxide gas provides a pathway to remove a detrimental nutrient responsible for coastal eutrophication and hypoxia (Rabalais and Turner, 1996). There is a wide range of denitrification rates across wetland systems indicating a differential ability specific to the wetland (Mitsch *et al.*, 2001). However, natural forested wetlands generally have a high denitrification capability (Ambus and Lowrance, 1991; Groffman *et al.*, 1992; Ullah *et al.*, in press). Not all restored wetlands have denitrification rates as high as their natural counterparts due to inadequate hydrology, little available carbon, or lowered microbial activity (Hunter and Faulkner, 2001). Research results suggest loading rates below 178 pounds of nitrate per acre per year will maintain >70% removal (Faulkner and Richardson, 1989; Mitsch *et al.*, 2001; Lane *et al.*, 2003).

In contrast to nitrogen, phosphorus has no gaseous outflow and, therefore, will accumulate in wetlands, primarily in the soil compartment (Faulkner and Richardson, 1989). In wetlands with mineral soils, phosphorus retention can be predicted by amorphous iron and aluminum oxides (Richardson, 1985). These oxides have a high surface area and are chemically reactive as evidenced by their ready dissolution in ammonium oxalate (hence the term, oxalate-extractable iron and aluminum). Phosphate coming into the wetland is adsorbed by these oxides and retained in the wetland soil. In wetlands with organic soils and little oxalate-extractable iron and aluminum, phosphate is taken up by plants and converted to the organic form.

In these wetlands, phosphorus is retained by the build up of soil organic matter, effectively burying the organic phosphorus with the organic matter (Craft and Richardson, 1998). While initial phosphorus retention by organic accumulation or oxalate-extractable iron and aluminum can be as high as 89.2 pounds per acre per year, this rate is not sustainable since these mechanisms have a finite capacity and, once filled, phosphorus will flow out of the wetland to downstream ecosystems (Richardson *et al.*, 1997). Analysis of outflow phosphorus concentrations as a function of mass loading rate for 126 natural and constructed wetlands across the U.S. indicates a change threshold at a loading rate of 8.9 pounds of phosphorus per acre per year (Richardson and Qian, 1999). Below this rate, outflow phosphorus concentrations are low and relatively constant while, above this value, outflow phosphorus concentrations increase significantly with increases in loading rate. Data from a eutrophication gradient in the Florida Everglades supports this hypothesis. In areas where phosphorus loading exceeded 8.9 pounds per acre per year, there were significant changes in dominant plant species from sawgrass to cattail with higher plant productivity, macroinvertebrate diversity, and carbon mineralization rates (Richardson *et al.*, 1997; Richardson and Qian, 1999).

Table 2. General wetland functions, related effects, and corresponding ecosystem services (adapted from National Research Council, 1995).

Function	Effects	Ecosystem Service
Hydrologic		
Short-term surface water storage	Reduced downstream flood peaks	Reduced damage from floodwaters
Long-term surface water storage	Maintenance of base flows, seasonal flow distribution	Provides fish habitat during dry periods
Maintenance of high water table	Maintenance of hydrophytic community	Plant and animal biodiversity
Biogeochemical		
Transformation, cycling of elements	Maintenance of nutrient stocks within wetland	Timber production
Retention, removal of nutrients, pollutants	Reduced transport of nutrients downstream	Maintenance of water quality
Accumulation of peat	Retention of nutrients, metals, carbon	Maintenance of water quality, carbon sequestration
Accumulation of inorganic sediments	Retention of sediments, some nutrients	Maintenance of water quality
Biotic		
Maintenance of characteristic plant communities	Habitat for animals and plants	Biodiversity, recreation, commercial harvests
Maintenance of characteristic energy flow	Food web support	Biodiversity, coastal fisheries

Forest systems change over longer time scales, so there are few data available to evaluate these effects on coastal wetland forests. While nutrient loading can have detrimental effects on natural wetlands, many areas of Louisiana's coastal wetland forests are sediment and nutrient deficient as a result of the Mississippi River levee system. Under these conditions, the addition of nutrients and sediments is the only way for these ecosystems to maintain their surface elevation relative to sea-level rise (Day et al., 2003). Rybczyk et al. (2002) found that wastewater additions to a forested wetland near Thibodaux, LA significantly increased accretion rates (0.43 inches per year) compared with an untreated control (0.06 inches per year). Most of the nitrate input is removed through the denitrification process (Boustany et al., 1997; Lane et al., 2003) and is lost to the system.

Flood Storage

Given their low-elevation landscape position and the high flood-tolerance of the cypress-tupelo forest, coastal wetland forests have both the capacity and opportunity to store floodwater. However, resources were not sufficient to estimate the magnitude of this function.

Fish and Wildlife Habitat

Coastal wetland forests provide important fish and wildlife habitat functions. Songbirds, wading birds, waterfowl, raptors, reptiles, amphibians, mammals, crawfish, and fish are all common inhabitants of Louisiana's coastal forests. Louisiana's coastal forests support up to six threatened and endangered wildlife and fish species (Table 3), although one of these species (Bachman's warbler) is believed to be extirpated from Louisiana and three other species (Gulf sturgeon, pallid sturgeon, Peregrine falcon) use coastal forests as incidental habitat, if at all (i.e., Gulf and pallid sturgeons). Few research studies have actually quantified habitat functions and values of Louisiana's coastal forests and research is desperately needed. However, from the few Louisiana studies and studies in other forested wetland systems, it is generally understood that the actual value of any particular tract is dependent upon the animal species of interest and numerous forest characteristics including geographic location and size of the forest stand, connectivity of the adjacent forest stands and habitats, landscape composition, hydroperiod, vertical structure, tree sizes and species composition (Merrell, 1977; Brody *et al.*, 1989; Mitchell and Lancia, 1990; Skelly, 1995; Schneider and Frost, 1996; Brokaw and Lent, 1999; Haila, 1999; Bodie and Semlitsch, 2000; Semlitsch, 2000; Barrow *et al.*, in press). It is beyond the scope of this report to review the life-history characteristics and habitat needs of all fish and wildlife species using Louisiana coastal forests, however, a few representative species or groups of species are discussed to illustrate some of the major structural characteristics and abiotic processes that are important components in determining habitat functions of Louisiana's coastal forests.

Table 3. Threatened and Endangered fish and wildlife species of Louisiana's coastal forests. Data are from the Louisiana Natural Heritage Program's website.

Common Name	State Status (year listed)	Federal Status (year listed)
Bachman's warbler[1]	Endangered (1989)	Endangered (1967; 1970)
Bald eagle	Endangered (1989)	Threatened (1995)
Louisiana black bear	Threatened (1992)	Threatened (1992)
Gulf sturgeon[2]	Threatened (1992)	Threatened (1991)
Pallid sturgeon[2]	Endangered (1992)	Endangered (1990)
Peregrine falcon[2]	Threatened/Endangered (1989)	Delisted (1999)

[1] Believed to be extirpated from Louisiana.
[2] Uses coastal forests incidentally.

The geographic location of Louisiana's coastal forests positions them within a major migration corridor for migrating North American landbirds and the majority of the following is summarized from Barrow *et al.* (in press). Each year millions of landbirds migrate across or near the Gulf of Mexico during their winter and spring migration. Virtually all of the eastern landbird species in the United States and numerous species from the western United States migrate through the coastal forests of Louisiana (Lowery, 1974a; Barrow *et al.*, in press). These forests are the last, or first, vestiges of land for many species prior to, or after, crossing the Gulf of Mexico, respectively. Thus, these sites provide important food and cover resources for songbirds that are either preparing for the trans-Gulf flight or that are recovering

from the flight. Coastal forested wetlands are important to many species, partly because these forests are often the largest remaining tracts of forests left along the Gulf Coast. While these sites are critically important, they do not provide habitat for all species. Species that rely on the understory and the forest floor for food resources are often not found in the most frequently flooded forests because of poor understory development. Thus, additional increases in flooding as a result of global climate change or hydrologic alterations, can degrade less frequently flooded forests and reduce their habitat quality for migrating songbirds.

While bottomland hardwood forests often support a high vertical and horizontal diversity, many cypress-tupelo forests naturally have low horizontal and vertical diversity because of frequent flooding and episodic periods of regeneration success. Even so, cypress-tupelo forests often support species that are not found in higher elevation plant communities (Wakely and Roberts, 1996). The number of species, however, is affected by forest conditions. Zoller (2004) found that the number of species of breeding migrant songbirds was less in forest degraded by hydrologic changes than in relatively undegraded or moderately degraded forests. The reduction in species was believed to be a result of a reduction in vertical structure as the forest declined.

The prothonotary warbler is typically associated with cypress-tupelo stands and because of the dramatic loss of these wetlands nationwide, the prothonotary warbler is listed as a Tier 1 priority species by Partners in Flight (http://www.rmbo.org/pif/pifdb.html). Thus, the extensive cypress-tupelo forests in Louisiana are extremely important for the long-term survival of this species. The prothonotary warbler is only one example of many songbirds that use Louisiana's coastal wetland forests for breeding and/or wintering habitat (Lowery, 1974a). The Atchafalaya Basin represents the single largest tract of wetland forests left in the Lower Mississippi River Alluvial Valley, and it is a critical component of songbird conservation efforts spearheaded by the Lower Mississippi River Valley Joint Venture Office. Although scientists are becoming increasingly aware of the impacts of hydrologic alterations on forest species composition, forest structure, and forest productivity, it is still unknown as to what impact these hydrologic alterations will mean to long-term avian productivity and community structure.

Two birds of prey, the swallow-tailed kite and the bald eagle, are also of interest in Louisiana's Coastal Wetland Forests. The swallow-tailed kite is listed as a Species of Special Concern by the State of Louisiana and is given the top priority by The Nature Conservancy among locally threatened birds (Coulson and Sherry 2004). The northern population of swallow-tailed kites, which includes Louisiana, has been slow to recover from declines observed at the turn of the 20th century (Bent, 1937; Cely, 1979). Swallow-tailed kites use tall (> 69 ft) and/or super-emergent trees for nesting. From 2002-2004, a total of 42 nests, old nests, and nest starts were found on and near Pearl River and Sherburne Wildlife Management Areas as well as in the region of the Joyce and Manchac Wildlife Management Areas (Coulson and Sherry, 2004). Swallow-tailed kites were observed on several wildlife management areas and surrounding private lands. Although nesting swallow-tailed kites are fairly tolerant of disturbance, they are sensitive to forest management activities. Thus, the Louisiana Department of

Wildlife and Fisheries has developed draft forest management guidelines for swallow-tailed kites (Coulson and Sherry, 2004).

Bald eagles, listed as Federally Threatened, commonly nest in Louisiana's coastal forests. In 2003-2004, there were 234 active bald eagle nests in Louisiana and an additional 84 inactive nests (George Melancon, Louisiana Department of Wildlife and Fisheries, personal communication). Parishes supporting coastal forests tended to have the highest densities of bald eagle nests. Terrebone (60), St. Mary (26), Assumption (25), St. Martin (25), St. Charles (19), and Lafourche (19) parishes supported the largest number of active nests; all other parishes had < 5 nests each. Bald eagles are particularly susceptible to disturbance during nesting, and the U.S. Fish and Wildlife Service Region 4 has guidelines governing activities, including forest management activities, around eagle nests.

Louisiana's coastal forests also provide important wading bird habitat (Kushlan, 1997; Michot *et al.*, 2003). White ibis, roseate spoonbills, wood storks, and a variety of herons, egrets, and other wading birds utilize Louisiana's coastal forests on a permanent or seasonal basis (Lowery, 1974a). Wading birds establish rookeries in coastal forests and marshes and use flooded forests, marshes, and/or aquaculture ponds as foraging areas for breeding adults or young. The quantity and quality of foraging habitat around rookeries are important in determining the presence, size, and success of a given rookery (Kushlan, 1978; Hafner, 2000). Water depth, food types, amount of cover, and concentration of food resources are among many factors determining the quality of foraging habitat for wading birds (Kushlan, 2000). Water depths that exceed the leg lengths of a specific wading bird species relegate those habitats as unsuitable. Drawdowns, or a drying out of the swamp, can concentrate food resources in drying pools and increase the quality of foraging habitat. In addition, this drawdown stimulates vegetative productivity which then stimulates productivity of invertebrates and vertebrate food resources.

Surveys of wading bird rookeries in South Louisiana in 2001, found 198 active wading bird colonies of which 78 were in saline marsh, 48 in fresh marsh, and 44 in forested wetlands (Michot *et al.*, 2003). Six bird species had declined since the 1990 survey, and Michot *et al.* (2003) suggested that habitat change in the study area should be evaluated as one possible explanation. These results should be viewed with caution as they explain the weaknesses of their approach and design, but their work is the best available to date.

Waterfowl also heavily utilize Louisiana's coastal forests. Wood ducks, mallards, hooded mergansers, gadwall, and other waterfowl utilize Louisiana's coastal forests on a permanent or seasonal basis for foraging and/or roosting habitat, thermal cover, or for reproductive activities such as pairing and brood rearing (Lowery, 1974a). As with wading birds, water depths are an important determinant of foraging habitat quality as are productivity of plant and invertebrate communities (Baldassarre and Bolen, 1994). Drawdowns stimulate the production of annual moist-soil plants that typically have high seed production (Fredrickson and Taylor, 1982). These seeds are used extensively during fall migration and early winter (Fredrickson and Heitmeyer, 1988). During spring, as waterfowl begin to shift into their breeding cycle, invertebrates become more important to females because of the high protein requirements necessary for egg production (Drobney and Fredrickson, 1979; Bellrose and Holm, 1994;

Demarest *et al.*, 1997). It is well documented that seasonally flooded wetlands support greater diversity of invertebrates and invertebrate densities are greater on vegetated sites (Batzer *et al.*, 1999; Wissinger, 1999). Thus, seasonal drawdowns can directly influence the diversity of invertebrates available as food for waterfowl, and indirectly influence abundance by affecting vegetation densities.

More recently, extensive areas of Louisiana's coastal forests have been impacted by common salvinia. Common salvinia, a native of South America, is an aggressive floating plant that prevents sunlight from reaching the water column and thus reduces aquatic and wetland plant productivity and presumably negatively impacts invertebrate communities. Common salvinia has dramatically reduced habitat quality for waterfowl in Louisiana's coastal forests. According to Robert Helm (waterfowl program leader, Louisiana Department of Wildlife and Fisheries), the Lake Maurepas basin was historically one of the most important basins for wintering waterfowl. In recent years, however, common salvinia has reduced wintering waterfowl numbers to < 20% of historic numbers. Several other forested wetland basins are also affected by this plant and by other invasive aquatic plants.

Louisiana's coastal forests are also important habitat for a variety of mammals including gray squirrel, nutria, otter, beaver, a number of bats, and the threatened Louisiana black bear. Several species of bats, including two species listed as federal species of concern (the southeastern bat and Rafinesque's big-eared bat (Martin *et al.*, 2002)), utilize hollow trees for roost sites (Hoffman, 1999; Cochran, 1999; Gooding and Langford, 2004). Rafinesque's big-eared bat frequently uses hollow water tupelo trees that are characteristic of older cypress-tupelo forests (Mirowsky, 1998; Cochran, 1999; Hoffman, 1999; Gooding and Langford, 2004). Although other species of trees, including baldcypress, may be used as roost trees, water tupelo and black gum appear to be most important to this species (Cochran, 1999; Lance *et al.*, 2001; Gooding and Langford, 2004). Gooding and Langford (2004) found that the average size of water tupelo trees used as roosts in Northeast Louisiana was 47 inches while Cochran (1999) found roost trees in the Mississippi River Valley in Arkansas to average 61 inches. Rafinesque's big-eared bats in several studies were associated with mature bottomland hardwood forest, abundant roost trees, and relatively close proximity to permanent water (Cochran, 1999; Lance *et al.*, 2001, Gooding and Langford, 2004). These results suggest that protection of existing roost trees, regeneration of water tupelo and black gum for future roost trees, and management for mature bottomland hardwood forests are important for this species (Gooding and Langford, 2004). It is worth noting, however, that Menzel *et al.* (2001) found Rafinesque's big-eared bats roosting in abandoned structures in upland habitats, and males commonly foraged among sapling stage pines. Thus, our understanding of habitat needs and the short- and long-term effects of forest management on this species is incomplete.

The threatened Louisiana black bear has received extensive attention and is a major component of habitat restoration efforts in the Lower Mississippi River Alluvial Valley. The Louisiana black bear has three populations in Louisiana: 1) Tensas, 2) inland, and 3) coastal. Louisiana black bear within the latter two populations rely extensively on coastal forested wetlands for dens, food, cover, and travel lanes.

The coastal population of bears typically uses ground dens made from brush piles and vegetation (Hightower *et al.*, 2002). This is common of coastal populations of black bears in other parts of the U.S. (Hellgren and Vaughan, 1989; Wooding and Hardisky, 1992), presumably because the milder climate does not necessitate tree dens. The interior population, however, uses tree dens and ground dens equally (Hightower *et al.*, 2002). Most bears in the inland population are located in commercial forests which may have limited availability of den trees (Hightower *et al.*, 2002). Den trees are important to black bears in frequently flooded environments as it reduces reproductive failure (Alt, 1984). In the absence of adequate tree dens, black bears may use ground nests in frequently flooded areas; however, the risk of cub mortality is higher and population growth may be limited (White *et al.*, 2001). Hightower *et al.* (2002) noted that black bears from the inland population could (and did) reproduce successfully in ground dens as long as flooding and human disturbance are minimized. Although den trees did not appear to be limiting to either the coastal or inland population, Hightower *et al.* (2002) recommended the protection of large den trees because a large proportion of the population occurs in the Morganza floodway and operation of the floodway would kill cubs in ground dens.

Large, hollow baldcypress trees are often used by denning black bears in Louisiana (Taylor, 1971; Weaver *et al.*, 1990). In other areas of the Mississippi River Valley, dens in other species of trees, such as overcup oak are also used (Oli *et al.*, 1997), thus, the frequency of use of baldcypress trees as dens may be partially a result of their size and abundance relative to those of other species. In fact, Hightower *et al.* (2002) observed bear dens in oaks, American elm, sweetgum, and water hickory. The U.S. Fish and Wildlife Service listing rule for the Louisiana black bear (U.S. Fish and Wildlife Service 1992) defines candidate den trees as baldcypress or water tupelo > 36 in dbh with a visible cavity, occurring along rivers, lakes, streams, bayous, sloughs, or other water bodies. Hightower *et al.* (2002) suggested that this should be expanded to include all tree species meeting the size and cavity criteria, regardless of location relative to water bodies. Oli *et al.* (1997) suggested that den trees should be protected, but management practices should also aim at increasing abundance of large trees that can be suitable den trees in the future. Although their study was conducted in Arkansas, the recommendations seem prudent for the Louisiana black bear as well.

Coastal forests are also important for black bear food and cover (Weaver *et al.*, 1990). In the Tensas Basin, black bears fed in openings created by forest management, some bears used logging slash as den sites, and thick cover, often a result of forest management in the past one to five years, was used extensively. Higher elevation ridges and bank tops were used as travel corridors (Weaver *et al.*, 1990). As flooding increases, the density of understory vegetation decreases and food and cover values begin to decline (Nyland and Pace, 1997). Furthermore, if den sites are limited, the risk of cub mortality can increase (Alt, 1984; White *et al.*, 2001). Forest management is an important component of black bear management (Weaver *et al.*, 1990), but specific practices should be implemented to maintain the vital requisites at the appropriate scale for the Louisiana black bear.

A variety of turtles, frogs, snakes, alligators, and amphibians use Louisiana's coastal forests (Dundee and Rossman, 1989). Reptiles and amphibians have experienced dramatic worldwide declines, with many of the declines related to habitat loss and degradation (Wake, 1998; Alford and Richards, 1999; Gibbons *et al.*, 2000). The U.S. Fish and Wildlife Service listed 70 species of reptiles as endangered and

another 18 species as threatened (Gibbons *et al.*, 2000). A total of 17 species of amphibians were listed as endangered and nine species were listed as threatened. Ernst *et al.* (1994) suggested that if current trends continue, all turtle species in North America will be threatened with extinction in the 21st century.

Habitat use of coastal forests by reptiles and amphibians varies among species, sex, age, and season (Hebrard and Mushinsky, 1978; Kofron, 1978; Dundee and Rossman, 1989; Petranka, 1998). While many reptiles and amphibians are considered aquatic, they often require terrestrial habitats for hibernation, dispersal, basking, and/or reproduction (Gibbons, 1970). Bodie and Semlitsch (2000) found that habitat use of false map turtles and slider turtles differed among seasons, gender, and age, but a diversity of habitats, including uplands, were heavily used. Alligator snapping turtles in northeast Louisiana used flooded baldcypress forests almost exclusively during post-breeding (Harrel *et al.*, 1996), but alligator snapping turtles (as do all Louisiana turtles) require elevated areas free from flooding for successful nesting to occur (Ernst *et al.*, 1994).

The actual species composition found within a given area will depend upon landscape structure, vegetation structure and composition, hydroperiod, and other factors. Some species of amphibians require drawdowns (e.g., American toad) for successful reproduction, whereas others (e.g., bullfrog) require permanent water. Turtles and alligators typically require access to higher elevation lands so that eggs can be laid without flooding. If these higher elevation sites are small isolated strips of land, predation by raccoons and other nest predators can be excessively high. Thus, the integration of wetland habitat types and associated higher elevation sites is important for the reproduction of many reptile and amphibian species.

Fisheries production in coastal forests is highly variable, in part, because of spatial and seasonal variability in water quality and vegetative characteristics of these habitats that can greatly impact fish distribution and abundance. Annual inundations of river-floodplains that make up a large component of coastal forests in Louisiana, such as the Atchafalaya and Pearl river basins, are important regulators of energy exchanges between permanent lotic and seasonally flooded areas (Junk *et al.*, 1989, Sparks *et al.*, 1990). The seasonal predictability of flood pulses over time have led to adaptations and strategies of fishes that allow efficient utilization of many habitats and resources created in coastal forests (Junk *et al.*, 1989). Spawning, for many fishes, occurs in association with spring floods, with fishes migrating into inundated areas for feeding and shelter (Bayley, 1983; Holland *et al.*, 1983; Welcomme, 1985). Post-spawning, coastal forests may serve as nursery habitat for many larval and juvenile fishes (Scott and Nielsen, 1989; Brown and Coon, 1994; Bayley, 1995; Sparks, 1995), providing nutrients for growth and survival.

While inundated coastal areas provide many benefits to fish production, changes in water quality associated with the flood pulse can negatively impact fish growth and survival. When rising floodwaters stabilize, microbial respiration overtakes primary production due to decomposition of large quantities of organic matter in seasonally flooded areas (Junk *et al.*, 1989; Bayley, 1995). In the Atchafalaya River Basin, this condition creates periods of environmental hypoxia (Fontenot *et al.*, 2001) where dissolved oxygen levels often drop below 2.0 ppm (Bryan and Sabins, 1979; Davidson *et al.*, 1998; Rutherford *et al.*, 2001). When floodwaters recede, hypoxic water drains from adjacent forested floodplains and mixes with the normoxic (> 5.0 ppm) water found in connecting bayous, canals, and lakes. Although adults of some fish species are able to efficiently extract oxygen or use alternative modes of oxygen uptake in hypoxic areas (Kramer, 1987), these hypoxic conditions can have a deleterious effect on fisheries production in backwater areas due to decreased availability of dissolved oxygen necessary for fish growth and survival (Aday *et al.*, 2000). While there is little direct evidence of historic changes in Atchafalaya River Basin water quality, anecdotal evidence from studies in the 1960s and 1970s (Bryan and Sabins, 1979; Holland *et al.*, 1983; Lambou, 1990) indicate that the spatial and temporal magnitude of hypoxia has increased in recent decades.

The invasions of exotic aquatic macrophytes such as common salvinia, hydrilla, and water hyacinth have also been shown to affect fisheries production in many coastal forest habitats. Aquatic macrophytes provide important habitat for shelter, breeding sites, and cover for numerous prey species (Balciunas and Minno, 1985) and often increase production, abundance, and species richness of resident fish assemblages (Killgore *et al.*, 1989). However, exotic macrophyte introductions displace native macrophytes such as Carolina fanwort and coontail, creating declines in submergent and emergent macrophyte diversity and abundance (Colle and Shireman, 1980; Keast, 1984) and altering the distribution and diversity of fish and invertebrate assemblages (Chilton, 1990; Chick and McIvor, 1994). Exotic macrophytes create dense homogenous beds in littoral areas of water bodies in the Atchafalaya River Basin, which may result in reduced access and foraging ability for littoral fishes (Savino and Stein, 1982) and cause additional reductions in water quality (Colle and Shireman, 1980; Langeland, 1996). Dense beds of aquatic macrophytes have been shown to alter vertical gradients of light, temperature, dissolved oxygen, and pH (Carpenter and Lodge, 1986; Madsen, 1997). Daytime dissolved oxygen concentrations near the bottom of hydrilla beds are frequently hypoxic while dissolved oxygen concentrations in the hydrilla canopy are normoxic. However, nighttime canopy dissolved oxygen concentrations often fall to hypoxic levels. The constantly fluctuating dissolved oxygen concentrations in hydrilla beds reduce the number of invertebrate prey and fishes that can survive in both canopy and sub-canopy habitats.

As noted above, aquatic and wetland invertebrates are a major link in the food chain of Louisiana's coastal forests. Differences in invertebrate composition and distribution among wetland types are driven by hydrologic regimes and vegetation structure (Murkin *et al.*, 1992). Wetland and aquatic invertebrate productivity is critical for maintenance of wildlife populations, as well as fish populations. Stagnant water, low dissolved oxygen, high water temperatures, and permanent flooding can reduce invertebrate productivity and/or diversity (Batzer *et al.*, 1999) and negatively affect fish and wildlife populations dependent upon invertebrates for a food resource.

The most economically important aquatic invertebrates in Louisiana are, the red swamp crawfish and the white river crawfish. As of 1991, Louisiana accounted for 90% of the North American harvest of crawfish (Huner and Barr, 1991), with the vast majority of wild crawfish captured in the Atchafalaya Basin. In the cypress-tupelo swamps of the Atchafalaya Basin that experience frequent overbank flooding (and presumably periodic drawdowns), over 2,000 lbs per acre of crawfish can be harvested in a given year. Studies in natural habitats in other areas of Louisiana indicate that

quantities of harvest do not exceed 20 lbs per acre. This is partially a result of the fact that many of the formerly productive areas outside of the Atchafalaya Basin have been lost or hydrologically modified (Huner and Barr, 1991). It is also worth noting, that despite its tremendous economic and cultural importance to the state of Louisiana, our understanding of abiotic and biotic processes that affect wild crawfish production in Louisiana are poorly understood and they have received little attention.

Louisiana's coastal wetland forests provide important habitat for a wide range of fish and wildlife species and continued degradation will negatively impact most fish and wildlife species that are dependent on these forests.

Wetland Ecosystem Services

Ecosystem services are the benefits that humans and society derive from the functions of an ecosystem and the value of these services can be quantified. Costanza *et al.* (1997) estimated the value of ecosystem services worldwide and determined that swamps and floodplains had the second highest economic value ($7,927 per acre per year), second only to coastal estuaries ($9,248 per acre per year). Forested wetlands provide a variety of ecosystem services including timber production, commercial fish, fur, and alligator harvests, recreation, flood storage, water quality maintenance and carbon storage (Messina and Conner, 1998). While there are no data specific to coastal wetland forests, the following information was derived from published data for coastal Louisiana that includes wetland forests.

Timber Production

Based on current stumpage volume and price, the value of the cypress-tupelo timber in the area delineated by the Science Working Group is $3.3 billion (Paul Frey, personal communication).

Commercial Fisheries, Fur, Alligator

The total value of freshwater fisheries and wildlife commodities in Louisiana in 2002 was $278,053,689 (Table 4). While this value is not exclusive to the area of coastal forested wetlands, many of these resources rely on the benefits provided by this ecosystem.

Recreation

Wildlife-associated recreation expenditures totaled $1.2 billion in Louisiana in 2001 (U.S. Department of Interior, Fish and Wildlife Service, 2001). While this value is not exclusive to the area of coastal forested wetlands, many of these resources rely on the benefits provided by this ecosystem. One growth industry in the state, and especially southern Louisiana, is ecotourism. Efforts to promote ecotourism in Louisiana have been undertaken by the office of the Lieutenant Governor and the Department of Culture, Recreation, and Tourism. Prominent among ecotourism businesses are swamp tours, where visitors are taken by boats through bayous and swamps. This industry is showing growth and is dependent on coastal forests for it's existence. As with recreation, no studies have been conducted to date to quantify the impact of this industry, but the importance of coastal forests to its development is evident.

In addition to swamp tours, bird watching (or birding) is a multimillion dollar industry in Texas and is growing in Mississippi. Efforts are underway to develop birding as an ecotourism industry in Louisiana, and coastal forests are integral in not only providing destinations for this activity, but for providing the habitat necessary for birds to survive and thrive.

Flood Storage/Storm Surge Protection

No economic data available.

Water Quality Maintenance

The biogeochemical functions of coastal wetland forests maintain/improve water quality by transforming and retaining nutrients and pollutants (Faulkner and Richardson, 1989; Lockaby and Walbridge, 1998), a potentially important ecosystem service in coastal Louisiana. The anaerobic conditions in the wetland drive the microbial conversion of nitrate (NO_3^-) to N_2 or N_2O, effectively removing NO_3^- from the system. Phosphorus and metals are generally attached to suspended particles and retained through wetland sedimentation processes (Faulkner and Richardson, 1989; Lockaby and Walbridge, 1998). At the watershed scale, this ecosystem service links coastal wetland forests to surrounding upland ecosystems (pollution sources) and protects downstream aquatic ecosystems through hydrologic pathways that extend beyond the wetland perimeter. Compared with conventional treatment facilities, estimated cost savings range from $500,000 to $1.9 million per wetland (Breaux *et al.*, 1995; Cardoch *et al.*, 2000).

Carbon

Although wetlands only comprise approximately four percent of the Earth's land area, they store almost 33% of the soil organic matter worldwide, constituting the largest global soil carbon reservoir (Eswaran *et al.*, 1993). High net primary production in wetlands combined with slowed decomposition of organic matter under anaerobic conditions results in soil carbon densities of 201 tons per acre for wetland forests compared with 40 tons per acre for upland forests (Trettin and Jurgensen, 2003). This disproportionate amount of carbon storage and the biogeochemistry of organic carbon cycling make wetlands an important component in global climate change, greenhouse gases, and carbon sequestration.

Carbon dioxide and methane account for 80% of the global warming potential of all greenhouse gases (IPCC, 1996), therefore, the release of these two gases from wetlands can have significant impacts on global climate change. When wetlands are drained and soil processes switch from anaerobic to aerobic, organic carbon is more

rapidly oxidized to carbon dioxide and the basic function of the wetland changes from being a carbon sink to a carbon source.

Table 4. Values of fisheries and wildlife commodities in Louisiana, 2002 (LSU Agricultural Center, 2004).

Commodity	Gross Farm Income	Value Added	Total Value
Aquaculture	123,715,104	80,414,818	204,129,922
Freshwater Fisheries	10,530,247	8,950,710	19,480,957
Marine Fisheries	161,313,290	153,247,626	314,560,916
Fur Animals	208,984	47,648	256,632
Alligators (wild)	5,426,685	2,713,343	8,140,028
Hunting Lease Ent.	40,407,546	2,020,377	42,427,923
Honey	3,618,228	—	3,618,228
Total	$345,220,084	$247,394,521	$592,614,605

Wetlands also release methane as an end product of methanogenesis and are responsible for 20% to 40% of the annual global atmospheric methane flux (Bartlett and Harriss, 1993). Methane is a powerful greenhouse gas with 20 times the warming potential of carbon dioxide, however, methane flux varies among wetland types. Tropical wetlands, with warm soil temperatures augmenting high microbial activity year-round, account for 51% of the total wetland flux while the lowest emissions come from temperate wetlands (10%) (Bartlett and Harriss, 1993). Many temperate wetlands are seasonally inundated during periods of lower soil temperature with lower water tables and aerobic soils in the upper part during warmer months. These conditions not only reduce gross methane production, but also allow for significant oxidation, which lowers the net methane emission (Updegraff *et al.*, 2001).

Predicted sea-level rise will inundate coastal wetland forests and convert them to open water, forever losing land area that currently sequesters carbon. The role of coastal wetland forests in the global carbon cycle and their close proximity to rivers and oceans make them an important component of any future climate change.

Economic Valuation

There are few data on the value of the specific ecosystem services provided by coastal wetland forests and it is beyond the scope of this effort to develop accurate estimates specifically for these wetlands. We can derive a rough estimate using Costanza *et al*'s (1997) value of $7,927 acre per year for swamps and floodplains multiplied by the estimated 845,692 acres of swamp forest area from USDA Forest Service data (see Historic and Current Conditions of Cypress-Tupelo Forests in Louisiana) for a total value of $6.7 billion per year. Based on the rate of swamp forest loss from Table 1 (232,067 acres) annualized over 50 years (4,641 acre per year) this yields an estimated value of $36,777,290 per year or about $1.8 billion in lost ecosystem services over 50 years.

The dominant species in Louisiana's coastal wetland forests, baldcypress and water tupelo, are adapted to deep and prolonged flooding during the growing season which gives them a competitive advantage over the less flood-tolerant species. If the hydroperiod is reduced enough to allow the less flood-tolerant species to become established, then those species will take over the site. It is much more likely that increased inundation (both depth and duration) and soil saturation associated with subsidence and sea-level rise will occur in coastal Louisiana.

The structure and function of Louisiana's coastal forests will be significantly affected by increased inundation. Plant community composition, ecosystem productivity, carbon cycling, and greenhouse gas production are all strongly influenced by hydrologic and redox processes in these forests. Species with morphological or physiological adaptations to flooding dominate lower elevation positions with flood-intolerant species relegated to the higher elevation ridges (Hodges, 1997). Despite these adaptations, flooding is a stress that significantly lowers aboveground net primary productivity (NPP) of southeastern floodplain forests and this impact is magnified in areas undergoing rapid hydrologic transformation (Megonigal *et al.*, 1997). In addition, baldcypress seeds require a bare, moist seedbed and will not germinate under water (Matton, 1915; DuBarry, 1963). The increased flooding depths and durations in south Louisiana's coastal wetland forests may be a factor in the poor baldcypress regeneration.

Impoundments have been shown to have detrimental effects on adult trees through reduced growth, crown dieback, increased susceptibility to insects and pathogens, decreased root mass and increased tree mortality (Conner *et al.*, 1981; King, 1995; Keeland *et al.*, 1997). The hydrologic changes produced by impoundment are rapid in comparison to those due to subsidence and sea-level rise and effects on forest productivity and turnover rates may differ between natural sites and artificial impoundments. Despite the prevalence of coastal forests in the southeastern United States and their critical location at the interface of aquatic and terrestrial systems, our specific understanding of their current ecosystem functions and responses to global climate change is, unfortunately, limited.

With increased subsidence and sea-level rise, saltwater intrusion into coastal wetland forests reduces productivity and can kill baldcypress and water tupelo (Allen 1992, Krauss *et al.*, 2000, Pezeshki *et al.*, 1990). Baldcypress appears to tolerate salinity to 8 ppt, but productivity and survival decline with salinity above 4 ppt (Pezeshki *et al.*, 1990; Conner and Askew, 1992; Conner, 1994; Pezeshki *et al.*, 1995; Allen *et al.*, 1996; Conner and Ozalp, 2002).

DEVELOPMENT OF LOUISIANA'S COASTAL WETLANDS

During the 20th century there was a massive loss of coastal wetlands, mostly marshes, in the Mississippi deltaic plain region of Louisiana. At present, planning for large-scale efforts to restore the delta, including forested wetlands, is occurring. In order to do this, it is necessary to understand both the processes that formed the delta as well as the forces that led to its deterioration. Natural processes and human activity over the past 100 years have reduced the area of coastal wetland forests in Louisiana. Natural loss processes are related to the delta lobe cycle of the Mississippi River, while human-induced losses result from directly converting forested wetlands to urban areas, suburban areas, agricultural areas, canals, and spoil banks. Analyses of topographic maps and aerial photographs have led to accurate estimates of marsh loss since the 1930s (Gagliano *et al.*, 1981; Britsch and Kemp; 1991, Barras *et al.*, 1994). Unfortunately, estimates of coastal wetland forest loss based upon comprehensive analyses of aerial photographs and satellite imagery are not yet available. It is possible, and recommended, that future researchers will use aerial photographs and satellite imagery to quantify the area of coastal wetland forests lost since the 1930s. It is not possible to accurately estimate wetland loss rates prior to the 1930s because there are no aerial photographs prior to the 1930s, and older maps lack the necessary accuracy.

Most coastal wetland forests in Louisiana are a product of the Mississippi River and therefore experience natural development and degradation cycles as do most coastal marshes. Although wetland loss is a natural process in southeastern Louisiana, the Mississippi River began creating wetlands about 7,000 years ago (Figure 3) and until the early 1900s, always created more wetlands than were lost (Stanley and Warne, 1994; Roberts, 1997). For example, extensive marshes filled Breton and Chandelier Sounds whereas extensive bays filled the Terrebonne and Barataria areas several thousand years ago but not when Europeans arrived in the 1600s (Coleman, 1988). While wetlands in Breton and Chandelier Sound were converting to a shallow bay, the Mississippi River deposited sediments in shallow bays that created new wetlands in the Terrebonne and Barataria areas. However, wetland creation was not a simple, gradual process. Instead, the river rapidly built wetlands and then gradually stopped flowing through them in favor of less obstructed paths to the bays. For centuries after they were deposited by the river, the sediments continued to compact, which caused the surface to subside (i.e., sink lower and lower). Despite ongoing subsidence, most wetlands persisted for centuries before flooding increased so much that vegetation drowned and the wetland converted to shallow open water.

A number of factors served to enhance the growth of the delta and retard its deterioration. With the exception of the first delta lobe (Maringouin), significant parts of all subsequent delta lobes have been incorporated into the current delta as a system of overlapping and interwoven distributary systems. Overbank flooding, crevasse splays, and reworking of sands have formed a skeletal framework of these natural levee ridges and barrier islands within which the deltaic plain formed (Kesel, 1989; Kesel *et al.*, 1992). Ecosystem functioning and sustainability of the delta is controlled by interactions of the Mississippi River and marine processes (Day *et al.*, 1997). The skeletal framework protected wetlands of the deltaic plain from erosion and salinity intrusion and slowed interactions between fresh-water and salt-water parts of the delta. Until modified by human activity, many of the distributaries continued functioning, delivering freshwater, sediments, and nutrients to large areas of the delta plain.

Freshwater forms a buffer against salinity intrusion, and provides mineral sediments, nutrients, and other materials, such as iron, that sustain healthier more productive wetlands. The distributary network was very efficient in sediment retention and about 25% of sediment flux was retained in the delta (Kesel, 1988). Because of the widespread freshwater input and the protection afforded by the skeletal network, floating marsh developed into a common marsh type. Riverine input was important for coastal forested wetlands for several reasons. Freshwater input was a buffer against saltwater intrusion, nutrients increased productivity, mineral sediments strengthened soils and helped build up the elevation of the land, and iron detoxified sulfide.

A very important mechanism in the formation and maintenance of the delta was the formation of crevasses (Davis, 2000). Crevasse splays occur where overbank flow becomes concentrated in a well-defined channel with enough scour capacity to erode permanent or semipermanent breaks in the levee. Deposition of both coarse and fine-grained sediments occurred in crevasse splays. Davis (2000) has documented hundreds of crevasses since European colonization began and it is clear that crevasses were an important element in the evolution of the delta. Forested wetlands often occur on crevasse areas that have subsided.

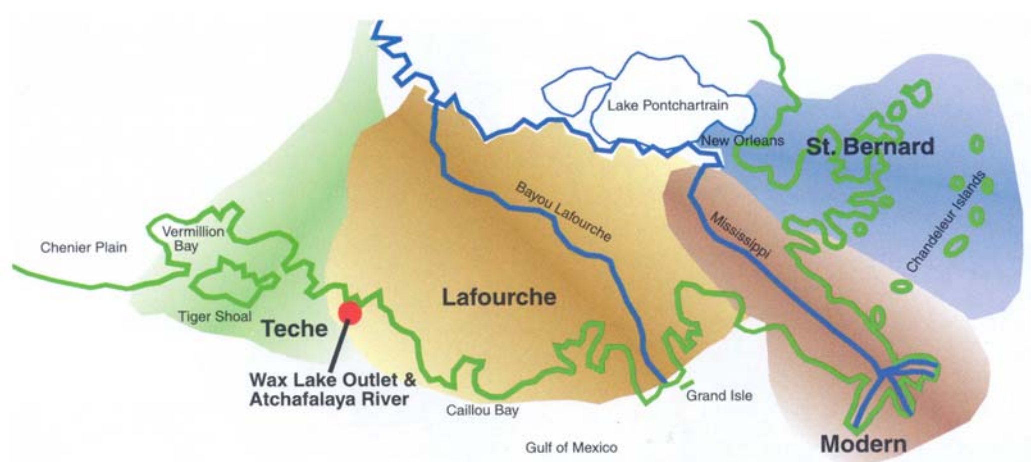


Figure 3. Delta lobe changes over time. The delta cycle is a natural cycle of building and disappearance of land. The river has built a new delta lobe about every 1,000 years since the end of the last ice-age, about 7,000 years ago. The "Modern" delta lobe started about 1,000 years ago. The previous one, Bayou Lafourche, started about 0 A.D. The delta lobe before that built most of St. Bernard Parish beginning about 1,000 B.C. Around 2,000 B.C., the river ran through the area now occupied by Bayou Teche. Natural wetland maintenance processes allowed the wetlands to persist for centuries after they were initially created despite ever-present subsidence of the delta lobes.

It is important to understand that there were large gains and losses of land as new channels were occupied and then abandoned, but there was a net overall gain of

wetlands. Thus, the delta cycle can be seen as a balance between the forces that lead to formation and maintenance of wetlands (the supply side) and the forces that lead to loss (the receding system).

An understanding of the causes of land loss is important not only for a scientific comprehension of the mechanisms involved, but also so that effective management plans can be developed to restore Louisiana's deteriorating wetland areas (see Boesch *et al.*, 1994 and Day *et al.*, 2000 for a review of these issues). In essence, human activity led to a reduction in the forces that led to delta growth and an enhancement of forces that lead to delta deterioration. A number of factors led to the massive loss of wetlands. Foremost among these are flood-control levees along the Mississippi River that resulted in the elimination of riverine input to most of the delta (Boesch *et al.*, 1994; Day *et al.*, 2000). In addition to the flood-control levees, most active distributaries were closed, crevasses have been mostly eliminated, and the river mouth was made more efficient for navigation. This has resulted in the loss of most river sediments directly to deep waters of the Gulf of Mexico. There has also been a reduction of the suspended sediment load in the Mississippi River caused by dam construction in the Upper Mississippi River (Kesel, 1988, 1989).

Within Louisiana's coastal area, pervasive altered wetland hydrology, mostly caused by canals, is another important factor contributing to wetland loss. Canals, originally dredged for drainage and navigation, are now overwhelmingly linked to the petroleum industry. Drilling access canals, pipeline canals, and deep-draft navigation channels have left a dense network of about 932 miles of canals in the coastal wetlands. Although canals are estimated to comprise about 2.5 percent of the total coastal surface area, their destructive impact has been much greater (Turner *et al.*, 1982). Spoil banks, composed of the material dredged from the canals, interrupt sheet flow, impound water, and cause deterioration of marshes. Long, deep navigation canals that connect saline and freshwater areas tend to lessen freshwater retention time, and allow greater inland penetration of saltwater.

In summary, there is a broad consensus that wetland loss is a complex interaction of a number of factors acting at different spatial and temporal scales (e.g., Turner and Cahoon, 1987; Day and Templet, 1989; Boesch *et al.*, 1994; Day *et al.*, 1995, 1997). Day *et al.* (2000) concluded that isolation of the delta from the river by levees was perhaps the most important factor.

For coastal wetland forests, taking the broader framework of the Mississippi delta brings into focus the factors responsible for their deterioration. The forces that led to the formation and maintenance of these forces have been reduced or eliminated in most areas of the delta. Overbank flooding has been mostly eliminated. With the exception of the bird's foot delta, crevasse formation has been stopped, and most distributaries have been closed. Thus, river input of freshwater, nutrients, and sediments have been eliminated for most coastal forested wetlands. Since subsidence continues unabated, forested wetlands have become continually more flooded.

Within the deltaic plain, the forces that lead to delta deterioration have been enhanced. Foremost of these with respect to forested wetlands is saltwater intrusion. Hydrological disruption via control of the river has reduced freshwater input, while canal construction has led to much greater saltwater intrusion into coastal wetlands. There are a number of examples where saltwater intrusion has caused mortality in forested wetlands. Perhaps the most notable case is the Mississippi River Gulf Outlet (MRGO) where large areas of coastal forests were killed by high salinity due to this major navigation canal. To a lesser extent, opening up of the coast exposes coastal forests to higher wave energy, and some forests are being lost along exposed shores.

Characteristics of Major Tree Species Growing in Louisiana's Swamp Forests

Baldcypress and water tupelo are the primary tree species in the coastal swamp forests of Louisiana. Sites where these species grow usually hold water for most of the year. In non-alluvial swamps, swamp tupelo is often the chief associate of baldcypress, but both tupelo species may be present. Baldcypress and water tupelo typically grow in more or less pure stands with black willow, red maple, water locust, overcup oak, water hickory, green ash, pumpkin ash, pondcypress, and red bay being common associates. Both baldcypress and water tupelo are extremely tolerant of flooding. Baldcypress is moderately tolerant of shade, while water tupelo is intolerant. Even though baldcypress and water tupelo grow in mixtures with other species, they do not tolerate heavy shade. Baldcypress that develop in heavy shade do not usually develop into large trees (Conner *et al.*, 1986a).

Baldcypress wood has traditionally been favored because of its decay resistance properties (Mattoon, 1915; Brown and Montz, 1986), although second-growth timber lacks the resistance of old-growth trees (Campbell and Clark, 1960; Choong *et al.*, 1986). Water tupelo has been valued because of its white color, lack of odor or taste, and good staining quality (Kennedy, 1982). Key to the management and conservation of these coastal forests is an understanding of the reproductive biology of these important tree species.

Flowering

Baldcypress, being a gymnosperm, does not produce flowers, but development and maturation of the microsporangiate (pollen-bearing) and ovulate cones will be generally referred to as flowering in the following. Baldcypress is monoecious-bearing microsporangiate and ovulate cones on the same tree. The microsporangiate cones, which are typically 3-5 inches long (Vines, 1960), initiate growth in mid- to late-summer, and complete development the following spring (Brown and Montz, 1986). Ovulate cones, which develop near the apex of twigs in the fall, complete maturation the following growing season (Brown and Montz, 1986).

Microsporangiate cones may begin shedding pollen as early as December, but typically release pollen in March and April (Vines, 1960; Brown and Montz, 1986). Wind carries pollen to the immature ovulate cone, which is typically 0.2 inches in diameter with 18 to 20 scales (Brown and Montz, 1986). Ovulate cones develop rapidly after pollination, producing a 1-1.5 inch subglobose cone with two ovules at the base of each scale (Vines, 1960). The maturation process for ovulate cones is generally completed in October through December (Wilhite and Toliver, 1990).

Water tupelo is a dioecious or sometimes polygamo-dioecious angiosperm (Vines, 1960), flowering in March through April (Bonner, in press a). Staminate

flowers are clustered while pistillate flowers are solitary on 1-2 inch peduncles (Vines, 1960; Radford *et al.*, 1987). Pollen is carried by wind and insects to pistillate flowers (Johnson 1990). Following pollination, the ovary and ovule develop into a 1-inch long drupe with a ridged stone maturing in September to October (Vines, 1960, Radford *et al.*, 1987).

Seed Production

Three-year old baldcypress saplings and water tupelo sprouts as young as two years old have been reported to produce viable seed (Priester, 1979; Brown and Montz, 1986). Though vigorous saplings and sprouts are capable of seed production, consistent mast crops do not occur in either species until trees grow appreciably larger, i.e. about 30 years old or 8 inches dbh for water tupelo (Johnson, 1990). Wilhite and Toliver (1990) noted that baldcypress trees will generally produce seed every year, but larger seed crops occur every three to five years. In contrast, water tupelo trees may consistently produce large seed crops on an annual basis (Johnson, 1990).

Ovulate cones of baldcypress sampled in Louisiana, Mississippi, Texas, Arkansas, and Illinois produced on average 14 to 17 seeds (Faulkner and Toliver, 1983). In poor cone production years, cones also tend to produce fewer seed (Faulkner and Toliver, 1983). Additionally, Bonner (in press b) noted that a large percentage (over 50%) of baldcypress seed will usually be unviable, because the seed lacks an embryo. Studies on water tupelo indicate that about 80% or more of mature seed are typically viable (Bonner and Kennedy, 1973, Bonner, in press a). Because practical techniques to predict seed crops and seed viability are not available, managers should routinely monitor cone and fruit production as well as seed development and maturation in stands designated to receive a regeneration harvest.

Seed Dispersal and Longevity in the Seed Bank

As mentioned above, ovulate cones of baldcypress complete maturation as early as October. Beginning at this time and continuing for several months, seed is released as cones break apart on the twig (Brown and Montz, 1986). Some cones fall from the tree whole, and these cones also eventually shatter and release seed (Brown and Montz, 1986). Fruit abscission in water tupelo occurs in October through December (Bonner, in press a).

Baldcypress and water tupelo seeds are primarily dispersed by water or hydrochory (Johnson, 1990; Wilhite and Toliver, 1990). Each species produces seed or fruit that will float for extended periods (Schneider and Sharitz, 1988), and seed that will remain viable under prolonged anaerobiosis (Applequist, 1959; Wilhite and Toliver, 1990). Schneider and Sharitz (1988) indicated that baldcypress cones or scale clusters floated for an average of 18 days, baldcypress seed floated on average 42 days, and water tupelo fruit floated on average 85 days. Seed of both species are dispersed non-randomly (Schneider and Sharitz, 1988), and this dispersal is driven by the timing, magnitude and flow direction of floodwater (Schneider and Sharitz, 1988; Middleton, 2000).

In addition to hydrochory, water tupelo seed could potentially be dispersed by animals. Several vertebrates are known to eat ripe water tupelo fruit, including raccoon, white-tailed deer, squirrels, wood ducks, and other birds (Halls, 1977; Leopold *et al.*, 1998), but these reports do not indicate if the stone is digested or voided. Baldcypress seed is not consumed as readily as water tupelo, but is a dietary component for squirrels, wild turkey, and occasionally ducks (Brunswig *et al.*, 1983). Additionally, evening grosbeak feeds on the seed when winter migratory patterns bring them into southern swamps (Brunswig *et al.*, 1983). Documentation of baldcypress seed dispersion by animals is not readily available in the literature.

Investigations indicate that baldcypress and water tupelo seeds that have been distributed by hydrochory tend to accumulate near emergent substrates such as logs and tree bases (Schneider and Sharitz, 1988). Seed viability for these species can decline relatively quickly in the seed bank if favorable environmental conditions are not present. Middleton (2000) reported that 58 % of baldcypress seed placed on the soil surface in an Illinois swamp were viable after 100 days, and about 6 % remained viable after a year. In contrast, Demaree (1932) demonstrated that some baldcypress seed can remain viable for as long as 30 months when submerged under water. Likewise, work conducted on water tupelo confirmed that seed could remain viable for up to 14 months when stored under water (Applequist, 1959). Nevertheless, baldcypress and water tupelo seed crops that have been in the seed bank for more than a year should probably not be considered reliable for producing a seedling cohort following a regeneration harvest.

Seed Germination and Seedling Establishment

While little silvicultural research has been conducted in cypress-tupelo forests, there has been some research on regeneration and successional patterns following disturbance. Natural regeneration of baldcypress was poor to non-existent in south Louisiana swamps following logging operations in the 1980s (Conner *et al.*, 1986a), mainly because the swamps remained flooded for much of the year. Baldcypress seeds cannot germinate in standing water (Demaree, 1932) or do not grow tall enough during short drawdown periods to survive subsequent flooding. In the Okefenokee Swamp, Georgia, over 90% of the pondcypress has been removed by logging, and there has been a shift of large pondcypress areas to mixed or bay swamps because of poor pondcypress regeneration (Hamilton, 1984). Limited regeneration of baldcypress occurred in logged or burned swamp forests in south Florida, but no regeneration was found in logged and burned sites (Gunderson, 1984). While surface fires may enhance cypress regeneration by reducing competition, severe or frequent fires generally result in conversion of cypress forests to prairie (Hamilton, 1984) or willow stands (Gunderson 1984). In swamps that have not received impacts to the hydrologic regime, natural regeneration can occur if favorable environmental conditions exist (Gardiner *et al.*, 2000).

Upon dispersal in the fall, seeds of baldcypress and water tupelo will typically exhibit dormancy. Seed dormancy for both species is broken by stratification in a cold, moist environment that softens the seed coat (Murphy and Stanley, 1975; Bonner, in press a and b), and the germination process is initiated when favorable environmental

conditions prevail in the seed bank. Germination by both species is epigeal - meaning that after the primary root emerges from the seed into the soil, cotyledons are pulled above ground by the hypocotyl (Maisenhelder, 1969; Raven *et al.*, 1999; Bonner, in press a and b). Though these plants thrive on anaerobic soil, the germination process is only initiated under aerobic conditions (DuBarry, 1963), such that the primary root avoids saturated soil and expanding cotyledons avoid overtopping by floodwater. Studies in controlled laboratory chambers indicate that a majority of stratified baldcypress and water tupelo seeds will germinate within 2 - 2.5 weeks of exposure to a favorable environment (Bonner, *in press* a and b).

Young seedlings in a wetland environment must grow rapidly to reduce the risk of canopy submersion by future floods during the growing season (Conner *et al.*, 1986a). Baldcypress is site exacting but regenerates well in swamps where the seedbed is moist during the time period of seed germination and seedling establishment. Baldcypress seedlings can withstand complete inundation for up to 45 days (Souther and Shaffer, 2000), but long-term flooding above the foliage results in high mortality. Flooding below the canopy of the developing seedlings will help reduce or eliminate competitors. As a result, baldcypress stands are usually made up of several even-aged classes that reflect isolated periods when a good seed crop was followed by low water (Mattoon, 1915). Once established, young seedlings grow rapidly, often reaching heights of 8-14 inches the first growing season and 16-24 inches the second season (Mattoon, 1915).

Few studies have documented the early survival and growth rates of baldcypress and water tupelo during natural regeneration. Keeland and Conner (1999) found successful regeneration of baldcypress along some shore edges of Lake Chicot when it was drawn down during 1986-1987 for dike repair. Baldcypress density averaged nearly two seedlings per yd^2 at the end of one growing season and throughout 11 growing seasons. Height of baldcypress seedlings averaged 30 inches, 124 inches, and 187 inches in 1987, 1992, and 1996, respectively. Water tupelo seedlings established in the Mobile Delta of Alabama averaged about 10 inches tall after 1 growing season, and developed to about 39 inches tall by the end of three growing seasons (Gardiner *et al.*, 2000). Baldcypress seedlings raised under the ideal conditions of a nursery bed grow 30-40 inches tall in a growing season (Williston *et al.*, 1980). However, height growth realized in the field by either species will ultimately be determined by several factors including germination date, growing season length, and various site factors such as substrate type, light level, water table depth, and amount of competition. When favorable conditions for germination and seedling growth do not immediately proceed a regeneration harvest, stand regeneration can only occur through coppice or artificial regeneration practices.

Fruit and Seed Pests

There are relatively few damaging agents reported for developing cones of baldcypress and developing flowers and fruit of water tupelo. The baldcypress coneworm can be a destructive pest, as the larvae tunnel into the ovulate cone and feed on the seed (Merkel, 1982). Two other species, the southern pine coneworm and the south coastal coneworm, have been collected on baldcypress cones, but the extent of their damage has not been determined (Merkel, 1982). Small galls containing larvae are formed in ovulate cones by the baldcypress seed midge and Faulkner and Toliver (1983) speculated that seed viability may be reduced as a result of larval feeding. Bonner and Kennedy (1973) noted that the forest tent caterpillar occasionally defoliates water tupelo stands, and in doing so destroys flowers. In his review of water tupelo seed, Bonner (in press a) did not document any insect pathogens on water tupelo fruit or seed.

Vegetative Reproduction

Vegetative reproduction by baldcypress and water tupelo is limited to sprouting of established stools. Following a disturbance that removes or kills the bole, sprouts of both species will originate over the remaining above-ground portion of the stem. Water tupelo sprouts originate from both latent and adventitious buds, with adventitious buds occurring most frequently near the ground-line (Hook and DeBell, 1970). It is not known if baldcypress sprouts originate from latent or adventitious buds, however, it is probable that the species produces both bud types.

Several factors may determine the coppicing ability of baldcypress and water tupelo stumps. In general, it is believed that sprouting for both species is most prolific on young stumps from stems that were harvested during the dormant season. For example, Williston *et al.* (1980) indicated that baldcypress stumps 10-14 inches in diameter reliably sprout when boles are harvested in the fall or winter. Mattoon (1915) reported that stumps of vigorous stock up to 60 years old can generally be counted on to send up healthy sprouts. Since the majority of Louisiana's virgin baldcypress was logged during 1890-1925, the second growth trees now being harvested are approximately 80-115 years old and may have passed the age of maximum sprouting potential. In addition to age and season of harvest, stump height, felling method, and harvesting level can influence the viability of stumps and vigor of sprouts (Ewel, 1996; Gardiner *et al.*, 2000; Hook and DeBell, 1970; Kennedy, 1982).

Though baldcypress and water tupelo apparently stump sprout readily, some investigators have observed poor vigor and high mortality rates of stump sprouts, decreasing the reliability of vegetative reproduction for these species on some sites. For example, Conner *et al.* (1986a), who studied stump sprouting of baldcypress following timber harvests in Louisiana in the 1980s, reported that 80% of all of stumps sprouted initially after logging, but fewer than 25% retained live sprouts four years after harvest. Conner (1988) included data from a number of studies in Louisiana with results of stump sprouting following partial harvesting. Stump sprouting was variable, but generally low to unacceptable (Table 5). Similarly, Ewel (1996) reported only 17% survival of pondcypress stump sprouts a few years after harvests in Florida swamps. Prenger (1985) noted that the amount of overstory removal in a Louisiana second-growth cypress-tupelo forest affected the number of live sprouts found three years after harvest. Stump sprouting was less successful in dense stands. It is not clear from this work, how many stumps were evaluated, but they did indicate that survival was very poor just three years after harvest, and the sprouts were not expected to develop into quality trees because of frequent and prolonged flooding.

Table 5. Survival of coppice regeneration on eight sites in south Louisiana following logging operations (Conner, 1988).

Area	Year harvested	Percent stump sprouts alive in 1987	Size of Area (acres)
1a	1980	6	618 = 1a and b combined
1b	1980	0	
2	1981	9	618
3	1982	11	32
4	1983	21	1850
5	1983	3 to 14	
6	1983	17 to 23	
7	1983	3 to 8	

Gardiner *et al.* (2000) studied regeneration after clearcutting in the Mobile-Tensas River Delta of Alabama. Harvesting was done in the winter (often reported by others to enhance sprouting) and was followed by a relatively dry summer (often reported to also enhance regeneration). The original stands consisted of 61% baldcypress. Seedling regeneration in this case was high (due to the dry summer), but stump sprouts represented only 7% of the first year regeneration. No long-term measurements were reported, but stump sprout survival would be expected to decline over time.

Spencer *et al.* (2001) conducted a study of 20 sites ranging from 3-17 years after harvest, but only two sites contained substantial number of baldcypress as overstory trees and three sites contained substantial numbers as understory trees. They found baldcypress was characterized by a low percentage of stems originating from stump sprouts. They also indicated that only small trees impacted by beavers sprouted well. Their data could easily be misinterpreted as they often combined all bottomland species when reporting sprouting.

Reliability of water tupelo stump sprouting is equally as questionable. Hook *et al.* (1967) described prolific stump sprouting of water tupelo stumps in South Carolina swamps, and Aust *et al.* (1997) indicated that stump sprouts were the source of over 80% of the overstory on a study site in the Mobile Delta, Alabama. Likewise, Gardiner *et al.* (2000) reported sufficient water tupelo stump sprouting to regenerate a Mobile Delta swamp. Kennedy (1982), however, observed substantial stump rotting and sprout mortality that led to a regeneration failure of water tupelo in the Atchafalaya Basin of Louisiana. Because of the variability in stump sprouting of baldcypress and water tupelo observed across the region, managers implementing regeneration harvests should familiarize themselves with the long-term coppicing potential of local stands prior to implementing regeneration harvests.

Most evidence suggests that stumps commonly sprout in large numbers, but most sprouts die within a few years. Use of early sprouting results, often highly inflates actual long-term regeneration estimates and probably leads to unreliable predictions of success and the final contribution of coppice regeneration to new stand establishment. We know of no studies that have followed coppice regeneration of baldcypress for more than five to eight years. Anecdotal evidence from those spending many years in the swamps suggests that some sprouts survive to older ages, but that the frequency of such trees may be low. It seems few studies of long-term stump sprouting as a form of regeneration in baldcypress have been conducted. A current survey of long-term stump sprout success is described in another section of this report.

Silvicultural Practices in Coastal Forested Wetlands

Managing forested wetlands for timber production is a difficult job because of the periodic to continuously flooded nature of these sites. Furthermore, management of these stands is made more difficult because hundreds of thousands of acres in the southern United States have been subjected to continual high-grading or harvesting of the better quality trees and leaving poor quality trees (Hanna, 1981). An additional current management problem was created by canal construction practices in previous centuries. During the late 1800s and early 1900s, logging methods in wet areas included construction of canals and railway lines for access and transport of logs as well as the construction of levees to keep forests flooded to float out logs (Davis, 1975). In addition, flood control canals, oil and gas canals, and road construction through wetland areas resulted in major changes to the natural hydrologic regime of much of coastal Louisiana (Conner *et al.*, 1981).

Although there is a considerable body of knowledge regarding silvicultural practices for the drier end of the forested wetlands continuum (e.g., wet pine flats), and a limited amount of silvicultural research regarding moderately well drained to poorly drained bottomland hardwoods, there has been little research into optimum silvicultural practices for the wetter portion of the forested wetlands continuum (e.g., swamp sites). Lacking long-term research information, management recommendations must be based on limited studies and general experience.

The majority of the virgin wetland forests were cut over during the late 1800s and early 1900s. Although there has been a general trend of land loss of these forested wetlands during the past 100 years (Frayer *et al.*, 1983; Dahl *et al.*, 1991), there are still vast areas of second-growth timber existing today (Williston *et al.*, 1980; Kennedy, 1982), and standing crop volumes have continued to increase since the 1950s (Brandt and Ewel, 1989; Conner and Toliver, 1990). Over 75% of the cypress growing stock is located in Florida, Louisiana, and Georgia (Table 6). Tupelo growing stock is more widespread among the southern states, and there is nearly twice as much of it as compared to baldcypress.

Table 6. Growing stock volume of cypress and tupelo by state[1].

State	Cypress[2]	Tupelo[3]
	------------------ million cubic feet	----------------
Alabama	160.0	1039.1
Arkansas	247.2	464.6
Florida	2328.8	1484.3
Georgia	800.3	1932.3
Louisiana	1462.5	1146.5
Mississippi	214.8	732.5
North Carolina	408.5	1571.3
South Carolina	522.8	1535.6
Tennessee	81.4	274.6
Texas[4]	109.4	247.7
Virginia	50.2	459.0

[1]From the most recent published U.S. Forest Service survey data available
[2]Includes baldcypress and pond cypress
[3]Includes both blackgum and other gums/tupelos
[4]East Texas only

Silvicultural Systems

Baldcypress trees should have annual growth rate of 0.2-0.3 inches in diameter and two feet in height during their first 50 years (Johnson and Shropshire, 1983). Water tupelo generally grows faster than baldcypress but does not live as long or reach as great a size on similar sites. Average annual growth of water tupelo should be 0.3 inches in diameter and two feet in height (Putnam *et al.*, 1960). Baldcypress can live for hundreds of years (Stahle *et al.*, 1988), but height growth generally ceases at about 200 years. It is common practice to harvest baldcypress and water tupelo before they reach 100 years in age (Hodges, 1994).

It has been suggested that baldcypress and tupelo stands should be managed on an even-aged basis because of the silvical characteristics of the species, the nature of the existing stands, and the sites they inhabit (Putnam *et al.*, 1960; Stubbs, 1973; Smith and Linnartz, 1980; Johnson and Shropshire, 1983). The most common regeneration method used is clearcutting when stems reach the desired size (Stubbs, 1973; McKnight and Johnson, 1975; Johnson and Shropshire, 1983). Residual stems should be removed or deadened to limit competition (Williston *et al.*, 1980).

Advance reproduction is usually sparse in these swamps because of the extremely dense nature of the stands allowing little sunlight to reach the forest floor and the standing water that is often present (Meadows and Stanturf, 1997). If the stand is very dense, a light thinning to reduce basal area to 130-150 square feet per acre may be necessary during a dry cycle to allow sufficient sunlight to the forest floor to encourage establishment and development of advance regeneration (Meadows and Stanturf, 1997). McKnight and Johnson (1975) recommend a series of periodic cuts beginning with a commercial thinning (removal of smaller trees of poorer quality) when dominant trees reach 8-10 inches in diameter. A second thinning should be done when dominant trees average 14-16 inches in diameter and a third cut when they average 20-22 inches. This is not easy to do in areas where standing water for most or all of the year is common.

Baldcypress tends to grow well at high densities (Wilhite and Toliver, 1990). Basal areas of 250-350 square feet per acre are common in cypress-tupelo stands. There is evidence that thinning enhances diameter growth in baldcypress (Table 7). The goal of thinning should be 100-110 square feet per acre or less. For economic reasons, it may be desirable to cut heavier amounts, but Williston *et al.* (1980) recommend leaving at least 70 square feet per acre. Crown thinning in baldcypress forests to 50% of original basal area increases diameter growth by 2.5 to 2.75 times that of unthinned stands (McGarity, 1977; Dicke and Toliver, 1988). Thinning to that level, however, may produce an abundance of epicormic branches (increase from <1% of trees in unthinned stand to 28% in thinned stand) which may lower timber value in the future. Dicke and Toliver (1988) recommended removing approximately 40% of the original basal area in closed canopy stands as the best alternative since this level produced good growth with fewer epicormic branches.

Table 7. Effect of thinning on diameter growth of baldcypress. Thinning treatment represents percent reduction in basal area.

Location	Thinning Treatment	Diameter Growth (in/yr)
Louisiana	Unthinned	0.06
(Dicke and Toliver, 1990)	18%	0.09
	36%	0.10
	54%	0.15
Florida	Unthinned	0.06
(McGarity, 1977)	38%	0.15
	57%	0.16
	76%	0.24

The results of thinning in tupelo stands are mixed. While McGarity (1977) reported that thinning increased growth of residual tupelo trees, Kennedy (1983) reported that thinning intensity had no significant effect on tupelo diameter and height growth. Defoliation of trees in the latter study by the forest tent caterpillar may be one explanation of the difference in response. Many tupelo forests along the Gulf of Mexico are defoliated annually and, while the trees do not usually die, their growth is retarded (Morris, 1975). See also the information on defoliation effects on growth in latter sections of this report.

Jackson and Stokes (1991) indicated that standard harvesting practices, consist of using rubber-tired feller bunchers and skidders but that other operations are sometimes practiced on wet sites in order to minimize harvesting impacts. These include the use of wider, high flotation tires for skidders and feller bunchers, wide-tracked feller bunchers, portable mats, tracked excavator-type machines, cable operations, and/or helicopter removal systems (Willingham, 1989; Aust *et al.*, 1990; DeCosmo *et al.*, 1990; Stokes and Schilling, 1997). In general these types of systems are used in order to minimize site disturbance and ensure the flow of wood from wet sites. Impacts of some of these logging techniques on forested wetland functions have been studied to a limited degree (Aust, 1989; Mader, 1990).

The impact of logging operations on productivity has only recently been studied. The clearcut method of regeneration is probably the best approach for harvesting and regenerating these swamp forests (Stubbs, 1973; McKnight and Johnson, 1975). Mader (1990) reported rapid recovery of aboveground primary production of water tupelo, ash, and baldcypress following clearcutting of water tupelo-baldcypress forest in a red river bottom in Alabama (Table 8). In addition, Mader found no significant difference in the response of the forest to helicopter or skidder logging operations, and he predicted that it would take only a few years for the disturbed sites to be as productive as the undisturbed forest. Gellerstedt and Aust (2004) remeasured this research project after 16 years and found that both the helicopter and skidder harvested sites were well stocked with baldcypress (90 and 93 stems per acre, respectively) and tupelo (543 and 676 stems acre, respectively). Both harvest methods had impressive timber volume at 16 years of age. The helicopter harvested sites averaged 42.4 tons per acre and the skidder harvested areas averaged 49.1 tons per acre. An important factor to remember when considering these studies is that both were conducted in areas with rapid natural reproduction and no major change occurred in site conditions. If hydrologic conditions have been changed, natural regeneration may be hampered and recovery rates may be much slower or even nonexistent (Sharitz and Lee, 1985; Conner *et al.*, 1986a).

Table 8. Aboveground net primary productivity (tons per acre per year) in a cypress-tupelo forest in Alabama following logging in 1986 (Mader, 1990).

Treatment	1987	1988
Control (no logging)	5.3	5.9
Helicopter logged	2.3	4.1
Skidder logged	3.4	4.2

Artificial Regeneration and Restoration

Because of the exacting requirements for germination and establishment (Stubbs, 1973; Brandt and Ewel, 1989) and the variable success of stump sprouting (Hook *et al.*, 1967; Kennedy, 1982; Conner, 1988), planting of baldcypress and water tupelo is likely necessary in many areas to ensure adequate stocking of future stands (Bull, 1949; Conner *et al.*, 1986a). While there has been little success in planting water tupelo (Silker, 1948; DeBell *et al.*, 1982), much better results have been obtained with baldcypress. Planting one-year-old baldcypress seedlings at least 3.3 feet tall and with root collar diameters larger than 0.5 inches improves early survival and growth (Faulkner *et al.*, 1985). An 8 x 8 foot spacing has been generally recommended, although regular spacing may not be possible unless the area was clearcut (Mattoon, 1915; Williston *et al.*, 1980). Even when planted in permanent standing water, height growth can average 8-12 inches per year when there are no herbivory problems (Conner, 1988; Conner and Flynn, 1989). Planting in areas that have not been clearcut can lead to poor establishment success if competition from other species is severe. Even in clearcut areas, competition from remaining understory tree and shrub species may lead to failure of regeneration to establish a new stand.

While data are limited, it seems that plantation-grown baldcypress grow quicker than natural stands and may even grow more rapid than some hardwood species (Krinard and Johnson, 1987). Planted baldcypress grew over 6.6 feet in height in five years in a Louisiana crayfish pond (Conner *et al*., 1993a). In Mississippi, a plantation established on an abandoned agricultural field resulted in baldcypress trees up to 69 foot tall at age 41 years (Williston *et al*., 1980). Another Mississippi baldcypress plantation contained trees 70 foot tall and 14 inches in diameter after 31 years (Krinard and Johnson, 1987). In comparison, Mattoon (1915) reported height growth of 42-52 foot by age 40 for naturally established second-growth baldcypress in Maryland and Louisiana.

Plantings Outside of Louisiana

Tennessee. The Tennessee Valley Authority was responsible for large-scale plantings of baldcypress in the 1930s and 1940s. Several hundred thousand baldcypress were planted along the margins of fluctuating reservoirs. Survival rates of 95% and height growths of 30 foot in 11 years were reported (Bull, 1949). Plantings by TVA personnel in 1970 and 1972 had survival rates of 95 to 100% after six years (Bates *et al*., 1979). Beaver and competition from herbaceous species were the major limitations to operational scale plantings in TVA plantings.

Ohio. The Ohio state forestry groups also encouraged the planting of baldcypress. Mattoon (1915) reported that over 75,000 seedlings were planted in Ohio before 1915. The only record that exists for those trees, however, is that they made satisfactory growth (Mattoon, 1915).

Mississippi. Krinard and Johnson (1976) reported that plantation-grown baldcypress grow as well as, or better, than hardwood species growing on loess soils in small, unthinned plantings. After four years, 62% of the baldcypress seedlings planted on a 6 x 10 foot spacing were still alive and averaged 7 foot tall. After 21 years, 41% of the trees were still alive, and the average diameter was 6 inches.

South Carolina. In South Carolina, DeBell *et al*. (1982) conducted a study of the growth of five species on drained lowland areas. They planted seedlings on a 2 x 2 foot spacing and remeasured the trees after five and twenty years. Baldcypress survival averaged 83% after five years, and the mean height was 4.6 feet. After 20 years, survival was still good, but growth had stagnated in the dense plantings.

One hundred root-pruned baldcypress seedlings were planted on February 25, 2002 on Hobcaw Barony, near Georgetown, South Carolina to demonstrate how the site could be reforested. The site was a 15 acre saw-grass marsh in the central portion of a drainage with mature baldcypress growing on the southern and western margins. Hydrology in the area was stabilized years ago with construction of a downstream pond, but does fluctuate some depending upon rainfall events. The site has very poorly drained, moderately permeable soils formed in organic deposits of the remains of herbaceous and woody plants. These very nearly level organic soils are covered by water most of the year. The marsh was burned during winter 2001 to remove the dead saw-grass material. All seedlings were enclosed in tree shelters because of the competition expected from the saw-grass. Survival was 100% after two years. The saw-grass grew back quickly after burning, but the seedlings continued to survive and

grow. Height growth during the first year was only four inches, but increased to 16 inches the second year.

Two hundred and fifty root-pruned baldcypress seedlings were planted on April 2, 2002 as a demonstration for the Natural Resources Conservation Service in the Pocotaligo Swamp near Sumter, South Carolina. Prior to 1950, the Pocotaligo Swamp was noted as a river-swamp system with many well-defined flowing streams, and dominated by a dense community of water tupelo and baldcypress. In the 1950s and early 1960s, most of the trees were harvested from the swamp north of U.S. Highway 301. Clear-cut logging operations left access roads (over 35 of them) across the swamp which blocked stream channels and obstructed the natural water flow within the swamp. Water levels in the swamp increased, which suppressed and prevented natural tree regeneration. This shallow, permanent flooding provided ideal conditions for aquatic weeds to grow. These aquatic weeds further reduced water flow and increased flood levels. Tree shelters were placed on all seedlings to protect them from beaver. Seedlings grew 21 inches the first year and 22 inches the second year with a 98% survival rate after two years. In other parts of the Pocotaligo Swamp, height growth of 17-20 inches has been reported (Conner *et al*., 1998). Reasons for the excellent growth of seedlings in this swamp include the open canopy allowing plenty of light to reach the forest floor. In addition, the swamp has been a receiving basin of water from a sewage treatment plant on the northern end of the swamp for many years, and the site is probably nutrient rich.

Restoration of bottomland and swamp sites on two stream systems on the Savannah River Site (SRS) has been occurring for the past 14 years. These sites were disturbed by effluents from nuclear production reactors that raised the water temperature and water depth. It was essential to replant these sites as they had been chronically disturbed for 40 years and no sprouting activity was possible from the long-dead, previously existing forests. A supplemental issue of Ecological Engineering (Vol. 15, Suppl. 1; 2000) summarized the results up to 1996. Baldcypress restoration is specifically discussed in articles by Conner *et al*. (2000), Dulohery *et al*. (2000), and McLeod (2000). These planting trials involved different planting stock types, habitats, tree shelters, root pruning, and competition controls. Baldcypress was easily the most successfully regenerated species in all of these trials, regardless of the planting situation.

The species trials planted in Fourmile Branch were resurveyed in 2002/03. Since 1996, baldcypress survival has changed very little, regardless of whether the trees were planted as root-pruned bareroot seedlings or large balled-and-burlapped saplings. The trees have grown tremendously, with baldcypress saplings now over 35 feet tall, with abundant seed production. These surviving and prospering individuals are now affecting the abiotic environment through shading. Subsequent forest succession will likely see additional species naturally invade the delta as a result of these changes. In addition, these larger individuals are now producing seed to potentially recolonize the habitat.

In one experimental trial, baldcypress were planted in fairly close proximity to a beaver lodge. Baldcypress not protected by tree shelters were repeatedly grazed by beaver, yet continued to resprout. Long-term detailed growth records on these resprouts are not readily available, yet they persist. In addition, when the stream delta flooded due to flooding of the Savannah River, beaver cut the saplings above the tree shelters. These saplings also readily resprouted.

Natural seedling establishment of baldcypress is also occurring in disturbed areas adjacent to undisturbed forests in both Fourmile Branch and Pen Branch. Rates of natural baldcypress establishment decrease with distance from the undisturbed forests.

North Carolina. In North Carolina, two plantings of baldcypress were done as demonstration sites. At White Oak River, survival was 96% the first year and 89% at the end of the second year (Conner, 2003). Height growth increased from 8 inches the first year to 12 inches the second year, resulting in seedlings with an average height of 47 inches by the end of the two years. This area had an overstory of mainly swamp blackgum, red maple, and ash. Even though there were many gaps in the canopy, the seedlings did not receive full sunlight. The second planting consisted of two 0.6 acre plots in a former agricultural field. Four hundred bareroot seedlings (half root-pruned and half with roots) were planted in each plot on January 31, 2002. The sites grew up quickly in dog fennel, which completely covered the planting sites, and towered above the tree shelters. Even under these conditions, 91% of the seedlings survived to the end of the second year. Height growth was 13 inches during the first year and 22 inches during second year. There was no difference in survival or height growth between the root-pruned and non-pruned seedlings.

Louisiana Planting Efforts

After the 1890-1925 logging of Louisiana's swamps, there were many areas in which baldcypress seedlings did not establish (Mattoon, 1915). Personnel of the Rathborne Lumber Company, Harvey, Louisiana, recognized that most of their cutover lands had little or no baldcypress regeneration, and without water level controls, natural reproduction could not be relied upon to restock the land (Bull, 1949). Therefore, nearly one million baldcypress seedlings were planted on company land. Ninety percent of the seedlings planted in 1949 and 1950 survived into 1951 and grew 12-18 inches in height by the end of the 1950 growing season. An additional 141,262 seedlings were planted in early 1951 and survival was 80 to 95 percent (Rathborne, 1951). Brown and Montz (1986) reported that many of the planted seedlings were killed later by animal browsing, and the project was abandoned.

The Rathborne planting inspired one landowner and the Soil Conservation Service to plant a flooded area in north Louisiana with baldcypress seedlings (Peters and Holcombe, 1951). Eighty-five hundred seedlings were planted during January to March 1951 in water 6-20 inches deep. When the seedlings were rechecked in April 1951, nearly 95% of them were growing vigorously and had increased in height an average of three inches.

Faulkner (1985) planted baldcypress seedlings in an old soybean field and in a commercial crawfish farm. In both areas, animal damage was high. On the soybean site, deer damaged 47% of the seedlings, but survival was still 98% at the end of two growing seasons. In the crawfish farm, crawfish girdled 78% of the seedlings (52% were completely girdled), but 95% of the seedlings or their sprouts were still alive after two growing seasons. In both cases height and diameter growth were negatively

associated with animal damage. Smaller seedlings had higher damage rates than did larger seedlings, indicating that the planting of larger seedlings might reduce the incidence of animal damage in this case.

Plantings by Conner (1988) in south Louisiana grew well if nutria were not a factor. Baldcypress seedlings averaged over 12 inches of height growth per year on Melodia Plantation near Thibodaux. Average seedling height after two growing seasons was 40 inches. Seedlings planted in a crayfish pond near Henderson, Louisiana during 1983-84 (Conner *et al.*, 1993a) had variable results. Seedlings planted in February 1983 averaged 12 inches more growth after one growing season than seedlings planted in July 1983 and continued to outgrow the July 1983 seedlings for five years. Growth of seedlings planted in July of 1983 and 1984 and February of 1984 was similar throughout the study. Five year height of February 1983 planted seedlings was 122 inches versus 81 inches for summer planted and February 1984 seedlings.

In 1991-96, approximately 10,000 baldcypress seedlings were planted on the Manchac landbridge, which lies between Lakes Pontchartrain and Maurepas in southeast Louisiana. These seedlings had 78% overall survival in 1998, when protected from nutria herbivory, but nearly 100% mortality if not protected from herbivores (Myers *et al.*, 1995). However, survival of protected trees fell to nearly zero during the 1999-2000 drought when saltwater intrusion events brought up to 9 ppt to the area (Shaffer *et al.*, 2003). In 1999, two baldcypress mitigation banks were established in the swamps of Lake Maurepas, one on the eastern side of the Lake (owned by Southeastern Louisiana University) and the other on the southwestern portion (owned by Glen Martin). Due to saltwater intrusion and nutria herbivory, survival has been poor at the eastern site, but up to 80% have survived at the southwestern site. Seedlings received plastic tree shelters and time-released fertilizer at both sites.

Current Methods Used in Planting

Innovative planting methods are often required for forested wetland sites because of standing water and unconsolidated sediments. One method of planting that has been tested extensively in the southern U.S. by Clemson University and University of Georgia researchers is to heavily root prune seedlings so that they may be planted by grasping the seedling at the root collar and simply inserting them into the soil or sediment, without digging a hole (Brantly and Conner, 1997; Conner, 1988, 1993; Conner and Flynn, 1989; Reed and McLeod, 1994; Hesse *et al.*, 1996). Habitats planted have ranged from standing water (backwater) to flowing water (stream); coastal to inland; and Louisiana and South Carolina. Bareroot seedlings of baldcypress and water tupelo have been successfully planted using this technique.

Pruned baldcypress seedlings have been planted in a number of sites throughout the southern United States with survival rates ranging from 0% to 100% depending upon herbivory. Use of plastic tree shelters is essential to reduce animal damage in many wetland areas. While 12-inch-tall shelters are generally sufficient to prevent clipping by rabbits or nutria, taller shelters are necessary to prevent excessive browsing by deer. Tree shelters have increased survival rates for baldcypress, water tupelo, and green ash in areas subject to herbivory (Conner, 1988, 1993; Reed and McLeod, 1994; Myers *et al.*, 1995; Schweitzer *et al.*, 1999).

Factors Affecting Regeneration and Growth of Baldcypress and Water Tupelo

Altered Hydrology

Hydrological patterns in the swamps of Louisiana have been altered tremendously during the last two centuries. During the original logging of Louisiana's swamps many logging companies maintained their own dredges to prevent delays in digging access canals (Davis, 1975). Average canal size was 10-40 feet wide and 8-10 feet deep, resulting in partial drainage of many swamps (Mancil, 1969, 1980). With the use of pullboat barges, trees could be pulled in from as far as 5,000 feet from the canal through runs spaced about 150 feet apart in a fan-shaped pattern. Runs were cleared of all trees and stumps and logs pulled to the canal. This skidding of timber across the swamp floor damaged and destroyed much young growth, and continual use of a run resulted in a mud-and-water-filled ditch 6-8 feet deep for the length of the run (Mancil, 1980). This operation left a distinctive wagon wheel-shaped pattern in the swamp forest that can still be seen on aerial photographs taken today. In other areas, railway lines were constructed. Railroad mileage in Louisiana between 1880 and 1910 increased from 650 miles to 5,553 miles. By 1920 however, the mileage began to decrease because of the abandonment of logging operations in cutover areas (Mancil, 1969).

More so than logging operations, oil and gas, flood control, navigation, road construction, and agricultural activities have done much to alter the original overland water flow patterns of the swamp. Large areas of swamp forest are now constantly flooded due to spoil banks associated with various activities that have occurred in the swamp (Conner *et al.*, 1981).

Apparent Water Level Rise

Another important factor that needs to be considered in Louisiana's coastal wetlands is increasing water levels resulting from eustatic sea-level rise (Gornitz *et al.*, 1982) and subsidence (Gosselink, 1984). Recent projections by the U.S. Environmental Protection Agency (Hoffman *et al.*, 1983) suggest that there will be a rise in sea level of 20-80 inches by the year 2100. The impacts of sea-level rise on coastal marshes has been detailed by a number of authors (Baumann *et al.*, 1984; Boesch, 1982; Hackney and Cleary, 1987; Salinas *et al.*, 1986; Stevenson *et al.*, 1986; Orson *et al.*, 1985; Kana *et al.*, 1986; Thomson *et al.*, 2002), but very little attention has been placed on the impact that rising water levels might have on the more inland coastal forests. Clark (1986) studied tide gauge records of sea-level rise in New York and discussed the importance for long-term change in forest population with rising sea level. Sea-level rise in the New York coastal forest has averaged 0.12 inches per year since 1930 (Clark, 1986). In Louisiana, however, water levels are rising rapidly

(DeLaune *et al.*, 1985), and it has been suggested that this will affect seedling survival (Conner *et al.*, 1986b; Salinas *et al.*, 1986).

Wetlands of Louisiana have historically been flooded by sediment-laden waters of the Mississippi and Atchafalaya rivers. Flood control levees along these rivers now reduce or prevent the flooding and sediment recharge of many wetland areas within the state. New sediments being deposited in many coastal wetlands now come only from erosion of local agricultural fields (Soil Conservation Service, 1978) or resuspended bottom sediments (Baumann *et al.*, 1984) rather than the entire Mississippi River drainage. Without the annual flood of new sediments, subsidence exceeds sedimentation in many areas, and most of coastal Louisiana is presently experiencing an apparent water level rise of about 3.3 feet per century (Salinas *et al.*, 1986).

The Barataria, Lake Verret, and Lake Pontchartrain basins, located in south central and southeastern Louisiana, contain extensive freshwater wetland forests. There are approximately 242,000 acres (98,000 ha) of seasonally (mostly permanently) flooded forests and wooded swamps in the Barataria Basin, 101,000 acres in the Verret Basin, and 213,000 acres in the Pontchartrain Basin. All of these watersheds were once overflow basins of the Mississippi or Atchafalaya rivers. With the construction of the flood protection levees along these rivers in the 1920-1940s, the only source of freshwater presently is rainfall or backwater flooding (Conner and Day, 1976; Conner *et al.*, 1986a). When these areas received riverine input, sediment deposition served to offset apparent water level rise due to land subsidence. With the cessation of sediment input, regional subsidence is leading to increased flooding of these areas.

Water levels in the Barataria, Lake Verret, and Pontchartrain basins historically followed a seasonal pattern of flooding and drying with the extent of flooding depending on the elevation of the site and seasonal water budget. In the Barataria and Pontchartrain basins, the swamp is very near sea level and is flooded almost year round with a short dry period generally during late July-early August, a time when rainfall is low and evapotranspiration is high (Conner *et al.*, 1986a). In the Lake Verret basin, bottomland hardwood forests are approximately 8-12 inches higher than the surrounding swamp forest areas. Flooding occurs during the winter and early spring, but for most of the growing season, the forest floor on the bottomland ridges is dry. Lower cypress-tupelo forests are flooded for most or all of the year. Conner and Day (1988, 1991) found that vertical accretion averaged 0.5 inch per year and 0.4 inch per year in cypress-tupelo forests of Barataria Basin and Verret Basin, respectively. They also used long-term tide gauge data to calculate relative sea-level rise, which was 0.3 and 0.5 inches per year for Barataria Basin and Verret Basin, respectively, and concluded that the Barataria and Verret basin swamps had accretion deficits of 0.1 and 0.2 inches per year, respectively. Relative sea-level rise is lower in the Pontchartrain Basin, estimated at 0.22 inches per year (Thomson *et al.*, 2002).

Barataria and Verret basins have experienced significant increases in water levels (Figure 4) and the total number of days flooded per year (Figure 5). The Verret Basin bottomland ridge did not experience any major flooding until the 1970s but since then has experienced a steady increase in the number of days flooded per year. Before 1970, the bottomland ridge was at an elevation to keep the forest floor from flooding. However, the lack of sedimentation in the area combined with apparent water level rise has resulted in the ridge now being at an elevation where flooding occurs frequently.

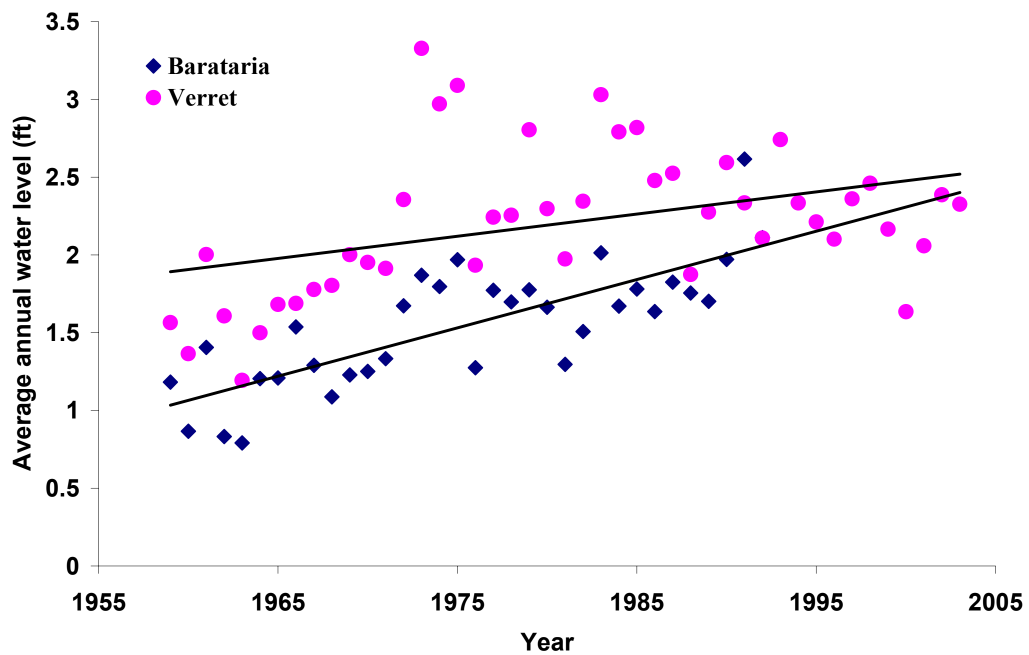


Figure 4. Average yearly water level for U.S. Army Corps of Engineer gauges at Chegby (Barataria Basin) and Attakapas (Verret Basin) in Louisiana.

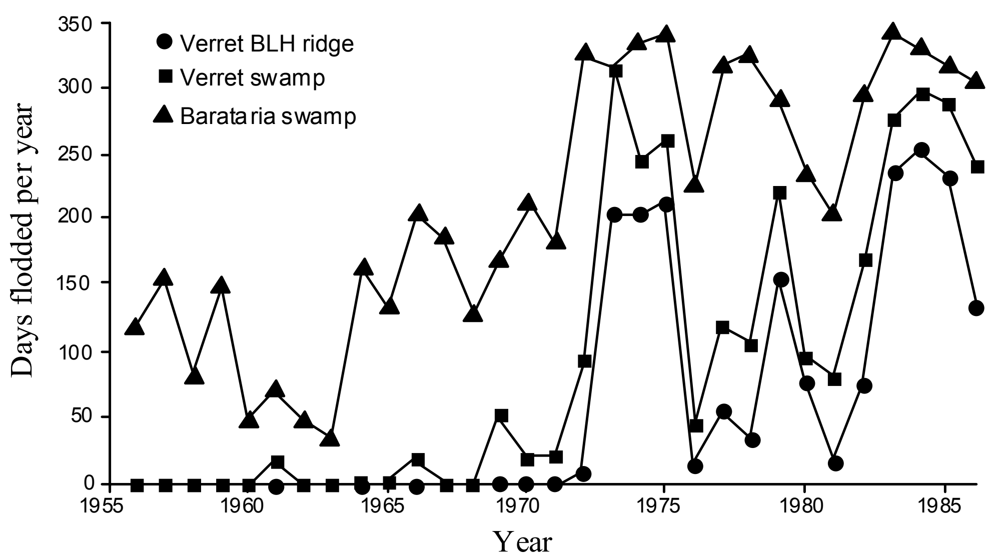


Figure 5. The number of days flooded per year in the Barataria and Verret swamp forests (Conner and Day, 1988).

In Barataria Basin, the swamps have always been flooded to some extent, but flooding has increased to where the forests are flooded almost year round. Even during dry periods such as 1981 and 1985-86, these forests were rarely free of standing water although the total days flooded decreased during these years. The history of flooding in

the Verret Basin swamp is similar to the bottomland ridge site except that increased flooding is evident by the late 1960s. The high flood years 1973-75 on the Atchafalaya and Mississippi rivers are evident more in the Verret Basin because the area is affected by backwater flooding from the Atchafalaya River more than the Barataria Basin is by Mississippi floodwaters. Since the 1950s, flood water levels in the swamps of the Pontchartrain Basin have doubled (Thomson *et al*., 2002).

As water levels continue to rise, the coastal forests will be subjected to more prolonged and deeper flood events. Even though many of the forest species growing in these areas are adapted to prolonged inundation (Kozlowski, 1984), extended flooding during the growing season can cause mortality of these tree species (Hall *et al*., 1946). Already many of the trees in these areas are showing evidence of severe stress (Conner and Day, 1987; Conner *et al*., 1981; Conner *et al*., 1986b; Shaffer *et al*., 2003). Even baldcypress and water tupelo, two of the dominant species in Louisiana's coastal forests (Conner and Sasser, 1985), slowly die when exposed to prolonged, deep flooding (Brown, 1981; Harms *et al*., 1980; Penfound, 1949; Eggler and Moore, 1961; Shaffer *et al*., 2003).

Another important factor to be considered in these coastal forests is the recruitment of new individuals into the forest. Buttonbush, black willow, cottonwood, and elm can germinate in standing water, while baldcypress and water tupelo must have dry periods for the seed to germinate and establish (DeBell and Naylor, 1972; Hook, 1984; Kozlowski, 1997). In many cases, this is not happening (Conner *et al*., 1986a) and if water levels continue to rise, coastal forested areas will eventually be replaced by scrub-shrub stands, marsh, or open water.

As water levels rise, one would expect that there would be a migration of the forest up the elevation gradient (Clark, 1986). In many areas, however, coastal forests are confined by man-made obstacles like flood-protection levees or occur on low ridges where the elevation gradient is truncated. Range extensions or shifts in forest areas as Clark (1986) suggested are not generally possible. Therefore, many of the coastal forests in Louisiana may be facing possible elimination or great reductions in area. The majority of swamps in the Lake Maurepas portion of the Pontchartrain Basin have been classified as "relic swamp" (Figure 6). If logged, these swamps are unlikely to regenerate, either naturally or artificially.

Salinity

Sea level rise will result in a gradual increase in flooding and/or salinity in coastal forested wetlands. Previous studies have shown that baldcypress is one of the most tolerant species of long flood durations and relatively deep flooding (Hook, 1984; Souther and Shaffer, 2000). Recent studies have shown that the species is also tolerant to flooding with water of low salinity (Allen *et al*., 1994, 1997; Conner, 1994; McLeod *et al*., 1996; Conner *et al*., 1997). There also seems to be some intraspecific variation in salinity tolerance at the seedling stage (Allen *et al*., 1994; Souther-Effler, 2004) and at the germination stage (Krauss *et al*. 1998, Souther, 2000). Rapid or large pulses of saltwater during storms are more likely to cause rapid and dramatic impacts, even for tolerant species like baldcypress.

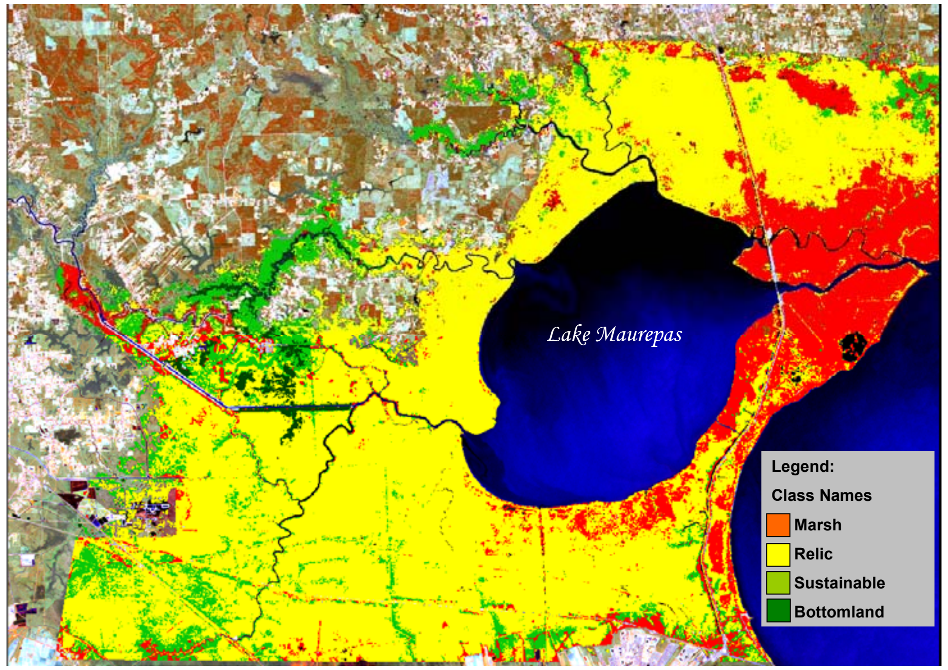


Figure 6. Preliminary classification of wetlands types in the Lake Maurepas swamp. Red areas indicate marsh, most of which was swamp in the mid 1950s. Yellow areas are classified as relic swamp in that the probability of regeneration following logging is low. Light green areas indicate swamp that will likely regenerate if properly harvested. Dark green areas indicate bottomland hardwood forest or pine. (Jason Zoller and Gary Shaffer, unpublished)

A recently completed study in the Lake Maurepas swamps (Souther-Effler, 2004) has produced several findings that may help predict future interactions of biotic and abiotic factors affecting forests throughout the coastal zone. Firstly, from a controlled study utilizing 2-4 year old water tupelo saplings exposed to flooding, low-level (3 ppt) salinity and insect herbivory, it was ascertained that defoliation reduced sapling productivity except when salt stress was an over-riding factor. Salinity alone, in excess of three ppt over a prolonged period was most detrimental, and when coupled with permanent flooding resulted in high rates of sapling mortality. Secondly, the presence of nutrient enhancement, as one would find in a river diversion scenario, ameliorated the effects of baldcypress leafroller defoliation on baldcypress sapling growth. Water tupelo growth, even with forest tent caterpillar defoliation, also was higher at nutrient-rich sites as long as the trees were not severely degraded by abiotic factors (salinity). Thus, it appears that insects will continue to act in concert with other stress factors to enhance the degradation of many forested wetlands unless depth and duration of flooding is reduced, and river diversions are implemented to provide an influx of nutrient-rich sediments.

The combination of salinity and flooding stress has greater effects than either alone and the negative impacts increase with increasing salinity (Conner, 1994; Allen *et al*., 1996). There is substantial intraspecific variability in salt tolerance within baldcypress species suggesting that more salt-tolerant strains can be developed (Allen, 1994; Allen *et al*., 1994; Krauss *et al*., 1998; Pezeshki *et al*., 1995; Krauss *et al*., 2000).

Nutria

Animal herbivory is a problem that has long existed in the swamps. The nutria is a native of South America that was introduced in California as early as 1899 (Willner, 1982), and is commonly found in low marshy places. Substantial populations today occur from Texas to Alabama, North Carolina to Maryland, and Oregon to Washington. Feral populations occur in 15-18 states (Adams, 1956; Willner, 1982), and sightings have been confirmed for all 48 lower states (Furcy Zeringue, USACOE, personal communication).

In Louisiana, nutria were first imported and released near Covington in 1933, but a population of animals failed to develop (Kays, 1956). Thirteen nutria were released in Iberia Parish in 1937 and several animals were released into the St. Bernard and Orleans Parish marshes several times prior to this without establishing a breeding population (O'Neil, 1949). Twelve nutria were imported to Avery Island in 1937 for experiments in pen raising for fur (Kays, 1956; Lowery, 1974b). In 1939 approximately 12 pair of the Avery Island animals escaped into the surrounding marshes. A hurricane in 1940 released another 150 animals. After this occurrence, landowners began releasing breeding stock into their marshes for fur and weed control. Two hundred and fifty nutria were released to the Mississippi River delta in 1951 and the population increased so rapidly that the marsh in the delta area was completely torn apart by 1957. By 1955-59, the nutria population in Louisiana was over 20 million animals (Lowery, 1974b). Nutria were firmly established in the freshwater area between the Atchafalaya River and the Texas state line by 1950 (Atwood, 1950) and north to the Red River by 1960 (Blair and Langlinais, 1960).

Nutria often clip or uproot newly planted baldcypress seedlings before the root systems are fully established, thus destroying the whole seedling. Nearly 1 million baldcypress seedlings were planted in 1949-51 in the swamp near Lac des Allemands by the Rathborne Lumber Company (Bull, 1949). Ninety percent of the seedlings planted in 1949 and 1950 survived into 1951. An additional 141,262 seedlings were planted in early 1951 and survival was 80-95% (Rathborne, 1951). Plans called for an additional 600,000 seedlings to be planted in 1951, but there is no record of what happened to those seedlings, although Brown and Montz (1986) reported that many of the seedlings were killed by animal browsing (nutria and rabbit) and the project was abandoned. During 1956-57, the Soil Conservation Service planted baldcypress seedlings in a cut-over swamp in south central Louisiana. After four months, 90% of the seedlings had been destroyed, and nutria were suspected as the cause. The Soil Conservation Service subsequently recommended that the planting of baldcypress be suspended until some means of nutria control were perfected (Blair and Langlinais, 1960).

Several alternatives have been proposed to prevent nutria from eating newly planted baldcypress seedlings. Reducing nutria populations is one alternative to the problem, but this method is expensive and would require expanding the current nutria harvest incentive program from coastal marshes to coastal forests. A harvest incentive program is currently in place in Louisiana and over 300,000 nutria were reported killed in 2003. In small scale studies in Louisiana, chickenwire fencing kept nutria out of planted areas, but in other parts of the country it has been shown to be costly and aesthetically displeasing (Jones and Longhurst, 1958; Mealy, 1969). It is often easier to protect seedlings by using a repellent rather than control the animal itself (Besser and Welch, 1959; Blair and Langlinais, 1960). However, chemical repellents are usually limited by their short-term persistence (Anthony 1982), and research into nutria repellents is non-existent.

Use of "Vexar" plastic seedling protectors provided excellent results for protecting conifer species from predation by animals in the northwestern United States. These relatively inexpensive, lightweight, photodegradable polypropylene plastic tubes have been tested and used to prevent damage by deer, rabbits, elk, and pocket gophers (Anthony *et al.*, 1978; Campbell and Evans, 1975; Anthony, 1982; DeYoe and Schaap, 1982).

During the 1980s, baldcypress seedlings were underplanted in five flooded stands typical of cypress-tupelo stands in southeastern Louisiana (Conner and Toliver, 1987). One-year-old bare-rooted baldcypress seedlings were planted in each stand. One-half of the seedlings were enclosed in "Vexar" photodegradable seedling protectors (available from Forest Protection Products Co., Inc., Coos Bay, OR). After three months, 86% of the seedlings had been clipped, uprooted, and destroyed (Table 9). Nutria seemed to have very little trouble getting into the Vexar tubes. They chewed a hole through the plastic netting at water level, clipped the seedling, and then pulled the tap root through the hole. In nearly every case, the stem of the seedling was left in the tube or adjacent to the tube. Rarely was anything except the bark of the tap root and root collar eaten.

In another Louisiana study (Conner and Toliver, 1988) baldcypress seedlings were planted in unlogged and logged areas of the Barataria Basin and underneath an existing canopy in the Verret basin. Of the unprotected seedlings planted in the Verret Basin, all were destroyed by the end of two months. Nutria were not known to be abundant in this area, but they obviously were a problem. Inside of chickenwire fences, there was little problem with nutria predation, survival ranged from 88-94% the first year but dropped to 64-70% the second year. On drier sites there was evidence of deer browsing. Deer have been identified as a problem with baldcypress seedlings planted in other areas (Faulkner, 1985).

Table 9. Characteristics of Louisiana cypress-tupelo stands and survival of planted baldcypress seedlings after three months (Conner, 1988).

	Overstory			% Survival	
Sites	# Trees/ac	BA (ft^2/ac)	# Seedlings Planted	Guarded[1]	Unguarded
1	161	88.9	600	8	10
2	179	115.9	400	16	5
3	179	192.5	300	96	87
4	219	110.6	150	0	0
5	156	100.6	150	0	0

[1] Guarded by "Vexar" plastic mesh seedling protector

Canopy Insect Herbivory

Forested wetlands in the coastal zone of Louisiana are affected by insect herbivory during spring months, depending on location and year. Though there are no known consistent populations of tree-killing beetles, borers, or diseases, both baldcypress and water tupelo are defoliated frequently by caterpillars. For decades, baldcypress was renowned for its lack of serious insect and disease problems (Brown and Montz, 1986). However, since the first recorded outbreak of the baldcypress leafroller (BCLR) in 1983, baldcypress has experienced significant, often repeated, springtime defoliation (Goyer and Lenhard, 1988; Goyer and Chambers, 1997). Although all sizes and maturity levels of trees are affected, pole-size trees, trees growing along edges of open water, and understory saplings appear most heavily and frequently defoliated by the immature stages of this insect.

Water tupelo, the other dominant wetland swamp species, has been defoliated regularly by the forest tent caterpillar (FTC) for decades, with regular outbreaks recorded since 1948 (Nachod and Kucera, 1971). In Louisiana, widespread, complete canopy defoliation by this insect has occurred over as much as 500,000 acres during a single season (Nachod, 1977).

Often, defoliation of water tupelo and baldcypress co-exists, and swamplands take on an appearance of winter-like dormancy prior to refoliation in late spring. A record of annual defoliation by FTC and BCLR detected by aerial surveys is depicted in Figure 7. It should be noted that even though water tupelo defoliation in the Calcasieu, Mermentau, and Pearl River basins occurs occasionally, it is not included in these data.

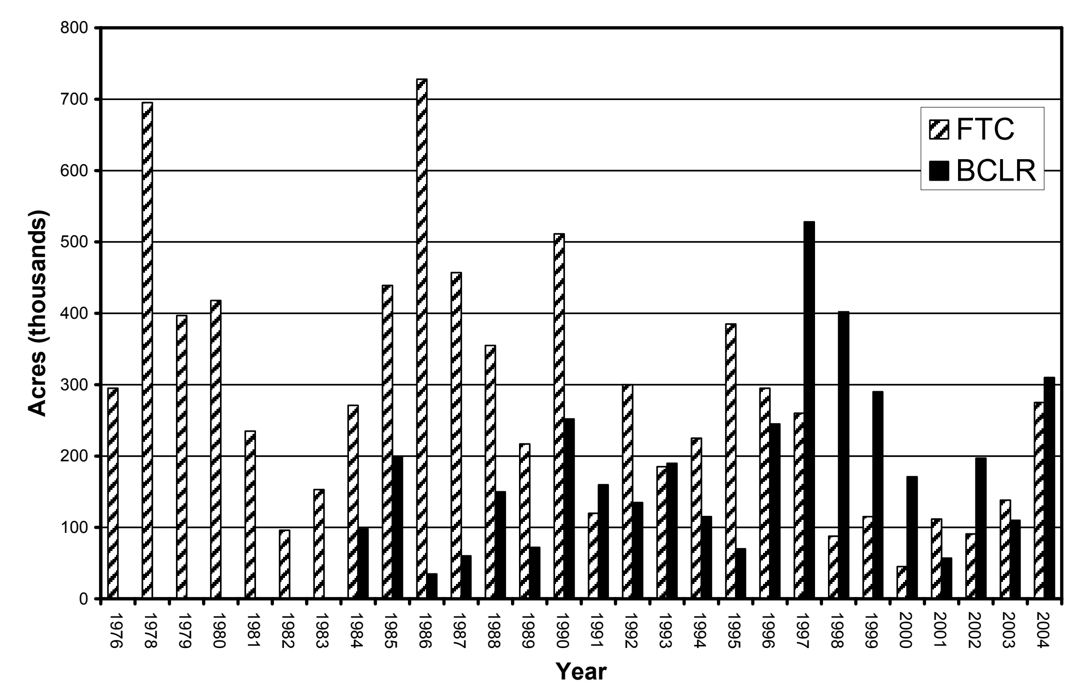


Figure 7. Defoliation by forest tent caterpillar (FTC) and baldcypress leafroller (BCLR) in Louisiana.

<u>Baldcypress.</u> Early descriptions of the vast, primarily pure stands of virgin baldcypress claim the species was mostly immune to serious insect and disease

problems, and include no pest descriptions until the 1950s, after much of the virgin stands had been cut (Mancil, 1972; Brown and Montz, 1986; Conner and Day, 1976). The cypress looper defoliated significant areas in Florida in the early 1980s, but has made little impact in Louisiana (Drooz *et al.*, 1981). The bagworm defoliated an area of baldcypress covering approximately 6,000 acres in the southern Atchafalaya Basin in 1994-1995 (Goyer, 2002), but it is not clear if this species will become a recurring pest. The most serious, consistent, economic insect pest reported to date is the BCLR. The BCLR was first reported in 1983 in the southern Atchafalaya Basin and watersheds to the east and south (Goyer, 2002). The larval stage of the leafroller feeds solely on baldcypress foliage, and since first discovery, populations have spread eastward from the epicenter near Bayou Pigeon, Louisiana, with the highest numbers primarily in the Atchafalaya River Basin south of Interstate 10, the nearby Lake Verret-Grassy Lake-Lake Palourde drainage system, and the Lake Maurepas-Pass Manchac-Lake Pontchartrain system (Goyer, 2002).

Impact caused by BCLR defoliation is of two main types – diameter growth reduction and dieback of canopy (followed in isolated cases by mortality). Since swamps often are stressed by both abiotic and biotic factors, determining the precise impact due to insect defoliation is difficult. A direct, linear relationship between the degree of defoliation of baldcypress and mean annual growth has been reported (Figure 8). Growth reduction caused by defoliation is often exacerbated by duration and depth of flooding and or saltwater intrusion (Goyer and Chambers, 1997; Allen *et al.*, 1998; Souther-Effler, 2004). The recognition of potential impacts is compounded by the somewhat small size and the cryptic leafrolling habit of BCLR. Until defoliation and desiccation of partially consumed needles becomes apparent (as red needles) in areas of epidemic populations, land managers often fail to notice early-season herbivory (see Braun *et al.*, 1990; Goyer and Lenhard, 1988; Allen *et al.*, 1998).

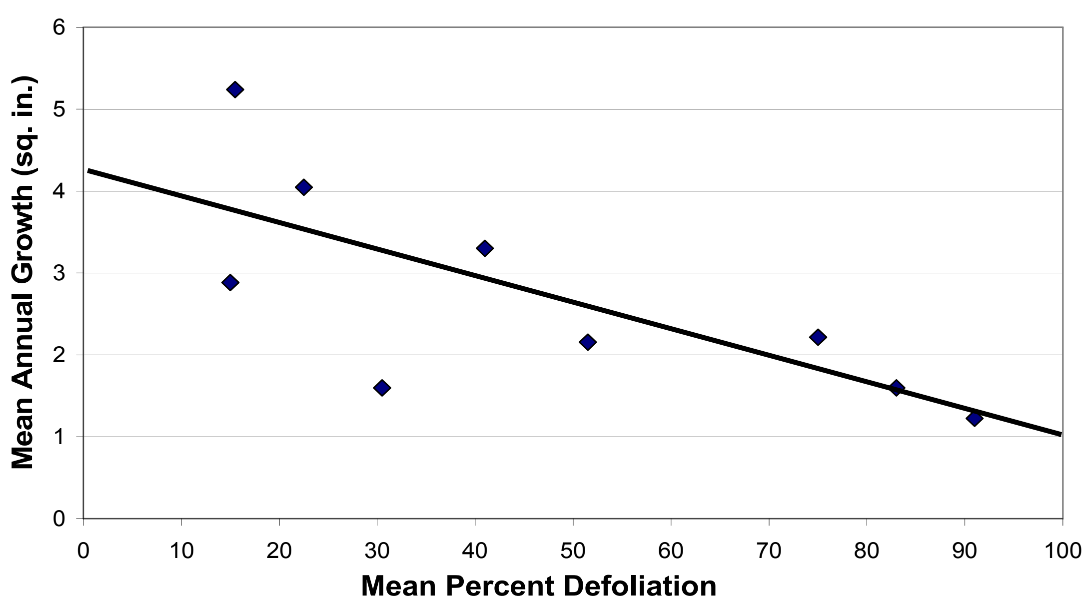


Figure 8. Regression of basal area growth versus percent baldcypress leafroller defoliation (n=80 trees over 10 years).

Baldcypress leafrollers often congregate on smaller trees, saplings and edge trees with pyramid-shaped, or conical, crowns. Thus, damage is often concentrated on understory saplings, resulting in their dieback and occasional death (Table 10) (see also Allen *et al.*, 1998). The future impact and extent of BCLR defoliation is uncertain. There appears to be an expansion of the long-lasting infestation into the upper reaches of the Pontchartrain Basin. However, little westward movement (beyond the Atchafalaya Basin) has been noted. In some areas of the Lake Verret Basin, defoliation by BCLR is less severe than it was 10 years ago, due in part to a build up of naturally occurring parasites and predators.

Table 10. Annual dieback (%) of understory baldcypress saplings (< 4 inches dbh) in open patches, Southern Louisiana.*

Year	1992	1993	1994	1995	1997	Change in %
Mean % (n=50)	31.0	39.9	46.0	55.4**	65.5**	34.3**
No. Dead	0	0	2	4	13	28.3

* Each year all saplings were 80-100% defoliated by BCLR
** Dead trees removed from calculations

<u>Water Tupelo</u>. Defoliation by the FTC appears to reduce radial growth of tupelo. Abrahamson and Harper (1973) report growth reductions of 40-60% (average 45%) when water tupelo trees had in excess of 60% of their leaf surface area removed by FTC herbivory. This is supported by findings in the coastal zone of Louisiana. Smith and Goyer (1986) found that FTC population levels, and hence defoliation, were tied closely to permanently flooded areas, due in part to the absence of naturally occurring parasites, predators, and diseases. Souther-Effler (2004) reported that nutrient inputs, as might occur from river diversions or agricultural run-off, led to shorter development times and larger FTC pupae indicating the potential for higher herbivory potential. However, insect herbivory impacts may be offset by increased tree growth in response to the same nutrient inputs, potentially balancing water tupelo productivity.

SURVEY OF BALDCYPRESS AND TUPELO REGENERATION AND ESTABLISHMENT ON HARVESTED SITES

Regeneration of wetland forests is of particular concern because of the exacting environmental requirements for successful establishment of seedlings to perpetuate the forest. Investigations of regeneration processes of baldcypress and tupelo have yielded insights into many of the mechanisms controlling regeneration success (see report chapter "Silvicultural Characteristics of Major Tree Species Growing in Louisiana's Swamp Forests"). However, because formal forest management in cypress–tupelo forests is less common than in many other forest types, there have been few published reports of natural regeneration after operational harvest activities.

Previous investigations of regeneration after harvesting cypress–tupelo forests have concluded that natural establishment of seedlings is closely tied to hydrological and light conditions (Meadows and Stanturf, 1997), and herbivory (especially nutria) (Blair and Langlinais, 1960; Conner and Toliver, 1987, 1988). Natural regeneration therefore may be absent for decades in places where deep flooding is permanent or nutria populations are large. Regeneration of wetland forest after harvesting on sites with excessive flooding or high nutria populations is not likely (Conner and Toliver, 1990), unless regeneration from stump sprouting (coppice) is strong.

Studies of coppice regeneration after harvest of baldcypress and water tupelo stands have resulted in mixed conclusions. Although stump sprouting is common in the first year after harvest, survival of sprouts decreases with time (Conner *et al.*, 1986). Also, age, season of harvest, stump height, felling method, and harvesting level can influence the viability of stumps and vigor of sprouts (Mattoon, 1915; Hook and DeBell, 1970; Williston *et al.*, 1980; Kennedy, 1982; Ewel, 1996; Gardiner et al., 2000). However, we know of no studies that have followed coppice regeneration of baldcypress for more than five to eight years. Therefore, one objective of the SWG was to gather empirical data on regeneration in coastal forests harvested ten to fifty years ago to evaluate whether such sites have regenerated, become established (long-term survival of desired tree species), and remained cypress–tupelo stands.

Methods

Eighteen coastal forest sites dominated by baldcypress and tupelo and with documented harvest activity between ten and fifty years ago were selected for study (Figure 9). At all but one site, baldcypress was the predominant species harvested and it was usually the only species harvested. We attempted to survey sites throughout the coastal forest area, but the distribution of study sites did not include all possible site conditions within the SWG identified coastal forest area.

The sampling system was targeted to provide information relevant to long-term establishment of regeneration by stump sprouting and natural regeneration, but was not designed to assess the general condition of the forest after harvesting. Data collection at each site used a series of transects 40 feet wide by 100 feet long to survey areas of previous harvest activity, as identified by the presence of stumps. Landowners or land managers furnished information as to age and flood water regimes. At least five transects were used at each site, but measurements were continued on additional transects as required to capture data from a minimum of 30 baldcypress stumps when possible (there were three sites where 30 total stumps could not be located within the sample area; study-wide minimum was 22 stumps, except on the St. Tammany water tupelo study site).

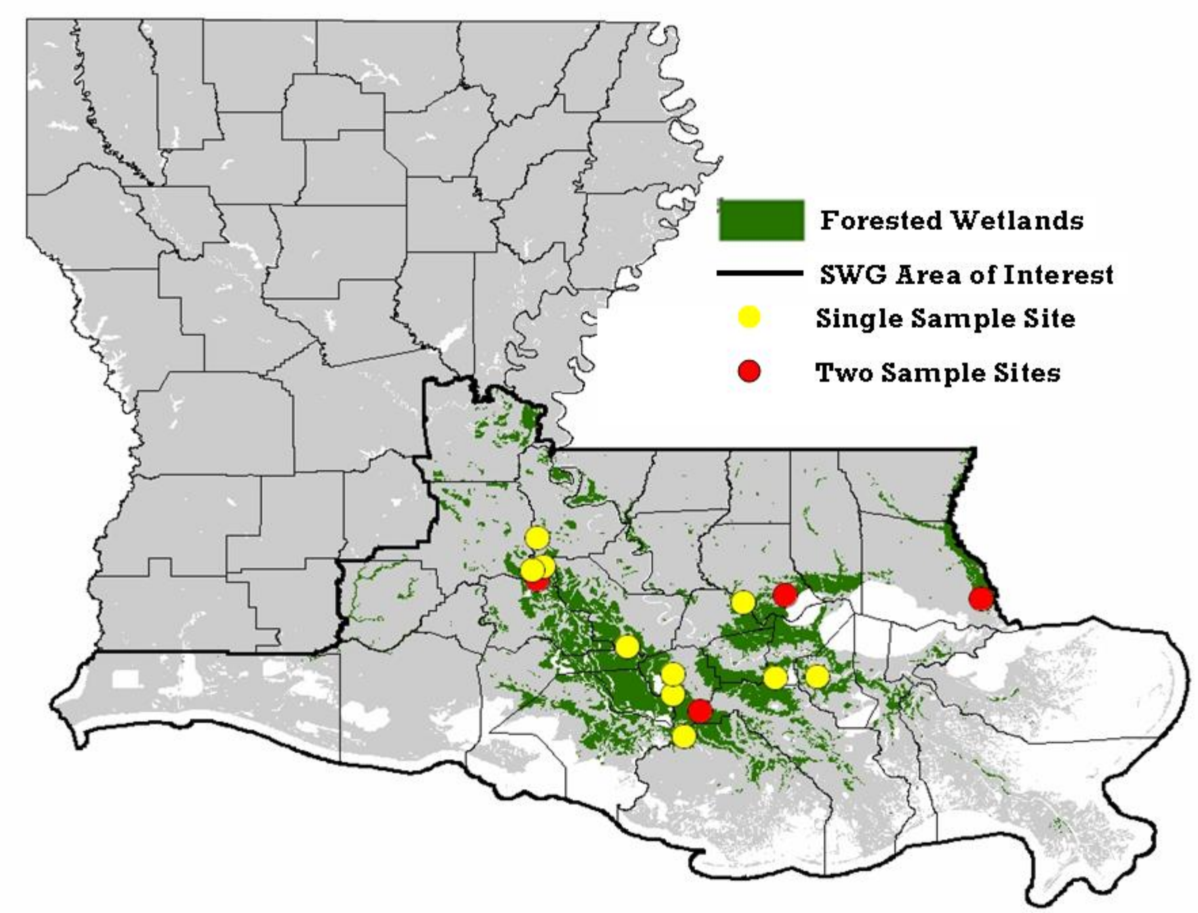


Figure 9. Site locations for coastal baldcypress–tupelo regeneration survey. The bold line indicates the SWG coastal wetland forest area.

Transect measurements included data from all stumps, seedlings, and standing trees. Data collected for each stump included stump height and diameter, depth of water adjacent to the stump, number of live sprouts, diameter and height of the largest sprout, and distance from the stump to the nearest–neighbor canopy tree. Data collected for each standing tree included diameter and species, and each was categorized as a tree, sapling, or seedling. Trees were $\geq$ 4 inches diameter at 4.5 feet height (dbh), saplings were > 4.5 feet tall but < 4 inches dbh, and seedlings were < 4.5 feet tall. Cores were collected from several baldcypress with an increment borer to determine ages and historical growth of trees, saplings, and stump sprouts. All trees were assumed to be three years old at dbh and all stumps were cored near the base within the assumed first year's growth.

Basal area (BA), the cross-sectional area of the tree stem, was calculated for all trees. The relative basal area of each species on an area was calculated as a measure of species dominance, using:

Relative basal area (percent) = (BA of a species/BA of all species) X 100.

Results

Across the sites, relative basal area of standing baldcypress ranged from 6.7 to 97.5 percent, and from zero to 93.2 percent for tupelo (Table 11). Baldcypress and tupelo together represented 66 to 100 percent of the stand BA and exceeded 75 percent on fifteen of the eighteen sites. Other important species in the overstory included the ashes, including green, pumpkin, and Carolina ash, red maple and swamp red maple, several oaks and other bottomland hardwood species.

Table 11. Estimated pre-harvest site characteristics for trees and current aquatic vegetation for surveyed sites.

Location, Parish (harvest type-age)[1]	Tree basal area (ft²/acre)	Trees /acre	Cypress RBA[2] (%)	Tupelo RBA (%)	Cypress and Tupelo RBA (%)	Aquatic vegetation[3]
Assumption 1 (I-20)	236.5	134	90.6	9.0	99.6	Scattered
Assumption 2 (P-20)	300.3	207	93.9	4.3	98.1	Heavy
Assumption 3 (P-19)	218.6	186	68.4	31.0	99.5	Light to moderate
Assumption 4 (P-18)	323.9	232	87.7	9.9	97.6	Heavy
Iberville (P-24)	408.2	432	97.5	2.5	100.0	n/a
Livingston 1 (C-11)	208.5	234	75.3	24.4	99.8	Heavy
Livingston 2 (P-11)	209.3	295	62.1	36.8	98.9	Heavy
Livingston 3 (P-10)	115.5	224	56.7	9.4	66.2	Scattered
Pointe Coupee (P-10)	230.2	215	67.4	4.1	71.5	n/a
St. Charles (P-24)	191.4	185	59.4	37.4	96.8	Light to moderate
St. John (P-17)	274.7	345	78.7	1.5	80.1	n/a
St. Landry (P-9)	127.1	208	66.2	0.0	66.2	n/a
St Martin 1 (P-8)	252.1	170	78.4	0.0	78.4	n/a
St. Martin 2 (P-11)	352.0	281	87.3	0.0	87.3	n/a
St. Martin 3 (P-8)	287.5	215	82.9	1.0	83.9	n/a
St. Tammany1 (C-18)	425.0	353	6.7	93.2	99.8	n/a
St. Tammany2 (P-22)	221.6	273	15.5	84.5	100.0	n/a
Terrebonne (P-41)	254.7	310	55.9	23.9	79.8	n/a

[1] Harvest treatment and years since harvest where: I =Improvement cut; P = Partial cut (generally based on smallest diameter to be cut); C = Clearcut (removal of all commercial baldcypress and tupelo)
[2] Relative Basal Area (RBA) = Cross sectional stem of specified species per acre divided by cross-sectional stem area of trees of all species x 100.
[3] Submerged, emergent, and floating aquatic vegetation

Density of saplings ranged from zero to 2,921 saplings per acre, with a median density of 391 saplings per acre (Table 12). Median density was 11 saplings per acre for baldcypress and about two saplings per acre for tupelo. Although the canopy at all

sites was dominated by baldcypress and tupelo, other species represented 41 to 89 percent of the saplings on sites with heavy understory (six sites had little understory). The dominant understory tree species likely to become canopy dominants were red maple and swamp red maple or the ashes. Species in the understory that will not become canopy trees because of their growth form, but represented competition for saplings of potential canopy species, included waxmyrtle, swamp privet, swamp and roughleaf dogwood, buttonbush, and Virginia-willow.

Table 12. Sapling density and relative density for selected species on surveyed sites.

Location, Parish (harvest type-age)[1]	Tupelo saplings/acre	Baldcypress saplings/acre	All species saplings/acre	Relative density[1] of tupelo (%)	Relative density of baldcypress (%)[2]
Assumption 1 (I-20)	0	11	11	0.0	100.0
Assumption 2 (P-20)	0	11	11	0.0	100.0
Assumption 3 (P-19)	22	10	103	21.9	9.4
Assumption 4 (P-18)	25	18	112	22.0	16.0
Iberville (P-24)	0	7	11	0.0	60.0
Livingston 1 (C-11)	52	38	391	13.2	9.8
Livingston 2 (P-11)	61	0	351	17.3	0.0
Livingston 3 (P-10)	0	14	1281	0.0	1.1
Pointe Coupee (P-10)	2	2	482	0.5	0.5
St. Charles (P-24)	7	56	1231	0.5	4.6
St. John (P-17)	15	6	950	1.6	0.6
St. Landry (P-9)	0	0	0	n/a	n/a
St Martin 1 (P-8)	0	130	1254	0.0	10.4
St. Martin 2 (P-11)	0	49	2921	0.0	1.7
St. Martin 3 (P-8)	1	63	498	0.2	12.7
St. Tammany 1 (C-18)	2	0	54	4.2	0.0
St. Tammany 2 (P-22)	28	0	39	71.4	0.0
Terrebonne (P-41)	3	16	483	0.7	3.3

[1] Harvest treatment and years since harvest where: I =Improvement cut; P = Partial cut (generally based on smallest diameter to be cut); C = Clearcut (removal of all commercial baldcypress and tupelo)
[2] Cross sectional stem of specified species per acre divided by cross-sectional stem area of trees of all species x 100.

Surveyed sites covered a range of site conditions from moist unflooded sites to permanently flooded areas. Baldcypress seedlings were rare in the surveyed areas; they only occurred on four of the 18 sites with density of 16, 44, 108, and 386 seedlings per acre (Table 13). There was no obvious common factor responsible for seedling presence or absence at these sites. Root systems of seedlings at the two sites with the greatest numbers of seedlings were suspended in a slurry of organic matter and unconsolidated sediments, and were not rooted in the mineral soil substrate. According to the landowner, these seedlings are ephemeral in nature on these sites.

Emergent aquatic vegetation and floating aquatic plants, both native and non-native, were absent on seasonally flooded sites, low on some, but covered large areas of others (Table 11).

For the sites where baldcypress was the primary tree harvested, stumps with live sprouts ranged from zero to 72 percent (median 10 percent; Table 14). However, only two of the 16 sites had more than 20 percent of the baldcypress stumps with live sprouts. On four sites, no stumps had live sprouts. The stumps, that sprouted, averaged 2.5 live sprouts per stump at time of measurement. The age of stump sprouts varied from 10 to 41 years based on harvest dates and ages obtained from cores.

The condition of the live sprouts was highly variable (Figure 10). However most sprouts were present on stumps with poor callus tissue formation (wound-covering tissue) and many had advanced decay. In many instances, decay was observed in the base of the sprouts themselves. The hollow nature of some sprouts, the narrow band of living tissue on the stump near the sprout, and the position of sprout-stump interface (36 to 45 inches above the ground) suggested that these sprouts would not likely survive to be mature trees. In some cases, almost the entire stump had callused over and despite minor decay the sprouts appeared to have a good chance of surviving to become mature trees (Figure 10 d). Correlation analysis did not reveal any significant, meaningful relationship between stump sprout survival or size and water depth or other site factors. Most of the stumps were at least 18 inches in diameter.

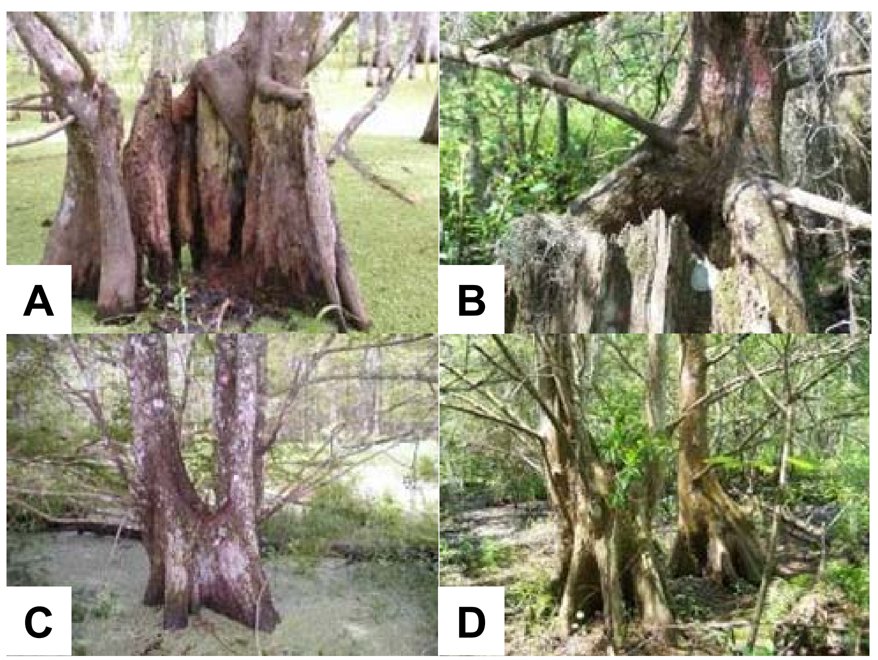


Figure 10. Typical stump sprout variety found on surveyed sites.

On only two (adjacent) sites were tupelo stump sprouts extant. At all other sites, we found very few identifiable tupelo stumps with sprouts, including sites where landowners indicated that tupelo had been cut. Apparently, decay of tupelo stumps was rapid after death of any early sprouts. We therefore lack the basis for calculating proportion of tupelo stumps with successful sprouts, but assume it is very low.

Table 13. Seedling numbers on surveyed sites.

Location, Parish (harvest type-age)[1]	Tupelo seedlings/acre	Baldcypress seedlings/acre
Assumption 1 (I-20)	0	386
Assumption 2 (P-20)	0	108
Assumption 3 (P-19)	0	0
Assumption 4 (P-18)	0	0
Iberville (P-24)	0	0
Livingston 1 (C-11)	0	0
Livingston 2 (P-11)	0	0
Livingston 3 (P-10)	0	0
Pointe Coupee (P-10)	0	0
St. Charles (P-24)	0	16
St. John (P-17)	0	0
St. Landry (P-9)	0	44
St Martin 1 (P-8)	0	0
St. Martin 2 (P-11)	0	0
St. Martin 3 (P-8)	0	0
St. Tammany 1 (C-18)	18	22
St. Tammany 2 (P-22)	48	11
Terrebonne (P-41)	0	0

[1] Harvest treatment and years since harvest where: I =Improvement cut; P = Partial cut (generally based on smallest diameter to be cut); C = Clearcut (removal of all commercial baldcypress and tupelo)
[2] Cross sectional stem of specified species per acre divided by cross-sectional stem area of trees of all species x 100.

The average diameter of the largest live sprout per stump across all sites was four inches, while average height was 22.3 feet. Accounting for varying sprout ages, site-average mean diameter growth ranged from 0.07 to 0.39 inches per year, and site-average mean height growth ranged from 0.5 to 2.7 feet per year. Stump sprout growth was moderately correlated to survival ($R^2 = 0.56$ for height and 0.49 for diameter) (Figure 11a). Sprout growth was also negatively correlated with age ($R^2 = 0.37$ for height and 0.27 for diameter) (Figure 11b).

Annual growth, calculated using tree rings, reveals that basal area growth of sprouts greatly exceeded that of trees from the study sites at similar ages (Figure 12). Mean basal area of sprouts, at age 10, was equal to mean basal area of trees currently in the overstory at age 28. Mean basal area of sprouts, at age 10, was also larger than mean basal area that current understory trees are likely to achieve before at least age 80 (Figure 13). However, it is important to remember that most of the largest trees were removed from the sites in diameter-limit cuts. Estimates of tree growth from current overstory trees are likely underestimates of seed-origin trees in open-grown stands.

Table 14. Baldcypress and tupelo stump sprout characteristics.

Location, Parish (harvest type-age) [1]	Number of stumps	Number of stumps with sprouts	Number of sprouts per stump	Percent of stumps with sprouts	Mean diameter of largest sprout (in)	Mean height of largest sprout (ft)
Assumption 1 (I-20)	29	2	1	6.9	3.6	10.7
Assumption 2 (S-20)	30	5	2.8	16.7	4.6	32.8
Assumption 3 (S-19)	31	6	2.7	19.4	5	28.9
Assumption 4 (S-18)	35	6	2.7	17.1	6.5	31.2
Iberville (S-24)	64	3	3.7	4.7	1.6	12.1
Livingston 1 (C-11)	33	24	5.7	72.7	4.3	26.9
Livingston 2 (S-11)	22	14	4.1	63.6	4.3	29.5
Livingston 3 (S-10)	25	0	0	0	n/a	n/a
Pointe Coupee (S-10)	36	1	1	2.8	2.8	16.4
St. Charles (S-24)	32	2	4.5	6.2	3.7	26.2
St. John (S-17)	30	3	2	10	5.4	33.5
St. Landry (S-9)	30	3	2.7	10	1.4	10.8
St Martin 1 (S-8)	31	4	3	12.9	2.2	14.8
St. Martin 2 (S-11)	36	0	0	0	n/a	n/a
St. Martin 3 (S-8)	30	0	0	0	n/a	n/a
St. Tammany 1 (C-18)	106	87	2.1	82.1	5.3	39.7
St. Tammany 2 (S-22)	7	7	2.7	100	4.2	28.2
Terrebonne (S-41)	30	0	0	0	n/a	n/a

[1] Harvest treatment and years since harvest where: I =Improvement cut; P = Partial cut (generally based on smallest diameter to be cut); C = Clearcut (removal of all commercial baldcypress and tupelo)

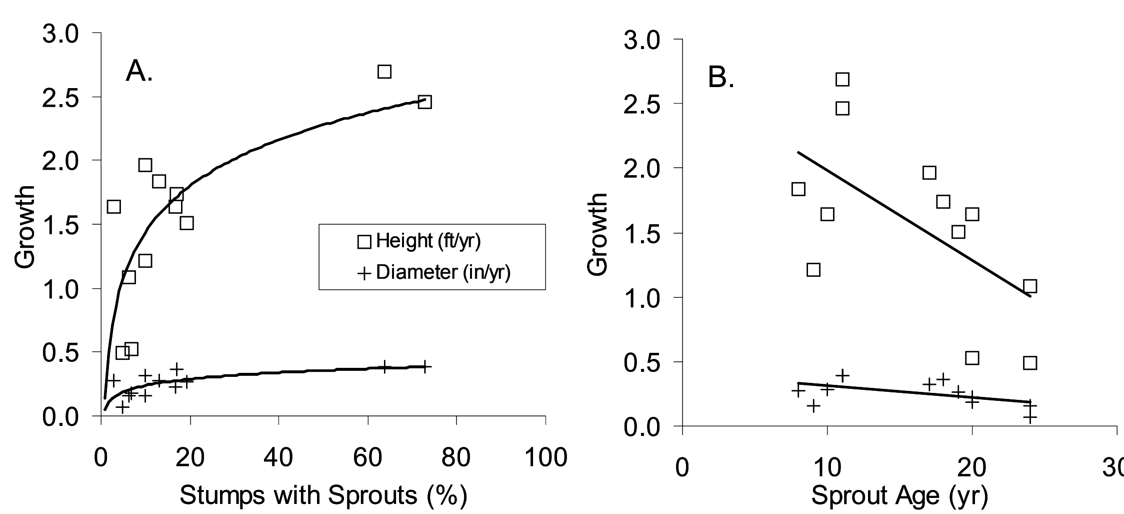


Figure 11. Relationship of baldcypress stump sprout growth (mean annual increment: MAI) to stump sprout occurrence (a) and age (b).

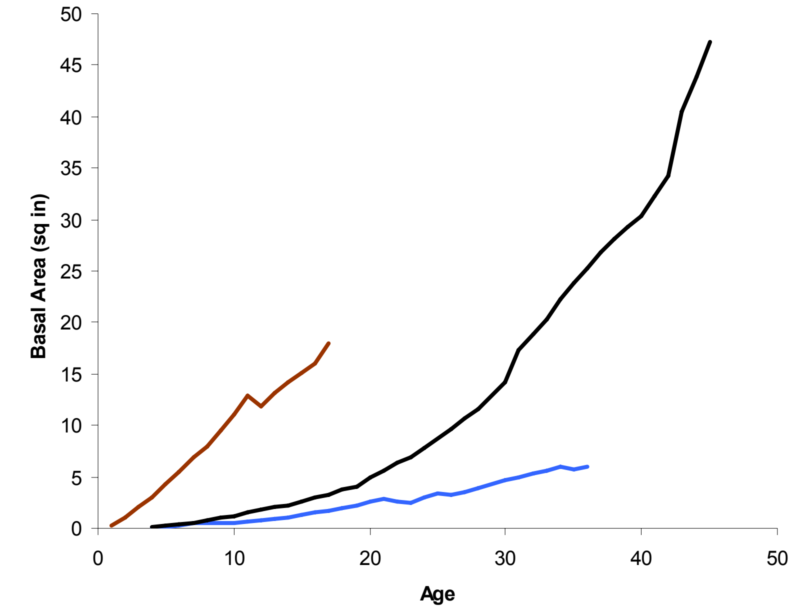


Figure 12. Growth of stump sprouts (brown line), overstory trees (black line) and understory trees (blue line) determined from tree ring analyses.

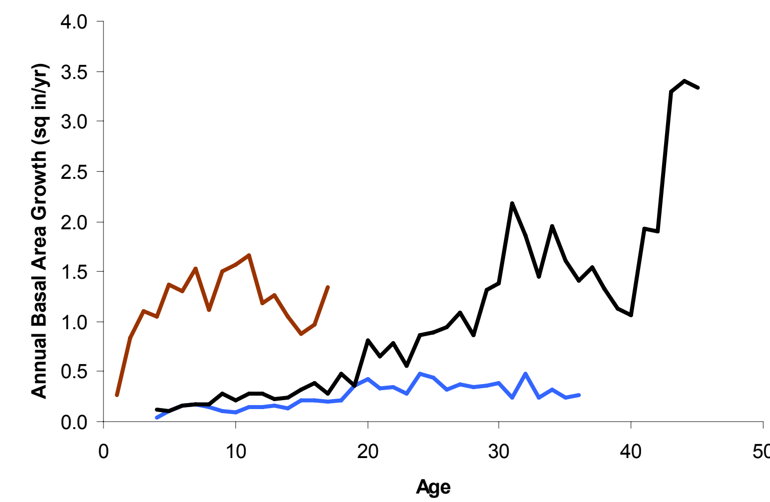


Figure 13. Annual growth of stump sprouts (brown line), overstory trees (black line) and understory trees (blue line) determined from tree ring analyses.

Discussion

The lack of seedlings and poor coppice regeneration for baldcypress and tupelo across the sites is evidence that successional processes will probably move species composition on many of the surveyed stands away from domination by baldcypress and tupelo. If the sites are not excessively flooded during the growing season they will likely become dominated by shade tolerant species. For example, red maple and ash appear poised to dominate the overstory of these somewhat drier survey sites, but with poor quality trees. Preferential harvesting of baldcypress or tupelo (selective harvesting) without specific provisions for baldcypress or tupelo regeneration will likely accelerate this species conversion. Properly designed forest management plans, specific to the site conditions, can help avert species conversion by providing for regeneration of desired species.

Harvesting of permanently flooded sites will eventually lead to major changes in species composition, lower productivity, and conversion to marsh or open water without aggressive artificial regeneration. On sites permanently flooded with deep water, conversion to non-forest conditions is almost certain because baldcypress and tupelo cannot regenerate under these conditions and artificial regeneration is either impractical or impossible.

Based on information from the surveyed sites, stump sprouts cannot generally be considered sufficient to establish a new stand of trees or effectively enhance regeneration under the conditions on the surveyed stands. Interpretation of the survey data as to the effectiveness of stump sprouts as a means of regeneration has several limitations. First, most of the surveyed sites were dominated by baldcypress, which were selectively cut from the stand. This harvesting treatment is probably not suited to produce regeneration of baldcypress or tupelo because light levels often remain relatively low. Second, the trees cut were primarily sawtimber-sized baldcypress trees with relatively large diameters, which have been found elsewhere to be less successful at generating vigorous stump sprouts compared to smaller stumps. Additionally, the partial cutting resulted in lower amounts of sunlight reaching the stump sprouts than in clearcuts or seed-tree cuts. Diameter-limit, partial cuts are common in wetland forests, so the study sites represented typical post-harvest conditions. Natural regeneration would likely improve if more light were available, provided hydrological conditions are suitable for regeneration, and competition and herbivory are not severe. However, these conditions are not common in much of the coastal forest of Louisiana.

Conclusions

The surveyed sites generally are not regenerating to cypress–tupelo forest. This situation is probably at least partially because a relatively dense overstory remained after cutting at some sites, which reduced light levels below those necessary for consistent regeneration from either seeds or stump sprouting. However, flooding appeared to be responsible for eliminating all regeneration from seedlings at many sites. Regeneration from stump sprouting was not sufficient to regenerate surveyed stands on its own. Although stump sprouts were locally vigorous, they were spatially not consistent and we found nothing to explain variation in stump sprout survival or vigor. Overall, the data from the survey were consistent with previous research that has found natural seedling regeneration to be lacking in Louisiana coastal forests, and suggested stump sprout regeneration will not be sufficient to compensate.

HISTORIC AND CURRENT CONDITIONS OF CYPRESS-TUPELO FORESTS IN LOUISIANA

Swamp forests represent a unique and important ecosystem in the southeastern United States. These forests are dominated by baldcypress and pondcypress, but pondcypress is of minor importance in Louisiana (Sternitzke, 1972). The natural geographical range of baldcypress begins in Delaware, extends along the Atlantic Coastal Plain to Florida and westward along the Gulf of Mexico to Texas, and extends up the Mississippi River floodplain as far north as southern Illinois and southwestern Indiana (Fowells, 1965). Very little seed matures at the northern limits of its range, but planted baldcypress can survive as far north as Massachusetts (Bonner, 1974) and New Hampshire (personal observation). The term baldcypress will be used whenever this species is discussed for Louisiana. The term cypress will only be used when it refers to both baldcypress and pondcypress.

Baldcypress-dominated ecosystems of coastal Louisiana have experienced widespread hydrological, biogeochemical, and biological changes over the past century, and declines in some populations have been apparent (Conner and Toliver, 1990). Little is known, however, about the present state of baldcypress ecosystems at the scale of the entire coastal Louisiana region. This knowledge gap has developed because of physical inaccessibility and lack of active forest management after a period of intense logging in the early 20th century.

This report reviews accounts of baldcypress forests from historic times and compares them to the best estimates of current conditions from the USDA Forest Service Forest Inventory and Analysis (FIA) to assess the state of coastal baldcypress-dominated forests in an historical context.

Historic Conditions

Baldcypress was a common and often dominant tree in the coastal plain of Louisiana when settlers first arrived in the state, prompting du Pratz to write in 1774 "... there is the greatest plenty immediately to the westward of the mouth of the Mississippi" (Tregle, 1975). Nearly pure stands of baldcypress were found in the back swamps and deep swampy portions of the river floodplains (Mattoon, 1915). The baldcypress forests seemed inexhaustible to these early settlers (Louisiana Department of Conservation 1926) with nearly 15 billion board feet of baldcypress estimated in the delta swamps at the time of settlement (Kerr, 1981). Wherever it occurred, baldcypress was characteristically the predominant tree (Mattoon, 1915). Other important species include red maple, ashes, and water tupelo (Conner and Day, 1976).

To the early settlers, these swamplands were considered dangerous and forbidding (Bartram, 1791 in van Doren, 1928). However forbidding the swamp forests appeared, the value of baldcypress wood was recognized early, and it was easily obtainable because swamps were located behind nearly every plantation home (Moore, 1967). Until the 1790s, baldcypress boards and timbers represented the main cash crop of the colonists in the state. Baldcypress remained a stable commodity of the lumber industry into the 1800s because of its durability and workability (Mattoon, 1915). Baldcypress was used extensively in house construction and was a preferred material for tanks used for water storage and by creameries, breweries, bakeries, dyeworks, distilleries, and soap and starch companies. It was also used for pumps, laundry appliances, caskets, and coffins. Baldcypress shingles were known to outlast all roofing materials except the best quality slate and tile (Mattoon, 1915).

In Louisiana, the area of greatest commercial production included all of the alluvial floodplain of the Mississippi River but mainly was concentrated in the area south of Baton Rouge (Mattoon, 1915). Unfortunately, detailed area, volume, and logging data do not exist for many areas (Norgress, 1947, Mancil, 1972). There are scattered records of varying reliability on the total area of baldcypress swamp in the state (Table 15, Figure 14) and some parish by parish harvesting records (see Conner, 1988 for parish details). Mattoon (1915), Norgress (1936, 1947), and Mancil (1972) have all described the history of baldcypress logging in Louisiana.

Table 15. Various estimates of the area of swamp lands in Louisiana.

Year	Land or forest type classification	Area (million acres)	Source
1848	swamp lands	2.27	Norgress 1947
1872	wooded swamps	2.74	Post 1969
1910	cypress and bottomland hardwood	2.89	Grace 1910
1915	permanent swamp	8.99	Mattoon 1915
1934	bottomland hardwood	7.46	U.S. For. Serv. 1955
1934	cypress and denuded cypress	1.65	Louisiana Dept of Conservation 1934
1935	cypress-tupelo	1.19a	Winters 1939;Winters *et al.* 1938
1954	bottomland hardwood	6.59	U.S. For. Serv. 1955
1954	oak-gum-cypress	5.90	U.S. For. Serv. 1955
1954	tupelo-cypress	1.06a	U.S. For. Serv. 1956
1964	oak-gum-cypress	5.83	Sternitzke 1965
1974	oak-gum-cypress	4.96	Earles 1975
1978	wooded swamp	1.63b	MacDonald *et al.* 1979
1980-81	cypress-tupelo	0.35c	Wicker *et al.* 1980, 1981
1984	oak-gum-cypress	3.93	Rosson and Bertleson 1985, 1986a-d
1991	oak-gum-cypress	4.35	Rosson 1995

[a] Only includes those parts of the state classed as north and south delta.
[b] Only includes the Mississippi River floodplain.
[c] Only includes the Louisiana coastal zone.

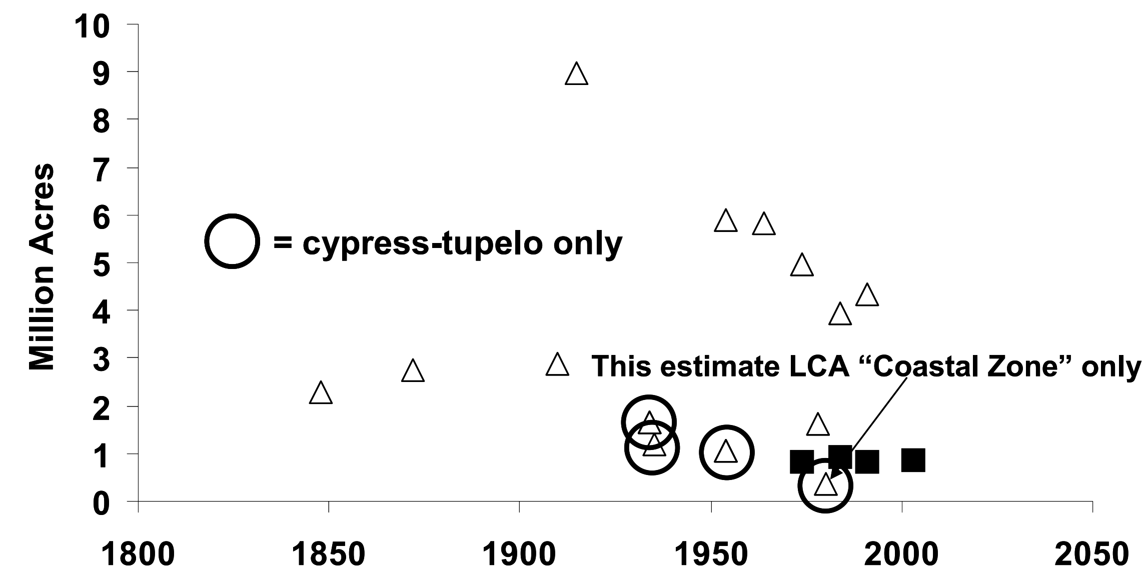


Figure 14. Estimates of historical area of Louisiana swamps. Triangles are estimates from Table 13 and squares are Forest Service FIA data from the combined South East and South Delta regions of Louisiana (Figure 1). Circled triangles are estimates of swamp area that include cypress-tupelo swamps only.

Baldcypress logging was originally limited to floating previously girdled trees out during high water periods, and was thus limited to areas near large rivers. During the 1890s, however, the pullboat, and later the overhead-cableway skidder, increased the range of the logger and the amount of timber that could be brought out of the forest. By the close of the 19th century, three billion board feet of baldcypress had been logged in Louisiana (Kerr, 1981). Extensive logging in the state led people to declare that the resource could not last for long. M. LePage du Pratz (Tregle ,1975) observed during the 18th century:

> "The cypresses were formerly very common in Louisiana; but they have wasted them so imprudently, that they are now somewhat rare. They felled them for the sake of their bark, with which they covered their houses, and they sawed the wood into planks which they exported at different places. The price of the wood is now three times as much as it was formerly."

Du Pratz's comments were a little premature, however, as considerable quantities of baldcypress timber were cut during the mid-1800s for use in mills along the Mississippi River (Post, 1969), and baldcypress lumbering continued to thrive in Louisiana with the period of highest production occurring between 1890-1925. Baldcypress timber production peaked in 1913 (Table 16, Figure 15) with over 700 million board feet being processed in 94 mills (Mattoon, 1915). Depletion of the vast virgin stands of baldcypress timber and the Great Depression caused most of the baldcypress mills to close (Burns, 1980).

Table 16. Volume of cypress cut in the state of Louisiana (Louisiana Department of Conservation, 1943; Steer, 1948; Louisiana Forestry Commission, 1957; Louisiana Forestry Commission Progress Reports, 1956-76; Mistretta and Bylin, 1987).

Year	Timber harvested 10^6 bd ft	Year	Timber harvested 10^6 bd ft
1869	7,000	1933	43,636
1879	45,000	1934	34,703
1889	100,000	1935	54,066
1899	248,532	1936	69,619
1904	432,233	1937	89,416
1905	487,504	1938	73,734
1906	573,096	1939	81,798
1907	509,665	1940	70,568
1908	488,670	1941	57,821
1909	608,854	1942	52,814
1910	653,699	1943	48,963
1911	682,867	1944	31,375
1912	653,727	1945	24,461
1913	744,581	1955	25,757
1914	672,211	1956	19,437
1915	560,751	1957	13,352
1916	527,425	1959	15,954
1917	509,659	1962	15,866
1918	296,986	1963	15,468
1919	308,139	1964	9,047
1920	273,116	1965	9,462
1921	348,568	1966	8,580
1922	364,687	1967	8,219
1923	307,283	1968	6,820
1924	299,664	1969	7,836
1925	274,040	1970	6,645
1926	230,782	1971	5,115
1927	185,543	1972	5,120
1928	147,162	1973	3,157
1929	111,739	1974	5,776
1930	108,713	1975	3,017
1931	52,060	1984	19,600
1932	38,586	1985	24,882

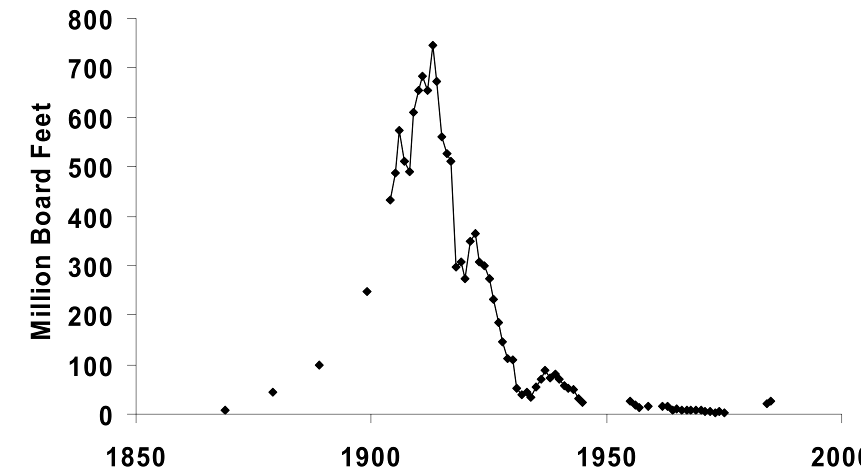


Figure 15. Volume of cypress cut in the state of Louisiana.

During the peak of the logging period, some landowners and loggers began to wonder about the future of their cutover lands. As early as 1872, Lockett (Post, 1969) thought that a great deal of the swamp land was reclaimable, but there was very little interest in the state at that time in trying to do anything. Mattoon (1915) considered that the cutover lands were mostly unproductive and were being held chiefly for their potential value for agriculture after draining and clearing. Mattoon also reported that very little serious consideration had been given to the question of the future use of logged baldcypress lands. He recognized that there was a strong tendency towards conversion and, as a result, many operators were in favor of taking every baldcypress tree of possible value and leaving none for future return.

Sonderegger (1922) estimated that baldcypress forests would be depleted by 1940. By 1924, the estimate had been revised to 1935 (Louisiana Department of Conservation, 1926), and this estimate held through 1931 (Maestri, 1931). A proposal was presented to the U. S. Department of the Interior to create a baldcypress swamp national monument in Louisiana before all the virgin timber was logged (King and Cahalane, 1939). However, no action was taken.

Even in the 1940s, there was little regard for ensuring that cypress would be a renewable resource. Norgress (1947) reported there were 1,628,915 acres of cutover cypress swamp lands in Louisiana and that by logging, the first step had already been towards converting these areas to its true function – agriculture.

Logging continued in the swamplands of Louisiana to some extent until the last baldcypress logging operation closed in 1956 at which point Mancil (1972) declared that the baldcypress industry was gone forever. He further stated these cutover stands were not likely to be regenerated because of the problems of reforestation and management of baldcypress.

However, some hardwood mills continued to harvest limited quantities of baldcypress (Mancil, 1980). Paul Frey (State Forester, Louisiana Department of Agriculture and Forestry) estimated that 120 million cubic feet were cut from 1986 through 2003, which would average roughly seven million cubic feet per year. It therefore appears that baldcypress harvest stabilized during the mid-1960s at 10-15% of the maximum harvests rates, which occurred almost 100 years ago. Growing stock volume since the 1950s continued to increase in the state until the 1980s (Figure 16), but seemed to be leveling off. However, the recent announcement of the building of a new cypress sawmill north of Hammond, Louisiana, recent cypress logging in south Louisiana, the new market for cypress mulch, and the rise in prices for cypress stumpage and lumber indicate a revived interest in harvesting baldcypress.

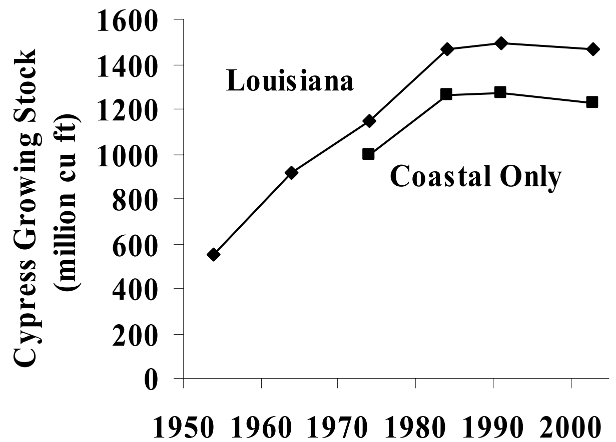


Figure 16. Baldcypress growing stock volume in Louisiana.

An accurate estimate of the area of baldcypress in the state of Louisiana is not available (Table 15, Figure 14) mainly because of the various ways the resource has been measured in the past. With the Swamp Land Act of 1849, 10 million acres of swamp lands were awarded to the state by the Federal government. Not all of these were baldcypress lands, however. Another estimate of swamp lands came from the Surveyor General's Office in 1848 which reported 2.3 million acres of swamp lands in the state, most of which was considered baldcypress (Norgress, 1947). Mattoon (1915) estimated that there were 9 million acres of permanent swamps in the state. Probably the most accurate estimate of baldcypress swamps in the state came from the Louisiana Department of Conservation (1934) which indicated that 22,356 acres of baldcypress were left in the state along with over 1.6 million acres of denuded baldcypress land. MacDonald *et al.* (1979) reported that there were 1.6 million acres of wooded swamp just in the Mississippi floodplain, but recent estimates by Wicker *et al.* (1980, 1981) indicate that only 345,911 acres of cypress-tupelo swamp exist in the state. Their estimate is low, since the area surveyed covers only the official coastal zone region of Louisiana, which does not include some baldcypress areas in the Barataria and Atchafalaya basins as well as in the northern and central parts of the state. Overall, it appears that that the area of baldcypress swamp land in Louisiana is declining.

Current Conditions: Forest Inventory and Analysis (FIA) Data

The most complete data available on the area of forest types in Louisiana comes from the U.S. Forest Service continuous forest inventory started in 1934. The program, now known as Forest Inventory and Analysis (FIA), has periodically

inventoried forests of the U.S. since 1930 by statistical extrapolation from periodically remeasured permanent plots. Routine reporting of these data by the Forest Service has historically consisted of state-level published summaries, with some data summarized by smaller subregions. Unfortunately, plot data older than 1974 were destroyed by routine purging of government documents, so it is not possible to analyze data by any criteria not reported in basic Forest Service summary publications for before that time.

It is difficult to use FIA reports to estimate historical changes in baldcypress swamp before 1974. Baldcypress swamp has not always been a separate category in reports, and has often been included in the oak-gum-cypress category. From an estimated 7.4 million acres in 1934 (calculated from U.S. Forest Service 1955 estimates of the amount of reduction in area between 1934 and 1954), the total area of oak-gum-cypress forest declined to 3.9 million acres in the mid-1980s (Rosson and Bertelson, 1985, 1986a-d) – nearly a 50% reduction in area in only 50 years. Turner and Craig (1980) noted that if the declining trend continued at the rate current at that time, the area of forested wetland in the state would be reduced by another 50% by the year 2000. However, much of the loss of oak-gum-cypress forest type in the state prior to the 1980s was by clearing of bottomland hardwoods for agriculture in the alluvial valley of the Mississippi River north of coastal wetlands (Shepard *et al.*, 1998).

To focus on coastal baldcypress swamps, we conducted new analyses of data from 1974, 1984, 1991 and 2003. Louisiana FIA surveys in 1991 and earlier (1934, 1954, 1964, 1974, and 1984) were statewide measurements of plots on a 3-mile grid, repeated approximately once per decade. Subsequent surveys are based on a new system whereby 20% of all plots are measured at higher frequency (these 20% blocks of plots are termed "panels"). Also, the new system (adopted 1998) incorporates a new, nationally standard plot spacing on a hexagonal grid. Converting from the old square grid to the new hexagonal grid means that some pre-1998 plots are being abandoned and new plots established. Because the first survey under the new hexagonal system has not yet been completed, no precise data yet exist on how many pre-1998 plots will remain part of subsequent surveys. As of December 2004, FIA has published data from 60% of new Louisiana plots measured through 2003. Of the first three panels to be measured and published, 826 are re-measured pre-1998 plots, 394 are new plots, and 42 are replacement plots.

Although the FIA data are extensive, the sampled proportion of land area is quite small. For the 30 parishes of the coastal area used in this report, there were 1603 pre-1998 plots, of which less than half were forested (Table 17). Of the forested plots, about 20-30% (depending on year) were in cypress-tupelo forest.

Table 17. Number of FIA plots in the SWG Coastal Wetland Forest Area of Louisiana

Sample Year	Total Plots	Forested Plots	Cypress-tupelo Plots
1974	1603	735	147
1984	1603	687	170
1991	1603	683	150
2003 (3 panels = ~60% of total)	1262	547	54[1]

[1]Thirty-seven former cypress-tupelo plots now abandoned; classified hazardous or access denied

Some parts of the coastal area have insufficient forest cover for surveying by FIA. Parishes that were never surveyed before 2003 are Cameron, Jefferson, Orleans, Plaquemines, and St. Bernard. Thus, FIA does not include information on baldcypress ecosystems over a portion of the edge of its range. Parishes that were surveyed but included very small numbers of forested plots are Lafayette (1 forested plot of 32 total) and Vermillion (2 forested plots of 78 total). The highest density of forested plots is in the Florida parishes, but forest cover is dominated by pine. The parishes with the most 1991 plots in cypress-tupelo forest were St. Martin (20), Assumption (11), Terrebonne (11), Lafourche (10), and St. John the Baptist (10). Parishes with no plots in cypress-tupelo forest in 1991 were E. Feliciana, Lafayette, Pointe Coupee, St. Helena, Vermillion, and W. Baton Rouge.

The abandonment of pre-1998 plots and establishment of many new plots in the conversion to the panel system beginning with the 2003 data has reduced the strength of comparisons among survey periods, at least between the two most recent surveys. Historically, the same plots were remeasured in each successive survey, so although samples sizes were still relatively small compared to the extent of baldcypress forests in Louisiana, each plot was followed through time and provided a long-term record of a particular site. The new system does not allow for reliable comparisons among 2003 (and future) surveys and past surveys because new plots have been established and some historic plots have been removed. Therefore, variability in baldcypress trends may partially be a result of the new sampling design rather than real changes in the forests. All interpretation of 2003 data should be considered preliminary and lacking in precision when making comparisons to previous surveys. Sample sizes in all years are too small for robust estimation of any summary data of baldcypress forests at the parish level or by geographical extent (e.g., Atchafalaya Basin, Lake Maurepas area) because FIA was not designed to allow monitoring of forest changes over spatial scales smaller than an entire state.

Results of FIA Analysis

Total forest cover in the study area decreased by 6% from 1974-2003, but area of baldcypress forest increased by 4% from 0.81 million acres to 0.85 million acres (Figure 17. The biggest changes in land area covered by cypress-tupelo forests occurred between 1974 and 1991, when about 125,000 acres were added from 1974-1984 and about 112,000 acres lost from 1984-1991 (net gain about 14,000 acres). This period was marked by additions from reversion from agriculture (mainly in the 1974-1984 period) and losses from agriculture and urbanization (1984-1991 period) of 11-15% of the total area. The FIA data show essentially no change (2% gain) in total area covered by cypress-tupelo forests during the period 1991-2003. There are some technical barriers to precise assessment of the area of cypress-tupelo forest over time. Timber types in FIA are assigned based on computer algorithms sensitive to stocking of particular species. Addition or subtraction of one or two trees on some plots over time might have led the forest classification to change between cypress-tupelo and, for example, sweet bay-swamp maple-tupelo. Small sample sizes mean that the fluctuation of 100,000 acres in the inventory arose from the change in classification of just 20 plots.

In 1991, 84% of the volume of baldcypress growing stock was in the cypress-tupelo forest type, and the remainder was mainly in bottomland hardwood associations. In 2003, this proportion remained stable at 85% of baldcypress volume in cypress-tupelo stands (data for 1974 and 1984 were not readily available). This means that FIA data on baldcypress volume and growth are dominated by baldcypress in its core habitat.

Cubic foot volume of wood in baldcypress growing stock increased by 27% from 1974 to 1984 (Figure 16). An additional 4% increase in volume occurred from 1984-1991, but a 3% decrease occurred from 1991-2003. Essentially, the standing volume of baldcypress has remained nearly unchanged since the 1984 survey. Using the volume of baldcypress over the entire state as an index for growth in the coastal region, it appears that growth rates of 20-30 million cubic feet per year from the 1950s to 1980s (Figure 16) has essentially ceased.

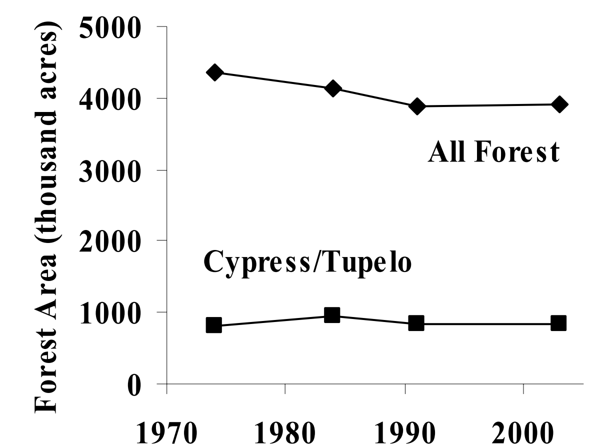


Figure 17. Forest cover in the SWG Coastal Wetland Forest Area of Louisiana

From 1974-2003, baldcypress has maintained or increased its relative dominance within cypress-tupelo forests (Figure 18). Basal area of baldcypress in cypress-tupelo stands has increased from an average of 56 square feet per acre in 1974 to 64 square feet per acre in 2003. In contrast, non-baldcypress (mainly tupelo) showed decreases in basal area from 87 square feet per acre to 70 square feet per acre from 1984 to 2003. Thus, while baldcypress is not growing quickly, it is at least maintaining its position in mixed stands. This decreasing non-baldcypress basal area also suggests that water tupelo may be in substantial decline.

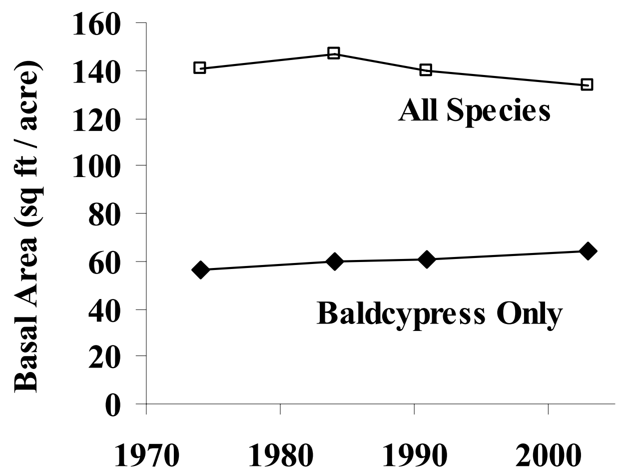


Figure 18. Basal area of cypress-tupelo forests in the SWG Coastal Wetland Forest Area of Louisiana.

Baldcypress forests of the region in 1974 were dominated by relatively small trees, but 29 years of growth has seen the size structure change to be dominated by larger trees (Figures 19 and 20). These trends follow classic patterns of stand development, and suggest that baldcypress is generally continuing to grow in the region. The fact that baldcypress trees are continuing to grow in diameter but little additional wood volume is accumulating (Figure 16) and basal area is increasing only slowly (Figure 18) indicates that most stands are either at high stocking or that environmental stresses are preventing stands from growing more dense. The stand densities of < 150 square feet per acre are below biological limits, suggesting that environmental stresses are suppressing stand growth.

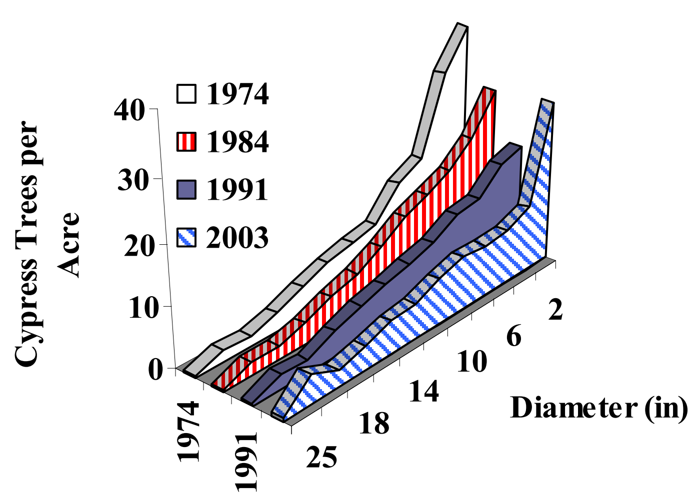


Figure 19 Size-class structure of baldcypress trees in the SWG Coastal Wetland Forest Area of Louisiana for four survey periods.

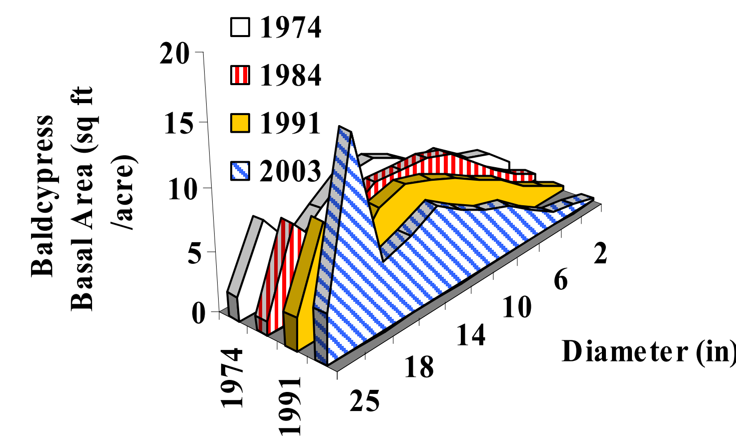


Figure 20. Basal area contributions of baldcypress trees of varying diameters in the SWG Coastal Wetland Forest Area of Louisiana for four survey periods.

Current Conditions: Summary

The FIA data suggest that baldcypress forests are approximately stable in extent, growing and maintaining themselves in mixed cypress-tupelo stands at the regional scale. However, the data are not well suited for making precise statements about geographical differences in the status of baldcypress forests within the coastal region because sample sizes are low. Thus, the data are insufficient to determine whether baldcypress forests are declining/stable/expanding and/or growing in coastal wetland forests. There are large areas within the study region where baldcypress growth and/or survival are known to be low or non-existent but the FIA data are insufficient to tease out any such local trends. The same limitations on the data prevent determination of whether the environmental stresses reducing growth are widespread or are local.

POLICIES AND REGULATIONS

A review of state policies and regulations relating to best management practices (BMPs) for timber harvest focused on coastal states across the United States. In general, state BMPs are concerned with impacts on water quality. The following is a summary of federal and state regulations affecting timber harvest.

Clean Water Act Section 404 and Silvicultural Exemptions

Federal Water Pollution Control Act (33 U.S.C 1251 et seq., amended 1977, amended through P.L. 107 – 303, November 2002) and commonly referred to as the "Clean Water Act"; Section 404; Title 33 – Navigation and Navigable Waters; Chapter 26 Water Pollution Prevention and Control; Subchapter IV – Permits and Licenses, Sec. 1344 – Permits for dredged or fill material.

This section of the Clean Water Act is one of two federal acts that govern timber harvest in coastal and freshwater wetlands, and is primarily regulated by the U.S. Environmental Protection Agency (U.S. EPA). As Section 404 defines permitted actions in wetlands, actions affecting water quality, and defined state administration, all state BMPs were viewed as modeled on regulations put forth in this act. Section 404 of the Clean Water Act (CWA) establishes a program to regulate the discharge of dredged or fill material into waters of the United States, including wetlands. Activities in waters of the United States regulated under this program include fill for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports), and mining projects. Section 404 requires a permit before dredged or fill material may be discharged into waters of the United States, unless the activity is exempt from Section 404 regulation (e.g. certain farming and forestry activities).

Activities regulated under Section 404 are reviewed through a three-part process, which entails avoidance, minimization, and compensation of adverse impacts to wetlands and other aquatic resources. This sequence requires that potential wetland impacts first be avoided and then minimized to the maximum extent practical. Compensatory mitigation is then required to offset unavoidable impacts, and is defined as the restoration, creation, enhancement, or (in exceptional circumstances) preservation of wetlands and/or other aquatic resources. This requirement allows for compensation for unavoidable adverse impacts that remain after all appropriate and practical avoidance and minimization has been achieved. Compensatory mitigation includes project-specific mitigation, mitigation banks, and in-lieu-fee mitigation.

Under Clean Water Act Section 404(f), a permit is generally not required if discharges of dredged or fill material are associated with normal farming, ranching, and forestry activities such as plowing, cultivating, minor drainage, and harvesting for the production of food, fiber, and forest products. This exemption pertains to normal farming and harvesting activities that are part of an established (i.e., ongoing) farming or silvicultural operations. If an activity involving a discharge of dredged or fill material represents a new use of the wetland (e.g. conversion to upland), and the

activity would reduce reach or impair flow or circulation of regulated waters, including wetlands, the activity is not exempt. Both conditions must be met in order for the activity to be considered non-exempt. In general, any discharge of dredged or fill material associated with an activity that converts a wetland to upland is not exempt, and requires a Section 404 permit. Determination of whether logging activities in cypress/tupelo swamps in coastal Louisiana are exempt under Clean Water Act Section 404(f) is currently being done on a case-by-case basis, after taking into consideration information specific to each proposed logging operation.

Rivers and Harbors Act of 1899

Rivers and Harbors Act of 1899 (amended 1994) (33 U.S.C., Sec. 403, Chapter 9, Subchapter I – Codification from Ch. 425, Section 10 Rivers and Harbors Act of 1899).

Section 10 of the Rivers and Harbors Act of 1899 (Section 10), prohibits the unauthorized obstruction or alteration of any navigable water of the United States, unless a Department of the Army (DA) permit has been issued by the U.S. Army Corps of Engineers (Corps). The Corps implementing regulations for Section 10 are found at 33 CFR part 322, and states a DA permit (via the Corps) is required for the construction of any structure in, over, or under navigable waters, the excavation of material from navigable waters, the deposition of material into navigable waters, or any other work that affects the course, location, condition, or capacity of navigable waters.

Navigable waters of the United States are defined at 33 CFR 329.4 as: "those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce." In tidal waters, the shoreward limit of navigable waters extends to the line on the shore reached by the plane of the mean high water (see 33 CFR 329.12(a)(2)). In bays and estuaries, Section 10 jurisdiction extends to the entire surface and bed of all bodies of water subject to tidal action (see 33 CFR 329.12(b)). In rivers and lakes, Section 10 jurisdiction extends laterally over the entire water surface and bed of a navigable waterbody, including all land and waters below the ordinary high water mark (OHWM), even though such waters may be extremely shallow or obstructed by shoals or vegetation (see 33 CFR 329.11(a)). Therefore, Section 10 jurisdiction extends to marshes and forested wetlands that lie between the channel and mean high water line or OHWM.

Unlike the Clean Water Act, there are no exemptions under Section 10 for regulated work within navigable waters of the United States. Examples of work associated with silvicultural activities that require Section 10 permits if they occur within navigable waters include: deposition or redistribution of fill material associated with logging roads, stream crossings, and staging areas; construction or placement of structures such as timber mats and loading/offloading ramps; stockpiling of timber; and excavating or dredging for any reason.

Existing State Regulations for Louisiana Coastal Forests

Landowners conducting timber harvest operations on lands located within the Louisiana Coastal Zone need a Coastal Use Permit before commencing work if the U.S. Army Corps of Engineers (USACE) has determined their operations are not exempt under Section 404 of the Clean Water Act or Section 10 of the Rivers and Harbors Act. Whereas the Louisiana Coastal Resources Program typically provides an exemption from permitting for normal silvicultural activities on lands consistently used in the past for such activities (La. R.S. 49:214.34.A.3), this exemption does not apply to those components of proposed timber harvest operations that require a permit from the USACE under either Section 10 of the Rivers and Harbors Act or Section 404 of the Clean Water Act (Louisiana Administrative Code, Title 43, Part I, Chapter 7, Section 723.B.7.a.ii).

State Best Management Practices (BMPs)

In general, the state BMPs reviewed followed the guidelines of Section 404 regulations and were aimed primarily at controlling nonpoint source pollution, protecting wetlands, and promoting water quality. Only two states (Alaska and Florida) mentioned particular species – spruce and cypress, respectively – in their BMPs. States varied in the attention given regeneration following harvest. Virginia included several chapters devoted to regeneration, emphasizing conventional silvicultural techniques for site preparation.

Louisiana: BMPs have specific guidelines for "normal silvicultural practices" that include defining normal silvicultural activities and established operations. Attention is given to operations in wetlands that would result in conversion from wetland to upland, but no mention is made of conversion of wetland to open water. Specific discussion is provided to determine activities that would result in a permit under Section 404.

Forested wetlands are given special attention in Louisiana's BMPs, with approximately one-third of the total BMPs guideline devoted to forested wetlands. These BMPs contain 15 mandatory practices for roads in jurisdictional wetlands, including water regime flow and vegetative disturbance resulting from road construction and maintenance, borrow and fill materials, and culverts. Mandatory BMPs also provide for protection of habitat for threatened and endangered species, breeding and nesting areas for waterfowl and spawning beds, and prohibitions for discharge in proximity of public water supplies, into concentrated shellfish populations, national wild and scenic river systems.

Alabama: Alabama's BMPs are found in a series of "Fact Sheets" detailing information on individual topics. Harvest, site treatments, and regeneration are focused primarily on pines. See http://www.forestry.state.al.us/

Alaska: Forest management practices on state, municipal, and private lands in Alaska are covered under the Alaska Forest Resources and Practices Act (FRPA AS 41.17). Best Management Practices (11 AAC 95) were included to address timber activities in riparian zones, aimed primarily at ensuring water quality and follow closely those provisions of Section 404 of the Clean Water Act. Aside from Florida, Alaska was the only state to make specific mention of tree species (spruce, *Picea sp.*) in BMPs. See http://www.dnr.state.ak.us/forestry/forestpractices.htm#act

Florida: Florida provides extensive BMP guidelines, with strong emphasis on protecting water quality. No specific mention is made of cypress harvests, however a separate document (Cypress Task Force Consolidated Report 1996-2002) details what is known to date of requirements for sustaining cypress regeneration following harvest. For Florida's BMP guidelines, see http://www.fl-dof.com/forest_management/bmp/index.html

Georgia: BMPs for Georgia were developed mainly to address impacts of timber harvest and management on water quality, specifically nonpoint source and thermal pollution. In 1999, Georgia's Forest BMPs were combined with Wetland BMPs into one comprehensive document. See http://www.gfc.state.ga.us/Publications/RuralForestry/GeorgiaForestryBMPManual.pdf

Hawaii: Hawaiian state regulations regarding timber harvest and forest management center on the effects of activities on water quality. Particular mention is given to sediment control, use of pesticides and herbicides, road construction, and harvest on steep slopes. State regulations for Hawaii go beyond Section 404 provisions to recognize the high potential for erosion on steep slopes. Recommended reforestation guidelines are to follow generally accepted silviculture techniques. See http://www.state.hi.us/dlnr/dofaw/wmp/bmps.htm

Maine: The primary focus of BMPs for Maine is water quality. All aspects of harvest are discussed in terms of reducing impact on isolated wetlands and riparian zones. Discussion of regeneration is aimed at reducing runoff and siltation, but does not mention regeneration of specific species. http://www.state.me.us/doc/mfs/pubs/bmp_manual.htm

Maryland: Maryland emphasizes wetland protection in that state's BMPs, and focuses discussion of timber harvest on controlling nonpoint source pollution and sedimentation. See http://www.dnr.state.md.us/forests/landplanning/bmp.html

Mississippi: Mississippi BMPs emphasize road construction, site preparation, harvesting, revegetation, and riparian zone protection. Revegetation is primarily concerned with soil stabilization to prevent erosion, and refer to

USDA Forest Service recommendation for seeding density. See http://msucares.com/forestry/education/bmp.html

North Carolina: The title of North Carolina's BMPs, "Forest Practices Guidelines Related to Water Quality," is descriptive of the content and focus of the document. Material related to timber harvest emphasizes water quality, with little discussion of regeneration aside from site treatment. See http://www.dfr.state.nc.us/water_quality/pdf/fpg.pdf

Oregon: Oregon's BMPs were codified in the Oregon Forest Practices Act of 1971, the first of its kind in the U.S. Regulations are centered on protecting waterways from nonpoint source pollution, sedimentation, and temperature fluctuations. Also included are regulations preventing fire resulting from timber harvests. http://www.odf.state.or.us/

South Carolina: South Carolina follows other states in designing BMPs to target water quality, however specific mention is made to on-site activities that may not affect water quality, such as timber harvest activities during wet seasons that may result in soil compaction or puddling. There is no special mention of coastal activities or tree species of concern. Reforestation recommendations follow established silvicultural practices. See http://www.state.sc.us/forest/rbth.htm#osi

Texas: BMPs for Texas are geared primarily toward silvicultural practices for timber harvest, with less emphasis on water quality as in other states. Little discussion of regeneration is provided beyond silvicultural practices for site stabilization following harvest. See http://texasforestservice.tamu.edu/pdf/forest/water/bmp_handbook2000b.pdf

Virginia: Forest BMPs are found in "Virginia's Forestry Best Management Practices for Water Quality." Extensive discussion is given to reforestation and site treatments (chapter 6), with recommendations made to follow specific silvicultural treatments (e.g., windrows, disking, and prescribed burns). No separate mention is made regarding coastal forest harvests or species of particular concern. See http://www.dof.virginia.gov/wq/index-bmp-guide.shtml

Washington: Forestry BMPs in Washington are designed to address the state's role in controlling nonpoint source pollution, especially sedimentation and water temperature. These BMPs also give attention to timber harvest on steep slopes, riparian corridor protection, and turbidity. Washington has also entered into a cooperative agreement with the USDA Forest Service to ensure these same protections are afforded timber operations on national forests. See http://www.ecy.wa.gov/programs.html

For a listing of all state BMPs on the internet see:
http://www.stateforesters.org/reports/BMP/BMP_Library.html

Conservation Policies

Several options exist to conserve coastal cypress forests, including conservation easements, set-aside programs, and mitigation. Each option is reviewed below.

Conservation Easements

These programs allow landowners to sell the rights to certain activities on their lands (for example building residential or commercial developments) while retaining other uses of the land not in conflict with the rights sold. Landowners could sell off the right to harvest timber and still use the land for agriculture, recreation, and other uses. The land is still transferable to descendents, however rights sold in easements remain with holder of easement. Conservation easements are typically held by land trusts or other private land conservation organizations. In the management of coastal cypress forests, conservation easements offer an alternative to harvesting while providing the landowner cash return from the timber. Another option is payment of taxes in exchange for easement on harvesting rights. Of all options to be considered for conserving private coastal cypress forests, conservation easements are most practical.

More information and examples can be found at:
http://www.lta.org/conserve/options.htm
http://nature.org/aboutus/howwework/conservationmethods/privatelands/conservationeasements/
http://laws.fws.gov/lawsdigest/taxdedu.html

Conservation Set-aside Programs

Set-aside programs are different from conservation easements in that these programs are usually contractual agreements between state or federal agencies and the landowner. The most widely known are the Conservation Reserve Program (CRP) and Conservation Reserve Enhancement Program (CREP). Set-aside programs are contractual agreements that typically pay the landowner to forego certain activities on the land for a specified period of time. For example, CRP pays landowners up to $70 per acre annually to keep land out of agricultural production, plant specific warm or cool weather grasses, and control erosion for a period of 10 or more years. Other activities, such as hunting, are permitted under the contract.

Reference sites:
http://www.fsa.usda.gov/dafp/cepd/crp.htm
http://www.nrcs.usda.gov/programs/crp/
http://www.attra.org/guide/crp.htm
http://www.fsa.usda.gov/dafp/cepd/crep.htm
http://www.dcr.state.va.us/sw/crep.htm
http://www.dnr.state.md.us/wildlife/milo.html
http://www.nrcs.usda.gov/programs/

Wetland Mitigation

Mitigating wetlands is a complex, often controversial management tool whereby an artificial wetland is created to offset the loss of a natural wetland (usually marsh or brushy wetland) to be destroyed by development, road construction, or other activity. Wetlands are difficult to construct from uplands and survival rates, determined after five years, are less than 50% in most regions. Critics claim that created wetlands are often of lower quality and less productive than those destroyed. Proponents state that mitigation provides no net loss of wetland acreage on a landscape scale. If mitigation is considered for replacement of coastal cypress forests, careful consideration must be given to the time-frame used to determine success. The 5-year benchmark typical of determining success of non-woody herbaceous wetlands would not be appropriate for determining success of mitigated cypress forests, as these stands take more than five years to become established. In addition, monitoring of stand establishment would have to be made annually to repair loss of seedlings/saplings and to prevent potential loss of the stand.

Reference sites:
http://www.epa.gov/owow/wetlands/facts/fact16.html
http://www.epa.gov/owow/wetlands/guidance/
http://www.usace.army.mil/inet/functions/cw/hot_topics/Mit_Action_Plan_24Dec02.pdf

Public Involvement

Public involvement is paramount if efforts to conserve Louisiana's coastal forests are to succeed. Key stakeholders such as landowners, developers, recreationists, and members of conservation organizations must be engaged in the process to ensure concerns are addressed. Although conventional public involvement processes of public hearings (where attendees provide comments to agency officials without response) and public meetings (where there is a presentation, question, and answer process between the public and agency officials) are the minimum required by federal statute (NEPA, 1969), these efforts do not capture the extent of public attitudes toward the issue (Miller, 2000). The main shortcoming of the public hearing/meeting format is that public input is easily biased, leading agency officials to at times mistakenly conclude public perception lies in a certain direction. Moreover, attitudes toward projects and plans may not be completely represented at the meetings. It is incumbent upon state officials to determine the extent of attitudes toward Louisiana's coastal forests. To ensure this need is met, it is necessary to conduct a quantitative scoping process including, but not limited to, surveying the attitudes of various stakeholders and the general public at large.

FINDINGS AND RECOMMENDATIONS

Findings

The SWG finds the following about Louisiana's coastal wetland forests:

1) Louisiana's coastal wetland forests are of tremendous economic, ecological, cultural, and recreational value to residents of Louisiana and the people of the United States and the world; and include:

- wildlife habitat (including migratory songbirds/waterfowl, threatened and endangered species),
- flood protection, water quality improvement (including nitrate removal), and storm protection,
- carbon storage and soil stabilization,
- economic benefits of fishing, crawfishing, hunting, timber production, and ecotourism

2) The functions and ecosystem services of Louisiana's coastal wetland forests are threatened by both large- and small-scale hydrologic and geomorphic alterations and by conversion of these forests to other uses.

- Subsidence, sea-level rise, and levee construction are the large-scale hydrologic and geomorphic alterations responsible for the loss of Louisiana's coastal wetland ecosystems including coastal wetland forests. Since Louisiana's coastal wetland forests are nutrient deprived as a result of the Mississippi River levee system, addition of nutrients and sediments is the only way for these ecosystems to maintain their surface elevation relative to sea-level rise.
- The cumulative effects of small-scale or local factors can be of equal or greater importance in coastal wetland forest loss and degradation than large-scale alterations. These factors include increased depth and duration of flooding, saltwater intrusion, nutrient and sediment deprivation, herbivory, invasive species, and direct loss due to conversion. Causal agents include highways, railroads, channelization, navigation canals, oil and gas exploration canals, flood control structures, conversion of forests to urban and agricultural land, and non-sustainable forest practices.
- Under less severe impacts, many of the important functions and ecosystem services are lost or degraded even though the trees may be intact and the forest may appear unaffected.
- Without appropriate human intervention to alleviate the factors causing degradation, most of coastal Louisiana will inevitably experience the loss of coastal wetland forest functions and ecosystem services through conversion to open water, marsh, or other land uses.

3) Regeneration is a critical process of specific concern in maintaining coastal wetland forest resources. Successful natural regeneration of this resource in the

1920s was due to fortuitous conditions existing at that time. Currently, there is a lack of regeneration in coastal cypress-tupelo forests that is a direct result of factors identified above and their interactions with regeneration processes.

4) In those areas where flooding prevents or limits the natural regeneration of the cypress-tupelo forest, artificial regeneration through tree planting is the only currently viable mechanism to regenerate the forest. Some swamps are altered to such a significant extent that even artificial regeneration is not possible. Coppice or stump sprouting does not provide sufficient numbers of viable trees to reliably regenerate the forest, even under optimum conditions.

5) Conditions affecting the potential for forest regeneration and establishment are recognizable based upon existing biological and physical factors. The SWG has developed a set of condition classes for the dominant wetland forest type in Louisiana's coastal cypress-tupelo forests. All references to flooding depths or durations assume average rainfall conditions, not extreme or unusual events. Sediment input is generally beneficial, but in localized situations, excessive levels can prevent or prohibit natural or artificial regeneration under SWG Condition Classes I and II. The SWG cypress-tupelo Coastal Wetland Forest Regeneration Condition Classes are:

SWG Condition Class I: Sites with Potential for Natural Regeneration

These sites are generally connected to a source of fresh surface or ground water and are flooded or ponded periodically on an annual basis (pulsing). They must have seasonal flooding and dry cycles (regular flushing with freshwater), usually have both sediment and nutrient inputs, and sites in the best condition are not subsiding. These sites have some level of positive tree growth, thereby providing increasing or stable biomass production, organic input, and experience re-charge of water table after drought periods. Sites in this category that are subject to increasing flood frequency, increased flood duration, or increasing flood water depths may eventually move into the next lower category unless action is taken to remedy these detrimental conditions.

SWG Condition Class II: Sites with Potential for Artificial Regeneration Only

These sites may have overstory trees with full crowns and few signs of canopy deterioration, but are either permanently flooded (which prevents seed germination and seedling establishment in the case of baldcypress and tupelo) or are flooded deeply enough that when natural regeneration does occur during low water, seedlings cannot grow tall enough between flood events for at least 50% of their crown to remain above the high water level during the growing season. These conditions require artificial regeneration, (i.e., planting of tree seedlings). Water depth for sites in this category is restricted to a

maximum of two feet for practical reasons related to planting of tree seedlings. Planted seedlings should have at least 12 inches of crown (length of main stem with branches and foliage present) and must be tall enough for at least 50% of the crown to remain above the high water level during the growing season. Sites with a negative trajectory (increasing average annual water depth) may eventually move into SWG Condition Class III unless action is taken to remedy this detrimental condition.

SWG Condition Class III: Sites with No Potential for either Natural or Artificial Regeneration

These sites are either flooded for periods long enough to prevent natural regeneration and practical artificial regeneration, or are subject to saltwater intrusion with salinity levels that are toxic to cypress-tupelo forests. Two trajectories are possible for these two conditions: 1) freshwater forests transitioning to either floating marsh or open fresh water, or 2) forested areas with saltwater intrusion that are transitioning to open brackish or saltwater (marsh may be an intermediate condition). SWG Category III sites are placed in specific subcategories relative to stress conditions as listed below. They may differ in the types of recommendations made or actions that should be taken relative to the particular stressing agent.

A. Forests with saltwater intrusion or high soil salinity:
   1. Chronic (semi-permanent) saltwater intrusion (e.g., coastal areas with high rates of subsidence). These are sites where saltwater intrusion is of a long-term nature and requires correction.
      a. For baldcypress, chronic levels of soil salinity of four ppt or greater increases mortality of seedlings and makes the likelihood of regeneration unreliable.
      b. For tupelo, chronic levels of salinity greater than two ppt increases mortality.
   2. Acute (temporary) flooding with saline waters such as from storm surges. These conditions are temporary and tolerance can be much higher.

B. Forests with water levels exceeding two feet at time of planting makes artificial regeneration impractical.

6) Physical and biological processes link coastal forests and coastal marshes. The current Louisiana Coastal Zone Boundary does not accurately reflect the full extent of Louisiana's coastal wetland forests. The lack of focus on large scale restoration and protection activities outside the Louisiana Coastal Zone Boundary makes them more vulnerable to loss and degradation from detrimental impacts.

7) Spatially explicit data of coastal wetland forest conditions necessary to guide restoration, regulatory, and management efforts are scarce. USDA Forest Service Forest Inventory and Analysis (FIA) data are inadequate for these purposes.

Recommendations

The SWG recommends that the Governor:

1. Adopt the following statement of mission and intent regarding coastal wetland forest ecosystem policy: The State of Louisiana will place priority on conserving, restoring, and managing coastal wetland forests, including collaborative efforts among public and private entities, to ensure that their functions and ecosystem services will be available to present and future citizens of Louisiana and the United States.

2. Recognize the regeneration condition classes (Finding 5) for cypress-tupelo forests developed by the Science Working Group (SWG) and use them to classify existing coastal forest site conditions for management, restoration, protection, and use purposes.

3. Place priority on maintaining hydrologic conditions on SWG Regeneration Condition Class I lands.

4. Delay timber harvesting on Condition Class III lands because these lands will not regenerate to forests. The goal is to allow time for hydrologic restoration and improvement of stand conditions to Class I or Class II lands. Place an interim moratorium on harvesting on state-owned Condition Class III lands. Develop mechanisms to delay timber harvesting on privately owned Condition Class III lands.

5. Before harvesting SWG Condition Class I and II sites, a written forest management plan with specific plans for regeneration must be reviewed by a state-approved entity so appropriate practices can be suggested based on local site conditions. The intent is to ensure that cypress-tupelo regeneration and long-term establishment take place and that species or wetland type conversion does not occur.

6. Develop spatially explicit data regarding SWG Condition Classes, existing hydrologic and geomorphic conditions, and current and future threats to coastal wetland forests. These data should be collected, evaluated, and updated by a consortium of state, local and federal agencies, universities and non-governmental organizations and made available to all entities. Adding remotely-sensed data to this data set should be aggressively pursued. Such data are critical to wisely manage and care for the coastal forest wetland ecosystem of Louisiana.

7. Establish and maintain a system of long-term monitoring of coastal wetland forest conditions, supplemental to FIA and Coastal Reference Monitoring System (CRMS) datasets, expanded to include the entire SWG coastal wetland forest area (see Figure 1). Additionally, monitoring of restoration should occur, and include measures to evaluate success. This may entail some long-term efforts because forests may take 25 years to establish functioning stands.

8. Coastal forests extend beyond the current Coastal Zone Boundary. Therefore, the target area for large scale restoration should be expanded to include coastal wetland forests as defined by the SWG (Figure 1), especially those in major river bottoms draining to the coast (e.g., Atchafalaya and Pearl River Basins) and those with extensive areas of coastal wetland forests (e.g., Lake Maurepas).

9. Direct all state and local agencies to review, evaluate and coordinate their activities in coastal wetland forests and develop guidelines and practices to prevent the loss and degradation of habitat, functions, and ecosystem services through official actions. The Governor should also officially request that federal agencies do the same.

10. Review and modify current accepted practices for mitigation of impacts on coastal wetland forests. Given the uniqueness of Louisiana's coastal wetland forests, all mitigation must be of the same forest type and occur within the same watershed where the impacts are located.

11. Encourage conservation and protection of coastal wetland forest areas by developing a Coastal Wetland Forest Reserve System.

12. Actively pursue restoration of degraded wetland forests, regardless of the SWG condition class. Encourage collaborative efforts between public and private entities including the development or modification of federal legislation to include degraded coastal wetland forests in landowner incentives programs.

13. Enhance wetland forest ecosystem functions and values as part of all hydrological management decisions, including management of point- and nonpoint-source inputs, floodways, creation of diversions, levee and highway construction, and coastal management.

14. Develop policies to ensure implementation of the above recommendations. Various incentive mechanisms should be explored as part of policy implementation.

Critical Research Needs

1. Restoration and management techniques need to be developed and evaluated for Louisiana's coastal wetland forests.

    - Establish and maintain a regeneration and tree improvement program focused on coastal wetland forests. Initial goals should be to identify and develop trees that are genetically resistant to salt stress in order to regenerate areas susceptible to saltwater intrusion.
    - Evaluate regeneration and establishment techniques as to their effectiveness and impacts in cypress-tupelo wetlands. Regeneration efforts should also focus on improving and expanding artificial regeneration methods in coastal wetland forests.
    - Evaluate the use of treated wastewater and stormwater runoff as a restoration technique to provide nutrients, reduce salinity stress, and promote tree growth and sediment accretion rates.
    - Explore herbivore (e.g., nutria, leaf roller, tent caterpillar) and invasive species control through wildlife management and insect, disease, and vegetation control research programs.
    - Develop a set of scientifically based Coastal Wetland Forest Best Management Practices (CWFBMPs) for each SWG Condition Class. This program might be modeled after the existing set of BMPs for upland forest management, but with the main difference that the stated goal of the CFBMPs is to foster continued productivity of the managed site itself (in contrast to existing BMPs that attempt to mitigate off-site effects). The BMPs should emphasize site evaluation, regeneration, pest management, and appropriate harvesting technology.
    - Require explicitly stated goals for restoration projects in degraded wetland forests and concurrent research to ensure efficacy and goal achievement.
    - Conduct research to reveal the relationship of soil types to regeneration condition classes and site productivity (forest health) in coastal wetland forests.
    - Hydrological studies are needed to understand ecosystem control of wetland forest water budgets. Attendant effects on forest composition and productivity may greatly affect restoration strategies.

2. Quantify stakeholder concerns regarding coastal wetland forests activities as part of development of coastal wetland forests policies. Public meetings alone are insufficient for this purpose.

3. Evaluate and quantify the habitat functions and values of Louisiana's coastal forests.

4. Develop educational programs for the public, land owners, loggers, land managers, teachers, etc., to encourage conservation, restoration, and proper management of coastal wetland forests.

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APPENDIX 1: GLOSSARY

abscission – natural separation a leaf petiole from its twig caused by weather or stress
abiotic processes – non-biological events or activities (e.g., deposition of sediments, flooding, and fire)
advance reproduction – seedlings or saplings that develop or are present in the understory
adventitious buds – buds arising at positions other than where leaves or stems ordinarily arise, such as on roots, at the base of trees, and often as a response to wounding
alluvial – soil developed from river/stream material and accumulated in delta-like fans or on lands of river overflow
anaerobic – the absence of oxygen
anaerobiosis – living in the absence of molecular oxygen
angiosperm – a plant producing flowers and bearing seeds in an ovary (fruit), such as broadleaf trees
artificial regeneration – renewal of the forest by planting seeds/seedlings and establishing a new stand of trees by planting seeds or seedlings by hand or machine
bareroot seedling – a tree seedling grown in a nursery bed - when large enough for transplanting, the seedling is lifted from the nursery bed, and the dirt is removed from the roots before packaging
basal area – the cross section area of a tree stem commonly measured at breast height (4.5 feet above the ground) and inclusive of bark - the area is generally expressed as square units per unit area - tree basal area is used to determine percent stocking within a stand
basin – an area drained by a river and its tributaries
best management practices (BMPs) – guidelines developed for foresters and other land managers to use in protecting water quality
biogeochemistry – interdisciplinary study of chemical reactions involving both biological and geochemical processes
biogeochemical – An exchange of chemicals between biological organisms and the non-biological environment integrating physical, chemical and biological processes.
biomass – all of the organic material on a given area
board foot – unit of measure represented by a board one foot long, one foot wide, and one inch thick
bole – a trunk or main stem of a tree
bottomland hardwoods – a forest type, dominated by hardwood species, that occupies floodplains and normally receives seasonal flooding
canopy – all the green leaves and branches formed by the tops of trees in a forest
clear-cut harvest – a harvesting and regeneration method that removes all trees within a given area - clear-cutting is commonly used in pine and hardwood forests, which require full sunlight to regenerate and grow efficiently
cohort – a group of trees developing after a single disturbance, commonly consisting of trees of the same age,
conservation – protection, improvement, and wise use of natural resources according to principles that will assure long-term economic, ecological and social benefits
constructed wetlands – wetlands built by humans primarily for treating polluted water
coppice – method of renewing forest in which reproduction is by sprouting from the stumps of cut trees
cotyledon – a primary leaf of the embryo
crevasse splays – sediment deposited by water flowing through a break (crevasses) in a levee
delta lobe cycle – periodic changes in location of delta accretion caused by changes in river course
denitrification – the microbial conversion of nitrate (NO_3) to nitrogen oxides (NO, N_2O) or nitrogen gas (N_2)
dessication – the loss of internal moisture required to maintain survival
diameter at breast height – (dbh) a common measurement of tree diameter that is defined as the outside bark diameter at 4.5 feet above the ground
diameter classes – classification of trees based on dbh
diameter-limit cut – removal of merchantable trees above a specified diameter
dioecious – trees in which the male and female flowers are produced on different plants – i.e., bears imperfect flowers, with the staminate and pistillate flowers borne on different plants
distributaries – (distributary) a river that flows out of another river

dominant trees – trees with crowns receiving full light from above and partly from the side; usually larger than the average trees in the stand with crowns that extend above the general level of the canopy and that are well developed
dormancy – a condition of arrested growth in which the plant and such plant parts as buds and seeds do not begin to grow without special environmental cues
drupe – a fleshy, indehiscent fruit with a stony endocarp surrounding a usually single seed
easement – public acquisition by purchase or donation to acquire certain rights on private lands
ecosystem services – the benefits that humans and society derive from the functions of an ecosystem
embryo – the young plant within a seed
environment – the interaction of climate, soil, topography, and other plants and animals in any given area - an organism's environment influences its form, behavior, and survival
epigaeal – a seedling which has above-ground cotyledons
eustatic – pertaining to global sea level
eutrophication – nutrient enrichment of an area that often changes ecosystem structure or function and leads to decreased water quality - cultural eutrophication is sometimes used to connote human-induced nutrient enrichment
eutrophication gradient – an area where nutrient enrichment decreases with increasing distance from the source of the nutrients
evapotranspiration – water movement into the atmosphere through evaporation from soil and transpiration from plants
even-aged – applied to a stand of trees in which relatively small age differences exist among individual trees
exotic – non-native plants or animals
forest restoration – establishment of a forest and the ecosystem functions and values to a former natural state
gall – an abnormal growth caused by insects
germination – rupture of the seed coat and concurrent development of the rootlet (radicle) and leaves (hypocotyls)
girdle (girdling) – a physical cutting or disruption of the cambial sap flow within a tree - girdling by humans, animals, or insects can result in mortality of the tree
growing stock – all trees in a forest or in specified area within the forest that meet specific standards of size and quality
gymnosperm – plants producing seeds which are not borne in an ovary (fruit), the seeds usually borne in cones
habitat – an area in which a specific plant or animal can naturally live, grow, and reproduce - for wildlife, habitat is the combination of food, water, cover, and space
hardwoods (deciduous trees) – trees with broad, flat leaves as opposed to coniferous or needled trees - wood hardness varies among the hardwood species, and some are actually softer than some softwoods
high-grading – removal from the forest of only the highest quality trees, leaving lesser quality stems for future harvests and as a source of seed
high-lead logging – cable system that involves accumulation of logs or trees in an area by means of a cable passing through a block at the top of the large tree
horizontal structure – a measure of the diversity of diameter sizes of trees within a given forest
hydrochory – seed dispersal by water
hydroperiod – the timing, duration, and frequency of flooding at a particular site
hydrophytic vegetation – plants typically adapted for life in saturated soil condition
hypocotyls – the portion of the embryonic stem below the cotyledons
hypoxia – oxygen-deficient (<2 milligrams per liter) condition in coastal waters resulting from the high oxygen demand associated with the decomposition of increased productivity in response to eutrophication of aquatic ecosystems
increment core – a radial cylinder of wood extracted from a tree; often used to determine age and/or annual growth of the tree
inundation – (inundate) - cover by water

impoundment – a body of water held back by a dam, dike, floodgate or any other barrier - all artificially ponded water, including natural bodies of water with artificially controlled water levels, except that captured directly as it falls from the atmosphere
landscape – the variation of land uses and land features across an area of a size defined by the investigator or of the question of interest
landscape composition – the types of land uses, plant communities, and natural features present in a particular landscape
landscape connectivity – the degree to which a landscape hinders or assists movements of fish and wildlife species or other processes of interest (e.g., nutrient transport)
latent buds (dormant bud) – buds which originally developed in a leaf axil and are connected to the pith by a bud trace
levee – embankment, natural or manmade, to prevent flooding
long-term establishment (forest or stand establishment) – the regeneration of a suitable number of trees (seedlings or coppice sprouts) that survive past the time when considerable mortality normally occurs
lotic – non-moving waters, lake-like
macrophyte – plants that are large enough to be apparent to the naked eye
mast – fruits or nuts used as a food source by wildlife - soft mast includes most fruits with fleshy coverings, such as persimmon, dogwood seed, or black gum seed - hard mast refers to nuts such as acorns and beech, pecan, and hickory nuts
methanogenesis – metabolic pathway where methanogens use carbon dioxide or organic compounds as terminal electron acceptors in anaerobic respiration producing methane
methanogens – specialized group of obligate anaerobic bacteria that carry out methanogenesis
microsporangiate – microspore (pollen) producing
monoecious – bears imperfect flowers, with the staminate and pistillate flowers borne on the same plant
natural stand (natural regeneration) – a stand of trees grown from natural seed fall or sprouting
net annual growth – change in volume of trees during a specified year including new growth minus losses to death and decay
net primary production – the amount of organic matter produced during the growth and reproduction of photosynthetic organisms minus the amount lost through respiration
nonpoint source pollution (NPS) – pollution without a single, defined source unlike pollution from industrial and sewage treatment plants - pollution from many diffuse sources
nutrients – elements necessary for growth and reproduction - primary plant nutrients are nitrogen, phosphorus, and potassium
overstory – trees in a forest forming the uppermost canopy layer
ovulate – producing ovules
oxidation – a chemical process that involves the loss of electrons, e^-
palustrine wetlands – all non-tidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all wetlands where salinity due to ocean-derived salts is below 0.5 ‰ that occur in tidal areas including open water wetlands or less than 20 acres
pistil – the female reproductive organ of a flower
pistillate – bearing a pistil or pistils, but lacking stamens
polygamo-dioecious – mostly dioecious, but with some perfect flowers
redox processes – processes involving the reduction (gain of electrons, e^-) and oxidation (loss of electrons, of primarily iron, manganese, nitrogen, and carbon compounds
reduction – a chemical process that involves the gain of electrons, e^-
regeneration – establishment of young trees either artificially or naturally
riparian zone – the terrestrial area adjacent to a waterbody such as a stream, river, lake or wetland that significantly influences and is influenced by the waterbody – area of variable width related to and in conjunction with a waterbody providing a terrestrial and aquatic ecosystem link
rookery – a colony of breeding waterbirds, such as herons and egrets
stream side management zone (SMZ) – area adjacent to a stream, lake or river where soils, organic matter and vegetation are managed to protect water quality
sapling – a young tree; often defined as greater than 4.5 feet tall and less than five inches dbh
shade tolerance – capacity of a tree to develop and grow in the shade of other trees
silviculture – the practice and science of managing a forest

skidder – machine used to remove trees and/or logs from the forest by dragging them along the ground
stamen – the male reproductive organ of a flower
stocking – the amount of trees in a given area relative to a pre-established standard
stand – a contiguous area of the forest with similar characteristics defined for the purposes of management or study
stand density – density of trees per land area - normally quantified by number of trees per area, cubic volume of wood per area, or basal area
stools – a living stump capable of producing sprouts
stratification – the process of exposing seeds to low, high, and/or alternating temperatures for an extended period prior to germination to break seed dormancy -for most forest tree species in Louisiana, stratification consists of exposure to low temperatures for prolonged periods
subglobose – almost spherical
subsidence – lowering of land surface elevation
substrate – the medium for plant growth - soil
transpiration – the loss of water vapor by plant parts, such as foliage, into the atmosphere
transgressive phase – The period of coastal land formation when the relative rise in sea level deposits marine sediments over previously deposited terrestrial or riverine sediments.
understory – plants growing beneath the forest canopy
vertical accretion – increase in land elevation by addition of organic or inorganic matter
vertical structure – a measure of the distribution of plant heights in a forest - a forest with high levels of vertical structure has plants with a diversity of heights, whereas a forest with low levels has plants of only one or a few heights
watershed – an area of land drained by a single stream or river
wetland functions – the physical, chemical, and biological processes that sustain the wetland ecosystem, irrespective of any interaction with humans
wetland structure – the physical attributes of the wetland such as soil and vegetation

APPENDIX 2: COMMON AND SCIENTIFIC NAMES OF PLANTS AND ANIMALS

PLANTS

American elm	*Ulmus americana* L.
ash	*Fraxinus* L.
green	*Fraxinus pennsylvanica* Marsh
pumpkin	*Fraxinus profunda* Bush
Carolina	*Fraxinus caroliniana* Mill
baldcypress	*Taxodium distichum* (L.) L. C. Rich.
black willow	*Salix nigra* Marsh.
buttonbush	*Cephalanthus occidentalis* L.
Carolina fanwort	*Cabomba caroliniana* Gray
cattail	*Typha domingensis* Pers.
common salvinia	*Salvinia minima* Baker
coontail	*Ceratophyllum demersum* L.
cottonwood	*Populus deltoides* or *Populus heterophylla* L.
hydrilla	*Hydrilla verticillata* (L. f.) Royle
overcup oak	*Quercus lyrata* Walt.
pondcypress	*Taxodium ascendens* Brongn.
red bay	*Persea borbonia* (L.) Spreng.
red maple	*Acer rubrum* L.
swamp dogwood (roughleaf dogwood)	*Cornus drummondii* C.A. Mey.
sawgrass	*Cladium jamaicense* Crantz
swamp red maple	*Acer rubrum* var. *drummondii* (Hook. & Arn. ex Nutt.) Sarg.
swamp privet	*Forestiera acuminata* (Michx.) Poir.
sweetgum	*Liquidambar styraciflua* L.
tupelo	*Nyssa* L.
water tupelo	*Nyssa aquatica* L.
swamp tupelo	*Nyssa biflora* Walt.
blackgum	*Nyssa sylvatica* Marsh.
Virginia-willow	*Itea virginica* L.
water hickory	*Carya aquatica* (Michx. F.) Nutt.
water hyacinth	*Eichormia crassipes* (Mart.) Solms
water locust	*Gleditsia aquatica* Marsh.
waxmyrtle	*Morella cerifera* (L.) Small

ANIMALS

alligator	*Alligator mississippiensis*
alligator snapping turtle	*Macroclemys temminckii*
American toad	*Bufo americanus*
Bachman's warbler	*Vermivora bachmanii*
bagworm	*Thyridopteryx ephemeraeformis*
bald eagle	*Haliaeetus leucocephalus*
baldcypress coneworm	*Dioryctria pygmaeella* Ragonot
baldcypress leafroller	*Archips goyerana* Kruse
bullfrog	*Rana catesbeiana*
cypress looper	*Anacamptodes pergracilis*
eastern gray squirrel	*Sciurus carolinensis*
eastern wild turkey	Meleagris gallopavo silvestris

evening grosbeak	*Coccothraustes vespertinus*
false map turtle	*Graptemys pseudogeographica*
forest tent caterpillar	*Malacosoma disstria* Hubner
gadwall	*Anas strepera*
Gulf sturgeon	*Acipenser oxyrhincus desotoi*
hooded merganser	*Lophodytes cucullatus*
leopard frog	*Rana pipiens*
Louisiana black bear	*Ursus americanus luteolus*
nutria	*Myocastor coypus*
pallid sturgeon	*Scaphirhynchus albus*
peregrine falcon	*Falco peregrinus*
raccoon	*Procyon lotor*
Rafinesque's big-eared bat	*Corynorhinus rafinesquii*
roseatte spoonbill	*Ajaia ajaja*
slider turtle	*Trachemys scripta*
snapping turtles	*Macroclemys temminckii*
south coastal coneworm	*Dioryctria ebeli*
southeastern bat	*Myotis austroriparius*
southeastern myotis	*Myotis austroriparius*
southern pine coneworm	*Dioryctria amatella*
swamp crawfish, red swamp crawfish	*Procambarus clarkii*
white ibis	*Eudocimus albus*
white river crawfish	*Procambarus. zonangulus*
white-tailed deer	*Odocoileus virginianus*
wood duck	*Aix sponsa*
wood stork	*Mycteria americana*

B - Other University/Community Plans/Reports

CAMPUS TREE CARE PLAN

University of Wisconsin – Stevens Point

December 2010

Prepared by: David Lein[1], Richard Hauer[2], and Les Werner[2]

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Special Thanks to the Forestry 333 (Urban Forest Management) Spring Class 2010

University of Wisconsin
Stevens Point

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Purpose

The University of Wisconsin – Stevens Point (UWSP) Campus Tree Care Plan was developed to foster a healthy and sustained tree population. This valued urban resource is vital to educate students as well as the public about quality tree care and sound urban forest management techniques. The campus tree care plan delineates the creation of policies, procedures, and practices advocating for a healthy and sustained urban forest. This plan follows the Arbor Day Foundation's Tree Campus USA program which helps establish and maintain healthy community forests on campuses. The five standards of the Tree Campus USA program are used to develop goals and objectives to help UWSP fulfill its urban forest mission. The UWSP's underlining mission in the creation of this plan is *to maintain a safe and diverse urban tree population that is sustainable and a visual and ecological foundation that is an integral part of the campus infrastructure*.

Standard One: Campus Tree Advisory Committee

A tree advisory group, board, or committee serves to provide direction and oversight for an urban tree population. They ideally represent the interest of the human population that the urban forest serves. This section depicts the role and committee members.

Committee Role: The purpose of the Campus Tree Advisory Committee (CTAC) is to guide and monitor this comprehensive tree care plan. The CTAC will have a minimum of one meeting a year to review tree projects, determine if tree care policies and goals are being met, propose solutions to campus tree issues, and to support the Arbor Day observances as well as service learning projects. The CTAC will be present at the Arbor Day observances and service learning projects as time allows.

Committee Members: The CTAC will comprise a representative collection of members that understand urban forest management principles and constraining factors of trees and other campus infrastructure. The members may change over time to better meet the mission set forward in this plan. These members are found in Table 1.

Table 1. Members of the UWSP Tree Advisory Committee.

UWSP Grounds Supervisor
UWSP Grounds Student Intern
UWSP Student Society of Arboriculture Officer/Member
UWSP Urban Forestry Professor
Community Professional (e.g., Stevens Point City Forester or Professional Arborist)
UWSP Student at Large (Proposed)
UWSP Representative to the Chancellor (Proposed)

Committee members shall serve an annual term coinciding with the academic year. There is no term limit for committee. The Grounds Department Supervisor will preside over the meeting in the absence of the committee chair. The committee chair will be selected by the committee members by vote.

Standard Two: Campus Tree Care Plan

The tree care plan presented below provides a means to maintain a campus tree population consistent with the mission of this plan. This is a set of guidelines to help manage the urban forest. They are not the end all for practices that may be needed to maintain the urban forest. The CTAC should regularly review and update this plan as needed so the best informed decision based on current scientific analysis is made. These guidelines may be modified if there is a scientifically based alternate tree care practice that is superior. The following tree care policies and practices should not be overlooked since history has shown that poor tree care practices and the lack of planning has the potential for unnecessary risks to public safety and a greater cost to maintain or treat trees. Common terms used throughout this plan are described in Appendix A.

Responsible Authority: The UWSP's Campus Tree Advisory Committee, Grounds Department, Student Society of Arboriculture (SSA), and students in urban forestry courses are entrusted with the authority to implement the campus tree care plan. When arboricultural work exceeds the capacity of those listed above to complete work safely and/or effectively, appropriately trained, qualified, and sufficiently insured contractors shall be used.

1) Goals & Targets

The UWSP was selected by the State of Wisconsin to become more sustainable through university actions in energy use, purchasing of supplies, and other actions. Reducing the campus reliance on non-renewable energy sources is one action. The campus urban forest can contribute to this goal from the strategic placement of trees to reduce energy consumption and develop a more energy efficient campus. While observing these expectations and adhering to UWSP's mission there are three proposed goals that will help achieve these targets and provide state of the art education opportunities for students.

Our first goal is to keep current the campus tree inventory we completed in 2010. The inventory data was analyzed with the i-Tree v3.0 program. One plan is for the SSA to keep this inventory current by having a SSA officer submit updates as trees are planted and removed.

Our second goal is to maintain the current spatial data layer using GPS/GIS. These maps will help us identify suitable tree planting sites and existing tree locations. With this information we will be able to assess our current canopy coverage and identify areas where the campus is able to maintain a canopy coverage that is appropriate for the campus. This layer can also be used in identifying where trees may be strategically planted to help reduce energy demands.

A third goal is to maintain the existing tree population and plant replacement trees for removed trees and to meet canopy goals. Safety is a priority and unsafe trees should be made safe or removed. Maintenance of the existing tree populations should be given priority over tree planting when budgets are limited. Tree planting is an important part of creating a visually and ecologically robust campus and an important part with the outdoor classroom for several college courses on campus.

2) Planting Process

Tree Selection: The CTAC will approve appropriate woody plants (trees, shrubs, and vines) to be planted on campus. Ample consideration shall be given to the outdoor classroom and teaching needs of courses on campus. For example, identification courses such as urban trees and shrubs, vascular plant taxonomy, and dendrology all benefit from a diverse urban tree and shrub population. Plant selections should also be based on site characteristics (e.g., soil characteristics, microclimate, drainage, water availability, orientation, available sunlight, proximity to infrastructure, etc.), maintenance requirements, and desired landscape design goals which include maintaining tree species diversity and determining the overall functionality of the mature tree form.

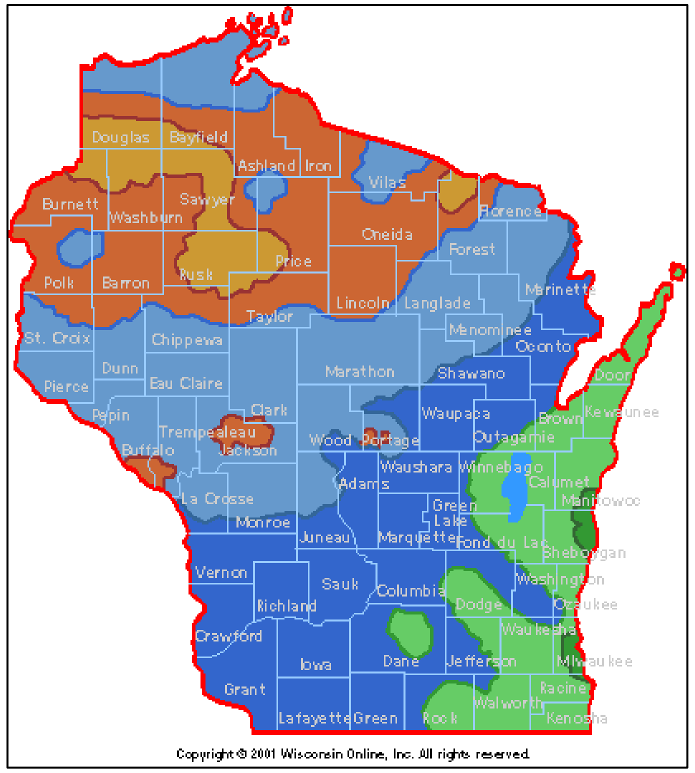

Figure 1. Hardiness zone map of Wisconsin.

As much as possible, species diversity will follow a 30-20-10 rule. This means that the entire tree population will have less than 30 percent of individuals from a scientific family, 20 percent of individuals from a single genus, and 10 percent from a single species. When possible, unique species that can be established and marginally hardy plants to campus will be planted for educational purposes.

Recommended/Prohibited Species: The CTAC will develop and update as needed a recommended and prohibited tree species list. The recommended tree species can either be a native or non-native species and should fit within the tree selection guidelines described in the above section. Prohibited species include any species listed on the Wisconsin Department of Natural Resources terrestrial restricted species list (Appendix B). Prohibited species may be planted on campus for educational purposes only as long as the species is sufficiently controlled. Trees that require excessive maintenance or significant pest problems should be minimized.

Planting: Tree planting specifications shall follow best management practices as prescribed by the International Society of Arboriculture, American Standards for Nursery Stock, and the Wisconsin Department of Natural Resources (Appendix C). In general, these steps should be taken to:

1) Locate the root collar of the tree and create a planting site hole that is no deeper than the root depth and ideally three times the diameter of the tree's root ball.
2) Remove any tags, tree wrap, plastic root ball containers, and/or the bottom half of the wire basket prior to placing in the planting hole.

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3) Plant with the tree's root collar at grade or one to two inches above the original grade of the site if root system is likely.
4) Remove any remaining twine, burlap, and wire basket from the root ball.
5) Remove any soil accumulations from the top of the root ball to expose the root collar if buried and remove any encircling roots or stem girdling roots.
6) Adjust the tree from different sides so that it is sitting straight (vertical).
7) Back fill the hole to the original soil grade, water to eliminate any air pockets, and ensure that the root collar is not buried.
8) Stake as needed using a wide band for one growing season.
9) Apply a three to four inches of mulch on top of the planting site leaving an area of bare soil one to two inches from the root collar.
10) Follow-up with watering as needed until established.

Establishment Period: Water the tree sufficiently with one to two gallons of water per diameter inch of the stem (Appendix D). In general, daily watering is needed after planting for several weeks. Watering frequency decreases to several times per week for the next several months and eventually to weekly watering until established. Only fertilize newly planted trees when a soil test requires it or based on landscape goals. Minimize any canopy pruning during the establishment period unless to prune broken or damaged branches. If pruning is to be done follow the proper pruning procedures below.

3) Maintenance & Landscaping

Tree Risk Assessment: Tree risk assessments should be performed as resources allow. Trees bordering high-use areas will receive more frequent inspection. Less frequent inspection will occur with trees in areas that have less frequent human activity. It is recommended that trees be inspected following significant weather loading events. The Grounds Department can decide whether or not to remove a high risk tree. Although CTAC may provide guidance in cases that warrant a final authority for decision making. Tree risk assessments will be scientifically based and use guidelines in the USDA Urban Tree Risk Management system (NA-TP-03-03) or any other approach that the CTAC deems sufficient.

Removals: Trees that are designated as hazardous to human or property and the hazard cannot be corrected will be removed. Only qualified personnel should remove trees. Once the tree and stump have been removed, the backfilled hole may be replanted as long as the replacement tree fits within the tree selection criteria as described in the previous section.

Pruning: The urban forest on campus will generally follow goal orientated pruning techniques that are based on a tree's age. The best time to prune will be determined by tree species, age, location, and the potential threat of pests. Trees within the vicinity of high-use areas such as walkways and roadways should be inspected for safety and clearance issues as resources allow. Recommended clearance heights of branches and foliage are eight feet above walkways and a minimum of 14 to 16 feet above roadways. All pruning activities must follow ANSI safety standards and the ISA's Best Management Practices - Tree Pruning Guide. Pruning of campus trees will be coordinated through the Grounds Department, arboriculture classes, and the SSA.

While pruning campus trees there are some important pruning recommendations that should be highlighted. Pruning should avoid damaging the branch collar (Figure 2). Branches should be removed prior to the branch reaching a diameter greater than two inches to reduce wound size. All pruning will be done on a priority basis whereas safety takes precedence followed by establishing proper tree structure and lastly aesthetics.

1) **Young Trees:** It is recommended that young established trees up to seven years old go through a training and structural pruning technique on an annual basis or as needed. The goal of the training technique is to establish and maintain a dominant central terminal leader and the lowest permanent scaffold limbs. The goal of structural pruning is to establish a branch architecture that reduces the chance of future branch failure. Structural pruning should maintain a live crown ratio of 60%, establish appropriate spacing between scaffold limbs, and remove any branches before they grow to reach half the diameter of where it is attached to the trunk. It is recommended that no more than 25% of the live crown of young trees shall be removed.

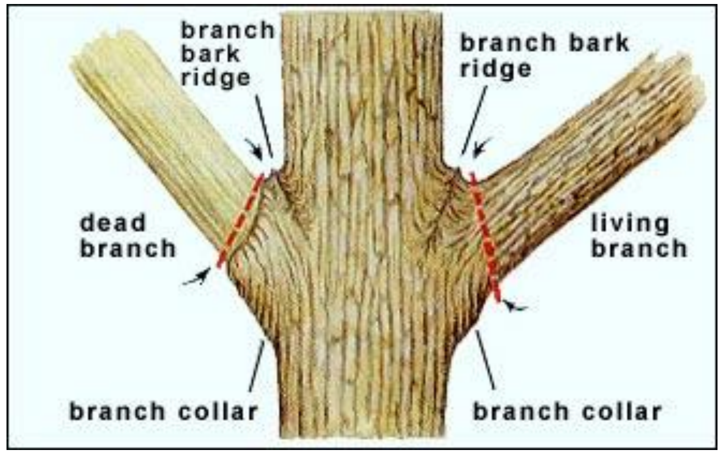

Figure 2. Pruning locations and terminology.

2) **Juvenile Trees:** Trees seven to twenty years of age should continue to receive structural pruning every three to five years. Similar to the young tree structural pruning technique a live crown ratio of 60% should be maintained, establish and maintain appropriate spacing between scaffold limbs, remove any branch before it grows to reach half the diameter of where it is attached to the trunk, and remove any temporary branch before it reaches two inches in diameter.

3) **Mature Trees:** Trees twenty years of age and older will use cleaning, thinning, raising, and reduction pruning techniques. These pruning techniques are used to improve tree structure and to the reduce the risk of injury to humans and property damage. The goal of cleaning is to remove dead, dying, diseased, sub-ordinate, and weakly attached branches. The goal of thinning is to reduce the number of scaffold branches to increase light/wind penetration, all while retaining the natural crown shape. The goal of raising is to remove lower branches and provide more clearance and to maintain at least a live crown ratio of 60%. The goal of reduction pruning is to remove a part of a branch back to a lateral branch in an effort to slow the branch's growth or redirect growth. It is recommended that no pruning will remove more than ten percent of a mature tree's live crown to minimize the wound surface area (wound diameter should not exceed one third of the trunk's diameter at that location).

Tree Health Care: Tree health care actions will be approved on an individual tree/incident basis. To help maintain the vitality of campus trees it is recommended that tree care personnel preform an ocular assessment of whether or not there is a pest infestation, nutrient deficiency,

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water stress, or any other unusual condition while preforming tree maintenance. When a tree health issue is identified, appropriate treatment options will be made based on funding, priority, and likelihood of success.

Catastrophic Events: A catastrophic event in the urban forest can be described as anything that suddenly inflicts major tree damage or death in a defined area without notice. Such events often include a major weather event or pest infestation. A preplanned response and recovery plan will be developed as resources allow.

A response portion of the plan typically develops a priority list of what areas need to be cleared of all safety hazards first. That list usually identifies high-use areas as the top priority and decreases priority as usage decreases. The recovery portion may establish protocols on how a landscape restoration project will be accomplished through priority based pruning and planting.
In the event that this plan is implemented an incident manager may want to provide an evaluation of what happened, what the plan addressed correctly, and what areas of the plan needs improvement.

Protection & Preservation: All trees should be considered for retention or transplanting in construction areas. Tree protection zones will be created prior to construction and a critical root zone established. Construction activities shall not occur in the critical root zone unless specifically authorized. It is recommended that all trees that are identified as needing protection within the designated work area have a Council of Tree and Landscape Appraisers (CTLA) value calculated prior to the start of the project and after the project is complete. When damage to a protected tree is identified the visiting project manager may be penalized based on the criteria described in the tree damage assessment section and as agreed to within a construction contract. Appendix E presents a proposed protection and preservation process.

Prohibited Practices: Vandalism or any tree care not authorized by the Grounds Department on campus is prohibited. This includes tree carving, attaching advertisements with the use of nails and staples, and removing parts of the tree or any other action that decreases the tree's vitality. Any tree, shrub, or vine that is planted without the guidance/approval of the Grounds Department is prohibited. Minor removal of tree parts for educational purposes is authorized.

Communication Strategy: The University of Wisconsin - Stevens Point Campus Tree Care Plan will be publicly displayed on the UWSP's website on the Grounds Department page. All related campus tree programs can be advertised to the student body by the campus e-mail distribution system, the official university website, and the weekly informational emailing to natural resource students and faculty.

To effectively communicate the proper policies, procedures, and practices outlined in the campus tree care plan it is suggested that all potential contractors be notified during a project bidding process to ensure full cooperation. UWSP may give a paper copy of the relevant campus tree care plan sections for a contractor to reference which helps eliminate any miscommunication prior to any work is to be initiated. UWSP may also want to provide a reference to the campus tree care plan for the student body in the student handbook, which is a handbook outlining all acceptable behavior.

Standard Three: Campus Tree Program with Dedicated Annual Expenditures

Currently an annual tree care budget of $52,100 is spent with managing the UWSP urban forest. The annual budget divided by an approximate 9,200 full-time students equates to $5.66 spent per student. This budget does not account for the value of present tree care equipment or the volunteer labor from the SSA, arboriculture classes, and service learning projects.

Table 2. Current annual tree care expenditures at UWSP.

Expense Area[1]	Cost ($)
Annual Planting	8,000
Annual Pruning	2,000
Annual Tree and Stump Removal/Disposal	3,000
Annual Pest and Disease Control	100
Annual Establishment/Irrigation	3,000
Annual Repair/Infrastructure Damage	12,000
Annual Litter/Storm Clean-up	4,000
Expenditure for Program Administration	10,000
Other Annual Expenditures	10,000

[1]From Forestry 333 Stratum Exercise: Parameter Input Data (2010)

Standard Four: Arbor Day Observance

An Arbor Day observance will be held on UWSP annually on the last Friday of April which is in accordance to the State of Wisconsin's law. Each Arbor Day celebration will be used as an opportunity to educate the campus community about the benefits of having trees in our community. The Arbor Day observance will be held on campus with a public invitation to the surrounding community. On Arbor Day UWSP may want to host guest lectures about the importance of having trees in our community, or have a ceremonial tree planting on campus with a short memorial portraying the importance of Arbor Day.

It is required by Tree Campus USA to record evidence of the annual Arbor Day observance. This evidence may be recorded in a log book that includes the date, time, location, and individuals participating in the event. Additional evidence that can easily be recorded is any media stories/advertisements by the student newspaper, city newspaper, county newspaper, and local news radio and television stations, or pictures and video recordings of the Arbor Day observance.

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Standard Five: Service Learning Project

UWSP inspires to share the importance that our campus's tree resource has with students, staff and community through service learning projects. Service learning is also important to the general education of students and is a current area being integrated into the general degree requirements for students at UWSP. Student organizations on campus including the SSA and Society of American Foresters have annual tree plantings that can easily be used to educate people on benefits trees provide. Below is a list of the service learning projects (pre-existing and proposed) that can be implemented at UWSP.

College Days for Kids (Pre-existing): College Days for Kids is a program designed for high - ability sixth graders. Participating schools bring these sixth graders to UWSP for a couple days to experience enrichment classes taught by university faculty and academic staff. The objective of this program is to expose the sixth graders to all of the potential degrees offered at UWSP in hopes to spark an interest. These students are exposed to the forestry programs by giving them hands-on activities and tree identification.

Arbor Day and Earth Day Tree Plantings (Pre-existing): UWSP has observed both Arbor Day and Earth Day by planting trees on campus. This event typically had an attendance composed of student and community volunteers, and campus officials. Volunteers are split into small groups and are typically assigned one SSA student to educate them on how to plant a tree correctly. Arbor Day and Earth Day tree plantings have been historically covered by many local media sources such as the Stevens Point Journal and by the campus newspaper.

Student Society of Arboriculture (Pre-existing): Campus pruning creates an opportunity for interested students to gain knowledge and experience in the field of arboriculture. Campus pruning consists of a head-pruning officer who takes other students around campus and gives them hands-on experience in the basics of pruning trees. The SSA has Experience Days that are another way to provide students with the chance to gain valuable work experience off campus. Another service is "Climbing for Kids" this program teaches children about careers as an arborist through climbing demonstrations.

Planting Week (Proposed): A proposed "UWSP Tree Care and Planting Week" (UWSP-TCPW) project may serve as an outreach opportunity to portray the spirit of the Tree Campus USA designation for the university. The UWSP-TCPW will also serve as an opportunity to engage the campus population, local public, and schools within the communities to learn how to plant trees, shrubs, and other vegetation on campus grounds, along with performing various arboricultural demonstrations on campus trees, shrubs, and other vegetation. The UWSP-TCPW will be a great opportunity for the campus population to work and educate community members and school children alike.

Lecture Series - Educating the Community in the Value of Trees (Proposed): Students may be selected to host a free informal lecture on campus about the values of neighborhood trees. The goal is that community members walk away with a greater understanding, as well as a renewed appreciation of the urban forest environment while student lecturers gain valuable experience in public speaking.

Conclusion

The University of Wisconsin - Stevens Point Campus Tree Care Plan was created to develop an initial set of proper policies, procedures, and practices advocating for a healthy and sustained urban forest. This plan followed the five standards that the Arbor Day Foundation's Tree Campus USA initiative to promote healthy community forests on campuses. It is expect that this plan will be revisited on a periodic basis to see if current approaches work, if areas important to urban forest management are missing, and to modify this plan as needed. This plan does not cover every possible aspect important to managing the urban forest. Rather, it provides an important basis to move a written and orderly process forward.

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Appendix A – Definitions of commonly used terms in the Campus Tree Care Plan.

Definitions: Below is a list of terms used in urban forestry that are presented here to aid in clarity and understanding of this document.

Branch Collar – The area where tree stem tissues and branch tissues overlap connecting the branch to the stem.
Canopy Cover – The extent of the outer layer of leaves over the ground below. It is the proportion of land that the canopy covers compared to the total land area.
CTLA – Acronym for Council of Tree and Landscape Appraisers, which is a tree appraisal that estimates the replacement cost of a tree with another tree of the same species, condition, and size.
DBH – Acronym for diameter at breast height which is the standard place of measurement, 4.5 feet, for a tree's stem diameter.
Hardiness Zone – A geographically defined area in which plant life is capable of growing. The United States is divided into 11 hardiness zones based on a plant's ability to withstand the minimum temperatures of that zone.
Internodal Pruning – Cuts made between branch unions or buds which may lead to branch dieback.
Native Species – A naturally occurring species of plant/tree that is indigenous to an area or region.
Pruning – The removal of any portion of a tree through the use of a cutting tool.
Root Ball – The collection of soil and roots of a tree that has been packaged to aid in transportation of the tree.
Topping – Internodal pruning at the top portion of a tree canopy.
Temporary branch – Any branch below the lowest permanent scaffold limb or any branch that is targeted to be removed in the future.

For more definitions see the "Techno Tree Biology Dictionary & Tree Care Information" website at: http://www.treedictionary.com/. This website has been provided by Keslick and Son Modern Arboriculture, Associates © 2009.

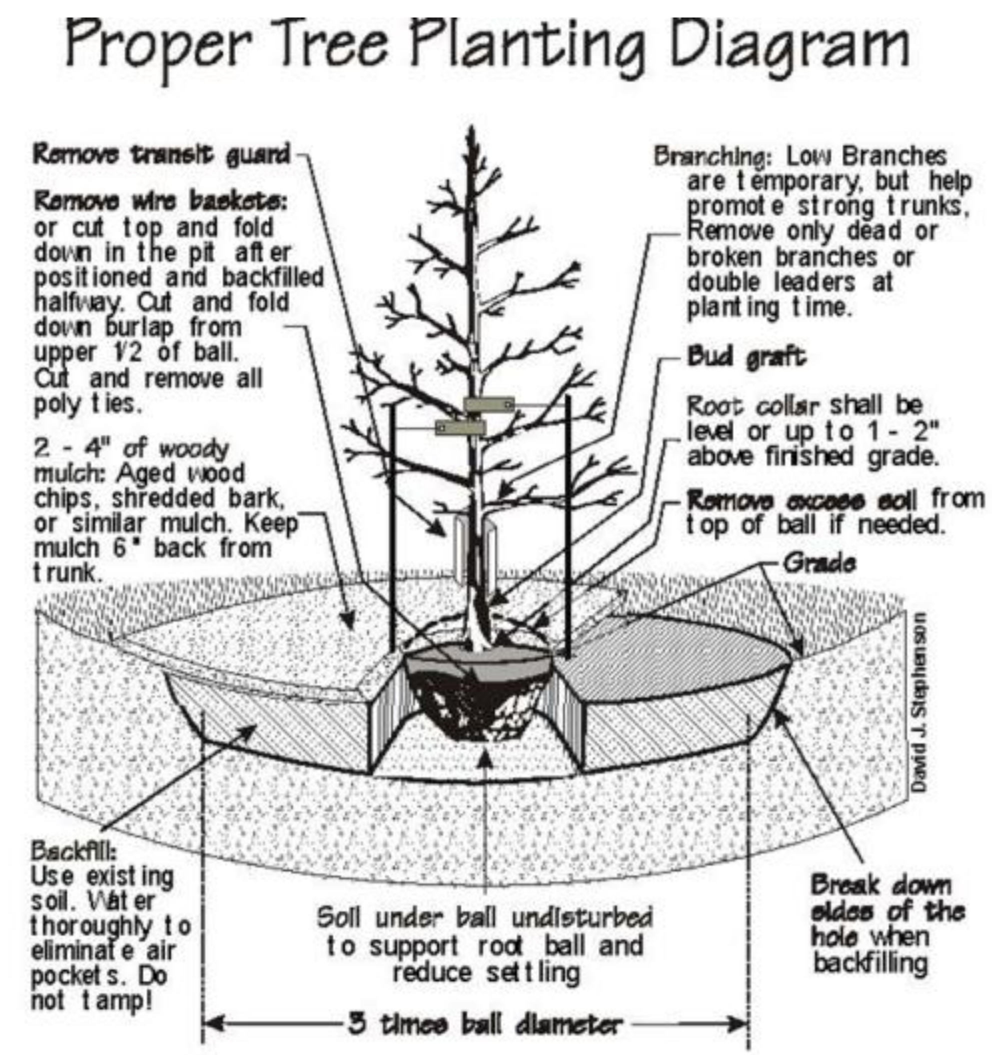
Appendix B – Wisconsin Department of Natural Resources - Terrestrial Restricted Species List

Classification[1]	Common Name	Scientific Name
P/R	Amur honeysuckle	*Lonicera maackii*
	Amur maple (CV)	*Acer ginnala*
R	Autumn olive	*Elaeagnus umbellata*
R	Bells honeysuckle	*Lonicera x bella*
	buckthorn	*Rhamnus spp*.
	Burning bush (CV)	*Euonymus alata*
NR	Callery pear	*Pyrus calleryana*
	Chinese elm	*Ulmus parvifolia*
R	Common buckthorn	*Rhamnus cathartica*
	English ivy	*Hedera helix*
	European barberry	*Berberis vulgaris*
	European mountain ash	*Sorbus acuparia*
R	Glossy buckthorn (CV)	*Frangula alnus*
	honeysuckle	*Lonicera spp*.
	Japanese barberry (CV)	*Berberis thunbergii*
P	Japanese honeysuckle	*Lonicera japonica*
R	Morrow's honeysuckle	*Lonicera morrowii*
R	Multiflora rose	*Rosa multiflora*
	Norway maple (CV)	*Acer platanoides*
R	Oriental bittersweet	*Celastrus orbiculatus*
P	Princess tree	*Paulownia tomentosa*
R	Russian olive	*Elaeagnus angustifolia*
P	Sawtooth oak	*Quercus acutissima*
NR	Scotch pine	*Pinus sylvestris*
	Siberian elm	*Ulmus pumila*
R	Tartarian honeysuckle	*Lonicera tatarica*
R	Tree-of-heaven	*Ailanthus altissima*
	Wayfaring tree	*Viburnum lantana*
	White mulberry	*Morus alba*
	White poplar	*Populus alba*
P	Wineberry	*Rubus phoenicolasius*

[1]Chapter NR 40 Classification Key: P=Prohibited; R=Restricted; C=Caution; NR=Non-restricted

For an updated list of the current invasive species please visit this website and click on - A Field Guide to Terrestrial Invasive Plants in Wisconsin
http://dnr.wi.gov/invasives/

Appendix C – Wisconsin Department of Natural Resources –Tree Planting Guidelines.



Stake only if you have to. Use 2-3"-wide webbing straps and secure to stakes with heavy gauge wire. The wire should be able to stick straight out from the stake and hold the webbing strap up, preventing it from sliding down the tree. Do not stake tightly - trees gain strength from movement. Remove all stakes after one year.

Use of tree wrap is not recommended, as it causes a number of problems for the tree.

Appendix D – Prescription or Dosage Based Watering

Labor to water trees is sometimes given as a reason or excuse used for not adequately watering newly planted trees. If the water requirements of newly transplanted trees cannot be met, planting smaller trees is recommended. For example, 1- and 2-inch caliper trees have less root loss and recover faster than trees 2 to 3 inches in stem caliper. Mulching trees to a 2- to 3-inch depth is recommended as it helps to reduce evaporation and conserve precious water. Incorporating the labor cost of watering trees within the tree planting budget should insure adequate watering occurs and trees establish successfully. If tree planting is part of the contract process, consider including watering as an additional component in the bid. Your community forestry program will be far better off if trees are adequately watered rather than continually replanting and not realizing the benefits that mature and established trees provide.

Irrigation Guidelines for Quickly Establishing Trees (Well- drained sites during the growing season in the Midwest)

- **Less than 2-inch caliper planting stock:** Water daily for 1 week; every other day for 1 to 2 months; weekly until established
- **2- to 4-inch caliper planting stock:** Water daily for 1 to 2 weeks; every other day for 2 months; weekly until established
- **4-inch caliper planting stock:** Water daily for 2 weeks; every other day for 3 months; weekly until established

Notes: Modified from Gilman, E.F. 1997. Trees for Urban and Suburban Landscapes. Delmar Publishers. 662 pp.

- Delete daily irrigation when planting in fall or early spring. Little irrigation is needed when planting in winter.
- Reduce frequency in cool, cloudy, wet weather if soil is poorly drained (soil drains less than 3/4 inches per hour). Eliminate daily irrigation in poorly drained soil. Following a rainfall wait until all free moisture drains out of the soil.
- Establishment takes 12 months per-inch-trunk caliper.
- Minimum frequency for survival could be once each week.
- Irrigation can cease once trees drop deciduous foliage in the fall.
- At each irrigation, apply 1 to 2 gallons for each inch of trunk diameter to the root ball.

Adapted from: Hauer, R.J. 2000. Tree Establishment: Water you going to do! Minnesota Shade Tree Advocate. 3(3):5-7

Appendix E – Protection & Preservation Process

Selection of trees to retain shall occur before construction occurs. The first step in this approach is to create or obtain a site map of the area that is designated for construction or renovation, including the buildings and their locations, the construction area(s), and the tree locations. While using this site map, identify all the trees whose root systems are likely to be impacted by the construction processes and all the trees whose branches may be damaged by construction equipment. These trees will then be considered to be potentially impacted. Once all of the potentially impacted trees are identified, they will then need to be prioritized or ranked. The potentially impacted trees will need to be ranked from high priority for preservation to low priority for preservation, and also ranked as not salvageable if necessary. High priority trees are those trees that are of medium to large size ranging from greater than 10-inches in diameter at breast height (DBH) to larger than 24-inches in DBH. High priority trees are also trees of desirable species that have good form and structure, are in good health, and have adequate room to continue growing. High priority trees should receive a high preservation and protection priority. In addition, large valuable trees should receive preservation consideration with construction alternatives allowing that the desired features and costs of the proposed buildings are maintained. Trees with a low priority for preservation are generally smaller trees with less than 10-inches in DBH. Trees that have a low priority ranking can also be those which have a relatively low landscape value, poor form and structure, species of relatively low landscape or educational value, and/or insufficient space for future growth. Trees that are deemed not salvageable from a construction or renovation area are those with characteristics such as undesirable species, very poor health, have a very low landscape or educational values, heavily diseased, heavily damaged, and have little chance of recovering their desirable form, structure, and function.

Protection of retained trees shall occur during construction activities. Once the areas containing high and low priority rankings for preserving trees are identified, these areas need to be zoned for protection. These tree protection zones need to be sheltered by tree protection fencing. The tree protection fencing must be installed around all groups of trees or individual trees designated as high or low priority rankings for preservation. The fencing must be installed at a distance from each tree or groups of trees of at least 1.25-feet per inch of trunk diameter, or 6-feet away, whichever distance is greater. The fencing must also be installed before any equipment arrives on the construction or renovation site. The area within the tree protection fencing zone must be mulched to a depth of 4-inches. The fencing must be maintained for the entire duration of the construction or renovation project and may be removed at the end of the project, provided that official permission has been granted by the committee. No activity shall occur within the tree protection fencing zone other than laying mulch. The project manager shall be held liable and will be penalized if events other than mulching occur within the tree protection fencing zone. (Please refer to the Tree Damage Assessment section for more information) The tree protection fencing must be 11.5-gauge, galvanized, chain-link fencing with a minimum of 1.625-inch outside diameter, tubular steel posts and top rails and a minimum height of 4-feet. Surface mounted fence panels may be used if approved by the Committee. Surface mounted fence panels must also be adequately braced to resist wind loading.

Georgia Tech Campus Tree Care Plan

I. The purposes of campus tree care plan are to:

- Facilitate the achievement of 55% tree canopy on campus as recommended by the 2006 Campus Landscape Master Plan.
- Facilitate the achievement of 22% woodlands coverage on campus as recommended by the 2006 Campus Landscape Master Plan.
- Protect and maintain the campus urban forest by managing the impact of development and constructions on campus trees.
- Provide protection and to make sure that removal of all trees on campus are conducted with proper considerations and adequate replacement program, according to our approved 2006 Campus Landscape Master Plan.

II. The responsibility of the Campus Tree Care Plan rests with Georgia Tech Facilities Department.

III. The Campus Tree Advisory Committee is composed of:

- Hyacinth Ide, Facilities Landscape Manager
- Anne Boykin Smith, Master Planner, Capital Planning & Space Management
- Jerry Young, Landscape Project Manager, Facilities Design & Construction
- Lisa Jackson, Information Analysis III, Center for GIS, School of Architecture
- Byron Amos, Vine City Neighborhood
- Dr. Gerald Pullman, Professor, School of Biology
- George Roberts, Construction Foreperson, Landscape Services
- Michael Walsh, Horticulturist II, Certified Arborist, Landscape Services
- Brett Testa, Horticulturist I, Certified Arborist, Landscape Services
- Donna Chronic, Horticulturist II, Landscape Services
- Ed Lanz, Project Superintendent, Georgia Certified Landscape Professional, Housing Department
- Paul Thurner, Home Park Neighborhood
- Marcia Kinstler, Director of Sustainability, Georgia Tech
- Brent Beamon, Arborist from the City of Atlanta
- Ritchie Brown, Senior Facilities Manager, Parking & Transportation, Georgia Tech
- Drew Getty, Kristie Champion, Deanna Murphy, Jason Vargo, Rahn Austin, Joseph Staubes, Yi Lin Pei, Student representatives (during the academic year August 2008 – June 2009)

Roles of Representatives

The committee members will accept to serve for a period of one calendar year with a renewal option. Members shall appoint officials who will conduct the day to day business of the committee. Committee members are expected to actively participate and contribute in policy/guideline issues as well as research/information gathering that would aid in the campus tree care plan.

Georgia Tech Care Policies – Tree Planting

Plant Selection

Plant species used on Georgia Tech campus will come from the list of the Landscape Standards in the 2006 Landscape Maser Plan. The list contains both native and exotic species that have been screened for adaptability to physical conditions and serviceability, to meeting planting needs based on site orientation, drainage, soil condition, use, etc. Where appropriate, the best plant shall be selected for a given site, which may or may not be a "native". Trees to be used on campus must be preselected at the farm or nursery for good quality and tagged. Only trees of 2"-2 ½" minimum caliper and maximum of 4"-4 ½" caliper will be planted.

Site Preparation

The planting hole should be dug no deeper than the rootball when measured from the bottom of the rootball to the trunk flare. If the hole is deeper than the rootball, it often results in the settling of the plant above the trunk flare and structure roots which can result in the rootball being planted too deep. But the width of the hole should be at least 2 to 3 times the diameter of the rootball with sloping sides.

Preventive Setting the Plant and Back Filling the Hole

Plants must be set with trunk flare 1"-2" above the existing grade. Once the plant is properly placed, all visible ropes and burlaps at the top one-third should be cut away. The top 8"-16" of the wire basket should be removed once the rootball is stable in the planting hole; backfill the planting hole with the existing soil. If the existing soil is of a poor quality, addition of soil amendment as recommended by the soil analysis should be used. The backfill soil should be tamped firm enough to remove large air pockets, but not too firm as to remove all fine air spaces needed for a well aerated soil for root development. Complete the backfill by making sure that the trunk flare is completely exposed, spread mulch at 2-4" depth but not touching the trunk, water the rootball and the planting area deeply.

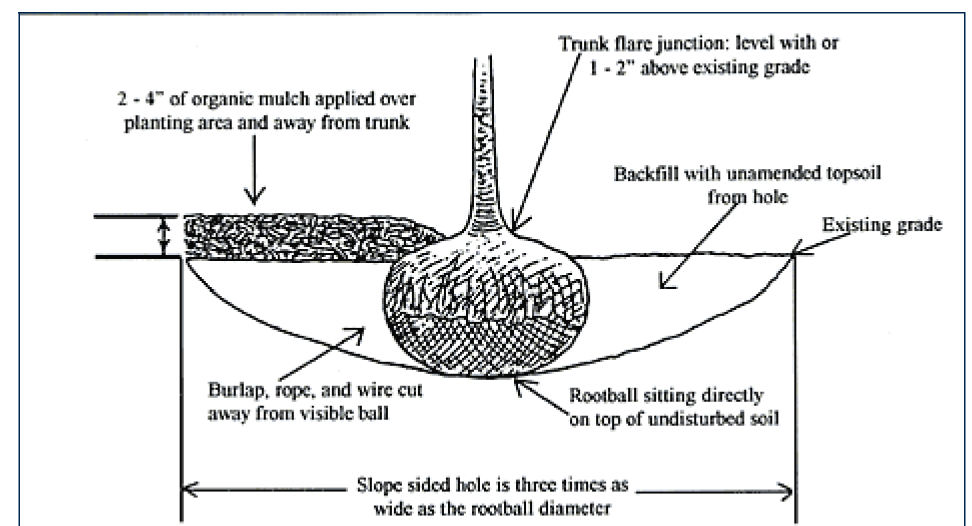


Diagram illustrating proper planting procedure for a tree or shrub.

Newly planted trees must receive adequate water weekly during the entire first growing season right up until dormancy in the fall, by irrigation or placement of ooze bag or hand watering.

Transplanting

Desirable trees in a development area or other construction sites shall be transplanted by staff if the tree caliper is between 2"-4" where there is an acceptable location and during the planting season (October to March). Trees of larger caliper shall be contracted out using comparable tree spades.

Fertilizing

Newly planted trees should not receive fertilization during the first growing season except in a situation where a soil test recommends its use. A slow release type of fertilizer should be used around the tree basin. Trees in poor condition should receive deep root fertilization of 5-35-10 plus micro nutrients, with repeat application if necessary. Also, when necessary, we shall use 10-20-10 for evergreen trees and 25-10-10 for general application. Routine tree fertilization is not recommended; however, campus trees receive adequate nutrients from turf, shrubs and groundcover routine application of fertilizers.

Staking

Staking of trees at planting is not required if the rootball is stable. If staking must be done, it will be done in accordance with ANSI most recent edition.

Pruning

After planting, only broken or damaged branches should be pruned. Tree wrapping is generally not recommended.

Landscaping

Landscaping on Georgia Tech campus must adhere to the five plant communities indicated in the 2006 Landscape Master Plan. They are Woodland, Parkland, Meadowland, Ornamental and Lawn. All landscaping, new and old shall use the list of acceptable plants in the Campus Landscape Master Plan. The best plant materials should be chosen based on the site conditions, not based solely on the merit of its being native. The objectives are to increase campus tree canopy to a minimum of 55% and campus coverage by Woodlands to 22%.



Georgia Tech Care Policies – Tree Maintenance and Removal

Preventive Maintenance Pruning

The tree team systematically prunes trees annually through a preventive maintenance pruning program. Preventive maintenance pruning is conducted on an as needed basis at this time. All campus trees are periodically surveyed and rated based on their pruning needs to determine scheduling priorities.

Service Requests

The tree team typically prunes 300 trees annually by service request. Requests are made by customers around campus, which is then followed up by an inspection of the trees by the staff arborist who generates the evaluation and tree rating to determine the type of pruning to be performed by staff. **See appendix A**, routine inspections by staff provide most of our pruning needs.

Fallen Limb Removal

When limbs fall from trees on campus, members of the campus community can call in or make a service request (via web base) and by staff inspection to promptly clean up the debris. Every attempt will be made to clean up dropped limbs within the same day, depending on the severity of the storm and the extent of the tree damage (except in the Greek and religious properties). We do not maintain private properties on Georgia Tech Campus.

Hazard and Emergency Tree Removal

From 2004-2008, Georgia Tech Landscape Services and new construction has removed a yearly average of 111 trees. During the same period, 428 trees were also planted annually. When a tree removal request is made, a certified arborist evaluates the tree in question and makes the determination for removal or not based, on the result. If the tree is considered a hazardous tree, it is then scheduled for removal. All hazardous trees have two things in common, a significant defect and a potential target for falling on a building, car or pedestrian. Most tree removals are done by staff or contractor. Very large trees needing a crane are contracted out.

Stump Grinding

After trees are removed the stumps are then scheduled for grinding, provided there is adequate access to the site. When the stump is ground out, the grindings are raked and left slightly mounded to allow for decay and settling to occur.

Managing for Catastrophic Events

In the event of severe weather conditions such as tornadoes or hurricanes, falling trees will be removed by Landscape Services staff or an outside tree removal company. Roads and streets shall be cleared first, then access to critical buildings, administration, buildings with critical labs, library, student center, etc. in that order. In the advance of severe weather conditions, all necessary equipment shall be checked for readiness and safety by staff.

Protection and Preservation Policies and Procedures

Tree protection zones shall be established and maintained for all trees to be preserved in a construction site. Construct a simple barrier for each tree or grouping to protect the trunk and root systems. This reduces damage from heavy equipment and trucks. Wood, plastic or chain link 4' fencing would be suitable. Install the barrier fence for every inch diameter of that tree's diameter breast height (DBH), provided that in no case shall the protection zone be less than a radius of 2.5 feet. No root raking shall be allowed within any tree protection zone at anytime during clearing, grading or construction of a project. No equipment or vehicle shall be parked or construction material stored, or substances poured or disposed of or placed within any tree protection zone at anytime during clearing or construction of a project. To the extent possible, all site work shall be planned and conducted in a manner that will minimize damage to protected trees from environmental changes such as altered site drainage or any other land disturbance within or immediately adjacent to the critical root zone of the tree.

New Building or Facilities Construction

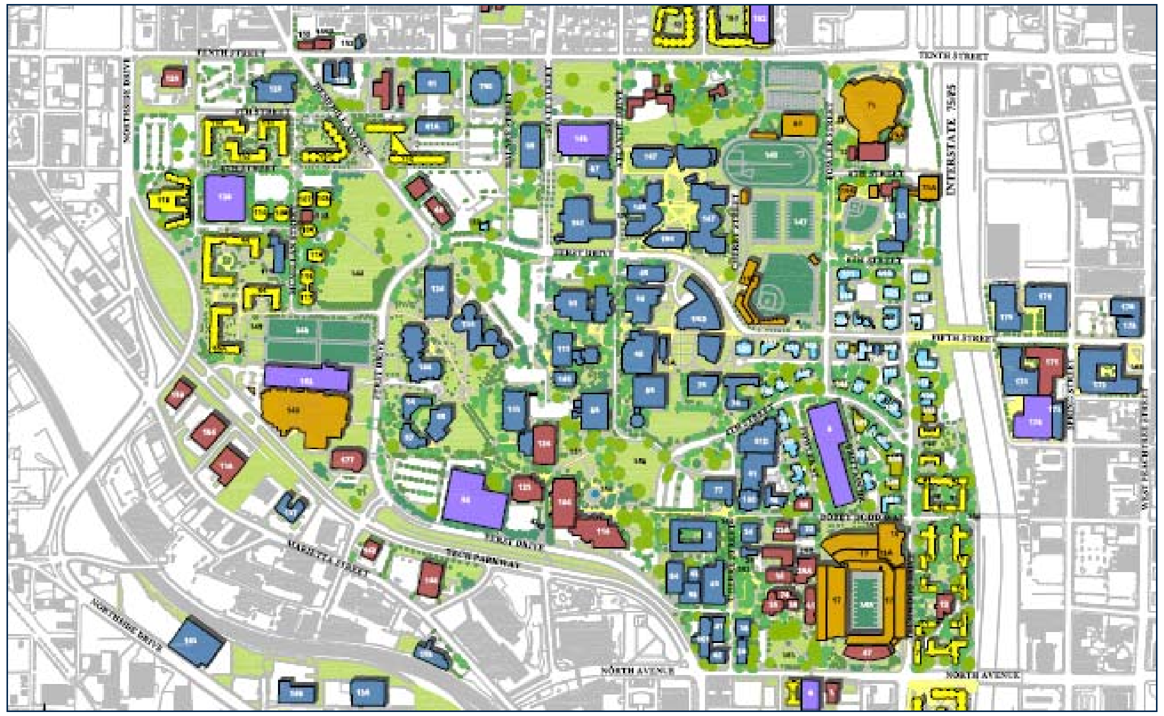
Development activities shall be planned to the extent possible in order to preserve and protect trees on Georgia Tech Campus. Any tree on Georgia Tech campus that must be removed to accommodate development, damage during storm events, disease and water/sewer repairs must be shown on the site plan and a method of compensation shall apply as prescribed by the 2006 Campus Landscape Master Plan, on page 65.

a) A 1" diameter tree shall be compensated with an equivalent monetary value.

b) A 1" diameter tree shall cost no less than $175.00 (2008 cost)

c) The sum total of the diameter of replacement trees (inches) shall be multiplied by that year's actual cost of the tree market value.

d) An account shall be created to receive and manage the tree replacement program. This will allow for the flexibility of planting time or the issue of not having ready site or if the site has insufficient space for tree planting and payment shall be made to the tree planting and replacement account. The tree replacement or planting account shall be a separate account so that the funds can be used from year to year for the purpose of tree planting and replacement only.



Design Requirements

Design of a new development or reconstruction shall include a green space plan in the proposal. Such plans shall include a tree protection, tree establishment and landscape plan. Such plan shall conform to the landscape standards as prescribed in the Campus Landscape Master Plan.

Goals and Targets

Develop an integrated, ecologically based landscape and open space system that will help Georgia Tech achieve its goal of environmental sustainability by 1) increasing campus tree canopy to a minimum of 55%, 2) increase campus coverage by Woodlands to 22% and 3) completion of a Campus Tree Inventory. In 2004, the campus tree inventory as indicated in the 2006 Campus Landscape Master Plan was 5000 trees and the tree canopy coverage was 15-18%. In 2008, there are about 6,700 trees on Georgia Tech campus providing approximately 33.8% of tree canopy. A GIS Tree Inventory is in progress to update the Campus Tree Inventory.

Tree Damage Assessment

All damaged trees on Georgia Tech campus shall be assessed by a Certified Arborists using the existing tree evaluation form. Results from the evaluation determines whether the tree should be removed, pruned or receive treatment such as fertilization, and insect/disease control, **see appendix B**. Removed trees are updated on the tree inventory list. Whenever it is determined that violation of this procedure has occurred, the Facilities representative or designee shall immediately issue written and oral notice to the person or company or department in violation, identifying the nature and location of the violation and specifying that remedial action is necessary to bring the violation into compliance. The person or company or department in violation shall immediately, conditions permitting, commence remedial action and shall have seven (7) working days after the receipt of the notice, or such longer times as may be specified in the notice, to complete the remedial actions required to bring the activity into compliance with this policy,

Prohibited Practices

Under no condition shall a tree be planted on Georgia Tech campus for dedication without pre-approval from the office of the Executive Vice President for Administration & Finance through the office of Capital Planning & Space Management.

Definitions

Caliper - *The diameter or thickness of the main stem of a young tree or sapling as measured at six (6") inches above ground level. This measurement is used for nursery-grown trees having a diameter of four inches or less.*

Canopy trees - *A tree that will grow to a mature height of at least 40 feet with a spread of at least 30 feet.*

Clearing - The removal of trees or other vegetation of two inches DBH or greater.

Critical Root Zone - *The minimum area surrounding a tree that is considered essential to support the viability of the tree and is equal to a radius of one foot per inch of trunk diameter (DBH).*

Development - *The act, process or state of erecting buildings or structures, or making improvements to a parcel or tract of land.*

Diameter, breast height (DBH) - *The diameter or width of the main stem of a tree as measured 4.5 feet above the natural grade at its base. Whenever a branch, limb, defect or abnormal swelling of the trunk occurs at this height, the DBH shall be measured at the nearest point above or below 4.5 feet at which a normal diameter occurs.*

Green space - *Any area retained as permeable unpaved ground and dedicated on the site plan to supporting vegetation.*

Green space plan - *A map and/or supporting documentation which describes for particular site where vegetation is to be retained or planted in compliance with these regulations. The green space plan shall include a tree establishment plan, or a tree protection plan, and a landscape plan.*

Impervious surface - *A solid base underlying a container that is nonporous, unable to absorb hazardous material, free or cracks or gaps and is sufficient to contain leaks, spills and accumulated precipitation until collected material is detected and removed.*

Landscape plan - *A map and supporting documentation which describes for a particular site where vegetation, is to be retained or provided in compliance with the requirements of this policy. The landscape plan shall include any required buffer elements.*

Native tree - *Any tree species which occurs naturally and is indigenous within the region.*

Tree establishment plan - *A map and supporting documentation which describes, for a particular site where existing trees are to be planted in compliance with the requirements of these regulations, the types of trees and their corresponding trees for reforestations.*

Tree protection plan - *A map and supporting documentation which describes for a particular site where existing trees are to be retained in compliance with the requirements of the regulations, the types of trees and their corresponding tree for reforestations.*

Tree protection zone - *The area surrounding a preserved or planted tree that is essential to the tree's health and survival, and is protected within the guidelines of these regulations.*

Communication Strategy

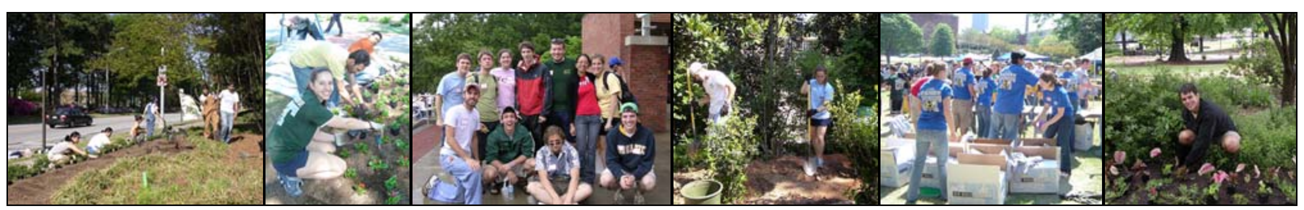
After the adoption of the Campus Tree Care Plan and Policies by the Advisory Committee and Georgia Tech Administration approval, an article on Georgia Tech's participation in the Tree Campus USA shall be placed in the student's newspaper "The Technique" and the staff news paper "The Whistle". Also, the adoptions shall be sent to the Georgia Tech community via the electronics email distribution system and placed on the Georgia Tech Facilities Website. Additionally, a press release shall be made to the local media through the office of Institute Communication & Public Affairs.

Dedicate Annual Expenditures for Campus Tree Program

Staff and Equipment

Georgia Tech has dedicated two full time employees (a certified arborist & equipment operator) and 1/3 of Foreperson's time totaling $138,518.39 for the tree program. On average, Georgia Tech Landscape Services spends $19,000.00 to purchase new trees per year. The following equipment is used in the maintenance and care of our campus trees.

Chipper truck with 25' bucket	$ 52,756.20
Vermeer 1250 Chipper	$ 20,000.00
Vermeer Stump Grinder	$ 11,542.90
New Holland Ford Backhoe	$ 55,542.90
Bobcat 863 Loader	$ 19,960.84
Chainsaw (4)	$ 3,600.00
Pole saw	$ 749.00
Climbing Gears	$ 1,122.75
Subtotal (Equipment Invested)	*$165,481.69*
Equipment Maintenance/yr	$ 1,722.69
Grand total on equipment	**$167,215.38**
Annual Contract Labor Cost	$ 18,590.00



Tech Beautification Day

The Georgia Tech Beautification Day and Earth Day held annually in April, account for over 500 students, faculty & staff volunteers. At 3 hours per volunteers x $18 equals $27,000.00 of volunteer labor per year. They participate in planting trees, shrubs, groundcover, flowers, laying sod, spreading pine straw and wood chips, pulling weeds, picking up trash, etc. on the Georgia Tech campus. Some Hands-On-Atlanta members also participate with the students, faculty and staff.

Other associated costs of the campus tree management are:

- Development of Georgia Tech Campus Landscape Master Plan in 2006
- Three staff members are Certified Arborists of the International Society of Arboriculture with assorted fees of $2,500.00
- Development of 5000 campus tree inventory in 2004 at $35,000.00

Summary

Summary of the dollar value dedicated to the tree program by Georgia Tech are:

Labor staff/yr	$138,518.39
Labor contract/yr	$ 18,590.00
Labor volunteer/yr	$ 27,000.00
Tree purchase/yr	$ 19,000.00
Materials/yr	$ 7,500.00
Equipment investment	$195,481.69
Equipment maintenance/yr	$ 1,722.69
Tree inventory cost	$ 35,000.00
Staff associations & training cost	$ 2,500.00
TOTAL	**$445,312.77**

Georgia Tech's full time student population is 19,410 x $3 annual expenditure requirement is $58,230.00. Therefore, Georgia Tech is well over the required amount of expenditures needed for Tree Campus USA participation.

CHAPTER 14

DEVELOPING AN URBAN FOREST MANAGEMENT PLAN FOR HURRICANE-PRONE COMMUNITIES

PUBLICATION Nº
FOR 121

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UF | UNIVERSITY of FLORIDA
IFAS Extension

Introduction

This chapter brings together the information and tools from previous chapters and changes the focus to the community rather than the homeowner, and from individual trees to the urban forest. The urban forest is the collective sum of all trees and vegetation in and around an urban area. Urban forests are an integral part of a community's well-being, so a management plan for its urban forest is essential to a community. An urban forest management plan should consider public and private trees as part of the urban ecosystem. An urban forest management plan does not allow a community to tell each individual or homeowner how to manage their property, but it does allow a community to take trees on private property into account so that planners can look at the entire forest as a resource to manage.

Communities (e.g. neighborhoods, homeowner associations, towns, or cities) can manage their tree resources to meet common goals using a management plan. By working together rather than as individuals, communities can maintain or enhance their urban forests and improve their well-being. This chapter along with preceding chapters can be used as a guide for citizen and tree care professional participation in managing the community's urban forest and for community leaders in developing a plan for their urban forest.

The process outlined in this chapter is dynamic and adaptable and can be used by any community, regardless of type or size. All the components of this process are related and are part of the overall objective of achieving a healthy, wind-resistant urban forest. A healthy urban forest is composed of trees that maximize ecosystem benefits and withstand natural and anthropogenic stresses and disturbances, such as wind from hurricanes and tropical storms, flooding, pollution, etc. Several urban forest management and street tree master plans were reviewed in preparation of this chapter. Additionally, conversations with urban foresters from across the Southeastern US and elsewhere were used to develop this outline to help a community start its own process.

Why Develop an Urban Forest Management Plan?

An effective urban forest management plan[1] should be developed and implemented before damage from a windstorm or hurricane occurs. It also can be used as a blue print for post-hurricane response to damages after a storm. Developing a management plan can:

- Create a safe and attractive environment.
- **Maintain or enhance public and private urban forest cover.**
- Provide ways of responding to the community's needs and requests.
- **Maximize the well-being of residents and visitors.**
- Minimize the costs of managing your trees and hazards to life and property.
- **Improve coordination of management activities with other associations, neighborhoods, departments or offices.**
- Establish measurable and long-term goals and objectives.

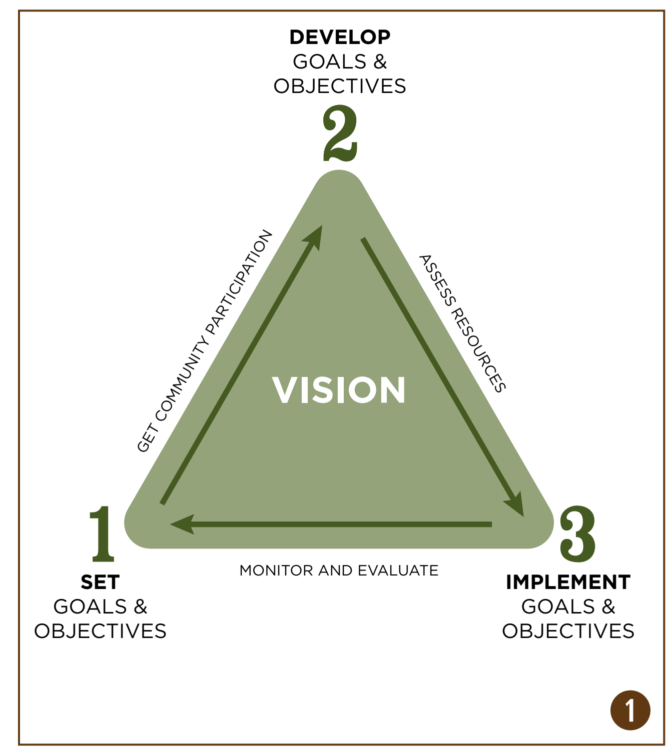

Figure 1

The process of developing an urban forest management plan for hurricane-prone communities.

1 An urban forest management plan outlines day to day management activities, or the who, what, when and how, that need to be accomplished to achieve a community's goals and objectives regarding their public and private trees. This is different from a street tree master plan, which involves specific goals and objectives and management related to public trees along streets and public rights of way (Hubbard 2000).

How to Develop an Urban Forest Management Plan for Hurricane-Prone Communities?

In general, a community urban forest management plan for hurricane-prone communities needs to be viewed as a process and not a product (Figure 1).

Figure 1 outlines a process that will answer four basic questions using seven general approaches:

What does the community want from its urban forest?

- Creating a vision (p. 2)
- Setting visions, goals and objectives (p. 3)
- Getting community participation (p. 3)

What is the community's urban forest resource?

- Assessing the community's tree, fiscal, and human resources (p. 5)

How can the community achieve the urban forest it wants?

- Developing goals and objectives (p. 4)
- Implementing a plan to meet the goals and objectives (p. 7)

Is the community achieving the urban forest it wants?

- Monitoring and evaluating (p. 8)

Creating a Vision

At the beginning of this process, the community should identify a vision for its urban forest to achieve a functional management plan (Figure 1). A vision statement will help define the goals and objectives, which lay the framework for the management plan. A vision is the desired future condition of the urban forest, and it should be concise and meaningful (Hubbard 2000). This vision needs to be created by and accepted by the community. Community consensus is critical in defining what goals are most important because the time and resources available to implement those goals are limited. For example, the vision of the Urban Forest Hurricane Recovery Program might be to promote a healthy and wind-resistant urban forest. It could be aimed at helping citizens and communities to restore an urban forest after storm damage and to set better urban forest management practices so that future storms are less devastating.

Setting Visions, Goals and Objectives

Goals

Goals are the general statements about what your community is trying to accomplish. Each goal statement then has its own set of objectives. A goal for hurricane-prone communities could be to maintain or increase tree cover, wind resistance, and tree diversity.

Objectives

Objectives are focused, measurable, result-oriented activities that support the completion of a goal and help the community meet its vision. Some example objectives for a wind-resistant urban forest might be to remove hazardous trees, initiate a pruning program, and plant wind-resistant trees of different ages and sizes in groups in appropriate locations.

Different goals do not have to be exclusive or independent of one another. They often can be linked to achieve multiple benefits. If other goals for a wind-resistant urban forest are to reduce storm water runoff and energy use, specific objectives could be to 1) use porous surfaces in parking lots and 2) plant groups of wind-resistant trees for shade. These combined objectives could result in reduced storm water runoff and increased urban forest cover in your community. So, by selecting species that are wind-resistant and planting them in groups in appropriate areas to reduce storm water runoff, the community increases its tree canopy and shade, improves wind resistance, reduces energy and thereby achieves all three goals (Figure 2). In the following sections we will explain how this publication can be used to help you select some goals and objectives toward creating a more wind-resistant urban forest.

Community Participation

To be effective, the vision statement and well defined goals and objectives should be a community activity (Figure 1). Establish a broad-based community working group or team (Letson, 2001). A meeting facilitator is often needed to ensure that everyone is heard and that all concerns are identified. The group should meet periodically. For example, the working group could consist of:

- Private citizens
- **Community and urban foresters**
- Tree care professionals
- **Parks and recreation, planning, zoning, and extension service representatives**
- Emergency management services
- **Media contacts**
- Public utility providers
- **Engineers**
- Local non-profit organizations, and
- **Other public entities depending on the characteristics of your community**

An example of a working group was the one that helped develop Miami-Dade County's Street Tree Master Plan which establishes the direction for planting and managing trees along streets and highways for beauty and environmental benefits. The group consisted of The Community Image Advisory Board, Department of Environmental Resources Management, Public Works, Planning and Zoning, Cooperative Extension, Office of Strategic Business Management, Parks and Recreation, Office of Emergency Management, among others (Miami-Dade County, 2007).

If the community has not participated in the development of the management plan from its outset, the plan should at least be presented to the community before it is implemented so that residents

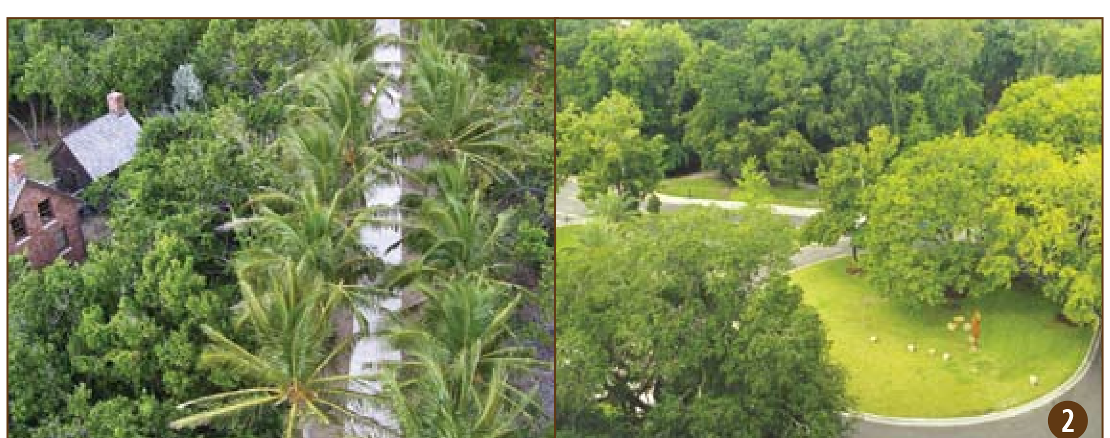

Figure 2

Combining different species and surfaces to meet multiple objectives.

and community planners can participate in the decision-making process and, if necessary, help develop alternative management options if initial proposals are not acceptable (Figure 1). Involving the community in the decision-making process will give the management plan a greater chance of acceptance and success:

- The community can help identify and develop alternative management options.
- **The team can discover new information relevant to the community and urban forest.**
- The plan and its actions will demonstrate fairness for all the members of the community.

Some ways of increasing community participation include:

- Discussing the plan with friends and neighbors.
- **Organizing outreach activities such as news releases and public meetings.**
- Developing educational programs for schools and other community groups.
- **Establishing your city as a Tree City USA.**

Developing Goals and Objectives

It is important to narrow down: (1) who will be responsible for implementing the plan; and (2) what and how and when the plan's activities will be carried out (establishing a timeline). The information, lessons, and strategies from previous chapters can be included directly as objectives in your plan. For example:

- An objective to reduce or prevent the number of tree wind failures can use information from *Chapter 6—Urban Design for a Wind Resistant Urban Forest*, which presents appropriate design and plan management strategies. This chapter and *Chapter 5—Lessons Learned from Hurricanes* also present urban design strategies for increased wind resistance, such as planting trees in groups rather than individually and giving trees enough rooting space for their size (Figure 3).
- Specific post-hurricane restoration objectives and activities in your plan can use information from *Chapter 4—Restoring Trees after a Hurricane*, which explains specific tree pruning activities necessary for restoring trees after hurricanes. Also *Chapter 12—Developing a Preventive Pruning Program: Young Trees* and *Chapter 13—Developing a Preventive Pruning Program: Mature Trees* outline preventative pruning programs for young and mature trees. These can be used as multi-year objectives that can reduce damage from future storms for new and existing trees.
- Use of wind-resistant tree species is one objective for achieving a wind-resistant urban forest. *Chapter 8—Selecting Southeastern Coastal Plain Trees Species for Wind Resistance* and *Chapter 9—Selecting Tropical and Subtropical Trees Species for Wind Resistance* list tree species that have been determined to be wind resistant.
- Objectives can also incorporate lessons from past hurricanes. *Chapter 5—Lessons Learned from Hurricanes* for example mentions removing hazard trees before the wind does and being careful not to damage or cut main support roots during construction, since this will damage the tree's anchoring system.
- After Hurricane Andrew, more trees were damaged as a result of hurricane debris clean up (Burban and Andersen 1994). By designating areas for debris storage and temporary housing, communities can avoid causing further damage to their urban forests.
- Additional goals and strategies to reduce your risk from tree damage can include maintaining diversity in your community by planting a mixture of species, ages, and layer tree and shrub canopies (Miller 1997).

Photo courtesy of the National Oceanic and Atmospheric Administration

Figure 3

Aerial view of the effects of a hurricane. Would proper species selection and planting trees in groups have prevented this?

Developing Goals and Objectives Specific to Your Climate

Among its urban forest master plan objectives, Rochester NY determined to select trees with strong branch structure to minimize ice storm damage, prohibit the planting of ash trees to minimize damage from emerald ash borer, and establish a database to identify and separate street segments covered by Federal Highway Administration reimbursement from those covered by Federal Emergency Management Agency (City of Rochester 2005). Other cities such as Urbana, Illinois have tree emergency response plans that closely follow their snow removal plan (Personal Communication, Mike Brunk, City Arborist).

Using the example from northern cities, hurricane-prone communities could develop emergency management goals as part of their plan (Letson, 2001). The draft urban forest management plan for Pineville, Louisiana, for example, calls for developing "storm plan" objectives to be followed when a storm occurs (City of Pineville, 2006). Although an objective like this might be complex for large metropolitan areas affected by the severe 2004-2005 hurricane season, it might be simple for smaller communities.

The working group needs to determine which goals and objectives are the highest priority and which can be achieved within current fiscal and resource limitations and then develop action items and specific steps necessary to achieve every objective. In fact, most objectives in a management plan need alternative options because of changes in funding, personnel, and community concerns (Figure 1). Objectives can also be presented as alternatives or designed to accommodate several goals and contingencies. For example, three alternative objectives for removing hazard trees in order to achieve the goal of a wind-resistant urban forest are:

Objective 1

Remove all hazard trees at once

This represents an improved efficiency and lower cost since work crews need to visit a neighborhood only once to remove undesirable trees. On the other hand, a significant portion of the canopy would be removed and this might upset residents who value these trees.

Objective 2

Remove hazard trees and wind-prone species as opportunities become available

This gradual change to the canopy might be less disruptive to the community but it will be less efficient and cost more than Objective 1 because crews will need to visit a neighborhood several times to complete the objective before a hurricane affects the community.

Objective 3

Leave hazard trees in place

This objective will prove catastrophically costly and inefficient if a storm strikes, but it may nevertheless be the most appealing to the community if it does not have any resources to allocate to tree removal.

As with most things in life, there will be trade-offs and these need to be assessed by the more specialized members of the working group (e.g. tree care specialists) and reviewed and accepted by the community. If the team and the community review the trade-offs together, there will be a greater chance of finding a compromise or solution acceptable to most of the community.

Assessing the Community's Tree, Fiscal, and Human Resources

Most communities will need some information to help develop the vision, goals and objectives. Some key questions this information should answer are:

- What should the urban forest look like and provide for the community?
- **How much urban forest do we want and need now and in the future?**
- Why do we want to manage the urban forest?
- **How will we respond in case of a hurricane?**

The information needed for your plan can come from several sources (Letson, 2001). Historical records, lessons learned from past hurricanes, library resources, and other community groups can have tree-related

information needed for developing your plan. *Chapter 4—Restoring Trees after a Hurricane* and *Chapter 5—Lessons Learned from Hurricanes* in this series can be especially useful for this. A systematic inventory of trees in your community is particularly useful for assessing, establishing, and measuring your goals and objectives. Keep in mind that data collection is expensive; measure only what is needed. Chapters 7 through 10 in this series and Miller (1997) will provide you with ideas for selecting appropriate trees including tree species, size, condition, location, growing space, and site history (see http://orb.at.ufl.edu/FloridaTrees/ for more information).

The working group needs to identify what information is necessary to accomplish the goals and objectives. This will help to identify problems and issues. But once the team has had community input, specialists should begin to lead the process (Figure 1). An urban forester or arborist on the team can determine what data to collect during an inventory to meet management objectives. Remember, there is no right or wrong type of assessment or inventory; this will depend on your community's vision, goals, objectives, and resources.

Information on current or past management practices (e.g., pruning history) and canopy characteristics is also useful for developing your objectives. For example, *Chapter 3—Assessing Hurricane-Damaged Trees and Deciding What to Do* indicates that species suffering high branch loss during hurricanes will need pruning and long-term monitoring. Reviewing current practices (such as tree planting, pruning and removal) and plans (such as street tree management, emergency response plans, ordinances, etc.) can also identify common goals and help to explore ways to integrate efforts (Letson, 2001). The urban forester or arborist in the working group can assess tree risk and pruning programs and prioritize areas for tree removal.

A Lesson Learned

Hurricane Andrew (Figure 4) revealed that unwise urban forest composition and planting practices resulted in extensive and unnecessary urban forest loss and associated damage to property (Burban and Andersen, 1994). Additionally, in many cases more trees were damaged as a result of hurricane clean up. Trees were used as brace posts to load debris and natural areas, and undamaged trees were bulldozed to make room for debris and temporary housing. Lessons from past experiences such as these can be used to assess the history of your tree resources and provide your community with insights on what is likely to happen after a hurricane (Letson, 2001). Chapters 1 through 3 in this series present tree-related hurricane response activities you might expect after a hurricane; some of these recommendations can be included in your plan as objectives.

Figure 4

Hurricane effects on palms in southern Florida: Hurricane Wilma (top) and Hurricane Andrew (bottom).

An Ecosystem Approach to Assess Your Urban Forest

The city of Tampa, Florida assessed their entire urban forest ecosystem (public and private trees) rather than just focusing on trees in streets and parks. The information gained through this city-wide assessment of Tampa's urban forest ecosystem will help the community develop a more comprehensive and effective management plan because public and private trees are included in the analysis (Figure 5). This ecosystem approach could also be used as baseline information for monitoring and assessing hurricane effects on trees and to provide information for emergency management agencies. Other cities such as Houston, Texas and Minneapolis, Minnesota have also used this approach for promoting and raising awareness of their urban forest (www.itreetools.org).

Figure 5

Aerial view of an urban forest ecosystem.

The team needs to assess the resources available—people, funding, and time—to manage the urban forest. Unfortunately, many activities that need to be done to create a wind-resistant urban forest might not be feasible. For example, species listed in *Chapter 8—Selecting Southeastern Coastal Plain Tree Species for Wind Resistance* and *Chapter 9—Selecting Tropical and Subtropical Tree Species for Wind Resistance* might not be available, or initiating preventative pruning programs from *Chapter 12—Developing a Preventive Pruning Program in Your Community: Young Trees* and *Chapter 13—Developing a Preventive Pruning Program in Your Community: Mature Trees* might be limited by budgets. An assessment of your resources will identify what can and cannot be done, thus defining the scope of the plan and its timeline (Figure 1).

Resource assessment is a critical step because it identifies limitations as well as potential avenues to minimize those limitations. For example, if funding is a critical issue, the team may want to apply for an urban community forestry grant to help offset costs. Similarly, if personnel is a critical issue, the team may want to hire a consulting firm specializing in urban forestry to do the inventory and data synthesis. Planners and working group members with fiscal experience can help assess available fiscal and human resources.

The state and private forestry organization of the USDA Forest Service and State Forestry Agencies, in partnership with national and local organizations, provide financial and technical assistance to plan, protect, and manage trees. Most states have urban and community forestry grant programs that can be used to fund tree inventories, management plan development, and other activities. For more information see http://www.arborday.org/programs/urbanforesters.cfm.

After assessing your urban forest and community resources, review the management plan's goals and objectives to ensure that they are still relevant in light of the information generated by your assessment or inventory (Figure 1).

Implementing the Goals and Objectives of the Plan

Once the community has selected objectives, it's time to carry them out to meet the agreed-upon goals.

Implementation is a continuing process in the long-term care of the urban forest, and should not be seen as the "last step" of a finite project (Figure 1). All of the planning and building of consensus up to this point

will help to ensure that the plan runs as smoothly as possible. But you should expect implementation to be an ongoing learning experience, and anticipate the need for contingency planning.

Some objectives can be achieved within a certain timeline, but this process needs to be updated regularly because your community, environment, resources and urban forest will change. Information from Chapters 4 through 13 of this publication series present several strategies that can be incorporated into your plan. In Florida, hurricane-prone areas are experiencing tremendous growth, and many new communities are being created every year. People and trees are constantly undergoing changes, and hurricanes will continue to strike Florida. It is essential for communities to plan as they grow to be in the best shape possible to withstand hurricanes. At this point in the urban forest management plan process, participation of team members representing emergency management services, public utilities, and municipal/county personnel is crucial.

It's Important to Adapt Your Plan

The city of Plantation, Florida developed its urban forest management plan in 2003. A tree inventory of over 5,000 trees served as the baseline information for developing their goals and objectives (City of Plantation, 2003). However, the 2004-2005 hurricane seasons affected the city's tree cover substantially. As a result, the inventory could no longer provide the information necessary for meeting the goals established in the plan. Rather than continuing with the original plan, the community will adapt their goals and objectives after conducting a new tree inventory. This type of change is inevitable and the ability to adapt is necessary in any hurricane-prone community.

Monitoring and Evaluating the Plan

During the implementation your plan, it will be necessary to establish procedures for monitoring and adapting your plan. A management plan should be viewed as a living document continually changing to reflect changes in resources and funding, and the needs of the community. In most existing urban forest management plans, monitoring is the most neglected step. Yet, it is one of the most critical elements of any plan because it will determine if the plan's goals and objectives are being met.

Monitoring is the collection of information to determine if the plan's goals and objectives are being met – in other words, is your plan effective? When monitoring the objectives and goals of your plan, the working group should ask the question "What are we doing to meet our goals and vision?" It is important to determine what your monitoring indicators or milestones will be. You can observe and collect information on many indicators. For instance, number of tree plantings, increases in tree cover, and number of trees pruned per year (use Chapters 11 through 13 to help you select indicators). Select indicators that are easily measured and repeatable so that the community can measure progress. Avoid collecting too much data and focus instead on the objective's relevancy to your goals. Make your monitoring efforts as explicit and simple as possible, and be sure they are clear to everybody on the team (Figure 6).

Figure 6

Monitoring urban trees after and before a hurricane.

Monitoring allows you to evaluate how well your activities are achieving your plan's objectives. Evaluate your monitoring information as a team, learn from other team members and modify or improve goals if necessary (Figure 1). Development of a management plan is a continual process and will not end with the writing of the plan. Monitoring will also provide feedback on how to improve your plan.

Evaluation May Mean Learning and Changing Your Plan

As part of their urban forestry management plan, the city of Charleston, South Carolina monitored and evaluated its tree maintenance operations. Charleston's urban forestry division's tree maintenance activities were compared to those of six other municipal forestry departments from other parts of the United States to determine how effectively the Charleston division was fulfilling its objectives (City of Charleston, 2000). Although Charleston was highly responsive to its citizens, it did not have a proactive pruning program. Initiating a proactive pruning program will allow the city to care for a greater number of trees and keep them maintained, reducing the need for "repair work" as the trees grow, which should in turn reduce the number of citizen complaints. Chapter 12 and 13 can be used to develop pruning program objectives in your plan.

The town of Leesburg, Virginia also evaluated its current tree management organization and determined that they needed to develop a clear urban forestry policy, improve the organizational structure and staffing levels, and provide adequate financial resources for urban forest management (Town of Leesburg, 2006).

Every community is different, and the task of balancing community needs with urban forest and budget needs is complex. But the results of monitoring and evaluation can also provide reasons to celebrate. Change is inevitable and not always bad. It's important to identify successes in your plan. When a milestone is met, this is reason to show the community the improvements to their environmental. Celebrate with press releases, arbor days, park openings and other publicity efforts to involve and educate the public. Keep in mind that a visible program results in more community support in both times of budget expansion and tightening.

Final Considerations

This publication series can provide you with a tool kit of information on how to develop and execute your urban forest management plan. Management is a continual process of learning and adapting to change (Figure 1). Reviewing the community management plan's vision, goals, objectives, and activities should be an important and on-going component of any management plan. A plan and its vision should not have a shelf life of 5, 7 or 10 years. If the ecological, economic or social assumptions that directed the initial plan change or become questionable, then the plan needs to be adjusted to meet the new realities.

In the aftermath of a hurricane, the health of a community's trees is about the last thing on anyone's mind. Urban forests will be secondary to ensuring public safety, mitigating hazards to property, cleaning debris, and restoring public services and utilities (Burban and Andersen 1994). In fair weather, however, urban forests should be a primary community concern. Careful planning for the allocation of resources to the urban forest will provide a community with a healthy, strong, wind-resistant forest that will help it withstand a hurricane. This fact should remind you of the need to consider hurricanes during your planning process and in fact, it makes considering hurricanes in your plans critical.

Things to Remember:

- Objectives can have time lines but the plan itself should allow for change.
- **A clear vision, community participation, monitoring, and the ability to adapt your plan for an eventual hurricane or other event is good fiscal policy and ensures the sustainability of the urban forest and its services.**
- By considering the approaches and information presented in this chapter and integrating the tools from previous chapters, communities can develop objectives that will help prepare them to effectively respond to a hurricane.
- **The lessons learned from previous hurricanes and the tools in this series can be used to design objectives that will help communities develop pre-hurricane goals, objectives, and activities and restore their urban forests after hurricanes**
- Success of an urban forest management plan will require the members of a community to cooperate with each other. Include on your team anyone with a stake in maintaining a healthy urban forest: public agencies, businesses, institutional landowners, green industry contractors, and emergency management services. Cooperation will create a common vision that values the urban forest and a community that works together to restore itself after a hurricane.

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2002 Community Forest Management Plan

City of Miami Beach, Florida
Hurricane preparedness fact sheet

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2001 Model urban forest book

City of Horn Lake, Mississippi
2004 Tree Inventory Management Plan

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2005 City of Charlotte, North Carolina Municipal Forest Resources Analysis. USDA Forest Service

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City of Charlottesville, Virginia

URBAN FOREST MANAGEMENT PLAN

May 2009

Table of Contents

Executive Summary

An Urban Forest Management Plan is intended to provide a framework for ensuring that the trees and forests of our City are appropriately cared for according to our community goals. It is a guide for City staff, landowners, utility companies, developers, and residents to follow when making decisions about trees, and the land they live on and are responsible for.

The City has a vision of becoming a Green City into the future such that:

> *Charlottesville citizens live in a community with a vibrant forest, tree-lined streets, and lush green neighborhoods. We have an extensive natural trail system, along with healthy rivers and streams. We have clean air and water, we emphasize recycling and reuse, and we minimize stormwater runoff. Our homes and buildings are sustainably designed and energy efficient – (Charlottesville City Council Vision- 2025)*

This plan discusses the benefits of trees and forests in urban areas, the current state of our forests, the people and programs that manage them, and proposed goals and actions to protect, enhance, and expand the urban forest and to promote staff, business, and citizen awareness and stewardship of this resource. The plan complements and furthers the Comprehensive Plan for the City.

Urban forests compete with many other human needs in a built environment, such as houses, sidewalks, and utility lines. It is very important to put the right tree in the right place, or the tree will either fail to thrive or create a myriad of side-effects that can be costly and detrimental to human habitation.

Basic goals of the Urban Forest Management Plan include:

- ***Preservation*** and ***Protection*** of existing forested areas and trees
- ***Enhancement*** and ***Restoration*** of forest quality
- ***Expansion*** of planted areas and total number of trees
- ***Monitoring*** and ***Documentation*** over time to track progress and needs
- ***Education*** and ***Outreach*** to involve the entire community
- ***Sustainability*** and ***Maintenance*** of plan and related codes and guides

The City's 2007 Comprehensive Plan established a goal of 40% tree canopy coverage for the City. This goal was based upon data that suggested the canopy coverage at the time was 31.6%. Further and subsequent analysis, which is detailed later in this plan, revealed that the City's current canopy coverage is actually much higher, at 46%. While this is good news, there are certain parts of the City that are deficient in their canopy coverage, and the overall quality of the urban forest still requires management, protection, and improvement. This plan will guide efforts to ensure that all areas of the City have the appropriate tree and forest presence based on land use and density characteristics.

Introduction to the Urban Forest Management Plan

<u>Plan Purpose</u>
The Urban Forest Management Plan has been developed to help improve and coordinate management of trees and forests in the City of Charlottesville. Over the years, various studies, proposals, and recommendations related to urban forestry have been made. This plan aims to consolidate these efforts into one comprehensive and cohesive document that will help ensure our management program can move forward in a planned and organized fashion based on sound science and policies. The plan is not meant to be a static report, but rather a plan that is continually updated and refreshed over time, much like the forest itself.

This plan aims to provide equitable forest benefits for all City residents, including access to forested areas for recreation and education, improved human and environmental health, and monetary savings generated by maintaining proper tree canopy levels.

<u>Background & Linkage to Comprehensive Plan</u>
For several years, the City of Charlottesville has undertaken a commitment to the stewardship of natural resources. The Charlottesville City Council has supported numerous initiatives in support of environmental sustainability within the community and the region. The City's 2025 Vision Statement presents Charlottesville as 'A leader in innovation, environmental sustainability, and social and economic justice.' Chapter Eight (8), <u>Environment</u>, of the *2007 Comprehensive Plan* for the City states in part:

> "The City of Charlottesville's environment includes a broad spectrum of elements and surroundings created by both natural and built systems. … Charlottesville's natural environment, which includes water, land, air, as well as its plant, animal and human inhabitants is equally important in providing a habitable City and is largely dependent on 'green infrastructure.' Similar to the 'grey infrastructure' of the built environment, 'green infrastructure' is the interconnected network of waterways, wetlands, woodlands, wildlife habitats, and other natural areas, greenways, parks, and other conservation lands and forests and open spaces that support native species, maintain natural ecological processes, sustain air and water resources and contribute to health and quality of life "

The City of Charlottesville lies entirely within the Rivanna River watershed, a part of the larger James River and Chesapeake Bay watersheds. The major waterways within the City, including the Rivanna River, Meadow Creek and Moores Creek, along with their tributaries, including Lodge Creek, Meade Creek, Pollock's Branch, Rock Creek, St. Charles Creek, Meadowbrook Creek, Fry's Spring, and Schenk's Branch, flow through both public and private property and are flanked by major riparian buffer areas. These forested stream valleys contribute healthy tree canopy, improve water and air quality and provide wildlife habitat, stream temperature regulation, and food for fish and other aquatic life. However, the health of these streams is undermined by uncontrolled stormwater runoff that contributes to major stream bank erosion, destruction of mature healthy trees, and the delivery of harmful pollutants. Healthy, diverse populations of native fish and other aquatic life cannot survive in urban streams severely affected by urban runoff. Invasive plant seeds are also spread by floodwaters and stormwater runoff.

Public perception of forest loss over time has led to a demand for improved tools for managing the trees in our City, both on public and private lands. The most recent Comprehensive Plan begins to address this issue, setting the stage for development of this plan. One of the four major sets of objectives in Chapter 8 of the *2007 Comprehensive Plan* focuses on the Urban Forest, with the stated Goal:

> ***Establish and maintain a 40% minimum urban tree canopy level in Charlottesville.***
>
> *Plan, develop and implement an Urban Forest Management Plan, which will serve as the City's comprehensive, long-range strategy for protecting, managing and expanding Charlottesville's urban tree canopy on public lands including streets, parks, schools and other City-owned properties as well as private lands.*

To that end, staff began working in mid-2007 on formulating the elements of an Urban Forest Management Plan (UFMP). Staff from the Department of Parks and Recreation, the Environmental Office of the Department of Public Works and Neighborhood Development Services met several times to perform a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis. Based upon that analysis, staff then began to prioritize identified items and create strategic elements and tactical actions for meeting the stated 40 percent tree canopy goal. (The complete results of the SWOT Analysis are included in Appendix 7).

It was clear through this analysis that the City is well positioned to undertake this effort and ensure its success. There is a clear recognition that the development and execution of this plan is a community priority and is directly aligned with City Council Vision Statements, the Comprehensive Plan and the Strategic Plan.

Current and Previous Urban Forestry Related Studies and Efforts

The City's commitment to environmental sustainability and management of green infrastructure resources is a key component in ensuring that the community's high quality of living can be maintained for years to come. Over the past several years, the City has taken the following steps that support this commitment:

1975 Street Tree Inventory

In 1975 the City developed a Street Tree Master Plan, which made general and specific recommendations on where and how to protect and expand street tree coverage in the City.

1998 Thomas Jefferson Planning District Sustainability Accords

These Accords were developed and distilled from a large set of objectives and concerns evaluated by the Thomas Jefferson Sustainability Committee from 1994 to 1998. Taken together, these Accords create an agenda on which the community can agree. Individually, each one provides an opportunity for individual and community action toward sustainability for the region. The Accords were included as part of the 2001 City Comprehensive Plan.

2002 Street Tree Inventory

Using a Global Positioning System (GPS) unit, major streets were field checked for trees in the City right-of-way, and limited information about each tree was collected. This data resides in the City Geographic Information System (GIS) and can be compared to future tree inventories to help track the state of street trees managed by the City.

2003 Environmental Sustainability Policy

This Policy notes that Charlottesville is building a distinctive world-class small city with the vision of ensuring the quality and sustainability of the natural and built environment as part of the City's responsibility to future generations. The policy adopted four environmental stewardship principles: conservation, cooperation, environmental compliance and risk reduction, and restoration. An important element of the Policy is the commitment to the development and implementation of an Environmental Management System (EMS) based upon the ISO 14001 International Standard. The EMS aims to reduce the environmental impacts of the City's operations while fostering a safer and healthier work environment for its employees. The Parks and Recreation Department has been operating under the EMS since 2003 and the EMS continues to be implemented throughout the rest of the City in a phased approach.

2004 Water Protection Ordinance

The Water Protection Ordinance amended Chapter 34 of the City Code (Erosion and Sediment Control) and re-designated Chapter 10 as the City's Water Protection Ordinance. The ordinance, adopted in September of 2004, accomplished the following:

- Amended and updated the City's local erosion and sediment control program,
- Established a local stormwater management program,
- Established protection of 100-foot wide riparian stream buffers on properties adjacent to the Rivanna River, Moores Creek, and Meadow Creek, and
- Prohibited illicit discharges and connections to the City's storm sewer system.

2005 Water Quality Management Study

This Study conducted and incorporated the results of stream corridor assessments, collated historic information regarding the condition of urban waterways conditions, completed mapping of the streams, and includes recommendations for future strategies for the City to consider as it seeks to protect its waterways and community health.

2005 Parks and Recreation Needs Assessment

This report documented the clear need and desire on the part of the citizens of Charlottesville to preserve natural environments and open space. Selected survey results indicated that:

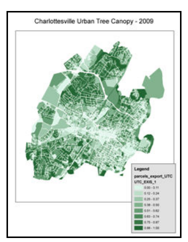
- 81% of survey respondents were supportive of purchasing land for passive park use
- 68% of survey respondents were supportive of protecting environmental areas in the City

- 59% of households indicate a need for natural trails/nature center
- 57% of households indicate a need for natural areas and wildlife habitat

2006 Thomas Jefferson Soil and Water Conservation District Membership
In November 2006, the Virginia Soil and Water Conservation Board approved a petition by the City of Charlottesville requesting inclusion in the Thomas Jefferson Soil and Water Conservation District (TJSWCD). The TJSWCD's mission is: "To exercise leadership in promoting natural resource protection."

2006 US Mayors Climate Protection Agreement Signatory
This agreement sets ambitious goals for improving air quality as part of the City's commitment to addressing global climate change. The City is implementing a Climate Protection Program in order to reduce greenhouse gas emissions from the community. The Mayor's office had an intern compile "Ideas for promoting tree coverage and tree planting programs in Charlottesville" in 2006, information from which was used in developing this plan.

2006 Citizen Committee for Environmental Sustainability
This Committee was charged with supporting City and regional commitment to environmental performance and stewardship, in line with the 1998 Sustainability Accords and the 2003 Environmental Sustainability Policy, and the U.S. Mayor's Climate Protection Agreement." The committee developed actionable recommendations for the City Council to consider.



2006 University of Virginia Urban Tree Canopy Study
Based on calculations made by a University of Virginia environmental planning class using CityGreen software in December 2006, it was determined that Charlottesville's urban tree canopy covered approximately 2,096 acres, or 31.6 percent of the City's total land area (6,656 acres). The canopy was estimated to absorb and filter more than 203,665 lbs. of air pollutants each year while storing up to 90,194 tons of carbon in biomass. According to the results of this analysis, the number of urban trees and extent of urban tree canopy in Charlottesville did not meet state averages or recommended national guidelines. (*See Appendix 8 for full version)*

2007 Tree City USA Designation
In April of 2007, Charlottesville received its designation as a Tree City USA from the National Arbor Day Foundation. This award demonstrates that the City has an urban forest program, spends

at least $2.00 per capita on trees, has an urban forester on staff, and has a tree ordinance. Tree City USA designation is a designation that showcases the City's appreciation and work for healthy trees and forests. The City has more work to do to improve and maintain its forests, and although this designation does not provide financial resources, the partnership with the National Arbor Day Foundation and access to the many resources the group has to offer will help Charlottesville continue to be a Tree City into the future.

2007 Invasive Plant Inventory and Management Plan
Non-native plant species (commonly referred to as 'invasives') are established and have spread throughout the City, both in developed and non-developed areas. Land Planning and Development Associates was hired to identify and map the presence of invasive plants and vines in City parks and school properties. The City is working with volunteers and staff to remove or hinder invasives and continues to monitor and restore affected lands over time to contain or eradicate these species. AmeriCorps volunteers spent six weeks of the spring of 2008 cutting vines out of trees on City lands in the areas identified as the highest priority in the Invasives Management Plan. One example of parkland in the midst of invasives management is Meadowcreek Gardens near Morton Drive. The full invasives report is too long to be included in the appendices to this report, but is available through the Parks Department, and maps are available in GIS format to assist in tracking, containment, and removal efforts over time.

State of the Urban Forest

Charlottesville's urban tree canopy is an important component of the community's green infrastructure. Our trees contribute to the City's beauty and provide a healthful environment for people, animals and birds. Forested areas provide opportunities for enjoying nature and environmental education along with numerous other environmental benefits. Within our urbanized ecosystem, trees play an important role. Amongst many associated benefits, they:

- Create shade and protection from weather and flooding
- Help improve air quality by removing significant amounts of particulate pollution from the atmosphere
- Provide areas for recreation and escape from urban pressures
- Protect water quality by absorbing and filtering stormwater runoff and recharging groundwater
- Conserve land by preventing soil erosion and decreasing the volume of stormwater run-off
- Moderate local climate by mitigating urban heat island effects
- Reduce energy demand from buildings
- Mitigate global climate change by sequestering carbon
- Provide a critical source of food and habitat for wildlife
- Buffer noise, wind, and differing land uses
- Increase real estate values
- Protect biodiversity

Urban forests can be considered in three general forms, large forested stands, smaller fragments of forest, and narrow corridors connecting fragments and stands. Individual or "specimen" trees standing by themselves in open areas are another component of the overall urban canopy. Charlottesville has examples of each type, each of which will have slight differences in uses, values, and management.

There are a number of large, particularly beautiful and/or historic trees within the City. These might be called "Champion", "Heritage", "Remarkable", or other names which imply their importance to residents. Charlottesville already has some trees included on state lists, such as the large white oak at Forest Hills Park. Protection of these special trees is of great concern to our citizens.

Charlottesville's forests have a lot of friends. The general public plays a major role in decision making and physical work involved in protecting and managing the urban forests of Charlottesville. Citizens have long been a voice in support of the forests, helping the City achieve the results it has thus far in protecting and expanding our urban canopy. There is a "Funds for the Forests" public account that people and organizations can donate to in support of City tree planting and urban forest management. Individuals and groups often spend time keeping the forests clear of invasives and litter, and helping to plant new trees. Private businesses are also supportive of the public efforts to retain a healthy forest canopy.

City of Charlottesville
Urban Forest Management Plan

Urban Forest Analysis and Data Collection

2008 Urban Forest Assessment

The Parks and Recreation Department hired Environmental Services, Inc. to identify and analyze all trees on City owned lands including parks, schools, City Hall and other built properties, street medians and other known street tree locations, and cemeteries. The study provided GPS location, number, species, variety, DBH (size), condition, monetary value, and other data on all trees for which the City has maintenance responsibility. For large forested areas, plot samples were taken and extrapolated to determine the general inventory and condition of trees. This data is critical in determining the species and age diversity of the trees, amount of invasive trees, and known maintenance needs for publicly managed trees and forests. The data is in GIS format, providing improved management and maintenance decision making tools regarding the urban forest in a format that has the ability to be updated, maintained and integrated into other City mapping and planning efforts. Future inventories will be helpful in tracking the management needs of the City's trees over time. Improvements to the GIS layer for parcels will enable more precise distinction between public and private street trees. (*See Appendix 2 for full draft)*

Diversity - Species diversity stabilizes the urban forest and helps protect against insect and disease infestations that could decimate large scale monoculture plantings. The diversity chart (Figure 2 in Appendix 2) shows a good level of mixed species throughout the urban forest as a whole (Pie Chart). Our most numerous species is 14% of the total (genus: cornus). Planning for tree plantings should always consider species diversity as a critical component.

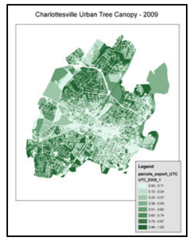
Diameter Distribution (chart) – The diameter distribution chart (Figure 1 in Appendix 2) shows a relatively young urban forest, which is consistent with development and increased tree planting on Parks and School grounds over the past 30- 40 years.

Estimated Appraised Value – The value of the trees in non-forested areas is approximately 34.1 million dollars. This figure is significant and justifies budgeting for maintenance and management to protect this resource.

Condition Rating and Risk/Hazard Assessment - These attributes provide information regarding an individual tree's health and its potential risk to people and nearby infrastructure based on its location and surrounding land use. This information is helpful in prioritizing inspections for maintenance.

Potential Planting Spaces – These locations will serve as a guide for future planting possibilities.

Forested Plot Data – Data shows the overall condition and diversity of the wooded portions of schools and parks is healthy and that the density varies with the age of the stand.



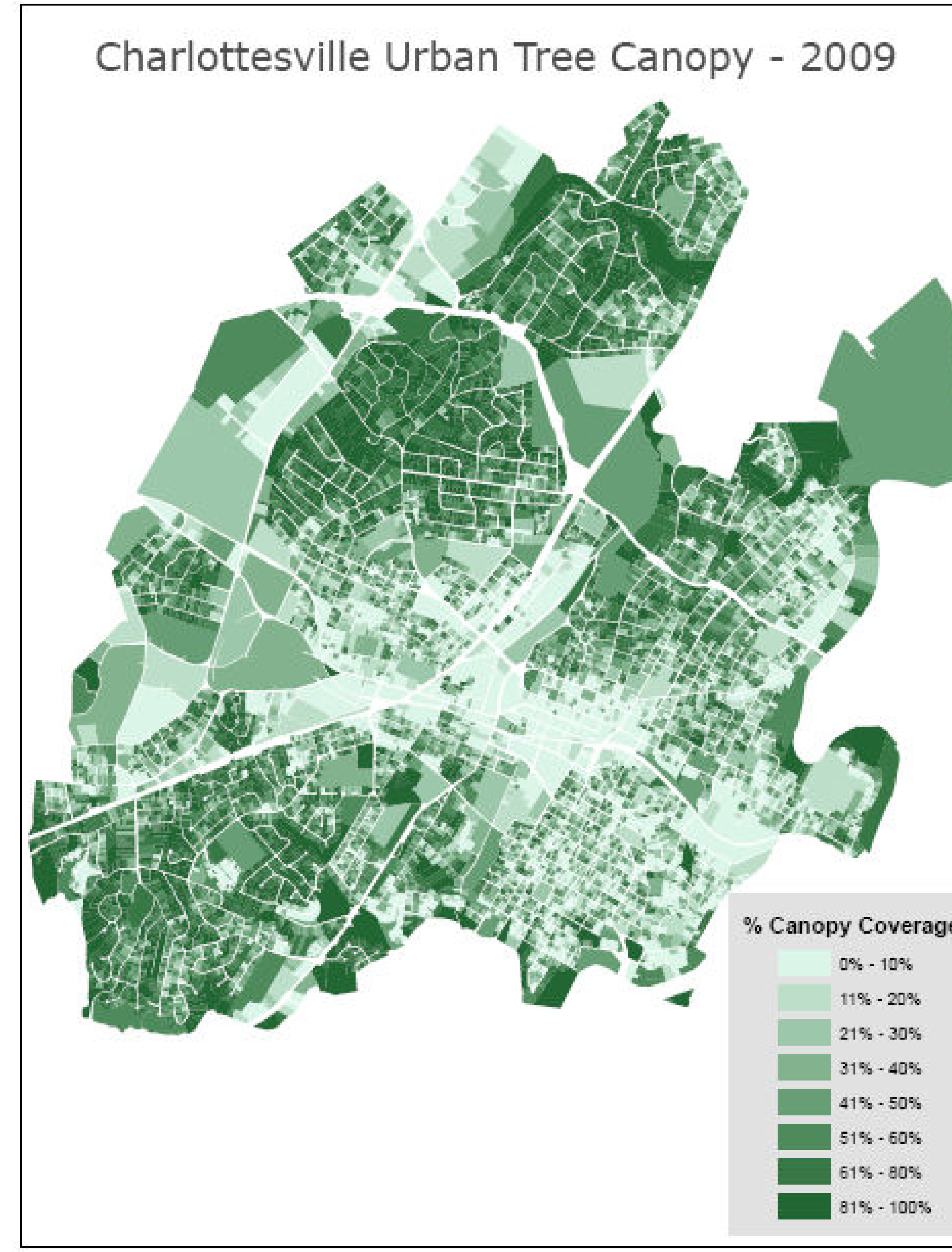
2009 Urban Tree Canopy Assessment

Working in cooperation with the Virginia Department of Forestry and Virginia Tech, the City conducted an analysis of the overall tree canopy for the land within the City limit, whether public or private. Aerial photography was taken with the leaves on the trees and included infrared and multi-spectral images for ease of analysis. GIS was used to analyze the photography and determine how much of the City has canopy coverage. Charlottesville was one of five localities in the Chesapeake Bay watershed to receive this analysis in order to refine the process in preparation of studying much more of the watershed in a similar manner.

Data is in GIS format to facilitate analysis and allow easy integration into other City mapping and planning efforts. Canopy coverage can be mapped by individual parcels, zones, or by land owner and other categories to create various reports and to determine which areas may be lacking in desired canopy coverage.

The data from the analysis shows that the City has an overall canopy coverage of 46.6%. This is higher than the 2007 Comprehensive Plan goal of 40%. The City will also be identifying different target canopy goals for different areas of the City, such as residential and business districts. With these new data in hand, we can see which neighborhoods have higher or lower canopy coverage than the target goal for their land use. Forest management efforts can then focus on expansion areas lower than desired, whereas preservation and/or enhancement might rank higher in areas already above the desired goal. All management methods will be used in all areas of the City at varying level, and these data are very helpful in setting priorities for action.

The City has a copy of the GIS model used to analyze the air photos. This will allow the City to run its own future models with the most current and best data available to track our progress. (*see Appendix 3 for full draft)*



2009 Leaf-on canopy analysis of Charlottesville
Virginia Department of Forestry and Virginia Tech

Urban Forestry Management

In developing this plan, it must be recognized that less than half of the trees and forested land in the City are publicly owned, and therefore under direct public control. The rest of the trees are on private lands. Management techniques, rules, timing, and other factors are different depending on the ownership of the land on which the trees grow.

The Parks and Recreation Department is responsible for the care and maintenance of trees throughout the City on publicly owned property. These locations include parks, school grounds, trails, street rights-of-way, thoroughfares and highway medians, cemeteries, the Downtown Pedestrian Mall and other public properties. The Department's Urban Forester and the City's tree maintenance contractor are professionally certified by the International Society of Arboriculture (ISA) as Certified Arborists.

Our goal is to provide a safe, healthy, sustainable urban forest canopy on public land through the latest industry standards supported by the I.S.A. and by following best management practices (BMPs) for urban forestry, and to provide excellence in customer service regarding tree issues. Procedures for accomplishing this goal are implemented as follows:

- Public Safety: The Parks Division receives direct contact from the public, staff, other City departments and as a result of inspections. Evaluations of individual trees are conducted and an assessment of the tree's health is made by the Urban Forester. Corrective action is initiated by the Urban Forester if safety concerns are discovered. These actions may include hazardous and dead tree removal or pruning of dead and decayed wood that represent a danger to the public. This work is accomplished by a combination of Parks Division maintenance staff and a qualified tree maintenance contractor. Hazard trees are trees that cannot be maintained in a safe condition and have significant potential for failure causing damage and destruction to targets within striking distance. Trees located on the City owned right of way along streets represent the largest portion of possible and probable hazard trees and trees requiring corrective pruning to eliminate hazardous portions including dead branches and storm damage. Charlottesville has over 150 miles of streets and the right of way is not standard throughout the system. Some streets have a very wide right of way and some have very little. The Parks Division often requests the help of engineering staff to determine if a particular tree is on City property; as the Parks Division only maintains trees on public property.

- Tree Planting: Tree removals are recorded and replacements are planted as close to the original location as possible. Limiting factors are underground and overhead utilities, adequate space for tree growth, ability to remove enough of the removed tree's stump to allow for planting, and sight distance and road frontage issues. The ability to provide water to the new plantings is another important factor. There are industry BMPs which address most of these issues and the Parks Division follows these as closely as possible.

- Tree planting in our open space areas, undeveloped park and school ground areas, and along trails on City land is accomplished by a combination of staff and volunteers. Through the

City of Charlottesville
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efforts of the Parks Division, significant numbers of seedling trees are planted each year. Citizens often participate in neighborhood plantings on "adopt a spot" areas of City-owned land where the Parks Division provides the materials and leads the planting process and the neighborhood provides the follow-up maintenance required to ensure survival of the plants mainly through watering and weeding. Occasionally citizens donate funds for tree planting.

- Tree Conservation, Preservation and Protection: The Parks Division is committed to tree canopy and stream buffer conservation and preservation on City owned land which contains predominately wooded and undeveloped areas. The main threats to these areas in terms of loss of tree canopy and stream buffer are invasive plants and soil erosion. The invasives assessment shows the extent of the problem and suggests steps which can be taken to provide preservation and protection of these areas. Tree protection refers to active steps which can be taken to preserve trees from damage in construction areas. Recommendations on protection measures are made according to industry accepted standards. Damage to tree roots through inadequate protection measures accounts for most tree death on construction sites.

- Preventive Tree Maintenance: In the past three (3) years the Parks Division has implemented a preventive tree maintenance program in addition to ongoing corrective work. The ability to perform preventive work provides a healthier and more resilient urban forest through structural pruning, weight reduction, and formative work on young trees. This allows for reduced future costs by reducing damage from high winds and storms and reduction of future safety pruning needs.

- Information to Citizens: As part of the Park Division's commitment to customer service, information sharing and response to citizens requests regarding tree issues are priorities.

The Department of Neighborhood Development Services handles tree related planning for developments and property redevelopments. The Department of Public Works also responds to field reports and staff identification of tree issues in public drainage areas and structures.

Private property owners, including homeowners, businesses, and railroads, are responsible for the maintenance of trees on their lands. Outside of a development activity, private landowners can generally plant, prune, or remove trees at will. Regulating tree management on private property is limited in the Unites States and Virginia, unless that property is undergoing a development or redevelopment large enough to require public reviews or rezoning.

Volunteers and non-profits are also involved in managing the urban forest. Groups including Charlottesville Area Tree Stewards, Master Naturalists, Rivanna Trails Foundation, The Nature Conservancy, Rivanna Conservation Society, Boy Scouts, and others are all involved in various efforts to protect, enhance, and restore the forests, and are of tremendous value in providing education about and interpretation of the wooded areas of the City.

Urban Forestry Management Plan Elements

The elements outlined below represent the strategic areas under which the City can accomplish the goal of comprehensive urban forest and natural resource management. Within each element description on the following pages, issues related to each element will be defined and tactical actions to be undertaken over the next several years to bring this plan to fruition will be recommended.

- Plan Element 1 – Protection and Preservation
- Plan Element 2 – Enhancement and Restoration
- Plan Element 3 – Expansion
- Plan Element 4 – Monitoring and Documentation
- Plan Element 5 – Education and Outreach
- Plan Element 6 – Sustainability, Management, and Maintenance BMPs

This plan creates a system-wide approach necessary to achieve the City's resource stewardship vision over the long term. Some of the plan's strategies can be accomplished with existing fiscal and personnel resources, while others will require additional support. Volunteers and partnerships will play a critical role in carrying out many of the strategies, as will private landowners.

There are some obstacles to the successful implementation of this plan. The City does not currently have adequate parkland protections that ensure conservation in perpetuity. Existing City codes are not strong enough to require significant tree preservation in by-right developments. Frequently, hard infrastructure can win the battle over natural resource preservation, particularly with most power lines in the City being overhead and not underground. Invasive plant species have overtaken many City and private properties, creating a major threat to the tree canopy and overall ecosystem health. Holistic ecosystem approaches to tree planting in redevelopment or new street tree plantings are lacking, resulting in monocultures that are not conducive to long-term tree health.

Rives Park

Element 1 – Urban Forest Protection and Preservation

Protection of existing trees and forested lands is a critical component of a management plan. Ensuring that trees which are already here are protected physically and legally will help sustain the canopy coverage, and prevent further degradation of the urban forest. Trees on public lands are generally well cared for and protected from loss by rule. In Charlottesville, private land owners also generally exhibit a high respect for and stewardship of trees. There is either a perception or a reality, however, that Charlottesville is losing its tree coverage over time to land and infrastructure development. Staff and residents would like to avoid further loss of existing trees where possible.

There is a great commitment among City residents to preserve and protect natural areas. There are numerous methods to accomplish this, including the use of conservation easements, land acquisition, stronger requirements during site plan review and development inspections, fostering an ethos of stewardship on City projects, and further codifying the permanent protection of park lands.

The Parks and Recreation Needs Assessment survey revealed the following:

- 81% of survey respondents were supportive of purchasing land for passive park use
- 68% of survey respondents were supportive of protecting environmental areas in the City

These figures represent a strong commitment statistically and are indicative of the very high value Charlottesville residents place on the protection and preservation of natural areas. There is strong support for enhancement of current policies as well as new policies that would focus on preservation and protection of natural areas and their associated tree canopy.

Acquisition of environmentally sensitive areas through fee-simple acquisition, conservation easements, life estates, and other donation methods may be pursued to ensure the protection of riparian buffers and significant forest stands throughout the City. The City should pursue legal avenues that will allow and encourage these types of transactions to take place to ensure the preservation of its natural areas. This effort will also help the City to address the existing parkland deficiencies outlined in the 2007 Comprehensive Plan.

The City's primary means of park land protection is the Park Protection Overlay within the Zoning Ordinance. This overlay allows for the sale of parkland only by a supermajority of City Council, a minimum of four votes in support of a sale. This provision in the Code may be insufficient to provide permanent protection of public lands and natural resources. Placement of conservation easements over parklands or strengthening the zoning protection of parks may be the next step.

New development and redevelopment of existing properties in the City present opportunities to either lose or expand the urban forest. The development process also includes the potential for the acquisition of environmentally significant properties and/or for their permanent protection through rezoning and the site planning process. The continued redevelopment of land within the City presents a unique opportunity to strengthen existing legal authority to meet community values, and to partner with other jurisdictions in the Commonwealth to lobby the General Assembly for changes to the Code of Virginia that promote preservation.

The City has taken steps to protect trees within the authority of the existing laws of the Commonwealth. Other opportunities beyond current legal authority may exist to strengthen existing codes and ordinances to enhance preservation of the tree canopy. These ordinances apply generally to land development. Investigation of what other jurisdictions in the Commonwealth have been able to achieve must occur to ensure that Charlottesville is among the leaders in preserving its tree canopy.

One of the primary tools for ensuring that land being developed retains or creates desired canopy levels is the site planning process. The City has a Design Manual showing land developers how to meet the intent of the City Code, and includes policies and guides on tree protection and preservation. The City would like to ensure the Design Manual follows the spirit of what we are attempting in urban forestry management efforts. Weaknesses that could result in urban forest degradation need to be tightened up. Some of the areas that should be examined include:

- Add a section detailing street shading trees as larger specimens.
- Require planting strips on all new development.
- Allowing narrower roads if no on-street parking to accomplish above.
- Encourage pervious parking driveways and spaces.
- Require raised curbs to direct stormwater runoff but encourage them to direct runoff be directed into recessed planting strips designed for street shading trees.
- Mandates appropriate width planting strips, denying any other narrower planting strip that would only allow grass or ornamentals.
- Require sidewalk designs (tight radii, widest that maximizes the ROW in order to capture the most public space in perpetuity for greenery.
- Require I.S.A Certified Arborists on site plans.

Current Initiatives

- The City has performed a tree inventory on public properties within the City. GPS data, size, species and condition have been assessed to guide future management actions.
- Chapter 10 of City Code, the Water Protection Ordinance, Article IV, Stream Buffers, established protection of 100-foot riparian buffers along the Rivanna River, Meadow Creek, and Moore's Creek.
- The City is pursing a conservation easement for Greenbrier Park and other City property along Meadow Creek where a major stream restoration project will occur in partnership with The Nature Conservancy with funding from the Virginia Aquatic Resources Trust Fund. In total, this project will bring approximately 60 acres of land, the majority of which is forested, under permanent protection.
- Development of the planned greenway/trail system is leading to acquisition of land and easements along streams and forested areas into public use and management.

This plan element recommends moving forward with tree and urban forest protection on three fronts:

1. Protect existing trees and forest on public lands with improved legal protection of public trees and acquisition of private forested lands into public ownership and management.
2. Protect existing trees on developing private property through site planning & zoning.
3. Protect existing trees on private properties through education and support.

Tactical Actions

1.1 Investigate and establish Conservation Easements or other legal protections on existing and future City-owned lands to preserve lands in perpetuity.

1.2 Incorporate vacant City lots and/or other City lands that are unplanned for development into park system.

1.3 Pursue additional protection for park and school lands that requires either a unanimous City Council vote or public referendum before park or school lands are sold.

1.4 Pursue land acquisition funding to purchase forested lands, especially for greenway development and to address existing riparian buffer gaps.

1.5 Determine private properties that can be placed under conservation easement.

1.6 Coordinate with Charlottesville City Schools to develop a strategy for management of large forest stands on school property.

1.7 Ensure implementation of existing stream buffer requirements (Chapter 10 of City Code, Article IV, Stream Buffers), including the provision that requires the restoration or evolution by natural succession of vegetation within 25 feet of the top of protected stream banks.

1.8 Explore expansion of stream buffer protections for all other streams in the City, beyond Moores Creek, Meadow Creek, and the Rivanna River.

1.9 Establish grading and compaction guidelines that do not alter drainage and natural moisture patterns to preserve healthy trees and incorporate these standards into the Design Manual (e.g. site plan review).

1.10 Create tree protection guidebook for developers and private landowners that summarizes codes, laws, BMPs and goals for projects in the City.

1.11 Investigate the presence of champion, heritage and specimen trees. Identify, label, and preserve them. Work to improve legal protections for these trees.

1.12 Adopt a Tree Protection Ordinance that includes a method to establish penalties if trees are lost.

1.13 Establish a City-wide Stream Management Strategy and Maintenance Standards.

1.14 Conduct a thorough review of the current Code of Virginia, City Code, Chesapeake Bay Protection Ordinances, and the ordinances of other jurisdictions to ensure that the City is doing all it can to protect trees and natural resources.

1.15 Pursue desired state legislative changes through the General Assembly. Involve the Thomas Jefferson Planning District Commission legislative liaison in discussions regarding the General Assembly.

1.16 Establish Construction Performance and Maintenance bonds during redevelopment for tree and landscape work and ensure enforcement of bonding requirements. Utilize City Code to require this is done through ISA Certified Arborists and to ensure the bonding requirements are sufficient to maintain the sustainability of a riparian buffer or tree screen.

1.17 Analyze City by entry corridor, parks and schools, zoning categories, and sub-watersheds to determine existing canopy coverage to compare with target canopy coverage goals.

Element 2 – Urban Forest Enhancement and Restoration

Protection or acquisition of natural areas as parkland or the planting of new trees is not enough to assure urban forest preservation. Natural areas undergo constant change and require active management to retain their functions and values, especially in an urban environment such as Charlottesville where the demands of the built environment and development can place tremendous stresses on natural areas.

Many areas of the City that are forested today were farms and fields as recent as the mid 20th century. The trees and forests we see today are a mix of purposely planted areas and places that naturally vegetated once crops and animals were removed from the land. In that sense, residential development has lead to increased tree coverage within the City limits.

The quality of the urban forest, in terms of species diversity, age, general health, and level of invasives, varies across the City. Some locations with high quality mature hardwood forests include western McIntire Park, areas along Moore’s and Meadow Creeks, and lower Pen Park. Most other forested areas in the City are somewhat degraded, most typically due to invasive species and vines that are preventing the trees from reaching their maximum potential. Improving the quality of existing forests is critical to ensuring they remain healthy stands into the future.

Current Initiatives

- The City has developed an Invasive Species Management Plan, which guides actions related to containing, suppressing, and eradicating invasive plant species.
- The City is collaborating with The Nature Conservancy on the Meadow Creek Stream Restoration Project, which will enhance and restore the riparian buffer along Meadow Creek with native tree plantings.

Tactical Actions

2.1 Implement the recommendations of the Invasive Species Management Plan.

2.2 Ensure adequate planning, staff and budget to manage trees on acquisitions that bring forested lands into public management.

2.3 Work with utilities on planning and design to get the right tree in the right place, use directional boring rather than trenching where possible, and to end tree topping and tunneling or convert to rubber coated wires.

2.4 Enhance and restore healthy forest canopy on vacant City lots and/or other City lands that are unplanned for development.

2.5 Establish a riparian buffer restoration program on private property.

2.6 Encourage forest species diversity to increase resistance to disease and pests, especially in development and redevelopment scenarios.

2.7 Plant native species where possible and use site adaptable trees otherwise.

Element 3 – Expansion

Planting new trees, especially in areas below targeted canopy levels, is the only way to expand the forest in urban areas. New trees can be used to add shade to hot areas, buffer differing land uses, create wind breaks, and to improve the appearance of properties.

Forested areas generally re-generate and change naturally over time. Planting efforts may still be needed in the forests to ensure proper species balance and to fill in areas that have losses due to invasives, floods, or other natural causes.

American Forests recommends the following urban tree canopy coverage for different zones within a community for metropolitan areas east of the Mississippi River:

Average tree cover counting all zones	40%
Suburban residential zones	50%
Urban residential zones	25%
Central business districts	15%

According to the results of the 2009 Urban Tree Canopy Calculation, Charlottesville has an average canopy cover of 46.6%, which exceeds the average recommended coverage, and the City's own goal of 40% coverage. When the City is analyzed by neighborhood, it becomes clear that some areas are above this average, and others are below. In order to bring more areas up to the minimum desired coverage, it will be necessary to expand the forest and tree canopy by planting new trees.

Charlottesville also intends to define forest canopy goals for other districts in the City including entry corridors, parks and schools, industrial zones and watersheds. Further analysis of the tree canopy data will provide current coverage for these districts. The Zoning Code has recommendations for desired coverage, as does the Center for Watershed Protection and the Arbor Day Foundation. Once canopy goals are set, staff can determine which areas are in need of work to achieve their target canopy coverage. For individual trees, heavily used park areas such as playgrounds lacking shade may be a higher priority for planting than the densely forested areas. Street trees may offer more benefits to more people than backyard trees, and might also rank high in need.

In those areas that are below the target canopy coverage levels, there are locations where new trees can be planted. For example, there is a high public desire for more street trees. Detailed information about nearby structures, utility conflicts, sidewalks and other hardscapes, clear zones for automobiles, fire lanes, and many other factors must be gathered in order to ensure the right tree is planted in the right place. Failure to consider the myriad of factors that can affect an urban tree's health and longevity will lead to increased maintenance costs, less healthy and attractive trees, and eventually, loss of the resource. Planting tall trees under power lines, or water-loving trees near sewer pipes will create conflicts. Sound initial planning will ensure that when the tree is planted, it can live long, grow well, and consume fewer of the City's limited resources.

Planting is not the only step in establishing new trees. New plantings must be watered for their first year to ensure survivability, and maintained for years. New trees create the need for more staff work, and this must be accounted for in budgets and schedules, and with the assistance of volunteer groups.

The City has investigated the possibility of establishing a tree nursery to help in forestry expansion and management. Given the large number of nearby private nurseries, it has been determined at this point in time that it is not cost-effective or the best use of staff resources to run a public tree nursery. The possibility of some sort of nursery remains an option if it proves cost effective and necessary in the future.

Current Initiatives

- Staff plant an average of 50 new trees annually in park and school areas.
- Volunteer plantings of seedlings and tube trees in stream buffers.
- Street trees are increasing as the City redevelops and creates new opportunities for planting.

Tactical Actions

3.1 Establish tree canopy goals for entry corridors, parks and schools, appropriate zoning categories, and watersheds.

3.2 Plant trees in appropriate public locations, including those identified in the 2008 Urban Forest Assessment.

3.3 Encourage plantings of new trees on private property through educational efforts and programs. Identify potential planting locations using City GIS and other data.

3.4 Continue tree planting programs in riparian areas for stream corridor management and health.

3.5 Establish City BMPs in line with industry BMPs for arboriculture. Ensure that these standards are required of developers during the site plan review process and construction.

3.6 Expand trail standard to include vegetative plans for areas within and adjacent to trail corridors.

3.7 Co-locate trails and utilities where appropriate to limit creation of multiple cleared corridors in forested areas.

3.8 Work with utilities on identifying good locations for tree planting near utility corridors.

3.9 Plant a tree on public property every Arbor Day as part of annual celebration.

Element 4 – Monitoring Forests and Plan Progress

Trees and forests are living entities and undergo constant change. Keeping up with these living resources requires constant monitoring to ensure management goals are attained. Trees can be added, removed, improved, moved, injured, or changed in other ways, all of which effect how the urban forest functions and their numerous benefits to quality of life.

Tracking the trees that are planted or removed on public properties will ensure the forest assessment and urban canopy calculation stays reasonably up to date, and can help analyze expected changes to overall forest age, diversity, and health. Records of tree work and updated GIS maps can alert staff and the public how forest management efforts are paying off over time, and if adjustments to the rate, direction, or priorities of forest management are still on track with community goals. Noting the presence of disease or pests with early detection can be critical in containing threats to the overall forest. It is vital to monitor both the forest and the plan over time if the goals are to be met in a responsible manner.

Current Initiatives

- The Urban Forest Assessment and Urban Tree Canopy Calculation are snapshot measurements to of the state of the City's forests. This data is comprehensive and can be replicated over time for comparison.
- Inclusion of tree and forest information in the City's GIS will assist in tracking over time and sharing with other City departments and City wide efforts.

Tactical Actions

4.1 Establish a methodology to track and maintain targeted healthy canopy coverage over time.

4.2 Load all relevant data into the City's GIS database for Citywide access.

4.3 Perform an assessment similar to the Forest Assessment every five years.

4.4 Acquire leaf-on aerial or satellite photography and perform an urban tree canopy calculation every five years.

4.5 Compare 5 year data with canopy goals set for various sub areas in the Comprehensive Plan.

4.6 Create and publish a report on the State of the Urban Forest every five years after new data collection and analysis is complete.

4.7 Include latest tree canopy information in City Comprehensive Plan updates.

4.8 Provide greater public access to forested areas to put more "eyes on the woods" to report possible concerns or changes.

4.9 Utilize a Risk Rating Index to rank tree risks.

4.10 Calculate and forecast carbon sequestration levels in the urban tree canopy as part of the climate protection agreement requirements.

4.11 Establish a Tree Commission or Board – consider using existing group, such as Parks and Recreation Advisory Board.

4.12 Track invasive species containment and removal efforts using GIS mapping.

4.13 Maintain GIS layer to include new and remove cut trees to keep inventory up to date.

4.14 Maintain records of utility work events that impact public forests (clearing land around lines).

4.15 Update GIS layers such that parcels, planning neighborhoods, and City boundary all encompass the same amount of land area.

4.16 Include tree and forest components and threat of loss in future build-out studies.

Element 5 – Education & Outreach and Partnerships

A critical element of any natural resource or urban forest management plan is increasing citizen, staff and decision-maker understanding of the value of natural resources, the importance of fiscal support for proper resource management, and the necessity of educating current and future generations about the natural world. Increasing threats to our environment from global climate change, uncontrolled stormwater runoff, air and water pollution, and invasive plant species require that education become a major component of the City's efforts.

City staff has recognized that education is vital. Dedicated educational initiatives on all levels, and partnering with other organizations in the region, will be extremely helpful to the City in creating a sustainable environment.

The development of school curriculum and City program offerings around environmental education and stewardship should be enhanced and increased. Education of City staff on important sustainable best management practices must take place. Further education of City decision-makers about the synergy between many of these issues is critical to ensure that the best and most sustainable decisions are made into the future.

Current educational initiatives among groups offering such programs in the region are not highly coordinated. Numerous entities, including the City, Albemarle County, the Ivy Creek Foundation, Tree Stewards, the Master Gardener and Master Naturalist programs, Native Plant Society, Virginia Department of Forestry, and many others offer natural resource education opportunities. Closer coordination between these groups to enhance partnerships and streamline offerings should occur to provide the holistic level of education truly required.

Current Initiatives

- The City's demonstration rain garden at Greenleaf Park has significantly furthered educational opportunities for area students and has raised awareness of stormwater management best practices.
- The Parks and Recreation Department's volunteer program incorporates environmental education during each volunteer project, and many projects include management of forests and trees.
- The City's Environmental Management System (EMS) program continues to contribute to the education of staff in various City departments about sustainable best practices.

Tactical Actions

5.1 Create, fund, and staff a City Environmental Educator position to coordinate efforts.

5.2 Develop and implement a comprehensive City staff education program. Consider using the City EMS as the tool for implementing this program.

5.3 Develop a public outreach strategy that will advance City staff and policy credibility, educate the public, and create documents for distribution.

5.4 Incorporate environmental interpretation into public education efforts in parks.

5.5 Create a public education campaign to share information on forestry and tree best management practices for public and private properties.

5.6 Develop a strategy to educate City decision makers on urban forestry BMPs.

5.7 Enhance partnership with local advocates, e.g. Tree Stewards, Neighborhood Associations, Master Naturalists & Gardeners, Native Plant Society.

5.8 Work directly with Charlottesville City Schools to enhance school curriculum on natural resources for SOL requirements.

5.9 Pursue programs for the planting of new trees on private property.

5.10 Explore options for establishing a botanical garden and/or arboretum on public lands.

5.11 Pursue funding and land to create an environmental education center.

5.12 Use the Annual Arbor Day celebration as an educational opportunity and to highlight partnerships.

5.13 Complete and utilize the planned and existing greenway system to educate trail users and park visitors about trees.

5.14 Utilize the upcoming Meadow Creek Stream Restoration project as an educational opportunity about forest management.

5.15 Promote the "Funds for the Forest" program as a means to collect donations to help implement the goals of this plan.

5.16 Inform the public about tree plantings on public lands.

Element 6 – Sustainability, Management and Maintenance Methods

As the City has gained experience with various environmental and sustainability initiatives in the past several years, it has become necessary to codify certain practices and integrate sustainable maintenance and best management practices into the daily operations of City departments. This is an important step to ensure that the culture change toward sustainability within the organization reaches all levels of staff.

The major effort that has led the way so far in this regard is the City's Environmental Management System (EMS) initiative. Begun in the Parks and Recreation Department and now being implemented in the Public Works Department and other City departments, this program uses structured objectives and targets to reach sustainability goals on many different fronts. Many of the elements described in this plan represent issues that have been brought to light through the work of staff on EMS.

As these issues and actions needed to address them have been identified, several specific initiatives have been undertaken.

Current Initiatives

- No-Mow Zones in riparian areas of parks have been identified and managed, reducing fuel consumption and air emissions and allowing natural re-vegetation to occur.
- An Invasive Species Assessment was completed in 2007, identifying those areas of public land heavily infested by invasives, and recommending management actions for control.
- Tree planting efforts in riparian areas have increased, with hundreds of tree saplings planted throughout the City.
- Industry BMPs for arboreal care are applied in all preventive and corrective tree work.

These shifts represent a major departure from the City's traditional maintenance methods and place the City in a position to continue to change the paradigm toward sustainability.

Tactical Actions

6.1 Prepare annual implementation plan to define scope of work for urban forest management.

6.2 Continue to manage Invasive Species, using recommendations contained in the Invasive Species Assessment and Management Plan.

6.3 Continue to integrate sustainable maintenance methods through the EMS for tracking and management purposes.

6.4 Adopt industry BMPs as part of the Parks and Recreation Departmental Maintenance Standards and all City landscaping decisions and new City projects.

6.5 Adopt a Wildlife Management Policy to guide staff actions when conflicts occur (e.g. with beaver, deer, Canada geese, rodents).

6.6 Expand No-Mow Zones to other areas of parks and schools, convert appropriate locations to interpretive educational areas such as meadows and rain gardens to advance educational opportunities.

6.7 Share BMPs with private landowners as information to consider in management of their tree and forest resources.

6.8 Encourage local utilities to become Tree Line USA certified through the Arbor Day Foundation.

6.9 Continue to review & update City Vegetative Debris Management Plan (See Appendix 6).

6.10 Update development codes to help ensure adequate forest canopy is preserved or replanted according to performance based standards.

6.11 Continue commitment that the City will pursue only green building practices for the development and redevelopment of all City lands, to include tree preservation tactics.

6.12 Promote urban forest tree species diversity through planting recommended site adaptable trees and encouraging (but not limiting to) use of native tree species.

6.13 Clarify property ownership of paper streets and alleys for future maintenance responsibility and planting opportunities.

6.14 Determine sustainable funding sources for urban forest activities including: Annual Operating Budget, the CIP, development proffers, non-profits, private contributions – "Funds for the Forest", grants, and the use of volunteers

6.15 Implement a stormwater utility to provide a dedicated funding stream to support a Water Resources Protection Program (WRPP) that will include stormwater management.

Implementation

Appendix 10 includes a table listing each of the tactical actions in the plan, a responsible lead department and a general timeline plan for taking action. This table is meant to be a guide for action over the next five (5) years. Many departments, agencies, and individuals may be involved in achieving these goals, and will need to be coordinated by the lead agency in each case.

Many of the recommendations in the plan can be achieved within the next five years, and others will require additional time for varying reasons. It is important to push forward on those goals that can be acted on in the near term. Those items that require major effort can be worked on over time, and as opportunities arise.

Tree maintenance, invasives removal, and new plantings are ongoing efforts that will never be complete due to the nature of trees and forests. Annual work plans for staff and volunteers will help guide these efforts. Actions that are policy oriented may be reasonably low cost in dollar terms, but could take many hours, weeks, or even years of staff time to become reality and general practice.

This plan should be revisited every five years, either as a separate plan or as part of the larger City Comprehensive Plan to compare progress with stated goals and determine if new actions are needed to continue movement towards goals. Park master plans should also be consulted when determining forest management actions specific to each park.

The plan will be most successful when it becomes a normal part of routine operations. Ensuring that the goals and policies of this plan are shared with all City departments, private landowners, and the general public is the best way to keep urban forest management a priority in the long term. These partnerships are also very helpful in implementing individual projects or policy adjustments.

Funding for implementation may come from a variety of sources, including public dollars, developer contributions, private donations, and grants. There is a limit on how many trees can be planted and watered in a given year, so funding may be better secured with relatively small annual amounts that can be sustained well into the future rather than one or two big investments with no identified maintenance budget.

Urban forestry management is a long-term task. The City has major challenges to accomplish to preserve, protect, enhance, and sustain its forests, but with continued dedicated work by staff, leaders, local businesses, and the general public, the goal of a healthy urban forest for Charlottesville can be achieved.

Summary

Charlottesville has always valued its trees and forests, and always will. This plan has been created to chart a future for those trees and forests, and to assist members of the community in realizing the future we envision. This plan, like our forests, should be treated as a living entity, which is in need of a regular check-up, the occasional adjustment, and a healthy environment in which to grow.

The protection of the City's biodiversity and its natural resources through the management of the urban forest allows those forests to perform their natural functions of recharging ground water, protecting streams, reducing heat islands, providing shade and wildlife habitat, and sequestering carbon and other air pollutants. Forests are a integral part of our urban green infrastructure, and this plan ensures they remain a priority.

While there is a lot of work to be done to restore and enhance our forests to their maximum potential, the City of Charlottesville's urban forests are in good overall condition. Efforts to expand the urban forest, especially along streets and in the developed areas of the City, will help ensure the contribution of our urban forest to the community's quality of life.

Starr Hill Park

Acknowledgements

The following individuals and City Departments provided their expertise and knowledge to the development of this plan.

Planning Commission	- Bill Emory - Mike Farruggio - Mike Osteen
Parks & Recreation Department	- Brian Daly, Acting Director - Tim Hughes, Urban Forester - John Mann, Landscape Manager - Chris Gensic, Park and Trails Planner
Department of Public Works	- Kristel Riddervold, Environmental Administrator - Dan Frisbee, Stormwater Program Coordinator - Marty Quinn, P.E., Utilities Engineer
Neighborhood Development Services	- Missy Creasy, Planning Manager - Brian Haluska, Neighborhood Planner - Nick Rogers, Neighborhood Planner - Ebony Walden, Neighborhood Planner
Information Technology	- Mark Simpson, GIS Coordinator
Virginia Department of Forestry	- Barbara White
Virginia Tech (via VDOF)	- James Pugh (GIS Analyst)

Appendix 1

Glossary of Terms

Urban Forest – Trees growing either individually, in small groups or under forest conditions on public and private lands in our cities, towns, and suburbs. *(Chesapeake Bay Program)*

Tree Canopy – the layer of tree leaves, branches, and stems that covers the ground when viewed from above. *(Chesapeake Bay Program)*

Land Cover – Physical features of the earth mapped from satellite imagery such as trees, grass, water, and impervious surfaces *(Chesapeake Bay Program)*

Existing UTC – Amount of urban tree canopy present when viewed from above using satellite or aerial photography.

Possible UTC – amount of land theoretically available for establishment of urban tree canopy. This excludes areas covered by existing tree canopy, roads, buildings, and water

Entrance Corridor – (from Code of City of Charlottesville)
(a) Subject to subsection (b), below, entrance corridor overlay districts are hereby established upon and along the following arterial streets or highways, which are deemed by the City council to be significant routes of tourist access to the City, or to designated historic landmarks, buildings, structures or districts within the City ("EC streets"):

- (1) Route 29 North from the corporate limits to Ivy Road;
- (2) Hydraulic Road from the corporate limits to the 250 Bypass;
- (3) Barracks Road from the corporate limits to Meadowbrook Road;
- (4) Ivy Road from the corporate limits to Emmet Street;
- (5) Fontaine Avenue/Jefferson Park Avenue from the corporate limits to Emmet Street;
- (6) Fifth Street, SW from the corporate limits to the beginning of the Ridge Street Architectural Design Control District;
- (7) Avon Street from the corporate limits to the CSX Railroad tracks;
- (8) Monticello Avenue/Route 20 from the corporate limits to Avon Street;
- (9) Long Street from the corporate limits to St. Clair Avenue;
- (10) East High Street/9th Street from Long Street to East Market Street;
- (11) Preston Avenue from McIntire Road to Rosser Avenue; and
- (12) McIntire Road, from Preston Avenue to Route 250.

Best Management Practice – Industry defined highest quality method of accomplishing a task or providing a service.

Appendix 2
City of Charlottesville:
Urban Forest Assessment

1 March 2009

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Prepared By:
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Environmental Services, LLC. (ESI) was contracted by the City of Charlottesville to conduct an inventory and assessment of the health and condition of trees on selected sites throughout the City. The specific goals of the project were to inventory and assess all trees in developed areas of parks, schoolyards, and other properties; produce a database, GIS layers, and a report on the tree inventory; and present findings to the Parks and Recreation advisory board, Planning Commission and City Council.

After receiving bid approval, ESI met with the City on the 12 June 2008. Areas to be assessed were initially provided to ESI by the City of Charlottesville in their initial Invitation for Bids (IFB) (Addendum A) and were further clarified during the meeting with the City. A memorandum of understanding was prepared by ESI and provided to the City to document the results of the discussion (Addendum B). Further adjustments to the footprint of the areas and parameters to be assessed were made through verbal approval by Tim Hughes during the course of the inventory.

Methodology and Qualifications

All fieldwork was conducted as per the International Society of Arboriculture (ISA) protocol as stated in the workbook from the *Guide for Plant Appraisal, 9th edition* (Council 2000) and *A Photographic Guide to the Assessment of Hazard Trees in Urban Areas* – Tree Hazard Form (Matheny and Clark 1994). Fieldwork was conducted from July 6, 2008 to October 29, 2008 by ISA certified arborists.

Street Trees

Parameters Assessed

For each tree in the street tree inventories, the following parameters were assessed:

- Unique ID
- Genus – Species was included whenever possible
- Diameter at breast height (DBH) – For multi trunk trees, diameter measurements were sampled at the union of all branches
- Root Condition – Assumed to be average, unless other evidence, such as girdling roots or obstructions such as pavement, were evident
- Trunk Condition – Evidence of mechanical or biological damage, as well as form
- Branch Condition – Evidence of mechanical or biological damage, as well as angle and placement of attachment
- Twig Condition – Evidence of dieback, galls or atypical growth such as witches broom
- Foliage Condition – Evidence of biological damage such as wilt, rust, or blight
- Failure Potential – Based on amount of decay, lean, position, and the combination of all other factors previously mentioned
- Size of Hazard – Approximate diameter of the largest part with failure potential
- Target – Potential target should failure of tree or portion of tree fail, including buildings, utilities, roadways, and people (based upon apparent frequency of use
- Placement – Includes aesthetic value and functional placement such as spacing and visibility issues, and other limiting factors such as buildings and overhead/underground utilities
- Comments – Comments include details of hazard/health issues and targets, maintenance recommendations, planting spaces and species recommendations, etc.

Valuation

Trees located within urban settings such as, but not limited to, roadway planting strips, playgrounds, and/or parking lot islands where assessed for both valuation and hazard rating using the above-mentioned workbooks. The valuation was determined by multiplying the condition, location and species ratings against the basic tree cost (BTC). Whereas the hazard rating was determined by adding together the failure potential, failure size and target values for each individual tree.

The Condition rating (CR) was determined by adding the values for the condition of the roots, trunk, branches, twigs and foliage; dividing by the total possible points, and multiplying by 100 to achieve a percentage:

CR = [(Roots+Trunk+Branches+Twigs+Foliage)/32]*100

The Location rating is the average of three sub-ratings: Site, Contribution, and Placement. This helps determine how the tree has been designed into the landscape, how much it contributes, and whether it is "working" to enhance that landscape. In the field we called it placement, and gave it a combined percentage. Whereas the Species rating was taken from either the 2007 ISA Mid-Atlantic tree species rating guide, or by determining the rate based on the hardiness zone, growth behavior, and tree form for the individual tree species. The average rating from the range for each species was used in the assessment.

Multiplying either the trunk basal area (TA) or the adjusted trunk area (ATA) measured at breast height to a unit cost of $75.00 determined the Basic Tree Cost (BTC). The unit cost was established by the ISA Mid-Atlantic Chapter and approved and accepted by the City of Charlottesville. Trees with a diameter of greater then 30 inches used the adjusted trunk area from Table 4.4 found in the Guide for Plant Appraisal, 9th edition. Once the BTC was calculated, it was then multiplied against the Condition, Location and Species ratings each as a percentage to produce the appraised value (AV) for the individual tree:

AV = BTC x Condition rating % x Location rating % x Species rating % = $

Per our meetings with the City of Charlottesville, a minimum replacement tree value of $1,500 was established. This was determined by the cost of purchasing a 2.5 to 3 inch caliper tree from the nursery, preparing the planting site both above and below ground, and guaranteeing/maintaining the tree for two years. Therefore, a minimum tree value of $1,500 was used and all values $5,000 or more were rounded to the nearest $100, while those values less than $5,000 were rounded to the nearest $10 per the Guide.

Hazard Rating

From *A Photographic Guide to the Evaluation of Hazard Trees in Urban Areas* (Matheny and Clark 1994); the Failure potential (FP), Size of defective part (SD), and Target ratings (T) were added together to determine the Hazard rating for an individual tree:

HR = FP + SD + T

Hazard ratings do not define 'danger', but assign the potential risk assessment associated with a tree depending on tree condition and proximity of potential targets and assist management in prioritizing workloads. "…hazard ratings define the seriousness and extent of potential danger to site users. They assign a level of risk to activity in and around individual trees. For trees where a hazard rating is 3, there is less concern about hazard than for trees with ratings of 12. Clearly the greater the hazard rating, the greater the risk associated with the tree" (Matheny and Clark 1994).

As the hazard rating guidelines specifically request that a given score not be assigned a qualifier, such as medium or moderate hazard, we have not provided one. However, within the stipulations provided for in *A Photographic Guide to the Evaluation of Hazard Trees in Urban Areas* we can state that a score of 1 is 'low hazard' and a score of 12 is 'high hazard'.

<u>Condition Rating</u>
The condition rating system utilized is provided by the *Guide for Plant Appraisal, 9th edition* (Council 2000). The condition rating was derived for each tree by summing the individual scores for roots, trunk, branches, twigs and foliage, dividing by the total possible points (32), and multiplying by 100. Where:

100 = No apparent problems
75 = Minor problems
50 = Major problems
25 = Extreme problems

<u>Specimen Trees</u>
Specimen trees were identified as any tree with a DBH greater than 30 inches and a condition rating of greater than 75 points. This formula was approved by Tim Hughes of the City of Charlottesville.

Forested plots

<u>Parameters Assessed</u>
Parameters assessed include all parameters previously stated for street trees, with the exception of placement, as it was not applicable to these areas.

<u>Valuation</u>
The same formulas stated above, with some modifications, were used to determine the value and condition of the tenth acre forested plots. Per the City of Charlottesville, the averages for the plots are to be used, the unit cost for a forest grown tree was $50, and the minimum replacement value was $500.

Such that the basic tree cost (BTC) for the forested plots was calculated by using the average trunk area for the trees measured and multiplying that by the unit cost of $50:

BTC = Average Trunk Area x 50 = $

The averages of all the different tree units measured were used in the formulas to determine the average tree per plot. Such as the average for each of the roots, trunk, branches, twigs, and foliage rates were used to calculate the Condition rating (CR) for the plots:

CR = [(Avg.Roots+Avg.Trunk+Avg.Branches+Avg.Twigs+Avg.Foliage)/32]*100

The Location Rating due to being a forested plot was given a constant value of 90% per the City of Charlottesville, and the Species rating was determined by a weighted average per volume of the tree species measured in each of the plots. Then these average ratings were used to calculate the Average Appraised value (AAV) for each tree:

AAV = BTC x Avg. Condition % x Avg. Location % x Avg. Species rating %

This AAV was then multiplied by the number of trees in each plot to determine the total plot value (TPV) for each site. The total plot values for each site were then summed up and divided by the total number of plots in the site to calculate an Overall Average Appraised value (OAAV) of the tenth acre plots for each of the forested sites:

OAAV = Σ TPV / # plots

This OAAV can be then used to determine the appraised value of the forested areas by multiplying the number of acres by tenth acre then by the OAAV.

Forested area value = OAAV x 10 x number of acres = $

<u>Forest Condition</u>
In the forested areas we were directed not to determine the hazard rating due to the decrease in targets, but to determine the condition of the plots by adding the averages of the Failure potential (FP) and Size of defective part (SD) for each of the plots. Again, this value does not determine the danger that may be associated with an individual tree, but this plot condition will assist management in shaping protocols for the forested areas located within the City of Charlottesville. The scoring system was as follows:

8 = No apparent problems
6 = Minor problems
4 = Major problems
2 = Extreme problems

<u>Summary of Findings</u>
As requested by the City of Charlottesville, findings are reported for number of trees inventoried, diameter distributions, genus distributions, and hazard distributions. Shape files for all trees assessed have been created which outline all relevant parameters for each tree. After additional consultation with the City a PowerPoint presentation will be created to highlight all relevant aspects of the assessment.

Inventory Numbers

A combined total of 61,508 trees were directly and indirectly (derived from plots) inventoried within all areas sampled in the City of Charlottesville. 5,988 trees were directly sampled; 2,577 within parks, 1,068 within schools, 693 within other facilities and 1,650 street trees. A total of 55,520 trees were estimated to be within the forested areas, expanded from the forested inventory. Park specific totals are included in table 1 below. Additionally, 211 potential planting spaces were identified with planting recommendations for size and type of tree based on a spot assessment of limiting factors such as power lines, sidewalks, roadways, etc. Please keep in mind spaces for potential plantings are very subjective, and may not take into consideration indeterminable factors such as underground utilities or infrastructure. Each planting space is indicated by a unique id and point on the shape files.

Trees Assessed in Non-Forested Areas
Direct Sample

Facilities	Number of Trees
Art Center	38
Community Attention	2
Courts	29
Downtown Mall	101
Downtown Pavillion	63
Gordon Library	51
Library	14
Maplewood Cemetery	66
Market Parking	12
Oakwood Cemetery	156
Public Works	108
Ridge Street Fire Station	16
Rothwell	11
Starr Hill	3
Starr Hill expansion	10
West Market	13
Total	**693**

Schools	
Buford School	108
Burnely Moran School	114
Charlottesville High School	361
Clark School	67
Greenbriar School	81
Jackson Via School	88
Johnson School	114
Venable School	62
Walker School	73
Total	**1,068**

Parks	Number of Trees
Azalea Park	28
Belmont Park	111
Craw Garden	13
Fivefille Park	8
Forest Hills Park	60
Greenleaf Park	57
Jackson Park	8
Jordan Park	17
Lee Park	35
McGuffey Park	35
McIntire Golf Course	148
McIntire Park	301
McIntire Skate Park	12
Meade Park	84
Northeast Park	106
Pen Park	1,087
Quarry Park	18
Riverview Park	22
Rives Park	58
Schenk's Greenway	82
Tonsler Park	126
Washington Park	161
Total	**2,577**

Other	
Streets and medians	1,650
Total	**1,650**

Grand Non-Forested Total	**5,988**

Trees Assessed in Forested Areas
Plot Sample

Parks	
Azalea Park	1250
Bailey Park	240
Greenbriar Park	6960
Greenleaf Park	1930
McIntire Park	14720
McIntire Golf Course and Skate Park	2430
Meadowbrook Park	180
Northeast Park	820
Pen Park	18030
Quarry Park	690
Riverview Park	2800
Schenk's Greenway	190
Washington Park	280
Total	**50520**

Schools	
Buford School	460
Charlottesville High School	1330
Greenbriar School	580
Jackson Via School	940
Johnson School	1550
Walker School	140
Total	**5000**

Grand Forested Total	**55,520**

Table 1. – Tree Totals Sampled by Location

Diameter Distributions

Diameter distributions have been created from the in field measurements for all non-forested (non-plot) trees. The diameter distributions represent the diameter class into which the majority of the trees inventoried fall. From this information additional assumptions can be made with regard to age, risk, and other factors. The majority of trees fell within the 2 inch to 20 inch diameter class, indicating a relatively young population.

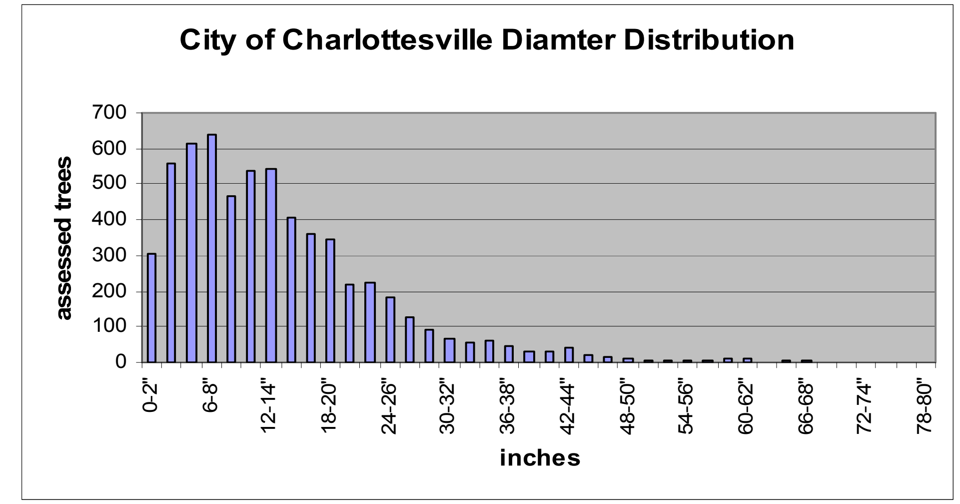


Figure 1 – Diameter Distributions

Genus Distributions

Genus distributions indicate the overall diversity of trees in the areas inventoried. The largest genus group was Cornus (dogwood) at 14%, followed by Quercus (oak) at 13%, and Acer (maple) at 12%. The "other" genus category is a pooling of all genus with a less than 4 % share of the distribution. A list including the name and number of trees in all genus is also included below.

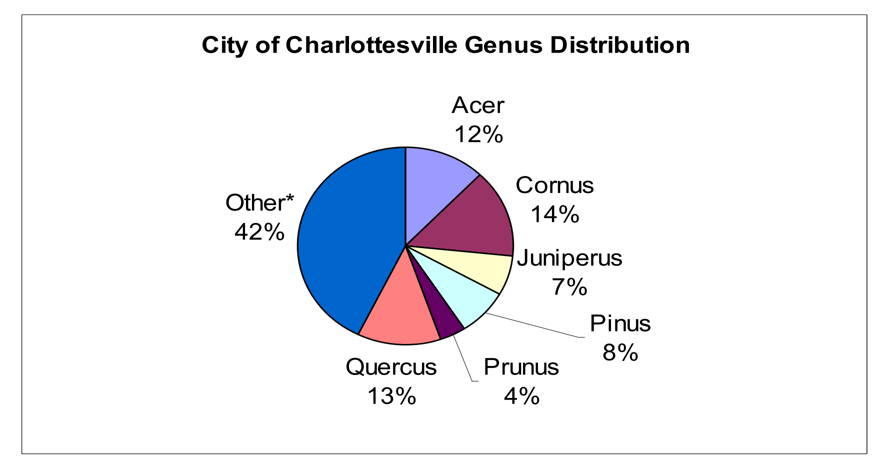


Figure 2 – Genus Distributions

Genus Distribution Table

Genus	Trees	Genus	Trees	Primary Genus	Trees
*Aesculus**	6	*Morus**	33	*Acer*	729
*Ailanthus**	17	*Nyssa**	29	*Cornus*	864
*Albizzia**	12	*Olea**	6	*Juniperus*	399
*Amelanchier**	35	*Ostrya**	3	*Pinus*	461
*Betula**	4	*Phellodendron**	13	*Prunus*	230
*Broussonetia**	3	*Photinia**	1	*Quercus*	754
*Buxus**	3	*Picea**	17		
*Camellia**	1	*Plantanus**	192		
*Carpinus**	60	*Pyrus**	58		
*Carya**	39	*Robinia**	67		
*Castanea**	4	*Salix**	8		
*Catalpa**	22	*Sassafras**	9		
*Cedrus**	3	*Sophora**	12		
*Celtis**	111	*Sorbus**	1		
*Cercidiphlum**	8	*Syringa**	21		
*Cercis**	173	*Taxodium**	8		
*Chamaecyparis**	35	*Taxus**	1		
*Crataegus**	69	*Thuja**	157		
*Cryptomeria**	2	*Tilia**	46		
*Cupressocyparis**	168	*Toxicodendron**	1		
*Diospyros**	12	*Tsuga**	23		
*Fagus**	33	*Ulmus**	23		
*Fraxinus**	113	*Vitex**	4		
*Ginkgo**	136	*Zelkova**	173		
*Gleditsia**	7				
*Gordonia**	1				
*Gymnocladus**	2				
*Halesia**	17				
*Heteromeles**	1				
*Ilex**	106				
*Juglans**	38				
*Koelreuteria**	29				
*Lagerstroemia**	109				
*Ligustrum**	9				
*Liquidambar**	58				
*Liriodendron**	115				
*Maclura**	8				
*Magnolia**	43				
*Malus**	47				
*Metasequia**	1				

Hazard (risk) Distributions

Hazard (risk) distributions have been created from the in field measurements for all trees sampled. This distribution illustrates the proportion of hazard trees within the City. The distribution indicates that the majority of tress fall within the 'average' risk class, with proportionally more weight toward higher hazard trees.

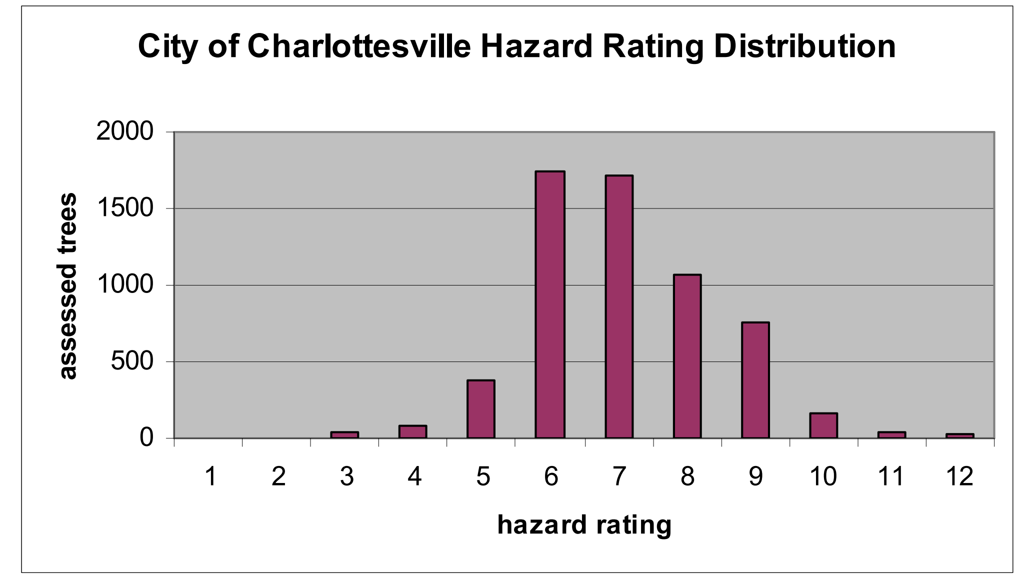
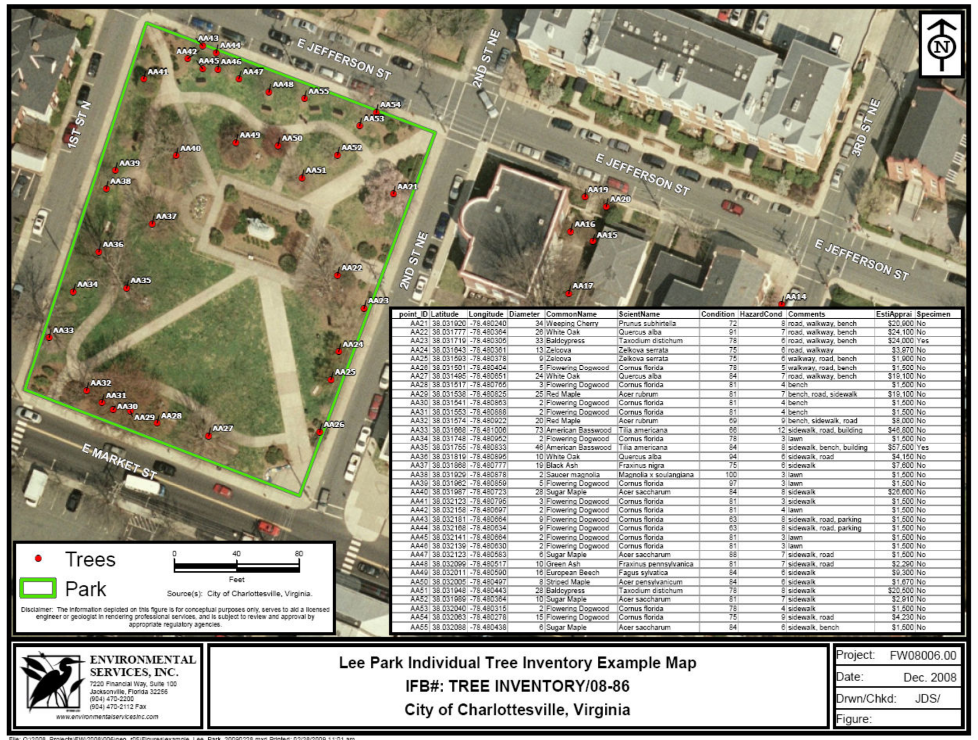


Figure 3 – Hazard Distributions*

* As the hazard rating guidelines specifically request that a given score not be assigned a qualifier, such as medium or moderate hazard, we have not provided one. However, within the stipulations provided for in *A Photographic Guide to the Evaluation of Hazard Trees in Urban Areas* we can state that a score of 1 is 'low hazard' and a score of 12 is 'high hazard'.
* Non-forested areas only.

Shapefiles

Shapefiles have been created which include parameters for each tree or forested plot assessed. For street/park trees the parameters include a unique tree ID, latitude and longitude, species, DBH, condition rating, hazard rating, appraised value, specimen trees, available planting spaces, and general comments. For each forested plot, the parameters include appraised value and a hazard rating. A sample shape file and data table for Mead Park is included below (Figure 4).



point_ID	Latitude	Longitude	Diameter	CommonName	ScientName	Condition	HazardCond	Comments	EstiApprai	Specimen
AA21	38.031920	-78.480240	34	Weeping Cherry	Prunus subhirtella	72	8	road, walkway, bench	$20,900	No
AA22	38.031777	-78.480364	26	White Oak	Quercus alba	91	7	road, walkway, bench	$24,100	No
AA23	38.031719	-78.480305	33	Baldcypress	Taxodium distichum	78	6	road, walkway, bench	$24,000	Yes
AA24	38.031643	-78.480361	13	Zelcova	Zelkova serrata	75	6	road, walkway	$3,970	No
AA25	38.031593	-78.480378	9	Zelcova	Zelkova serrata	75	6	walkway, road, bench	$1,900	No
AA26	38.031501	-78.480404	5	Flowering Dogwood	Cornus florida	78	5	walkway, road, bench	$1,500	No
AA27	38.031495	-78.480651	24	White Oak	Quercus alba	84	7	road, walkway, bench	$19,100	No
AA28	38.031517	-78.480765	3	Flowering Dogwood	Cornus florida	81	4	bench	$1,500	No
AA29	38.031538	-78.480825	25	Red Maple	Acer rubrum	81	7	bench, road, sidewalk	$19,100	No
AA30	38.031541	-78.480863	2	Flowering Dogwood	Cornus florida	81	4	bench	$1,500	No
AA31	38.031553	-78.480888	2	Flowering Dogwood	Cornus florida	81	4	bench	$1,500	No
AA32	38.031574	-78.480922	20	Red Maple	Acer rubrum	69	9	bench, sidewalk, road	$8,000	No
AA33	38.031668	-78.481006	73	American Basswood	Tilia americana	66	12	sidewalk, road, building	$46,800	No
AA34	38.031748	-78.480952	2	Flowering Dogwood	Cornus florida	78	3	lawn	$1,500	No
AA35	38.031755	-78.480833	46	American Basswood	Tilia americana	84	8	sidewalk, bench, building	$57,500	Yes
AA36	38.031819	-78.480895	10	White Oak	Quercus alba	94	6	sidewalk, road	$4,150	No
AA37	38.031868	-78.480777	19	Black Ash	Fraxinus nigra	75	6	sidewalk	$7,600	No
AA38	38.031929	-78.480878	2	Saucer magnolia	Magnolia x soulangiana	100	3	lawn	$1,500	No
AA39	38.031962	-78.480859	5	Flowering Dogwood	Cornus florida	97	3	lawn	$1,500	No
AA40	38.031987	-78.480723	28	Sugar Maple	Acer saccharum	84	8	sidewalk	$26,600	No
AA41	38.032123	-78.480795	3	Flowering Dogwood	Cornus florida	81	3	sidewalk	$1,500	No
AA42	38.032158	-78.480697	2	Flowering Dogwood	Cornus florida	81	4	lawn	$1,500	No
AA43	38.032181	-78.480664	9	Flowering Dogwood	Cornus florida	63	8	sidewalk, road, parking	$1,500	No
AA44	38.032168	-78.480634	9	Flowering Dogwood	Cornus florida	63	8	sidewalk, road, parking	$1,500	No
AA45	38.032141	-78.480664	2	Flowering Dogwood	Cornus florida	81	3	lawn	$1,500	No
AA46	38.032139	-78.480630	2	Flowering Dogwood	Cornus florida	81	3	lawn	$1,500	No
AA47	38.032123	-78.480583	6	Sugar Maple	Acer saccharum	88	7	sidewalk, road	$1,500	No
AA48	38.032099	-78.480517	10	Green Ash	Fraxinus pennsylvanica	81	7	sidewalk, road	$2,290	No
AA49	38.032011	-78.480590	16	European Beech	Fagus sylvatica	84	6	sidewalk	$9,300	No
AA50	38.032005	-78.480497	8	Striped Maple	Acer pensylvanicum	84	6	sidewalk	$1,670	No
AA51	38.031948	-78.480443	28	Baldcypress	Taxodium distichum	78	8	sidewalk	$20,500	No
AA52	38.031989	-78.480364	10	Sugar Maple	Acer saccharum	81	7	sidewalk	$2,910	No
AA53	38.032040	-78.480315	2	Flowering Dogwood	Cornus florida	78	4	sidewalk	$1,500	No
AA54	38.032063	-78.480278	15	Flowering Dogwood	Cornus florida	75	9	sidewalk, road	$4,230	No
AA55	38.032088	-78.480438	6	Sugar Maple	Acer saccharum	84	6	sidewalk, bench	$1,500	No

Figure 4 - Sample shape file and data set for Lee Park

Conclusion

The City of Charlottesville has a unique resource in the aesthetic, environmental and historic value of its trees. Our inventory found that the general condition of the trees was above average for a City of this size. Notably, there are many trees worthy of comment due to their age, size, and history. These traits and additional comments have been noted within the attribute tables for each tree. ESI has enjoyed the opportunity to work with the City of Charlottesville and in particular, the staff of the Parks and Recreation Division. Upon request, we will be glad to provide any clarifications necessary.

REFERENCES

Council of Tree and Landscape Appraisers, Guide for Plant Appraisal, ninth edition, International Society of Arborculture, Savoy, Il, 2000.

Matheny, N. P., and J. R. Clark. 1994. A photographic guide to the evaluation of hazard trees in urban areas. International Society of Arboriculture, Savoy, II, 85 P. (Second Edition)

Appendix 3
Urban Tree Canopy Calculation

The City of Charlottesville applied for assistance from the Virginia Department of Forestry to analyze our urban forestry canopy in 2006. The City was awarded a grant through the Urban and Community Forestry program. The City purchased a handheld GPS and software to help analyze aerial photography in order to take stock of our urban forest. The Department of Forestry then partnered with Virginia Tech to analyze five localities in the state that are within the Chesapeake Bay watershed in order to help determine if the state is close to meeting its goals under the Bay Act and Charlottesville was selected for the project.

Aerial photograph was flown in July 2008 under leaf-on conditions. Data from this photograph is loaded into a model that can assess the overall canopy of the City and project areas where trees might be planted in the future. While the model is not intended to be an exact determination of canopy coverage, it is a reasonably accurate tool to use for general planning purposes.

The model started out with a basemap DOF landcover, classifying what exists on the surface of the earth, whether vegetation, pavement, buildings, or water. The City provided local data layers including the City limit, property parcels, and rights-of-way (streets). The model can subtract buildings or pavement from its measurement of areas that could be planted to expand canopy coverage.

Since the model is an extension of GIS, City staff can replicate it, and use it to analyze the City by sub-zones. For example, staff can define the area that makes up an entry corridor, measure existing canopy and project locations for possible planting. The more detailed our input data is, such as location of utilities, the more accurate the list of possible planting sites will be.

The model is only as accurate as the data loaded into it, and there are some City data sets that are not completely accurate and may need to be adjusted to improve the model's value. These data inaccuracies should be corrected for this model and for future planning purposes.

Model Definitions
UTC existing=
UTC possible
UTC veg
UTC – imperv..

Appendix 4

2007 Comprehensive Plan
Goals and Objectives and Action Items
Urban Forest Management

<u>**Chapter 6 – Transportation**</u>

Modal Goals and Objectives – Goal I - Increase safer accommodations for pedestrians, bicyclists and citizens with disabilities while within existing roadway network.

Objective C: Evaluate how street trees, sidewalk width and buffers between motor vehicles and sidewalks can enhance pedestrian travel, especially in development corridors.

<u>**Chapter 8 – Environment**</u>

Climate Protection – Goal I - Strategically continue, expand, and implement environmentally sustainable initiatives and measures that contribute to climate protection and support key actions outlined in the US Mayor's Climate Protection Agreement.

Objective I: Maintain healthy urban forests; promote tree planting to increase shading and to absorb CO2 (addressed extensively in a subsequent section of this chapter).

Water Quality, Stormwater, and Watershed – Goal I - Promote, protect and restore riparian (streamside) and stream ecosystems to protect habitat and water quality for people and animals.

Objective B: Promote and participate in existing programs to accept conservation or open-space easements of forested stream-side lands to ensure permanent protection.

Objective E: Restore degraded stream buffers through voluntary planting programs and the removal of pollution sources and invasive plants.

Objective H: Examine the feasibility of adding vegetated buffer requirements of varying widths to Schenk's Branch, Lodge Creek, Pollock's Branch, St. Charles Creek and Rock Creek and their tributaries under the City's Water Protection Ordinance. (See Potential Streams Buffers Map, Fall 2006)

Urban Forest – Goal I - Establish and maintain a 40 percent minimum urban tree canopy level in Charlottesville.

Objective A: Plan, develop, and implement an Urban Forest Management Plan, which will serve as the City's comprehensive, long-range strategy for protecting, managing and expanding Charlottesville's urban tree canopy on public lands including streets, parks, schools and other City-owned properties as well as private lands.

Objective B: Create a mechanism for evaluating how increasing tree canopy will meet the U.S. Mayor's Climate Protection Agreement.

Objective C: Building on the 2006 street tree inventory, conduct inventories to document the characteristics and location of the City's street trees and urban tree canopy to inform the tree planting, adoption, and maintenance program across City neighborhoods.

Objective D: Develop a City-owned tree nursery for saplings that will be planted throughout Charlottesville in partnership with City residents to provide an ongoing source for new tree planting.

Objective E: Expand the City of Charlottesville's tree planting list provided to developers to include a larger variety of tree options to ensure a diversity of species with an emphasis on native species.

Objective F: Share information with community members about tree protection, proper maintenance and replanting opportunities and programs through brochures, workshops and City newsletters.

Objective G: Maximize opportunities for restoring existing trees lost to development and improving the diversity of trees on development sites by requesting that larger, native Virginia trees are selected.

Objective H: Consider offering incentives, such as reduced setbacks or increased building densities in exchange for further tree preservation, maintenance, and/or expansion of trees on sites.

Objective I: Educate developers and contractors about the importance of implementing protective measures for trees and tree roots prior to the construction process and strictly enforce these measures during construction.

Objective J: Develop and implement management strategies over the next five years that acts upon the recommendations of the invasive species assessment and management plan developed for the Department of Parks and Recreation in 2006.

Implementation - Key Actions

Key actions are those recommendations that should be undertaken within the next five years. This work program should be updated each year as the plan is reviewed.

Comp Plan Chapter	Key Action	Parties Responsible	Estimated Cost	Timeframe
Transportation	16. Provide design features on existing roadways to improve the safety and comfort level of all users by enhancing the pedestrian and bicycle facility network, using the Safe Routes to School program in the vicinity of schools and consistently applying ADA standards to facility design. An example would be establishing planting strips between the sidewalk and the road.	Neighborhood Development Services, Parks and Recreation Department, Public Works	N/A	Undetermined
Transportation	17. Complete the sidewalk network using a priority system of: dual-side safe	Neighborhood Development Services,	N/A	Undetermined

Comp Plan Chapter	Key Action	Parties Responsible	Estimated Cost	Timeframe
	routes to all City schools; dual-side routes along all arterial and collector routes; dual-side routes to parks and public facilities; completing routes that have less than ¼ mile sections missing; mitigating rain runoff and drainage problems and citizen agreements to implement shade tree planting and maintenance programs	Parks and Recreation Department, Public Works		
Environmental Sustainability	2. Promote and participate in existing programs to accept conservation easements or open-space easements of forested stream-side lands to ensure permanent protection	Public Works Parks and Recreation Department	N/A	Ongoing
Environmental Sustainability	5. Restore degraded stream buffers through voluntary planting programs and the removal of invasive species	Public Works	N/A	Ongoing
Environmental Sustainability	8. Examine the feasibility of adding vegetated buffer requirements to Schenks Branch and tributaries, Lodge Creek, Pollocks Branch, St. Charles Creek, and Rock Creek under the City's Water Protection Ordinance	Neighborhood Development Services	N/A	FY 2008
Environmental Sustainability	24. Plan, develop, and implement an Urban Forest Management Plan to serve as the City's comprehensive strategy for protecting, managing, and expanding Charlottesville's urban tree canopy on public and private lands	Parks and Recreation, Neighborhood Development Services, City Council	N/A	FY 2010
Environmental Sustainability	25. Create a mechanism for evaluating how increasing tree canopy will meet the U.S. Mayor's Climate Protection	Parks and Recreation Department, Neighborhood	N/A	FY 2009

Comp Plan Chapter	Key Action	Parties Responsible	Estimated Cost	Timeframe
	Agreement	Development Services, City Council, City Manager's Office		
Environmental Sustainability	26. Building on the 2006 street tree inventory, conduct additional inventories to document the characteristics and location of the City's street trees and urban tree canopy to inform the tree planting, adoption, and maintenance program across City neighborhoods	City Council, City Manager's Office, Parks and Recreation Department	N/A	FY 2009
Environmental Sustainability	27. Consider developing a City-owned tree nursery for saplings that will be planted throughout the City, in partnership with City residents	City Council, City Manager's Office, Parks and Recreation	N/A	FY 2010
Environmental Sustainability	28. Expand the City of Charlottesville's tree planting list provided to developers to include a larger variety of tree options to ensure a diversity of species with an emphasis on native species	Neighborhood Development Services	N/A	Spring 2007
Environmental Sustainability	29. Share information with community members about tree protection, proper maintenance and replanting opportunities and programs through brochures, workshops and City newsletters.	Neighborhood Development Services	N/A	Spring 2007
Environmental Sustainability	30. Maximize opportunities for restoring existing trees lost to development and improving the diversity of trees on development sites by requesting that larger, native Virginia trees are selected	Parks & Recreation	N/A	Ongoing
Environmental Sustainability	31. Consider offering developers incentives in	Neighborhood Development	N/A	FY 2008

Comp Plan Chapter	Key Action	Parties Responsible	Estimated Cost	Timeframe
	exchange for further tree preservation, maintenance, and/or expansion of trees on sites	Services		
Environmental Sustainability	32. Educate developers and contractors about the importance of implementing protective measures for trees and tree roots prior to the construction process and strictly enforce these measures	Neighborhood Development Services	N/A	FY 2008
Environmental Sustainability	33. Develop and implement management strategies over the next five years that acts upon the recommendations of the invasive species assessment and management plan developed for the Department of Parks and Recreation in 2006	Parks & Recreation	N/A	FY 2013

Appendix 5
Charlottesville Code of Ordinances - Trees
Code of Ordinances, Charlottesville Virginia, codified through Sept. 19, 2006

Sec. 34-868. Trees, generally.

(a) All trees to be planted shall be selected from the City's list of approved plantings, or a substitution approved by the director, and shall meet the specifications of the American Association of Nurserymen.
(b) The planting of trees shall be done in accordance with either the standardized landscape specifications jointly adopted by the Virginia Nurserymen's Association, the Virginia Society of Landscape Designers and the Virginia Chapter of the American Society of Landscape Architects, or the road and bridge specifications of the Virginia Department of Transportation.
(c) Planting islands shall contain a minimum of fifty (50) square feet per tree, with a minimum dimension of five (5) feet, in order to protect landscaping and allow for proper growth. Wheel stops, curbing or other barriers shall be provided to prevent damage to landscaping by vehicles. Where necessary, trees shall be welled or otherwise protected against grade changes.
(d) Only trees having a mature height of less than twenty (20) feet may be installed under overhead utility lines.
(9-15-03(3))

Sec. 34-869. Tree cover requirements.

(a) The provisions of the City's tree canopy ordinance adopted June 25, 1990, are hereby continued in effect and incorporated in this zoning ordinance, as follows:
(1) All developments, public or private, requiring submission and approval of a site plan shall include provisions for the preservation and planting of trees on the site to the extent that, at ten (10) years from planting, minimum tree canopies or covers will be provided as follows:
TABLE INSET:

Zoning Districts	Percentage of Site Cover
R-3, B-1, B-2, B-3, IC	10 percent
R-2	15 percent
R-1, R-1A	20 percent

The area to be occupied by the building footprint(s) and driveway access area(s) proposed for a development site shall be subtracted from the gross site area before calculating required tree coverage only when the site is located within that portion of the City described in section 34-971 (parking exempt area). This exclusion from gross site area calculations shall be allowed whether or not the proposed development will add more than ten (10) percent floor area to an existing building or is found to be newconstruction in the context of the off-street parking requirements.

(2) Existing trees infested with disease or insects or structurally damaged to the extent that they pose a hazard to persons or property, or to the health of other trees on site, shall not be included to meet the tree cover requirements.
(3) The requirements of this section may be waived, in whole or in part, by the director of neighborhood development services or the planning commission in the following circumstances: to allow for the reasonable development of areas devoid of woody materials, dedicated school sites, playing fields and other non-wooded recreation areas, and other facilities and uses of a similar nature; to allow for the preservation of wetlands; or when strict application of the requirements would result in unnecessary or unreasonable hardship to the developer.
(b) Within all zoning districts other than those specifically referenced within paragraph (a), above, tree cover shall be provided to the extent that, at twenty (20) years, minimum tree canopies or covers will be provided (relative to the gross area of the development site) as follows:
(1) Ten (10) percent canopy for a development site zoned for business, commercial or industrial use;
(2) Ten (10) percent for a development zoned for residential use at a density of twenty (20) or more units per acre;
(3) Fifteen (15) percent for a development zoned for residential use at a density of more than ten (10) but less than twenty (20) units per acre; and
(4) Twenty (20) percent for a development zoned for residential use at a density of ten (10) units per acre or less.
(5) The area to be occupied by the building footprint(s) and driveway access area(s) proposed for a development site shall be subtracted from the gross site area before calculating required tree coverage only when the site is located within that portion of the City described in section 34-971 (parking exempt area), or within one (1) of the following mixed-use zoning districts: Downtown (D); West Main North (WM-N), and West Main South (WM-S). The following areas may be deducted, at the option of the developer, from the gross area of the site: required recreation areas; required open space areas; land dedicated to public use; playing fields and recreation areas attendant to schools, day care, and similar uses; areas required for the preservation of wetlands, floodplain or other areas required to be maintained in a natural state by this chapter or other applicable law; and other areas approved by the director as part of a variation or waiver of the landscape plan requirements.
(6) For any mixed-use development: whether such development falls within the category of a site zoned for residential, commercial or industrial use shall be determined by the principal (predominant) use.
(c) Where existing trees are preserved on the development site, a bonus shall be granted as follows ("tree canopy bonus"): in calculating the coverage provided by trees shown on the approved landscape plan, an existing tree included on the developer's conservation checklist shall be deemed to cover an area equal to one and one-half (1.5) times the diameter of the tree's existing dripline. In order to qualify for this bonus, an existing tree must have a caliper of at least eight (8) inches.
(d) Streetscape trees required by section 34-870 may be counted toward tree cover requirements.
(e) Within the City's list of approved plantings, the director shall designate any tree species that cannot be planted to meet minimum tree canopy requirements due to tendencies of such species to: (i) negatively impact native plant communities; (ii) cause damage to nearby structures and infrastructure; or (iii) which possess inherent physiological traits that cause such trees to structurally fail.

(9-15-03(3))

Sec. 34-870. Streetscape trees.

(a) Streetscape trees shall be planted along all existing or proposed public streets; however, the following areas are exempt from the requirement of streetscape trees:
(1) Areas subject to a zero (0) building setback requirement, or
(2) Areas where the maximum permitted building setback is fewer than ten (10) feet.
(b) Streetscape trees shall be large canopy trees; however, upon a determination by the director that site conditions warrant smaller trees, the director may approve the substitution of a medium canopy tree.
(c) Streetscape trees shall be planted with even spacing in a row, at intervals sufficient to allow for their healthy growth and development.
(1) One (1) large tree shall be required for every forty (40) feet of road frontage, or portion thereof, if twenty-five (25) feet or more; or,
(2) Where permitted, one (1) medium tree shall be required for every twenty-five (25) feet of road frontage, or portion thereof, if twenty (20) feet or more.
(3) Where required along the edge of a parking lot (as set forth within section 34-873, one (1) large tree shall be required for every fifteen (15) feet of street frontage.
(4) There shall be a minimum distance of thirty (30) feet between a large and medium tree planted adjacent to one another. Flowering understory trees shall be planted in groups; there shall be a minimum distance of fifty (50) feet between such groups.
(d) Streetscape trees shall be planted outside existing or proposed rights-of-way, but within fifteen (15) feet of the edge of such rights-of-way; however:
(1) Streetscape trees shall be planted within five (5) feet of the edge of the right-of-way within an entrance corridor overlay district, and
(2) For certain parking lots adjacent to public rights of way (see section 34-873), streetscape trees shall be planted within ten (10) feet of the edge of the right-of-way.
(e) In the case of a development subject to the Virginia Property Owners' Association Act, required streetscape trees shall be designated as part of the common area to be maintained by a property owner's association. Otherwise, maintenance of the required streetscape trees shall be the responsibility of the owner of the lot on which such trees are located.

Sec. 34-871. Screening--Generally.

(a) For the purposes of this section, the terms "screening" and "screen" shall be deemed synonymous with "buffering" and "buffer."
(b) When required by this chapter, screening shall consist of a planting strip, existing vegetation, a slightly opaque wall or fence, or combination thereof, to the reasonable satisfaction of the director. The following types and categories of screening shall apply throughout this chapter:
Screen 1 ("S-1"). The S-1 buffer/screen requires an open landscaping scheme, and is generally to be utilized between relatively similar land uses. Plantings allowed by the S-1 designation consist of the following (an applicant has the option of selecting the combination of plantings from among options "A", "B" and "C" within this screen-type):

TABLE INSET:

Screen 1 (Expressed as a number of plant units per square foot of area to be covered)			
Type of Plant	A	B	C
Large Canopy Trees	1/1000 SF	1/1000 SF	1/1,000 SF
Medium Canopy Trees	1/1000 SF	1/1000 SF	1/1,000 SF
Understory Trees	n/a	1/1000 SF	n/a
Evergreen Trees	n/a	n/a	1/350 SF
Shrubs	1/100 SF	1/100 SF	1/200 SF

Screen 2 ("S-2"). The S-2 buffer/screen requires a semi-opaque landscaping scheme, which should partially block views between adjacent properties. This type of screening is generally to be utilized between dissimilar land uses, and the plantings allowed by the S-2 designation consist of the following (an applicant has the option of selecting the combination of plantings from among options "A", "B" and "C" within a designated screen-type):

TABLE INSET:

Screen 2 (Expressed as a number of plant units per square foot of area to be covered)			
Type of Plant	A	B	C
Large Canopy Trees	1/1000 SF	1/750 SF	1/1000 SF
Medium Canopy Trees	1/1000 SF	1/1000 SF	1/1,000 SF
Understory Trees	n/a	1/500 SF	n/a
Evergreen Trees	1/500 SF	1/500 SF	1/175 SF
Shrubs	1/100 SF	1/100 SF	1/200 SF

Screen 3 ("S-3"). The S-3 buffer/screen requires an opaque landscaping scheme, one that blocks views between two adjacent properties. This type of screening is for use between dissimilar land uses, where the maximum amount of visual shielding is desired. The plantings allowed by the S-3 designation consist of the following (an applicant has the option of selecting the combination of plantings from among options "A", "B" and "C" within a designated screen-type):

TABLE INSET:

Screen 3 (Expressed as a number of plant units per square foot of area to be covered)			
Type of Plant	A	B	C
Large Canopy Trees	1/1000 SF	1/1000 SF	1/1,000 SF

Medium Canopy Trees	1/1000 SF	1/1000 SF	1/1,000 SF
Understory Trees	1/500 SF	1/250 SF	1/500 SF
Evergreen Trees	1/500 SF	1/500 SF	1/175 SF
Shrubs	1/100 SF	1/100 SF	1/200 SF

With the approval of the director, an opaque wall or fence may be utilized for, or as part of, a required S-3 screen. Where allowed, such wall or fence (including any gate(s) forming a portion of such structure) shall be at least six (6) feet tall, or an alternate height deemed necessary by the director to protect required sight distances along a public right-of-way.
(9-15-03(3))

Appendix 6

Parks and Recreation Department Vegetative Debris Management Plan

Adopted December 2007

Debris handling options are listed in priority order in each debris category.
NOTE: Emergency (weather) situations supersede all of the handling options.

A. <u>Woody Debris (for mulch)</u>
All woody material resulting from maintenance projects should be field chipped wherever possible:

1. Distribute mulch on site if possible in natural areas.
a. Direct chipper chute to fan out mulch on banks, un-mowed fields, woods or reclamation sites.
b. Spread mulch out to depth not to exceed 4 inches.

2. Wood chip mulch may be piled in designated location at Pen Park Shop for use:
a. Suitable for landscape mulch
b. Suitable for trail mulch
c. Incorporated into planting areas as soil amendment.
d. Used to improve topsoil pile at Oakwood Cemetery
e. Distributed in natural areas for "sheet composting".
f. Schedule Mulch distribution give-a ways for public.

3. Wood mulch unsuitable for landscape use ("*stringy*", "*twiggy*"),
a. Full truck load is to be taken to Panorama Farms for composting. (*Operations Manager has the entry card required for admittance to Panorama dump site*).
b. Distribute mulch in an appropriate natural area for sheet composting.
c. Partial load may be piled at Pen Park Shop with materials unsuitable for chipping to be transferred to Panorama Farms for composting.

B. <u>Woody Debris (logs)</u>
Stockpiling of logs at Pen Park Shop is to be avoided:

1. Woody materials over 6 inches in diameter or tree debris that is not chip-able:
a. To be cut into 16" log lengths at removal site and placed in designated "wood only" pile at Pen Park Shop. City Employees may remove or cut firewood for personal use after work hours at their own risk from this pile.
b. Wood cut to size on site may be given to, and removed by City residents who request it, at the discretion of Tree Crew Supervisor.
c. Wood not suitable for firewood or excessive quantities of wood are to be placed in "Wood Only" pile to be shredded by contracted tub grinder every other year or as needed by Urban Forester.

C. <u>Woody Debris -Contracted Tree Services</u>

1. Tree Contractor is to be directed and contract administered by Urban Forester as to how woody debris is to be handled:

a. Contractor is to remove and dispose all wood debris from removal site.
b. Contractor is to cut logs into 16" lengths and place them in "wood only" pile at Pen Park Shop.
c. Contactor is to dump only suitable wood chip mulch in designated wood mulch pile at Pen Park Shop on an "as needed" basis only.

D. <u>Herbaceous/ Woody (non-tree) Vegetative Debris</u>

1. Weeds, plant materials or brush unsuitable for chipping are to be piled in designated pile at Pen Park Shop area, separately from woody materials.
a. The pile must be kept pushed together and is to be collected with the claw truck when sufficient quantity allows collection and delivery to Panorama Farms.
b. Lumber, treated lumber, metal, concrete, garbage and trash are not to be in vegetative debris piles.
c. Large quantities of "cut back" materials may be left on site for claw truck pick-up.
d. Invasive plant materials are to be placed in pile at Pen Park Shop.

2. Leaves and grass clippings (mowed sites)
a. Are mower ground up on site for natural decomposition.
b. Small quantities may be placed adjacent to community garden sites.
c. Additional collected leaves are placed in designated herbaceous debris pile for transport to Panorama Farms.

3. Leaves collected from Downtown Mall
a. Are placed in designated herbaceous debris pile.
b. Garbage and trash are not to be in vegetative debris piles and must be removed.

E. <u>Management of Vegetative Debris Piles</u>

1. **Treated lumber, metal, concrete, garbage and trash** are not to be in vegetative debris piles (place in designated locations in shop yard).
2. Use of claw truck from Public Works, **pile management**, and bills from Panorama farms or landfill to be directed by the Operations Manager or designee.
3. **Firebreaks** must surround piles to allow clear passage of a vehicle.
4. Double ground and shredded wood mulch should be **piled no higher than 5-6 feet**.
5. **No burying** of vegetative debris is permitted (exclusive of wood chip mulch incorporation for soil amendment).
6. Vegetative piles are to be **inspected monthly** using inspection form by the Operations Manager or designee, corrective actions made, completed inspection forms to be filed in EMS fenceline representative's office.
7. **Records of loads** of chipped material used in maintenance or materials taken to Panorama farms must be reported by supervisors to EMS Fenceline representative for recycling records.
8. **Excessive storm damage debris** may need a permit for temporary site storage through DEQ, application and management of permit is directed by Environmental Management Office.
9. **Repeated violations** of pile management procedures may result in disciplinary actions for those involved.
10. **Emergency notification** in the event of piles catching fire must be reported to Fire Department, P&R Assistant Director, and Operations Manager.

Appendix 7
Summary of Staff Strengths, Weaknesses, Opportunities, and Threats (SWOT) Analysis

Executive Summary – (Where we are today-snapshot in time)

Strengths

- (10) Recognition of the UFMP as a community value and objective aligned with the City Council Vision Statements / Community Interest, Support, Passion, Availability of Volunteers, City Leadership/City Council is also interested.
- (7) Quantity of Tree Canopy (initially estimated at 31%-requires confirmation)
- (4) Skilled and professional staff w/ multi disciplinary experience
- (1) Diversity and quality of trees, in terms of age, size and species
- (1) Space is still available for additional trees on public and private land
- Consistent maintenance by the same department (Parks & Recreation) on parks and schools

Weaknesses

- (10) City codes for tree protection and preservation are simplistic and basic / Lack of enforcement of existing codes and buffer ordinances / Existing codes are not strong enough to ensure tree preservation in new development, by-right zoning does not help / Permanent Conservation of lands is not in place
- (5) Hard infrastructure frequently "wins the battle" over natural resources / Existing right-of-way and streets are not always suitable for tree planting / overhead utility lines require maintenance and destruction of trees / competition with underground utilities with tree roots / A holistic approach to street trees and right of ways is not taken, rather a spot-by-spot approach in isolation
- No true tree inventory for public land and rights-of-way

Opportunities

None identified from SWOT for the Executive Summary

Threats

- (6) Invasive Plant Species
- "Green" initiatives get cut in tough budget times
- Global warming / climate change

Inventory of Tools Cross-Check

- Council 2025 Vision Statements
- GIS / Green City Software / 2006 Tree Canopy baseline
- Park & Recreation Needs Assessment / Strategic Plan
- Water Protection Ordinance
- Professional Standards / Industry Best Management Practices
- EMS

- Mayor's Climate Protection agreement
- City Sustainability Policy
- Professional Standards / Industry Best Management Practices
- Support from the community and elected officials
- Credible and knowledgeable staff
- Other existing UFM Plans in other communities

Element: Water Quality & Air Quality

Strengths

None

Weaknesses

- (2) No stream management plan in place or maintenance standards for streams – no recognition that longitudinal stream movement is natural and healthy. Who is responsible for stream management and maintenance?

Opportunities

- (7) Link the Plan to air and water quality

Threats

- (7) New development / policy conflicts in new development: not all development is consistent with stated goals and visions
- Uncontrolled stormwater runoff
- Global warming / climate change

Inventory of Tools Cross-Check

- Stream Corridor Assessment
- Water Protection Ordinance

Potential Tactics

Energy Conservation

- Buffer restoration program on private properties where there are gaps in the buffer-possibly funded through the stormwater utility down the road.
- Calculating and forecasting carbon sequestration in the canopy as part of the climate protection agreement requirements.
- Establish a City-wide Stream Management Strategy and Maintenance Standards – tie back to water quality standards
- Establish or reforest vacant City lots or other City lands that are unplanned

Things in the pipeline

- Proposal to expand the stream buffer protections-going to the Planning Commission in September for all other streams in the City beyond Moore's, Meadow Creeks and the Rivanna River
- Stormwater Utility proposal in September, 2007

Benefits of this Element that can be included in the narrative portion of the element
Wildlife habitat
Erosion and flooding control
Protection of biodiversity
Recharge ground water
Manage reduce and treat storm water
Reduce greenhouse gases,
Reduce heat islands, provide shade, reductions in energy usage

Element: Private Land (as an opportunity)

Strengths
- New development in City offers opportunities

Weaknesses
- (10) City codes for tree protection and preservation are simplistic and basic / Lack of enforcement of existing codes and buffer ordinances / Existing codes are not strong enough to ensure tree preservation in new development, by-right zoning does not help / Permanent Conservation of lands is not in place
- Lack of trees on private land

Opportunities
- (7) New development & re-development is a trigger for additional trees
- (3) Land acquisition

Threats
None

Inventory of Tools Cross-Check
- Developers willing partner

Potential Tactics
- Quantify value of trees monetarily through appraisals by Certified Arborists like Arlington and Fairfax have done. There are penalties equivalent to the value of the tree when developers screw up.
- Protect existing trees and encourage plantings of new trees on private property through educational efforts and programs like Neighborwoods.
- Establish a heritage, specimen or champion tree program through inventory and clear definition of what heritage, specimen or a champion tree means.

Staff Responsible
Parks, NDS, Legal, Private landowners, developer representation

Element: Legal and Ordinances

Strengths
- Some existing codes and ordinances exist
- New development in City offers opportunities

Weaknesses
- (10) City codes for tree protection and preservation are simplistic and basic / Lack of enforcement of existing codes and buffer ordinances / Existing codes are not strong enough to ensure tree preservation in new development, by-right zoning does not help / Permanent Conservation of lands is not in place
- (2) No mechanism to assign a monetary or environmental value to trees that are lost.
- Many new landscape "designs" are monocultures of all the same tree species
- Dillon Rule/ Commonwealth laws

Opportunities
- (3) Land acquisition
- (3) Get clarity of property ownership / easements / alleys / Inconsistency of maintenance on utility easements
- Create a tree commission

Threats
- (8) No permanent land protection measures exist
- (7) New development / policy conflicts in new development: not all development is consistent with stated goals and visions

Inventory of Tools Cross-Check
- Zoning Code
- Water Protection Ordinance

Potential Tactics
- City-wide Green Building Policy for all new City buildings – this is in the works currently
- Review of Existing codes and ordinances
- Review applicability and enact Chesapeake Bay Protection Ordinances and Regulations that expand the City's ability to protect trees
- Construction Performance and Maintenance bonds for tree and landscape work and enforcement of those bonding requirements; specify or change City code to determine how this is done through Certified Arborists; and to ensure the bonding requirements ensure the sustainability of a buffer or screen, etc.
- Research legislative authority that already exists and what other Va. Jurisdictions are doing

- Proffers – for all public improvement needs and into a "Tree Fund" that could be used for maintenance.
- Our own internal standards must be equal or stronger and better that what the City requires others to do.
- Include the Planning District Commission legislative liaison in this discussion so that these desires are communicated to the General Assembly, coordinate with other jurisdictions in the Commonwealth.

Element: Preservation and Protection Policies

Strengths
- (5) Invasive Species Assessment is completed / Funding in CIP in place / EMS / Staff has become proactive with arboreal maintenance / Needs Assessment and Strategic Plan in place / The Urban Forest Management Plan is in the City's 2007 Comprehensive Plan
- New development in City offers opportunities
- Some land acquisition through easements has taken place

Weaknesses
- (10) City codes for tree protection and preservation are simplistic and basic / Lack of enforcement of existing codes and buffer ordinances / Existing codes are not strong enough to ensure tree preservation in new development, by-right zoning does not help / Permanent Conservation of lands is not in place
- (2) No mechanism to assign a monetary or environmental value to trees that are lost.
- There are numerous City-owned parcels that are not classified as Parks or for other uses – Maintenance responsibility for these parcels is cloudy
- Lack of innovation on our own City projects, without an ethos of stewardship
- Staff resources are stretched on the maintenance end / We plant a lot of trees but do not have the resources to keep them all alive / Massive invasive species problems, without the resources to tackle it.

Opportunities
- (7) New development & re-development is a trigger for additional trees
- (3) Land acquisition
- Create a tree commission

Threats
- (8) No permanent land protection measures exist
- (7) New development / policy conflicts in new development: not all development is consistent with stated goals and visions
- (6) Invasive Plant Species
- Uncontrolled stormwater runoff
- School and Housing Authority land could be sold, loss of trees
- "Green" initiatives get cut in tough budget times

- Disease and insects

Inventory of Tools Cross-Check
- Zoning Code
- Invasive Species Assessment
- Stream Corridor Assessment
  Water Protection Ordinance
- Professional Standards / Industry Best Management Practices

Potential Tactics
- Establish Permanent Conservation Easements on City-owned lands to permanently preserve lands in perpetuity
- Separate Preservation or Conservation policies through protection when construction is on-going – grading policies, compaction, and alteration of drainage and natural moisture patterns. Health of the forest and active management plans are critical to develop within this element
- Protection Policies are reflected through disease control, invasive control, etc.
- Focus on
- Balance between Hard and Soft Infrastructure
- Arboriculture standards for Charlottesville, using industry BMP's (e.g. critical root zones for certain species)
- Look for champion trees, preserve them
- Establish a date by which the City will reach the stated 40% tree canopy goal.
- Establish quickly those properties that can be placed under conservation easement within the next 12 months.

Element: Education & Outreach / Collaborations

Strengths
- Some well organized neighborhood associations

Weaknesses
- (3) City Staff are not perceived as credible or knowledgeable by City Council, BAR and even some in City Administration
- Minimal recognition on the part of the community that trees are renewable resources, not permanent fixtures
- Interdepartmental communication at a Policy level is weak
- Internal education of staff is required to effectively enforce codes – staff must be properly equipped
- The BAR is not educated on Best Management Practices for Forestry / There is tremendous community passion on this issue, but the community is not always knowledgeable about BMP's
- There is not a balance between maintenance responsibilities and public "passion"
- Many new landscape "designs" are monocultures of all the same tree species

- Lack of innovation on our own City projects, without an ethos of stewardship

Opportunities

- (8) Engage Energetic community partners

Albemarle Tree Stewards	Master Gardeners
Master Naturalists	Friends of Parks & Recreation
Sustainability Committee	Department of Forestry
Native Plant Society	Rivanna Conservation Society
The Nature Conservancy	Rivanna Trails Foundation
UVa.	Etc.

- (3) Get clarity of property ownership / easements / alleys / Inconsistency of maintenance on utility easements
- Enhance school curriculums and City program offerings

Threats

- (2) The BAR is perceived as not fully educated on forest management, and not focused on best management practices
- Charlottesville is defined by its history and can't seem to look forward

Inventory of Tools Cross-Check

- Stream Corridor Assessment
- Department of Forestry assistance
- Staff Resources and Volunteer energy
- Ability to make connections between public bodies
- Support from the community and elected officials
- Grant Funding
- Staff to implement the plan
- Developers willing partner
- Cooperative partners in Albemarle County and UVa.

Potential Tactics

- Staff education
- Marketing strategy to 1-advance credibility, 2-educate, 3-documents for distribution
- Interpretation
- Public education of BMP's particularly on private property for routine and other tree care/maintenance
- Educate leaders of BMP's – Council, PC, BAR
- Website promotion
- Tree Stewards/Partnerships/Neighborhood Associations
- 5 year report on state of the Urban Forest
- Staff requirements for interpretation, environmental education,
- Enhance school curriculum
- Neighborwoods or similar planting programs

- Virtual tour of specimen trees of cool things in the City right now on our website or

Element: Sustainability, Management and Maintenance Methods

Strengths

- (5) Invasive Species Assessment is completed / Funding in CIP in place / EMS / Staff has become proactive with arboreal maintenance / Needs Assessment and Strategic Plan in place / The Urban Forest Management Plan is in the City's 2007 Comprehensive Plan
- (4) Skilled and professional staff w/ multi disciplinary experience
- Consistent maintenance by the same department (Parks & Recreation) on parks and schools

Weaknesses

- (5) Hard infrastructure "wins the battle" over natural resources / Existing right-of-way and streets are not always suitable for tree planting / overhead utility lines require maintenance and destruction of trees / competition with underground utilities with tree roots / A holistic approach to street trees and right of ways is not taken, rather a spot-by-spot approach in isolation
- (2) No stream management plan in place or maintenance standards for streams – no recognition that longitudinal stream movement is natural and healthy. Who is responsible for stream management and maintenance?
- There is not a balance between maintenance responsibilities and public "passion"
- Many new landscape "designs" are monocultures of all the same tree species
- Lack of innovation on our own City projects, without an ethos of stewardship
- Staff resources are stretched on the maintenance end / We plant a lot of trees but do not have the resources to keep them all alive / Massive invasive species problems, without the resources to tackle it.

Opportunities

- None

Threats

- (6) Invasive Plant Species
- Uncontrolled stormwater runoff
- "Green" initiatives get cut in tough budget times
- Disease and insects
- Underground utility maintenance and replacement

Inventory of Tools Cross-Check

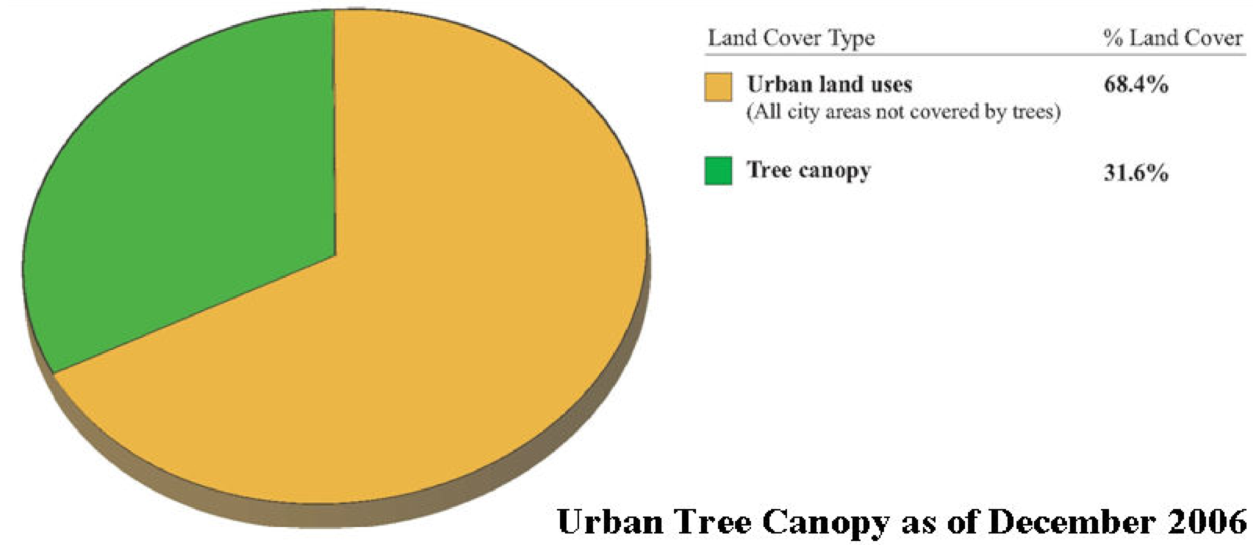
- Invasive Species Assessment
- Professional Standards / Industry Best Management Practices
- Staff to implement the plan

Potential Tactics

Invasive Species Management
Street Tree Assessment
Tree Canopy Assessment/Analysis what does 40% actually mean
Roll into EMS
Review of other plans and BMP's
Planting in Riparian areas
No-Mow Zones
School Grounds – opportunities
Track Progress annually
Variety in tree species
Establish a tree nursery
Adopt Industry BMP's as part of our Departmental Maintenance Standards and all City landscaping decisions or City-owned developments and new City projects

Appendix 8
UVa Canopy study 2007

Figure 1



Urban Tree Canopy as of December 2006

Appendix 9
Forestry Resources and Other Plans

Numerous other urban forest and natural resource management plans exist in communities across the nation. These plans take several forms dependent upon each community's values, environment and existing resources. The plans listed below are a representative sample of the type of plan that Charlottesville has strived to create for its community.

Urban Forestry Resources

Virginia Department of Forestry
http://www.dof.virginia.gov

USDA Forest Service
http://www.fs.fed.us

Chesapeake Bay Local Assistance Division

Virginia Extension Office

Virginia Urban Forest Council
http://www.treesvirginia.org

Arbor Day Foundation
http://www.arborday.org

American Forests
http://www.americanforests.com

National Association of Homebuilders
http://www.nahb.org

Virginia Native Plant Society

VA DCR?

Tree Stewards
Trained volunteers whose mission is to support rural and urban forests, to increase public awareness of he value and beauty of trees, to educate the public about trees and tree care, and to partner with local government agencies and civic groups to improve and restore the area's tree canopy.

City of Charlottesville
Urban Forest Management Plan

Other Urban Forestry Plans

Arlington County, Virginia – Urban Forest Master Plan
http://www.arlingtonva.us/departments/ParksRecreation/scripts/planning/ParksRecreationScriptsPlanningComprehensivePlanning.aspx

Town of Leesburg, Virginia – Urban Forestry Management Plan
http://www.leesburgva.org/Services/planning/doc/UFMPL_06-02-28.pdf

City of Kirkland, Washington – Natural Resource Management Plan
http://www.ci.kirkland.wa.us/__shared/assets/Nat_Rsrc_Mgt_Plan_II352.pdf

Park and Recreation Commission for the Parish of East Baton Rouge, Louisiana - Cultural, Historical and Natural Resource Management Plan
http://www.brec.org/assets/docs/iyp_chapter09.pdf

Fairfax County Park Authority, Fairfax, Virginia – Natural Resource Management Plan
http://www.fairfaxcounty.gov/parks/GMP/nrmpfinal1-14-04.pdf

City of Baltimore, Maryland – Report on Tree Canopy – Prepared by the Maryland Department of Natural Resources
http://parksandpeople.org/publications/special_reports/Baltimore%20UTC%20report%20FINAL.pdf

National Park Service – Natural Resource Challenge
http://www.nature.nps.gov/challenge/challengedoc/NatRes2.pdf

Appendix 10
Implementation Tables

1. Preservation and Protection

Number	Tactic	Lead Department	Time Frame
1.1	Investigate and establish Conservation Easements or other protections on existing and future City-owned lands to preserve lands in perpetuity.	Parks, Attorney's Office, City Manager	medium
1.2	Incorporate vacant City lots and/or other City lands that are unplanned for development into park system	Parks, Attorney's Office, City Manager	medium
1.3	Pursue additional protection for park and school lands that requires either a unanimous City Council vote or public referendum before park or school lands are sold.	Parks, NDS, Attorney's Office	medium
1.4	Pursue land acquisition funding to purchase forested lands, especially for greenway development and to address existing riparian buffer gaps.	Parks	ongoing
1.5	Determine private properties that can be placed under conservation easement.	Parks, Attorney's Office, Environmental	long
1.6	Coordinate with Charlottesville schools to develop a strategy for management of large forest stands on school property.	Parks, schools	medium
1.7	Establish 50 foot vegetated riparian buffers (25 on each side) for creeks in protection	Landowners	ongoing
1.8	Explore expansion of stream buffer protections for all other streams in the City, beyond Moore's Creek, Meadow Creek, and the Rivanna River.	NDS	medium
1.9	Establish grading and compaction guidelines that do not alter drainage and natural moisture patterns to preserve healthy trees.	NDS, Parks	ongoing
1.10	Create tree protection guidebook for developers and private landowners that summarizes codes, laws, BMPs and goals for projects in the City	Parks, NDS	short
1.11	Investigate the presence of champion, heritage and specimen trees. Identify, label, and preserve them. Work to improve legal protections for these trees.	Parks	short
1.12	Adopt a Tree Protection Ordinance that includes a method to establish penalties if trees are lost	NDS, Parks	long

1.13	Establish a City-wide Stream Management Strategy and Maintenance Standards	Parks, Public Works	medium
1.14	Conduct a thorough review of the current Code of Virginia, City Code, Chesapeake Bay Protection Ordinances, and the ordinances of other jurisdictions to ensure that the City is doing all it can to protect trees and natural resources.	NDS, Parks, Attorney's Office, Public Works	long
1.15	Pursue desired state legislative changes through the General Assembly. Involve the Thomas Jefferson Planning District Commission legislative liaison in discussions regarding the General Assembly.	Attorney's Office	ongoing
1.16	Establish Construction Performance and Maintenance bonds during redevelopment for tree and landscape work and ensure enforcement of bonding requirements. Utilize City Code to require this to be done through ISA Certified Arborists and to ensure the bonding requirements are sufficient to maintain the sustainability of a riparian buffer or tree screen.	NDS	medium
1.17	Analyze City by entry corridor, parks and schools, zoning categories and sub-watersheds to determine existing canopy coverage to compare with target canopy coverage goals.	IT, Public Works, Parks, NDS	short

2. Enhancement and Restoration

Number	Tactic	Lead Department	Time Frame
2.1	Implement the recommendations of the Invasives Species Management Plan	Parks	ongoing
2.2	Ensure adequate planning, staff and budget to manage trees on acquisitions that bring forested lands into public management.	Parks	ongoing
2.3	Work with utilities to end tree topping & tunneling, or convert to rubber coated wires	Attorney's Office, Parks, City Manager	long
2.4	Enhance and restore healthy forest canopy on vacant City lots and/or other City lands that are unplanned for development	Parks	medium
2.5	Establish a riparian buffer restoration program on private property	Parks, PW, NDS	medium
2.6	Encourage forest species diversity to increase resistance to disease and pests, especially in development and redevelopment scenarios	Parks	ongoing
2.7	Plant native species where possible and use site adaptable trees otherwise	Parks, NDS, PW	ongoing

3. Expansion

Number	Tactic	Lead Department	Time Frame
3.1	Establish tree canopy goals for entry corridors, parks and schools, appropriate zoning categories, and watersheds.	NDS, Parks, PW	short
3.2	Plant trees in appropriate public locations, including those identified in the 2008 Urban Forest Assessment	Parks	short
3.3	Encourage plantings of new trees on private property through educational efforts and programs. Identify potential planting locations using City GIS and other data	Parks, PW, NDS	medium
3.4	Continue tree planting programs in riparian areas for stream corridor management and health	Parks	ongoing
3.5	Establish City BMPs in line with industry BMPs for silviculture. Ensure that these standards are required of developers during the site plan review process and construction	Parks, NDS	medium
3.6	Expand trail standard to include vegetative plans for areas within and adjacent to trail corridors	Parks, NDS, PW	ongoing
3.7	Collocate trails and utilities where appropriate to limit creation of multiple corridors in forested areas	Parks, PW, NDS	ongoing
3.8	Work with utilities on identifying good locations for tree planting near utility corridors	Parks, NDS, PW	ongoing
3.9	Plant a tree on public property every Arbor Day as part of annual celebration	Parks	ongoing

4. Monitoring

Number	Tactic	Lead Department	Time Frame
4.1	Establish a methodology to track and maintain targeted healthy canopy coverage over time	Parks	short
4.2	Load all relevant data into the City's GIS database for Citywide access	IT, Parks	short
4.3	Perform an assessment similar to the Forest Assessment every five years	Parks	5 years
4.4	Acquire leaf-on aerial or satellite photo and perform an urban tree canopy calculation every five years	Parks	5 years
4.5	Compare 5 year data with canopy goals set for various sub areas in the Comprehensive Plan	Parks, NDS, Public Works	5 years
4.6	Create and publish a report on the State of the Urban Forest every five years after new data collection and analysis is complete	Parks	5 years
4.7	Include latest urban tree canopy information in comprehensive plan updates	Parks, NDS	5 years
4.8	Provide greater trail access into public forested areas	Parks	medium
4.9	Utilize a Risk Rating Index to rank tree risks	Parks	ongoing
4.1	Calculate and forecast carbon sequestration levels in the urban tree canopy as part of the climate protection agreement requirements	Parks, PW	short
4.11	Establish a Tree Commission or Board – consider using existing group, such as Parks and Recreation Advisory Board	Parks, NDS, Manager	short
4.12	Track invasives species removal using GIS mapping	Parks, IT	ongoing
4.13	Maintain GIS layer to include new and remove cut trees to keep inventory up to date	Parks, IT	ongoing
4.14	Maintain records of utility work events that impact public forests (clearing land around lines)	Parks	ongoing
4.15	Update GIS layers such that parcels, planning neighborhoods, and City boundary all encompass the same amount of land area	Parks, IT, NDS	ongoing
4.16	Include tree and forest components and threat of loss in future build-out studies	NDS, TJPDC	medium

5. Education and Outreach

Number	Tactic	Lead Department	Time Frame
5.1	Create, fund, and staff a City Environmental Educator position to coordinate efforts	Parks, Public Works	short
5.2	Develop and implement a comprehensive City staff education program. Consider using the City EMS as the tool for implementing this program.	Parks, Public Works	medium
5.3	Develop a public outreach strategy that will advance City staff and policy credibility, educate the public, and create documents for distribution		medium
5.4	Incorporate environmental interpretation into public education efforts in parks	Parks, Public Works	medium
5.5	Create a public education campaign to share information on forestry and tree best management practices for public and private properties	Parks, NDS	medium
5.6	Develop a strategy to educate City decision makers on urban forestry BMPs		medium
5.7	Enhance partnership with local advocates, e.g. Tree Stewards, Neighborhood Associations, Master Naturalists & Gardeners, Native Plant Society	Parks, Public Works, NDS	medium
5.8	Work with Charlottesville City Schools to enhance school curriculum on natural resources for SOL requirements	Parks, Schools	medium
5.9	Pursue programs for the planting of new trees on private property		ongoing
5.10	Explore options for establishing a botanical garden and/or arboretum on public lands	Parks	medium
5.11	Puruse funding and land to create an environmental education center (possibly shared with the botanical/arboretum)	Parks, Public Works, NDS	medium
5.12	Use the Annual Arbor Day celebration as an educational opportunity and to highlight partnerships	Parks	annual
5.13	Complete and utilize the planned and existing greenway system to educate trail users and park visitors about trees	Parks, NDS	medium

5.14	Utilize the upcoming Meadow Creek Stream Restoration project as an educational opportunity about forest management	Parks, NDS, Public Works	short
5.15	Promote the "Funds for the Forest" program as a means of collecting donations to implement the goals of this plan	Parks, NDS, Public Works	short
5.16	Inform the public about tree plantings on public lands	Parks	ongoing

6. Sustainability and Management

Number	Tactic	Lead Department	Time Frame
6.1	Prepare annual implementation plan to define scope of work for urban forest management	Parks	annual
6.2	Continue to manage Invasive Species, using recommendations contained in the Invasive Species Assessment and Management Plan	Parks	ongoing
6.3	Continue to integrate sustainable maintenance methods through the EMS for tracking and management purposes	Parks, PW	ongoing
6.4	Adopt industry BMPs as part of the Parks and Recreation Departmental Maintenance Standards and all City landscaping decisions and new City projects	PW, NDS	medium
6.5	Adopt a Wildlife Management Policy to guide staff actions when conflicts occur (e.g. with beaver, deer, Canada geese, rodents, etc.)	Parks	short
6.6	Expand No-Mow Zones to other areas of parks and schools, convert appropriate locations to interpretive educational areas such as meadows and rain gardens to advance educational opportunities	Parks	ongoing
6.7	Share BMPs with private landowners as information to consider in management of their tree and forest resources.	Parks	medium
6.8	Encourage local utilities to become Tree Line USA certified through the Arbor Day Foundation	Parks	medium
6.9	Continue to review & update City Vegetative Debris Management Plan (See Appendix 6)	Parks, PW	ongoing
6.10	Update development codes to help ensure adequate forest canopy is preserved or replanted according to performance based standards	NDS	medium
6.11	Continue commitment that the City will only pursue green building practices for the development and redevelopment of all City lands, to include tree preservation tactics	NDS, Parks, PW, Manager	ongoing
6.12	Promote urban forest tree species diversity through planting recommended site adaptable trees and encouraging use of native tree species	Parks, NDS	ongoing
6.13	Clarify property ownership of paper streets and alleys. Inconsistency of maintenance on utility easements; potential for new tree planting in alleys that are truly private property	NDS, IT, PW, Parks	medium

6.14	Determine sustainable funding sources for urban forest activities including: Annual Operating Budget, CIP budget, development proffers, non-profits, private contributions – "Funds for the Forest", grants, and use of free volunteers	Parks	ongoing
6.15	Implement a stormwater utility to provide a dedicated funding stream to support a Water Resources Protection Program (WRPP) that will include stormwater management improvements	PW	short

C - Federal Urban Forestry Program Information

What is i-Tree?

i-Tree is a state-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban forestry analysis and benefits assessment tools. The i-Tree Tools help communities of all sizes to strengthen their urban forest management and advocacy efforts by quantifying the structure of community trees and the environmental services that trees provide.

Since the initial release of the i-Tree Tools in August 2006, numerous communities, non-profit organizations, consultants, volunteers and students have used i-Tree to report on individual trees, parcels, neighborhoods, cities, and even entire states. By understanding the local, tangible ecosystem services that trees provide, i-Tree users can link urban forest management activities with environmental quality and community livability. Whether your interest is a single tree or an entire forest, i-Tree provides baseline data that you can use to demonstrate value and set priorities for more effective decision-making.

i-Tree Tools are in the public domain and are freely accessible. We invite you to explore this site to learn more about how i-Tree can make a difference in your community.

i-Tree Manuals & Workbooks

Resources

Manuals & Workbooks

Video Learning

Archives

Reports

Project Profile

Academic

Presentations

Workshops

i-Tree User Manuals

Why i-Tree?

i-Tree Software Suite v5.0

- i-Tree Eco V5.0
- i-Tree Streets V5.0
- i-Tree Vue V5.0

i-Tree Software Suite v4.0

- i-Tree Eco
- i-Tree Streets
- i-Tree Hydro
- i-Tree Species
- i-Tree Storm
- i-Tree Vue

i-Tree System Requirements (Hardware, Software & Data Collection Devices) & Basic Installation Document for i-Tree v5.x

- i-Tree v5.x system requirements and basic installation document

i-Tree Pest Detection

- i-Tree Pest Detection Protocol Manual 1.47MB
- i-Tree Pest Detection Field Guide 38.7MB
- i-Tree Pest Detection Field Guide - Printer Friendly Version 2.81MB
- i-Tree Pest Detection Field Data Entry Tip Sheet 229KB
- Pest Detection Tatum Guide

i-Tree Workbooks

Creating Random Plots for Eco using ArcGIS

Whether you choose purely random or pre-stratified random sample plots, we have a couple options to guide you in defining your i-Tree Eco project area.

ArcGIS v10.x with the Spatial Analyst extension

(These are generic instructions using most versions of ArcGIS. However, the basic concepts should apply to other GIS packages as well.)

- Random Plot Workbook - No Stratification
- Random Plot Workbook - Pre Stratification

ArcGIS v9.3

(These instructions are specific to ArcGIS 9.3 using the VBA tools contained within the now unsupported itree.mxd ArcGIS project file.)

1. Download the Random Plot Workbook which is applicable to your i-Tree Eco project.
    - Random Plot Workbook - No Stratification (ArcGISv9.3)
    - Random Plot Workbook - Pre Stratification (ArcGISv9.3)
2. Download and extract the iTree.mxd ArcMap project file from the archive below. The ArcMap file is common for both random plot applications and is to be used with one of the above workbooks and ArcGIS v9.3 only.
    - iTree.mxd ArcGIS Project File

ArcView 3.x

(The following is an unsupported UFORE/i-Tree Eco sample plot generator for ArcView 3.x See the README.doc after downloading and installing).

- ArcView 3.x Plot Generator

Random Street Segment Workbook for i-Tree Streets & i-Tree Storm

The following workbook can be used to generate random street segments for an i-Tree Streets sample project or an i-Tree Storm project. The procedures outlined within the workbook should be compatible with most versions of ArcGIS. In some cases, some modifications may be required.

- Random Streets Segment Workbook

i-Tree Academic

- Resources
- Manuals & Workbooks
- Video Learning
- Archives
- Reports
- Project Profile
- Academic
- Presentations
- Workshops
- Why i-Tree?

Overview

The goal of the i-Tree Academic Project is to integrate the i-Tree software suite into university and technical school curriculum. We at the i-Tree Development Team feel that it is of the utmost importance to familiarize the next generation of Urban Foresters, Arborist, Urban Planners, Consultants, and Natural Resource Managers to the i-Tree software as to better prepare them for their professional endeavors. With your help we would like to bring i-Tree to our future community foresters.

On our end, we are opening a line of communication between members of the academic community to facilitate the exchange of curriculum materials, thoughts, and ideas in regards to familiarizing students with i-Tree.

It is only through the participation of the academic community though that this project will be successful. We strongly encourage you to download, use, and even modify the materials on this website to best suit your method of instruction. Furthermore, we request that if you develop your own materials or methods that you feel are useful then to please share your ideas with your colleagues by Submitting Material or posting your ideas on our Discussion Board. A small effort by many goes a long way!

Meeting Information

i-Tree

Resources

Resources

Manuals & Workbooks

Video Learning

Archives

Reports

Project Profile

Academic

Presentations

Workshops

Why i-Tree?

It is our goal to offer you the resources needed to understand and utilize the i-Tree suite of software tools in your community. Below are links to training opportunities, presentations, reports, technical papers, research and other i-Tree initiatives.

Manual & Workbooks

Manuals for i-Tree applications and utilities can be accessed from the Manuals & Workbooks page. In addition, workbooks used for plot and street segment generation can be accessed from this page.
Learn more >

Video Learning

Visit this page to access online learning content such as instructional videos and archived webinars on the i-Tree Tools. Content and links are periodically updated as new material becomes available.
Learn more >

i-Tree Methods, Technical Papers, & Archived Resources

Want to learn more about the research behind the i-Tree applications and utilities? Access technical documents & links related to the i-Tree software tools from this page.
Learn more >

i-Tree Reports

Want to see how others have utilized the i-Tree tools to assess the benefits of their community tree resources? Check out i-Tree Reports to learn more.
Learn more >

i-Tree Project Profile

See how communities, academic institutions, non-profit organizations, urban forestry coordinators and consultants are using thee i-Tree Tools to improve understanding and management of urban natural resources.
Learn more >

i-Tree Academic

Learn how the i-Tree Academic Initiative is developing and integrating i-Tree related curriculum and exercises into university and technical courses to train future urban foresters.
Learn more >

i-Tree Presentations

Want to see a presentation on i-Tree or download a past presentation? Visit i-tree presentations to learn more about the i-Tree tools.
Learn more >

i-Tree Workshops

Want to participate in an upcoming i-Tree workshop? Please check the i-Tree Workshop page for upcoming opportunities. Past i-Tree workshops are also listed for reference or downloading materials.
Learn more >

Why i-Tree?

Want to know how i-Tree software tools can make a difference in your community? Check out fact sheets describing how specific user groups and community types can use, or have used, the i-Tree suite of software tools to benefit their tree program.
Learn more >

Why i-Tree?

Resources

Manuals & Workbooks

Video Learning

Archives

Reports

Project Profile

Academic

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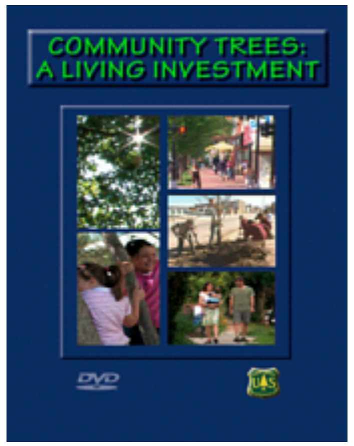
Workshops

Why i-Tree?

Why i-Tree?



The i-Tree suite of software tools was developed to help users identify and manage the structure, function, and value of urban tree populations regardless of community size or technical capacity. i-Tree allows you to promote effective urban forest management and sound arboricultural practices by providing information for advocacy & planning, baseline data for making informed decisions, and standardization for comparisons with other communities. It promotes a better understanding of the benefits and services provided by community trees, increases in investment in stewardship, operations, and maintenance.

Explore the documents and video below to learn more about the i-Tree suite of software tools and the importance of community trees.

- i-Tree v5.0 Summary
- A Guide to Assessing Urban Forests
- i-Tree Design Fact Sheet
- i-Tree Brochure
- Community Trees: A Living Investment (video)

Tree Campus USA Program

Tree Campus USA program recognizes college and university campuses that:

- Effectively manage their campus trees.
- Develop connectivity with the community beyond campus borders to foster healthy, urban forests.
- Strive to engage their student population utilizing service learning opportunities centered on campus, and community, forestry efforts.

Colleges and universities across the United States can be recognized as a Tree Campus USA college by meeting five standards developed to promote healthy trees and student involvement.

Tree Campus USA Standards

Standard 1 — Campus Tree Advisory Committee

A Campus Tree Advisory Committee comprised of members representing the diverse audience of those with a stake in campus trees is established and meets regularly.

This committee must include a representative from each of the following audience:

- Student (undergraduate or graduate).
- Faculty.
- Facility Management.
- Community — for example — city forester, municipal arborist, community tree board member.

Each individual campus may also have other interested student organizations, alumni, faculty, or staff that could be represented such as administration, sustainability coordinator, professor emeritus, etc.

While responsibility of the campus trees often ultimately lies with the campus forester, arborist, landscape architect, or designated facilities department, the Campus Tree Advisory Committee can assist in providing guidance for future planning, approval of a comprehensive campus tree plan, education of the campus population as to the benefits of the campus trees, and development of connectivity to the community.

Standard 2 — Campus Tree Care Plan

A Campus Tree Care Plan should be flexible enough to fit the needs and circumstances of the particular campus. The Tree Care Plan should be goal oriented and provide the opportunity to set good policy, like that listed in the ANSI A300 standards for tree care and management, and clear guidance for planting, maintaining, and removing trees. It also provides education to the campus community, citizens, contractors, and consultants about the importance of the campus forest and the protection and maintenance of trees as part of the growth and land development process.

A Campus Tree Care Plan must include:

1. Clearly stated purpose.
2. Responsible authority/department — who enforces the Campus Tree Care Plan.
3. Establishment of a Campus Tree Advisory Committee, terms of the representatives, and role committee plays.
4. Campus tree care policies for planting, landscaping, maintenance and removal including establishing and updating a list of recommended and prohibited species; managing for catastrophic events.
5. Protection and Preservation policies and procedures — include process for implementing tree protection plan including step-by-step process that every project must follow including construction and trenching.
6. Goals and Targets — develop at least one goal and target for your Campus Tree Plan. These could include (but are not limited to) tree canopy target, development of a link between the Campus Tree Plan and other green initiatives on campus or in the community; completion of a campus-wide tree inventory, etc. Include how the goal will be measured.
7. Tree damage assessment — enforcement, penalties, and appeals.
8. Prohibited practices.
9. Definitions of terminology related to campus trees.
10. Communication strategy — how the campus tree care plan will be communicated to the college community and contractors to heighten awareness about policies and procedures as well as the goals of the institution.

Standard 3 — Campus Tree Program with Dedicated Annual Expenditures

A college campus, to be designated a Tree Campus USA, must allocate finances for its annual campus tree program. Evidence should be shown that an annual work plan has been established and expenditures dedicated towards that work plan.

It is suggested, but not mandatory, that campuses work towards an annual expenditure of $3 per full-time enrolled student. The national average among recognized Tree Campus USA colleges and universities is currently $9 - $11. Expenditures may take place on or off campus, like in the case of an urban campus that does not have room to plant or care for trees on their own campus but works with a nearby elementary school to plant and care for the trees there.

Expenditures could include, but are not limited to:

- Cost of trees purchased
- Labor, equipment and supplies for tree planting, maintenance (pruning, watering, fertilization, mulching, competition control, etc.) and removal, if needed
- Value of volunteer labor (# of hours × $22) and other contributions from student or civic organizations
- Staff time dedicated to campus forest planning, tree care contractors
- All associated costs of the campus tree management including:
    - public education related to the campus forest;
    - professional training;

- related association memberships (International Society of Arboriculture and local chapter, Society of Municipal Arborists, state urban forest council, etc.);
- campus tree inventory

Standard 4 — Arbor Day Observance

An Arbor Day observance provides a golden opportunity to educate the campus community to the benefits of the trees on their campus property and in the community. The Arbor Day observance can be on the campus or held in conjunction with the community where the campus is located. Your event may be held at an appropriate time for your campus.

Evidence — recording of date observance was held with attachment that includes program of activities, news coverage, and/or pictures.

Standard 5 — Service Learning Project

The Service Learning Project should be an outreach of the spirit of the Tree Campus USA initiative. This project should provide an opportunity to engage the student population with projects related to trees and can be part of a campus or community initiative. The project must be done within the course of the year application is submitted.

Project ideas include, but are not limited to:

- Volunteer tree plantings or tree maintenance
- Tree inventory (campus or community)
- Establish a Nature Explore Classroom for young children at an early childhood development center on your campus or in your community.
- Establishment of campus arboreta
- Student-led effort to have community designated a Tree City USA
- Coordinate internships with the urban forestry or parks department in your community
- Assist Project Learning Tree or other programs centered around trees in training teachers at schools near your campus or organize training for your school's College of Education
- Other tree-related service learning or educational programs for students
- Partnership with state forestry departments on regional projects

Why Should my School Participate?

You know that trees benefit the environment. Trees provide shade, protect us from the wind, clean our air…

But your campus can benefit as well:

- A commitment to trees on your campus can, in turn, significantly reduce the amount of energy a campus, and community, needs to generate.
- Planting, and maintaining, trees on your campus and in the community reduces carbon dioxide in the atmosphere — which is one of the important roles that trees play.
- Green spaces give students and faculty the setting to relax with others, or on their own. What better way to study or take a break than by being outside.

By meeting the annual standards and being recognized as a Tree Campus USA college, you will create a campus that not only benefits the environment but instills pride in the students, faculty, and community.

Tree Campus USA colleges will receive recognition materials that can be showcased throughout the campus, as well as press releases to be distributed on campus and in the community.

Southern University will strive to be part of Tree Campus USA Program and adhere to the guidelines and recommended practices for the care of the trees.

D - Erosion Control/Bio-Engineering Information

CHAPTER 3

SEDIMENT AND EROSION CONTROL

Soil erosion and sediment controls are measures which are used to reduce the amount of soil particles that are carried off of a land area and deposited in a receiving water. Soil erosion and sediment control is not a new technology. The USDA Soil Conservation Service and a number of State and local agencies have been developing and promoting the use of erosion and sediment control devices for years.

This chapter provides a general description of some of the most commonly used measures today and a method to select the most appropriate measures for your project. The descriptions contained in this chapter are very simple and are intended to provide general understanding rather than specific design information. You are encouraged to consult your State or local guidance books for sediment and erosion control measure design standards. You are also encouraged to consult the design fact sheets contained in Appendix B of this manual.

3.1 SELECTION OF SOIL EROSION AND SEDIMENT CONTROL PRACTICES

Your selection of the best soil erosion and sediment controls for your site should be primarily based upon the nature of the construction activity and the conditions which exist at the construction site.

The soil erosion and sediment control portion of the Storm Water Pollution Prevention Plan should:

- Minimize the amount of disturbed soil
- Prevent runoff from offsite areas from flowing across disturbed areas
- Slow down the runoff flowing across the site
- Remove sediment from onsite runoff before it leaves the site
- Meet or exceed local or State requirements for sediment and erosion control plans.

Your soil erosion and sediment control plan should meet each of the objectives listed above. How you meet these objectives depends primarily on the nature of the construction activity and the characteristics of the site. The following subsections are presented in a question and answer format. The questions concern certain characteristics of your construction site. Your answer to each of these questions will help you determine what sediment and erosion control practices are best suited for your construction project.

Appendix A includes an Erosion and Sediment Control Checklist. This checklist can be used in your review of the erosion and sediment control portion of your Pollution Prevention Plan to evaluate compliance with typical storm water construction permit requirements. You should also review your projects.

The major problem associated with erosion at construction sites is the movement of soil off the site and its impact on water quality. Construction site erosion is a source of sediments, toxicants, and nutrients which pollute the receiving water(s). Clearing, grading, or otherwise altering previously undisturbed land at a construction site increases the erosion rate by as much as 1,000 times the pre-construction rate. Millions of tons of sediment are generated annually by the construction industry in the United States alone, and erosion rates, typically 100 to 200 tons per acre, have been reported as high as 500 tons per acre (State of North Carolina, 1988).

Q. What is Erosion?

Erosion, by the action of water, wind, and ice, is a natural process in which soil and rock material is loosened and removed. There are two major classifications of erosion: (1) geological erosion, and (2) man-made erosion.

Geological erosion, which includes soil-forming as well as soil-removing, has contributed to the formation of soils and their distribution on the surface of the earth. Man-made erosion, which can greatly accelerate the natural erosion process, includes the breakdown of soil aggregates and the increased removal of organic and mineral particles; it is caused by clearing, grading, or otherwise altering the land. Erosion of soils that occurs at **construction sites** is **man-made erosion.**

Factors Influencing Erosion by Water

Erosion of the land surface may be caused by water, wind, ice, or other geological agents. **Water erosion**, which is the focus of this document, is the loosening and removal of soil from the land by running water, including runoff from melted snow and ice. The major factors affecting soil erosion are soil characteristics, climate, rainfall intensity and duration, vegetation or other surface cover, and topography.

Understanding the factors that effect erosion makes it possible to predict the extent and consequences of onsite erosion.

3.1.1 Minimize the Amount of Disturbed Soil

Why?

Minimizing the amount of disturbed soil on the construction site will decrease the amount of soil which erodes from the site, and it can decrease the amount of controls you have to construct to remove the sediment from the runoff.

Q. How does disturbing soil cause erosion?

Disturbing soil can remove the vegetation. Vegetation is the most effective way to control erosion. Vegetative covers reduce erosion by: (1) shielding the soil surface from the impact of falling rain and thus reducing runoff; (2) dispersing and decreasing the velocity of surface flow; (3) physically restraining soil movement; (4) increasing infiltration rates by improving the soil's structure and porosity through the incorporation of roots and plant residues; and (5) conducting transpiration, which decreases soil moisture content and increases soil moisture storage capacity. Figure 3.1 illustrates some of the ways that vegetation helps control erosion.

Nonvegetative covers such as mulches and stone aggregates similarly protect soils from erosion. Like vegetative covers, these ground covers shield the soil surface from the impact of falling rain, reduce flow velocity, and disperse flow. Each of these types of cover provides a rough surface that slows the runoff velocity and promotes infiltration and deposition of sediment. The condition as well as the type of ground cover influences the rate and volume of runoff. It should be noted that although impervious surfaces (such as parking lots) protect the covered area, they prevent infiltration and consequently increase the peak flow rate which increases the potential for erosion at the discharge area.

Q. Did you develop a site plan that does not require a significant amount of grade changes?

A construction project site should be selected and laid out so that it fits into existing land contours. When you try to significantly change the grades in an area you can increase the amount of disturbed soil which increases the amount of erosion which will occur. Significant regrading can also disturb the natural drainage of an area, and can be more costly.

Q. Are there portions of the site which will not have to be cleared for construction to proceed?

Only clear and grub the portions of the site where it is necessary for construction. When less area is disturbed for construction, there is less erosion of soil. Natural vegetation can also improve the aesthetics of the site. See page 3-24 Preservation of Natural Vegetation for further discussion on this BMP.

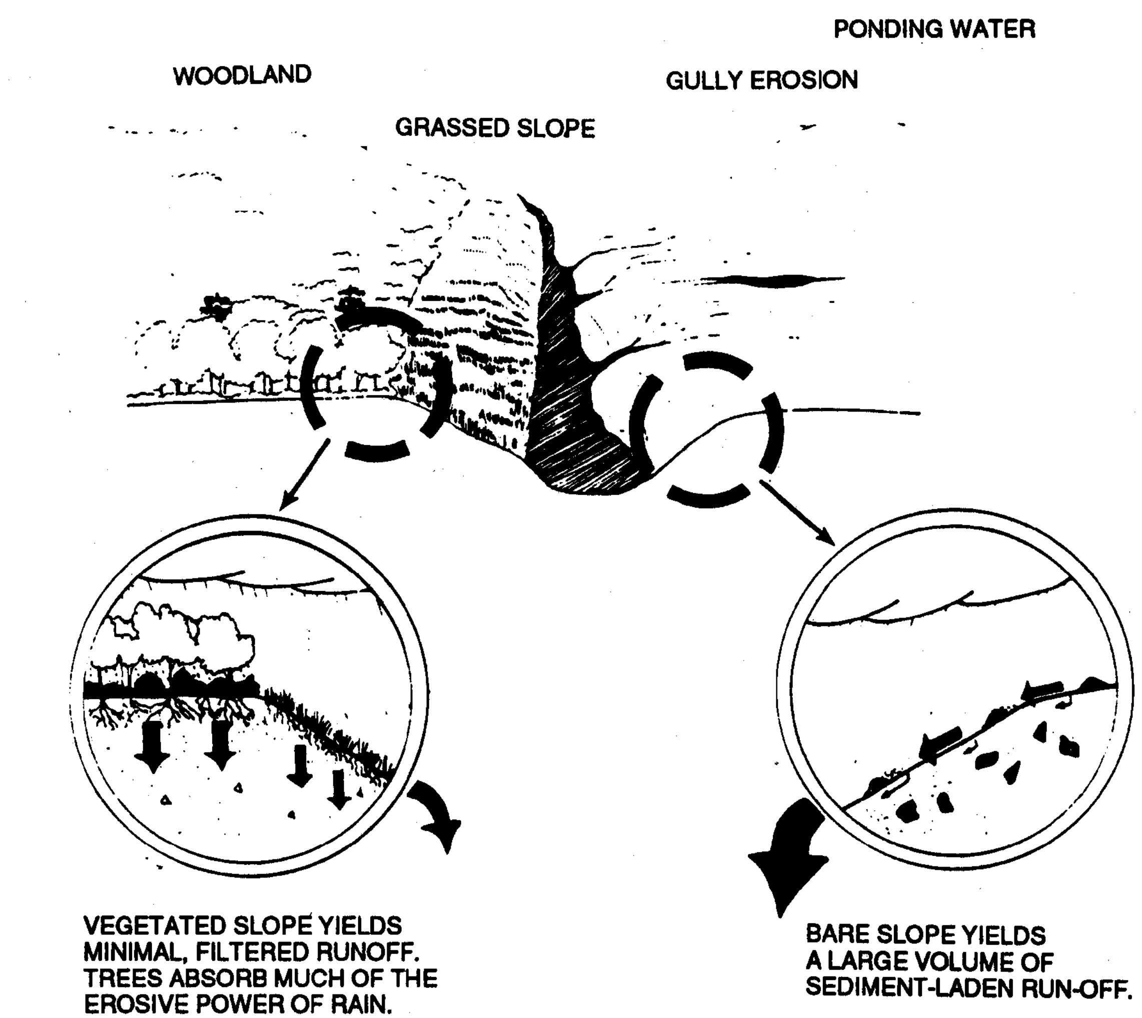


FIGURE 3.1 EROSION PREVENTION BY STABILIZATION
(From State of North Carolina, 1988)

Q. Can the construction be performed in stages, so that the entire site does not have to be cleared at one time?

If your construction project will take place over a wide spread area, consider staging the project so that only a small portion of the site will be disturbed at any one time. For example, if you were developing a 100-acre housing subdivision, rather than clear the entire 100 acres at the start of construction, only clear a 20-acre parcel, grade the area, install the utilities, pave the roads, construct the houses, landscape and seed the lawn areas, then move on to the next 20-acre parcel. Phased construction helps to lessen the risk of erosion by minimizing the amount of disturbed soil that is exposed at any one time.

Q. Are there portions of the site which will be disturbed then left alone for long periods of time?

If there are disturbed portions of the site that will not be re-disturbed for a long period (check your permit to see what the maximum time is), then these areas should be stabilized with Temporary Seeding (see page 3-14) or Mulching (see page 3-16). This will reduce the amount of erosion from these areas until they are disturbed again. For example, if soil excavated from a temporary sediment trap is stockpiled to be used later to backfill the trap (when the area is stabilized) then the stockpile should be stabilized with temporary seed.

Q. Do you stabilize all disturbed areas after construction is complete?

By permanently stabilizing the disturbed areas as soon as possible after construction is complete in those areas, you can significantly reduce the amount of sediment which should be trapped before it leaves your site. An area can be stabilized by Permanent Seeding and Planting (see page 3-20), Mulching (see page 3-16), Geotextiles (see page 3-17), and Sod Stabilization (see page 3-26).

Q. Does snow prevent you from seeding an area?

If snow cover prevents you from seeding a disturbed area or planting other types of vegetation, then you should wait until the snow melts before stabilizing the area.

Q. Is there not enough rainfall to allow vegetation to grow on your construction site.

If there is not enough rainfall on the area you have disturbed to allow vegetation to grow then you should;

- Seed and irrigate the disturbed area (if allowed by your permit-see non storm-water flows) or,
- Stabilize the disturbed areas by non-vegetative methods (See Mulching (page 3-16), Geotextiles (page 3-17), or Chemical Stabilization (page 3-19).

3.1.2 Prevent Runoff From Offsite Areas From Flowing Across Disturbed Areas

Why?

Diverting offsite runoff around a disturbed area reduces the amount of storm water which comes into contact with the exposed soils. If there is less runoff coming in contact with exposed soil, then there will be less erosion of the soil and less storm water which has to be treated to remove sediment.

Q. Does runoff from undisturbed uphill areas flow onto your construction site?

Overland flow can be diverted around a construction site by installing an Earth Dike (see page 3-37), an Interceptor Dike and Swale (see page 3-41), or a Drainage Swale (see page 3-39). Your choice of diversion methods depends upon the size of the uphill area and the steepness of the slope the diversion must go down. Interceptor dikes and swales are effective in diverting overland flows from smaller areas (3 acres or less) down gentle slopes (10 percent or less). A temporary swale is most effective diverting runoff from concentrated channels and an earth dike is capable of diverting both sheet and concentrated flows from larger areas down steeper slopes. (See Appendix B for specific design information regarding each of these diversion measures.) These devices should be installed from the uphill side of the site down to a point where they can discharge to an undisturbed area on the downhill side of the site.

Q. Will runoff flow down a steeply sloped, disturbed area on the site?

Steeply sloped areas are especially susceptible to erosion. If there are steep areas on your site which will be disturbed, then an Earth Dike (page 3-37) or Interceptor Dike and Swale (page 3-41) may be used to divert the runoff from the top of the slope to the inlet of a Pipe Slope Drain (page 3-48) or to a less steeply sloped area. These measures will minimize the amount of runoff flowing across the face of a slope and decrease the erosion of that slope.

Q. Is there a swale or stream which runs through your construction site?

Swales and streams which run through construction sites must be protected from erosion and sediment because they can be significantly damaged. Streams and other water bodies should be protected by Preservation of Natural Vegetation (see page 3-24) or Buffer Zones (see page 3-22). Where possible, these techniques should also be used to protect swales or intermittent streams.

Where construction requires that the stream or swale be disturbed, then the amount of area and time of disturbance should be kept at a minimum. All stream and channel crossings should be made at right angles to the stream, preferably at the most narrow portion of the channel. Once a stream or swale is disturbed, construction should proceed as quickly as possible in this area. Once completed, the stream banks should be stabilized with Stream Bank Stabilization (see page 3-28), Gabions. Swales and intermittent streams disturbed by construction should be seeded and stabilized with Geotextiles (see page 3-17) as soon as possible.

Q. Does construction traffic have to cross a drainage swale or stream?

If it is necessary to cross a swale or stream to get to all or parts of your construction site, then before you begin working on the opposite side of the stream, you should construct a Temporary Stream Crossing (see page 3-43). Stream crossings can be either permanent or temporary depending upon the need to cross the stream after construction is complete.

3.1.3 Slow Down the Runoff Traveling Across the Site

Why?

The quantity and size of the soil particles that are loosened and removed increase with the velocity of the runoff. This is because high runoff velocities reduce infiltration into the soil (and therefore also increase runoff volume) and exert greater forces on the soil particles causing them to detach. It is no surprise, therefore, that high flow velocities are associated with severe rill and gully erosion.

Q. Is your site gently sloped?

When preparing the grading plan, try to make grades as gradual as possible without modifying the existing site conditions significantly. Steeper slopes result in faster moving runoff, which results in greater erosion. Erosion can occur on even the gentlest of slopes depending on soil and climate conditions. The State/local representative of the Soil Conservation Service is a good source of area-specific considerations. (The USDA defines slopes of 2 to 9 percent as gently sloping; slopes of 9 to 15 percent are considered moderately steep; slopes of 30 to 50 percent are considered to be steep slopes; and slopes greater than 50 percent are considered very steep slopes.)

Q. Are there steeply sloped areas on your site?

Steeply sloped areas can be protected from erosion in a number of ways. Section 3.1.2 describes how flow can be diverted away from the face of the slope; however, this technique does not address runoff from the slope itself. Gradient Terraces (see page 3-70) should be used to break the slope and slow the speed of the runoff flowing down the hillside. Surface Roughening (see page 3-67) can also be used on sloped areas as a method to slow down overland flow on a steep slope.

Q. Is your site stabilized with vegetation?

In addition to holding soil in place and shielding it from the impact of rain drops, vegetative cover also increases the roughness of the surface runoff flows over. The rougher surface slows the runoff. An area can be stabilized by Permanent Seeding (see page 3-20), Mulching (see page 3-16), Geotextiles (see page 3-17), and Sod Stabilization (see page 3-26).

Q. Does runoff concentrate into drainage swales on your site?

Concentrated runoff can be more erosive than overland flow. Runoff concentrated into swales or channels can be slowed by reducing the slope and increasing the width of a channel. When site conditions prevent decreasing the slope and widening a channel, then runoff can be slowed with Check Dams (see page 3-65). Runoff can also be slowed in channels by establishing a vegetative cover. Geotextiles (see page 3-17) are often used to hold the channel soil in place while the grass is growing.

3.1.4 Remove Sediment From Onsite Runoff Before it Leaves the Site

Why?

Despite the many advances in meteorology, it is not possible to predict more than a few days in advance when it will rain. It takes several weeks to establish a grass cover which can effectively control erosion, and, even if there were advanced warning of rainfall, it is not always possible to halt construction activities in an area to allow grass to grow. Therefore, it is necessary on most construction sites to install measures which can remove sediment from runoff before it flows off of the construction site.

Q. Does your construction disturb an area 10 acres or larger that drains to a common location?

The sediment control device which is most suitable for large disturbed areas is the Sediment Basin (see page 3-60). A sediment basin should be installed at all locations where there is an upstream disturbed area of 10 acres or more. Only if a sediment basin is not attainable should other sediment controls be installed. A sediment basin may not be attainable at a location if:

- Shallow bedrock prevents excavation of a basin
- Topography in the common drainage location prohibits the construction of a basin of adequate storage volume
- There is insufficient space available at the common drainage location to construct a basin, due to the presence of existing structures, pavement, or utilities which cannot be relocated
- The only common drainage location is beyond the property line or "right of way" of the construction activity and a temporary construction easement cannot be obtained
- State, local, or other Federal regulations prohibit a basin or the construction of a basin in the common drainage locations.

Q. Does your construction disturb an area less than 10 acres that drains to a common location?

Disturbed areas less than 10 acres in size have more variety in the measures which are suitable for sediment control. Several types of measures can be used for sediment control including: Sediment Basins, Sediment Trap, Silt Fence, and Gravel Filter Berms. The selection among these measures depends upon a number of criteria. The following questions should help you determine which is the most appropriate.

Q. What if a sediment basin is not attainable on a site where there are 10 or more disturbed acres which drain to a common location?

If you cannot install a sediment basin on your site, then you should install Sediment Traps (see page 3-58), Silt Fences (see page 3-52), or other equivalent sediment control measures such as Gravel Filter Berms (see page 3-54).

Q. Does runoff leave the disturbed area as overland flow?

Sediment can be removed from overland flow using filtration controls such as Silt Fences (see page 3-52) and Gravel Filter Berms (see page 3-54). These methods have limitations (which are described in Section 3.2.2) regarding the specific conditions in which they are effective.

Overland flow runoff from a disturbed area can also be directed to a Sediment Trap (see page 3-58) or a Temporary Sediment Basin (see page 3-60) using diversion devices such as an Earth Dike (see page 3-37) or an Interceptor Dike and Swale (see page 3-41).

Q. Is flow concentrated in channels as it leaves the disturbed area?

Sediment should be removed from concentrated runoff by either a Sediment Trap (see page 3-58) or a Temporary Sediment Basin (see page 3-60) depending upon the disturbed area upstream. Filtration measures are generally not effective when used in concentrated flow because flow will back-up behind the filter until it overtops it.

Q. Are structural controls located along the entire downhill perimeter of all disturbed areas?

Runoff which passes over disturbed soil should pass through sediment controls before it can be allowed to flow off of the construction site. Therefore the entire downslope and side slope borders of the disturbed area should be lined with filtration devices, such as silt fence, or with a diversion device which will carry the runoff to a sediment basin or sediment trap prior to discharging it off site.

Q. Is there a piped storm drain system with inlets in a disturbed area?

If there is a yard drain or curb inlet which receives flow from a disturbed area then a Sediment Basin, Sediment Trap, or Inlet Protection should be constructed to remove the sediment from the runoff before it flows into the inlet.

3.1.5 Meet or Exceed Local/State Requirements for Erosion and Sediment Control

Why?

Many State and local authorities also have sediment and erosion control regulations in place. It is important that these requirements still be met. The NPDES storm water permit your construction project may be required to obtain for storm water is not intended to supersede State or local requirements. It is intended to provide another means to regulate storm water.

Q. Does your State or local government require erosion and sediment control for construction projects?

Consult State or local authorities to determine what, if any, requirements there are for sediment and erosion control on construction projects. Many State and local authorities provide their own design manuals or guidance to assist in preparing a plan which meets their requirements. These State and local requirements should be incorporated into the pollution prevention plan.

If the State or local authority requires review and approval of the sediment and erosion control plan, then a reviewed and approved copy of that plan should be included in the pollution prevention plan.

Q. Does your State or local government have an erosion and sediment control requirement which is different from the requirements of your NPDES storm water permit?

Although most of the provisions of the NPDES storm water permits for construction activities are consistent with most State and local requirements, there may be differences in the specific requirements for control measures. When there is a difference in requirements, you should use the more stringent one. For example, your State may only require you to stabilize a disturbed area within 30 days of the last disturbance; however, the your permit may require you to stabilize an area 14 days after the last disturbance. Under this example, you would be required to stabilize after 14 days.

3.2 SEDIMENT AND EROSION CONTROL PRACTICES

Any site where soils are exposed to water, wind or ice can have soil erosion and sedimentation problems. Erosion is a natural process in which soil and rock material is loosened and removed. Sedimentation occurs when soil particles are suspended in surface runoff or wind and are deposited in streams and other water bodies.

Human activities can accelerate erosion by removing vegetation, compacting or disturbing the soil, changing natural drainage patterns, and by covering the ground with impermeable surfaces (pavement, concrete, buildings). When the land surface is developed or "hardened" in this manner, storm water and snowmelt can not seep into or "infiltrate" the ground. This results in larger amounts of water moving more quickly across a site which can carry more sediment and other pollutants to streams and rivers.

The following sections describe stabilization practices and structural practices for erosion and sediment control. Using the measures to control erosion and sedimentation is an important part of storm water pollution prevention. These measures are well established and have been required by a number of State and local agencies for years.

3.2.1 Stabilization Practices

Preserving existing vegetation or revegetating disturbed soil as soon as possible after construction is the most effective way to control erosion. A vegetation cover reduces erosion potential in four ways: (1) by shielding the soil surface from the direct erosive impact of raindrops; (2) by improving the soil's water storage porosity and capacity so more water can infiltrate into the ground; (3) by slowing the runoff and allowing the sediment to drop out or deposit; and (4) by physically holding the soil in place with plant roots.

Vegetative cover can be grass, trees, or shrubs. Grasses are the most common type of cover used for revegetation because they grow quickly, providing erosion protection within days. Other soil stabilization practices such as straw or mulch may be used during non-growing seasons to prevent erosion. Newly planted shrubs and trees establish root systems more slowly, so keeping existing ones is a more effective practice.

Vegetative and other site stabilization practices can be either temporary or permanent controls. Temporary controls provide a cover for exposed or disturbed areas for short periods of time or until permanent erosion controls are put in place. Permanent vegetative practices are used when activities that disturb the soil are completed or when erosion is occurring on a site that is otherwise stabilized.

EPA BASELINE GENERAL PERMIT REQUIREMENTS
Stabilization Requirements
Part IV.D.2.a.(1).
Except as provided in paragraphs IV.D.2.(a).(1).(a), (b), and (c) below, stabilization measures shall be initiated as soon as practicable in portions of the site where construction activities have temporarily or permanently ceased, but in no case more than 14 days after the construction activity in that portion of the site has temporarily or permanently ceased. (a). Where the initiation of stabilization measures by the 14th day after construction activity temporary or permanently cease is precluded by snow cover, stabilization measures shall be initiated as soon as practicable. (b). Where construction activity will resume on a portion of the site within 21 days from when activities ceased, (e.g. the total time period that construction activity is temporarily ceased is less than 21 days) then stabilization measures do not have to be initiated on that portion of site by the 14th day after construction activity temporarily ceased. (c). In arid areas (areas with an average annual rainfall of 0-10 inches) and semi-arid areas (areas with an average annual rainfall of 10-20 inches), where the initiation of stabilization measures by the 14th day after construction activity has temporarily or permanently ceased is precluded by seasonal arid conditions, stabilization measures shall be initiated as soon as practicable.

The remainder of this section describes the common vegetative practices listed below:

- Temporary Seeding
- Mulching
- Geotextiles
- Chemical Stabilization
- Permanent Seeding and Planting
- Buffer Zones
- Preservation of Natural Vegetation
- Sod Stabilization
- Stream Bank Stabilization
- Soil Retaining Measures
- Dust Control.

Temporary Seeding

What Is It

Temporary seeding means growing a short-term vegetative cover (plants) on disturbed site areas that may be in danger of erosion. The purpose of temporary seeding is to reduce erosion and sedimentation by stabilizing disturbed areas that will not be stabilized for long periods of time or where permanent plant growth is not necessary or appropriate. This practice uses fast-growing grasses whose root systems hold down the soils so that they are less apt to be carried offsite by storm water runoff or wind. Temporary seeding also reduces the problems associated with mud and dust from bare soil surfaces during construction.

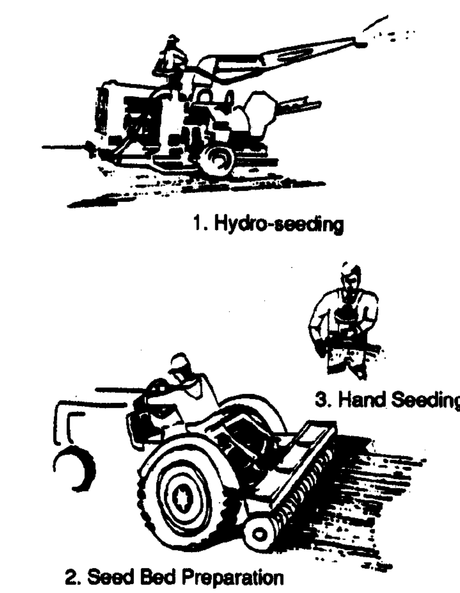


FIGURE 3.2 SEEDING PRACTICES
(Modified from Washington State, 1992)

When and Where to Use It

Temporary seeding should be performed on areas which have been disturbed by construction and which are likely to be redisturbed, but not for several weeks or more. Typical areas might include denuded areas, soil stockpiles, dikes, dams, sides of sediment basins, and temporary roadbanks. Temporary seeding should take place as soon as practicable after the last land disturbing activity in an area. Check the requirements of your permit for the maximum amount of time allowed between the last disturbance of an area and temporary stabilization. Temporary seeding may not be an effective practice in arid and semi-arid regions where the climate prevents fast plant growth, particularly during the dry seasons. In those areas, mulching or chemical stabilization may be better for the short-term (see sections on Mulching, Geotextiles, and Chemical Stabilization).

What to Consider

Proper seed bed preparation and the use of high-quality seed are needed to grow plants for effective erosion control. Soil that has been compacted by heavy traffic or machinery may need to be loosened. Successful growth usually requires that the soil be tilled before the seed is applied. Topsoiling is not necessary for temporary seeding; however, it may improve the chances of establishing temporary vegetation in an area. Seed bed preparation may also require applying fertilizer and/or lime to the soil to make conditions more suitable for plant growth. Proper fertilizer, seeding mixtures, and seeding rates vary depending on the location of the site, soil types, slopes, and season. Local suppliers, State and local regulatory agencies, and the USDA Soil Conservation Service will supply information on the best seed mixes and soil conditioning methods.

Seeded areas should be covered with mulch to provide protection from the weather. Seeding on slopes of 2:1 or more, in adverse soil conditions, during excessively hot or dry weather, or where heavy rain is expected should be followed by spreading mulch (see section on Mulching). Frequent inspections are necessary to check that conditions for growth are good. If the plants do not grow quickly or thick enough to prevent erosion, the area should be reseeded as soon as possible. Seeded areas should be kept adequately moist. If normal rainfall will not be enough, mulching, matting, and controlled watering should be done. If seeded areas are watered, watering rates should be watched so that over-irrigation (which can cause erosion itself) does not occur.

Advantages of Temporary Seeding
$ Is generally inexpensive and easy to do
$ Establishes plant cover fast when conditions are good
$ Stabilizes soils well, is aesthetic, and can provide sedimentation controls for other site areas
$ May help reduce costs of maintenance on other erosion controls (e.g., sediment basins may need to be cleaned out less often)
Disadvantages of Temporary Seeding
$ Depends heavily on the season and rainfall rate for success
$ May require extensive fertilizing of plants grown on some soils, which can cause problems with local water quality
$ Requires protection from heavy use, once seeded
$ May produce vegetation that requires irrigation and maintenance

Mulching

What Is It

Mulching is a temporary soil stabilization or erosion control practice where materials such as grass, hay, woodchips, wood fibers, straw, or gravel are placed on the soil surface. In addition to stabilizing soils, mulching can reduce the speed of storm water runoff over an area. When used together with seeding or planting, mulching can aid in plant growth by holding the seeds, fertilizers, and topsoil in place, by helping to retain moisture, and by insulating against extreme temperatures.

When and Where to Use It

Mulching is often used alone in areas where temporary seeding cannot be used because of the season or climate. Mulching can provide immediate, effective, and inexpensive erosion control. On steep slopes and critical areas such as waterways, mulch matting is used with netting or anchoring to hold it in place.

Mulch seeded and planted areas where slopes are steeper than 2:1, where runoff is flowing across the area, or when seedlings need protection from bad weather.

What to Consider

Use of mulch may or may not require a binder, netting, or the tacking of mulch to the ground. Final grading is not necessary before mulching. Mulched areas should be inspected often to find where mulched material has been loosened or removed. Such areas should be reseeded (if necessary) and the mulch cover replaced immediately. Mulch binders should be applied at rates recommended by the manufacturer.

Advantages of Mulching
$ Provides immediate protection to soils that are exposed and that are subject to heavy erosion
$ Retains moisture, which may minimize the need for watering
$ Requires no removal because of natural deterioration of mulching and matting
Disadvantages of Mulching
$ May delay germination of some seeds because cover reduces the soil surface temperature
$ Mulch can be easily blown or washed away by runoff if not secured
$ Some mulch materials such as wood chips may absorb nutrients necessary for plant growth

Geotextiles

What Are They

Geotextiles are porous fabrics known in the construction industry as filter fabrics, road rugs, synthetic fabrics, construction fabrics, or simply fabrics. Geotextiles are manufactured by weaving or bonding fibers made from synthetic materials such as polypropelene, polyester, polyethylene, nylon, polyvinyl chloride, glass and various mixtures of these. As a synthetic construction material, geotextiles are used for a variety of purposes in the United States and foreign countries. The uses of geotextiles include separators, reinforcement, filtration and drainage, and erosion control. We will discuss the use of geotextiles in preventing erosion at construction sites in this section.

Some geotextiles are also biodegradable materials such as mulch matting and netting. Mulch mattings are materials (jute or other wood fibers) that have been formed into sheets of mulch that are more stable than normal mulch. Netting is typically made from jute, other wood fiber, plastic, paper, or cotton and can be used to hold the mulching and matting to the ground. Netting can also be used alone to stabilize soils while the plants are growing; however, it does not retain moisture or temperature well. Mulch binders (either asphalt or synthetic) are sometimes used instead of netting to hold loose mulches together.

When and Where to Use Them

Geotextiles can be used for erosion control by using it alone. Geotextiles, when used alone, can be used as matting. Mattings are used to stabilize the flow on channels and swales. Also, matting is used on recently planted slopes to protect seedlings until they become established. Also, matting may be used on tidal or stream banks where moving water is likely to wash out new plantings.

Geotextiles are also used as separators. An example of such a use is geotextile as a separator between riprap and soil. This "sandwiching" prevents the soil from being eroded from beneath the riprap and maintaining the riprap's base.

What to Consider

As stated above, the types of geotextiles available are vast, therefore, the selected fabric should match its purpose. Also, State or local requirements, design procedures, and any other applicable requirements should also be consulted. In the field, important concerns include regular inspections to determine if cracks, tears, or breaches are present in the fabric and appropriate repairs should be made.

Effective netting and matting require firm, continuous contact between the materials and the soil. If there is no contact, the material will not hold the soil and erosion will occur underneath the material.

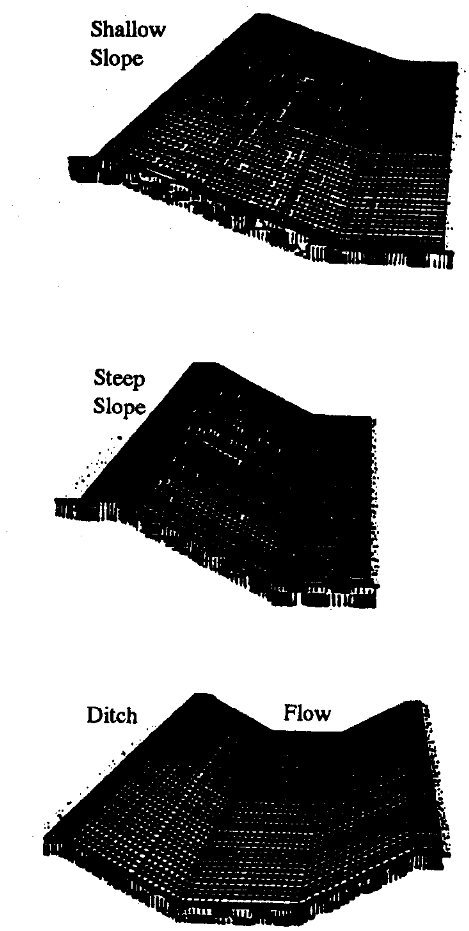


FIGURE 3.3 ORIENTATION OF MULCH NETTING AND MATTING (Modified from County of Fairfax, 1987)

Advantages of Geotextiles

- Fabrics are relatively inexpensive for certain applications
- Offer convenience to the installer
- Design methodologies for the use of geotextiles are available
- A wide variety of geotextiles to match specific needs are available
- Mulch matting and netting are biodegradable

Disadvantages of Geotextiles

- If the fabric is not properly selected, designed, or installed, the effectiveness may be reduced drastically
- Many synthetic geotextiles are sensitive to light and must be protected prior to installation

Chemical Stabilization

What Is It

Chemical stabilization practices, often referred to as a chemical mulch, soil binder, or soil palliative, are temporary erosion control practices. Materials made of vinyl, asphalt, or rubber are sprayed onto the surface of the soil to hold the soil in place and protect against erosion from storm water runoff and wind. Many of the products used for chemical stabilization are human-made, and many different products are on the market.

When and Where to Use It

Chemical stabilization can be used as an alternative in areas where temporary seeding practices cannot be used because of the season or climate. It can provide immediate, effective, and inexpensive erosion control anywhere erosion is occurring on a site.

What to Consider

The application rates and procedures recommended by the manufacturer of a chemical stabilization product should be followed as closely as possible to prevent the products from forming ponds and from creating large areas where moisture cannot get through.

Advantages of Chemical Stabilization

- Is easily applied to the surface of the soil
- Is effective in stabilizing areas where plants will not grow
- Provides immediate protection to soils that are in danger of erosion

Disadvantages of Chemical Stabilization

- Can create impervious surfaces (where water cannot get through), which may in turn increase the amount and speed of storm water runoff
- May cause harmful effects on water quality if not used correctly
- Is usually more expensive than vegetative cover

Permanent Seeding and Planting

What Is It

Permanent seeding of grass and planting trees and brush provides stabilization to the soil by holding soil particles in place. Vegetation reduces sediments and runoff to downstream areas by slowing the velocity of runoff and permitting greater infiltration of the runoff. Vegetation also filters sediments, helps the soil absorb water, improves wildlife habitats, and enhances the aesthetics of a site.

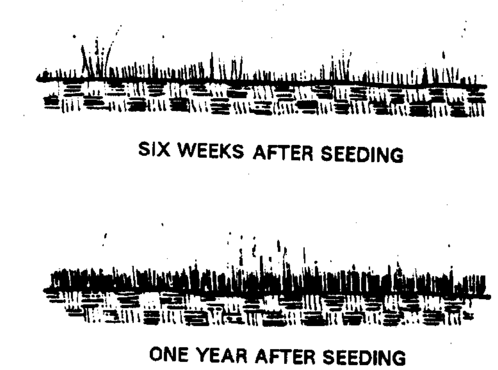


FIGURE 3.4 ESTABLISHING PERMANENT COVER WITH VEGETATION (Modified from State of North Carolina, 1988)

When and Where to Use It

Permanent seeding and planting is appropriate for any graded or cleared area where long-lived plant cover is desired. Some areas where permanent seeding is especially important are filter strips, buffer areas, vegetated swales, steep slopes, and stream banks. This practice is effective on areas where soils are unstable because of their texture, structure, a high water table, high winds, or high slope.

What to Consider

For this practice to work, it is important to select appropriate vegetation, prepare a good seedbed, properly time planting, and to condition the soil. Planting local plants during their regular growing season will increase the chances for success and may lessen the need for watering. Check seeded areas frequently for proper watering and growth conditions.

When seeding in cold climates during fall or winter, cover the area with mulch to provide a protective barrier against cold weather (see Mulching). Seeding should also be mulched if the seeded area slopes 4:1 or more, if soil is sandy or clayey, or if weather is excessively hot or dry.

Plant when conditions are most favorable for growth. When possible, use low-maintenance local plant species.

Topsoil should be used on areas where topsoils have been removed, where the soils are dense or impermeable, or where mulching and fertilizers alone cannot improve soil quality. Topsoiling should be coordinated with the seeding and planting practices and should not be planned while the ground is frozen or too wet. Topsoil layers should be at least 2 inches deep (or similar to the existing topsoil depth).

To minimize erosion and sedimentation, remove as little existing topsoil as possible. All site controls should be in place before the topsoil is removed. If topsoils are brought in from another site, it is important that its texture is compatible with the subsoils onsite; for example, sandy topsoils are not compatible with clay subsoils.

Stockpiling of topsoils onsite requires good planning so soils will not obstruct other operations. If soil is to be stockpiled, consider using temporary seeding, mulching, or silt fencing to prevent or control erosion. Inspect the stockpiles frequently for erosion. After topsoil has been spread, inspect it regularly, and reseed or replace areas that have eroded.

Advantages of Permanent Seeding and Planting

- Improves the aesthetics of a site
- Provides excellent stabilization
- Provides filtering of sediments
- Provides wildlife habitat
- Is relatively inexpensive

Disadvantages of Permanent Seeding and Planting

- May require irrigation to establish vegetation
- Depends initially on climate and weather for success

Buffer Zones

What Are They

Buffer zones are vegetated strips of land used for temporary or permanent water quality benefits. Buffer zones are used to decrease the velocity of storm water runoff, which in turn helps to prevent soil erosion. Buffer zones are different from vegetated filter strips (see section on Vegetated Filter Strips) because buffer zone effectiveness is not measured by its ability to improve infiltration (allow water to go into the ground). The buffer zone can be an area of vegetation that is left undisturbed during construction, or it can be newly planted.

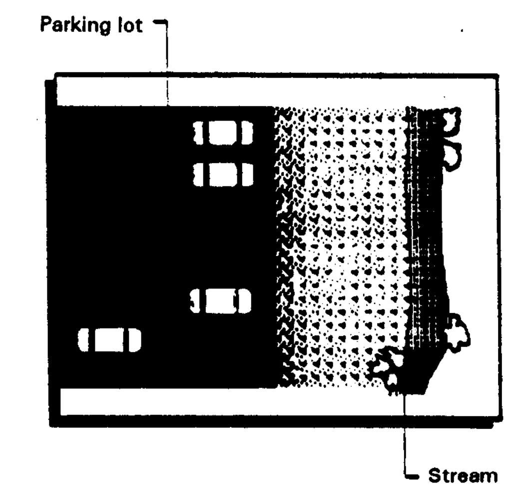


FIGURE 3.5 EXAMPLE BUFFER ZONE (Modified from Washington State, 1992)

When and Where to Use Them

Buffer zones technique can be used at any site that can support vegetation. Buffer zones are particularly effective on floodplains, next to wetlands, along stream banks, and on steep, unstable slopes.

What to Consider

If buffer zones are preserved, existing vegetation, good planning, and site management are needed to protect against disturbances such as grade changes, excavation, damage from equipment, and other activities. Establishing new buffer strips requires the establishment of a good dense turf, trees, and shrubs (see Permanent Seeding and Planting). Careful maintenance is important to ensure healthy vegetation. The need for routine maintenance such as mowing, fertilizing, liming, irrigating, pruning, and weed and pest control will depend on the species of plants and trees involved, soil types, and climatic conditions. Maintaining planted areas may require debris removal and protection against unintended uses or traffic. Many State/local storm water program or zoning agencies have regulations which define required or allowable buffer zones especially near sensitive areas such as wetlands. Contact the appropriate State/local agencies for their requirements.

Advantages of Buffer Zones
$ Provide aesthetic as well as water quality benefits $ Provide areas for infiltration, which reduces amount and speed of storm water runoff $ Provide areas for wildlife habitat $ Provide areas for recreation $ Provide buffers and screens for onsite noise if trees or large bushes are used $ Low maintenance requirements $ Low cost when using existing vegetation
Disadvantages of Buffer Zones
$ May not be cost effective to use if the cost of land is high $ Are not feasible if land is not available $ Require plant growth before they are effective

Preservation of Natural Vegetation

What Is It

The preservation of natural vegetation (existing trees, vines, brushes, and grasses) provides natural buffer zones. By preserving stabilized areas, it minimizes erosion potential, protects water quality, and provides aesthetic benefits. This practice is used as a permanent control measure.

When and Where to Use It

This technique is applicable to all types of sites. Areas where preserving vegetation can be particularly beneficial are floodplains, wetlands, stream banks, steep slopes, and other areas where erosion controls would be difficult to establish, install, or maintain.

What to Consider

Preservation of vegetation on a site should be planned before any site disturbance begins. Preservation requires good site management to minimize the impact of construction activities on existing vegetation. Clearly mark the trees to be preserved and protect them from ground disturbances around the base of the tree. Proper maintenance is important to ensure healthy vegetation that can control erosion. Different species, soil types, and climatic conditions will require different maintenance activities such as mowing, fertilizing, liming, irrigation, pruning, and weed and pest control. Some State/local regulations require natural vegetation to be preserved in sensitive areas; consult the appropriate State/local agencies for more information on their regulations. Maintenance should be performed regularly, especially during construction.

Advantages of Preservation of Natural Vegetation
$ Can handle higher quantities of storm water runoff than newly seeded areas $ Does not require time to establish (i.e., effective immediately) $ Increases the filtering capacity because the vegetation and root structure are usually denser in preserved natural vegetation than in newly seeded or base areas $ Enhances aesthetics $ Provides areas for infiltration, reducing the quantity and velocity of storm water runoff $ Allows areas where wildlife can remain undisturbed $ Provides noise buffers and screens for onsite operations $ Usually requires less maintenance (e.g., irrigation, fertilizer) than planting new vegetation
Disadvantages of Preservation of Natural Vegetation
$ Requires planning to preserve and maintain the existing vegetation $ May not be cost effective with high land costs $ May constrict area available for construction activities

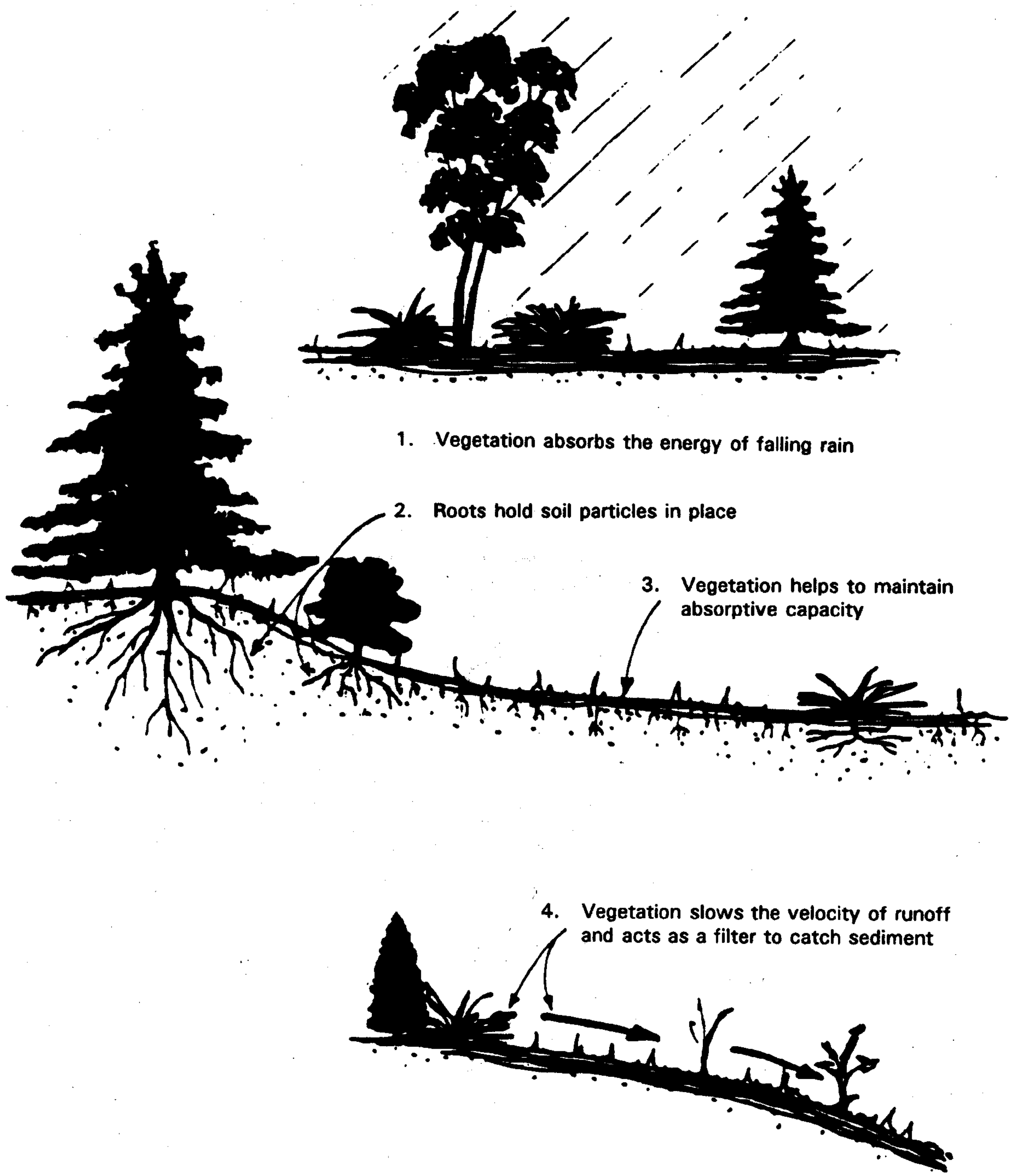


FIGURE 3.6 BENEFITS OF PRESERVING NATURAL VEGETATION
(Modified from Washington State, 1992)

Sod Stabilization

What Is It

Sodding stabilizes an area by immediately covering the surface with vegetation and providing areas where storm water can infiltrate into the ground.

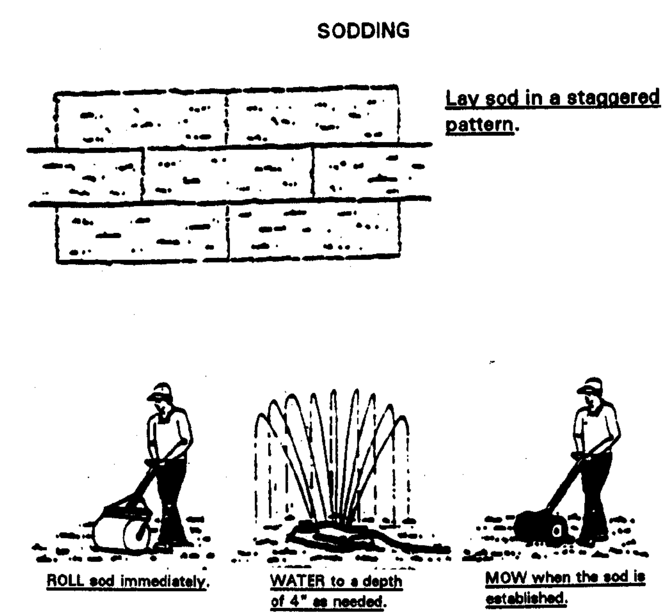


FIGURE 3.7 SODDING
(Modification from County of Fairfax, 1987)

When and Where to Use It

Sodding is appropriate for any graded or cleared area that might erode and where a permanent, long-lived plant cover is needed immediately. Examples of where sodding can be used are buffer zones, stream banks, dikes, swales, slopes, outlets, level spreaders, and filter strips.

What to Consider

The soil surface should be fine-graded before laying down the sod. Topsoil may be needed in areas where the soil textures are inadequate (see topsoil discussion in section on Permanent Seeding and Planting). Lime and fertilizers should be added to the soil to promote good growth conditions. Sodding can be applied in alternating strips or other patterns, or alternate areas can be seeded to reduce expense. Sod should not be planted during very hot or wet weather. Sod should not be placed on slopes that are greater than 3:1 if they are to be mowed. If placed on steep slopes, sod should be laid with staggered joints and/or be pegged. In areas such as steep slopes or next to running waterways, chicken wire, jute, or other netting can be placed over the sod for extra protection against lifting (see Mulching and Geotextiles). Roll or compact immediately after installation to ensure firm contact with the underlying topsoil. Inspect the sod frequently after it is first installed, especially after large storm events, until it is established as permanent cover. Remove and replace dead sod. Watering may be necessary after planting and during periods of intense heat and/or lack of rain (drought).

Advantages of Sod Stabilization
$ Can provide immediate vegetative cover and erosion control $ Provides more stabilizing protection than initial seeding through dense cover formed by sod $ Produces lower weed growth than seeded vegetation $ Can be used for site activities within a shorter time than can seeded vegetation $ Can be placed at any time of the year as long as moisture conditions in the soil are favorable
Disadvantages of Sod Stabilization
$ Purchase and installation costs are higher than for seeding $ May require continued irrigation if the sod is placed during dry seasons or on sandy soils

Stream Bank Stabilization

What Is It

Stream bank stabilization is used to prevent stream bank erosion from high velocities and quantities of storm water runoff. Typical methods include the following:

$ **RiprapB**Large angular stones placed along the stream bank or lake

$ **GabionB**Rock-filled wire cages that are used to create a new stream bank

$ **Reinforced ConcreteB**Concrete bulkheads and retaining walls that replace natural stream banks and create a nonerosive surface

$ **Log CribbingB**Retaining walls built of logs to anchor the soils against erosive forces. Usually built on the outside of stream bends

$ **Grid PaversB**Precast or poured-in-place concrete units that are placed along stream banks to stabilize the stream bank and create open spaces where vegetation can be established

$ **AsphaltB**Asphalt paving that is placed along the natural stream bank to create a nonerosive surface.

When and Where to Use It

Stream bank stabilization is used where vegetative stabilization practices are not practical and where the stream banks are subject to heavy erosion from increased flows or disturbance during construction. Stabilization should occur before any land development in the watershed area. Stabilization can also be retrofitted when erosion of a stream bank occurs.

What to Consider

Stream bank stabilization structures should be planned and designed by a professional engineer licensed in the State where the site is located. Applicable Federal, State, and local requirements should be followed, including Clean Water Act Section 404 regulations. An important design feature of stream bank stabilization methods is the foundation of the structure; the potential for the stream to erode the sides and bottom of the channel should be considered to make sure the stabilization measure will be supported properly. Structures can be designed to protect and improve natural wildlife habitats; for example, log structures and grid pavers can be designed to keep vegetation. Only pressure-treated wood should be used in log structures. Permanent structures should be designed to handle expected flood conditions. A well-designed layer of stone can be used in many ways and in many locations to control erosion and sedimentation. Riprap protects soil from erosion and is often used on steep slopes built with fill materials that are subject to harsh weather or seepage. Riprap can also be used for flow channel liners, inlet and outlet protection at culverts, stream bank protection, and protection of shore lines subject to wave action. It is used where water is turbulent and fast flowing and where soil may erode under the design flow conditions. It is used to expose the water to air as well as to reduce water energy. Riprap and gabion (wire mesh cages filled with rock) are usually placed over a filter blanket (i.e., a gravel layer or filter cloth). Riprap is either a uniform size or graded (different sizes) and is usually applied in an even layer throughout the stream. Reinforced concrete structures may require positive

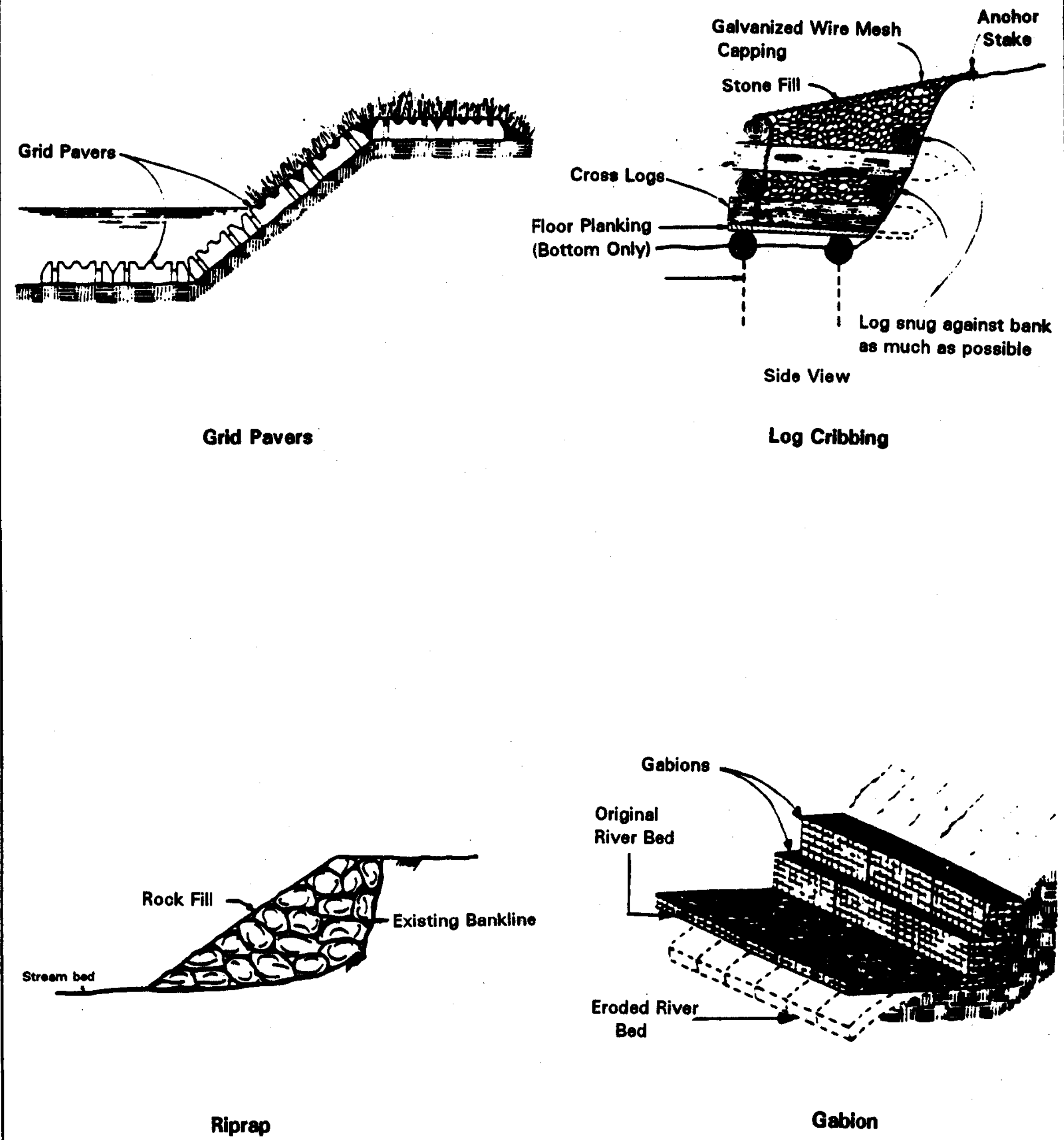


FIGURE 3.8 EXAMPLES OF STREAM BANK STABILIZATION PRACTICES
(Modified from Commonwealth of Virginia, 1980, and Commonwealth of Pennsylvania, 1990)

drainage behind the bulkhead or retaining wall to prevent erosion around the structure. Gabion and grid pavers should be installed according to manufacturers' recommendations.

Stream bank stabilization structures should be inspected regularly and after each large storm event. Structures should be maintained as installed. Structural damage should be repaired as soon as possible to prevent further damage or erosion to the stream bank.

Advantages of Stream Bank Stabilization
- Can provide control against erosive forces caused by the increase in storm water flows created during land development - Usually will not require as much maintenance as vegetative erosion controls - May provide wildlife habitats - Forms a dense, flexible, self-healing cover that will adapt well to uneven surfaces (riprap)
Disadvantages of Stream Bank Stabilization
- Does not provide the water quality or aesthetic benefits that vegetative practices could - Should be designed by qualified professional engineers, which may increase project costs - May be expensive (materials costs) - May require additional permits for structure - May alter stream dynamics which cause changes in the channel downstream - May cause negative impacts to wildlife habitats

Soil Retaining Measures

What Are They

Soil retaining measures refer to structures or vegetative stabilization practices used to hold the soil firmly to its original place or to confine as much as possible within the site boundary. There are many different methods for retaining soil; some are used to control erosion while others are used to protect the safety of the workers (i.e., during excavations). Examples of soil retaining measures include reinforced soil retaining systems, wind breaks, and stream bank protection using shrubs and reeds.

Reinforced soil retaining measures refer to using structural measures to hold in place loose or unstable soil. During excavation, for example, soil tiebacks and retaining walls are used to prevent cave-ins and accidents. But these same methods can be used to retain soils and prevent them from moving. While detailed discussion of soil retaining methods is beyond the scope of this manual, several are briefly described.

- **Skeleton Sheeting**CSkeleton sheeting, the least expensive soil bracing system, requires the soil to be cohesive (i.e., like clay). Construction grade lumber is used to brace the excavated face of the slope.

- **Continuous Sheeting**CContinuous sheeting involves using a material that covers the face of the slope in a continuous manner. Struts and boards are placed along the slope which provide continuous support to the slope face. The material used can be steel, concrete, or wood.

- **Permanent Retaining Walls**CPermanent construction walls may be necessary to provide support to the slope well after the construction is complete. In this instance, concrete masonry or wood (railroad tie) retaining walls can be constructed and left in place.

When and Where to Use Them

Use reinforced soil retaining methods where using other methods of soil retention (e.g., vegetation) is not practical. Some sites may have slopes or soils that do not lend themselves to ordinary practices of soil retention. In these instances, a reinforced soil retaining measure should be considered.

What to Consider

As emphasized earlier, the use of reinforced soil retaining practices serve both safety and erosion control purposes. Since safety is the first concern, the design should be performed by qualified and certified engineers. Such design normally involves understanding the nature of soil, location of the ground water table, the expected loads, and other important design considerations.

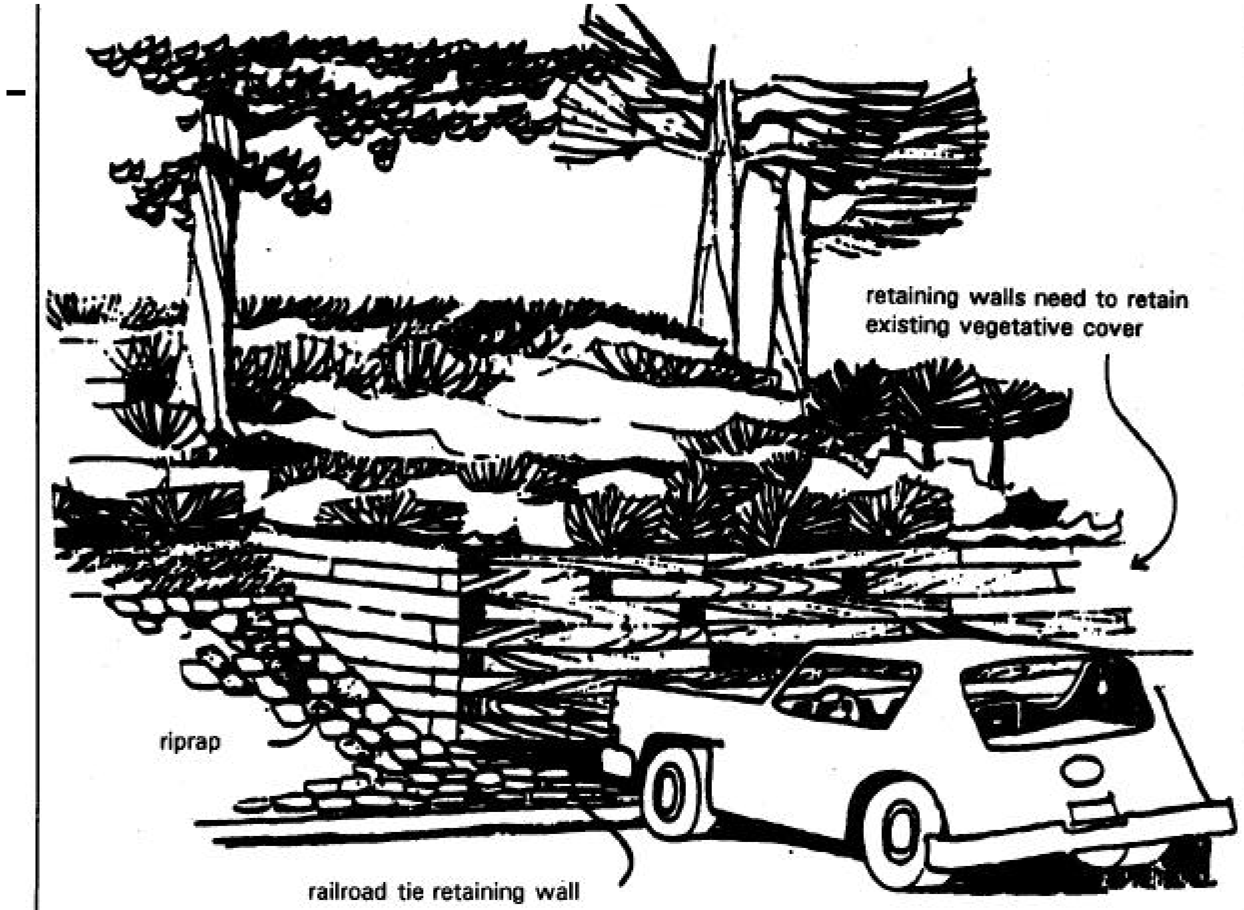


FIGURE 3.9 USE OF RETAINING WALLS
(Modification from Washington State, 1992)

Advantages of Soil Retaining Measures
• Provide safety to workers, and some types of reinforced retention can be left as permanent structures • Prevent erosion of soil difficult to stabilize using conventional methods
Disadvantages of Soil Retaining Measures
• Require the expertise of a professional engineer and may be expensive to design and install

Dust Control

What Is It

Wind is capable of causing erosion, particularly in dry climates or during the dry season. Wind erosion can occur wherever the surface soil is loose and dry, vegetation is sparse or absent, and the wind is sufficiently strong. Wind erodes soils and transports the sediments offsite, where they may be washed into the receiving water by the next rainstorm. Therefore, various methods of dust control may need to be employed to prevent dust from being carried away from the construction site. There are many ways to accomplish this and some are described below:

$ **Vegetative CoverC** For disturbed areas not subject to traffic, vegetation provides the most practical method of dust control (see Temporary Seeding and Permanent Seeding and Planting).

$ **Mulch (Including Gravel Mulch)C** When properly applied, mulch offers a fast, effective means of controlling dust (see Mulching).

$ **Spray-on AdhesiveC** Asphalt emulsions, latex emulsions, or resin in water can be sprayed onto mineral soil to prevent their blowing away (see Chemical Stabilization).

$ **Calcium ChlorideC** Calcium chloride may be applied by mechanical spreader as loose, dry granules or flakes at a rate that keeps the surface moist but not so high as to cause water pollution or plant damage.

$ **SprinklingC** The site may be sprinkled until the surface is wet. Sprinkling is especially effective for dust control on haul roads and other traffic routes.

$ **StoneC** Used to stabilize construction roads; can also be effective for dust control.

$ **BarriersC** A board fence, wind fence, sediment fence, or similar barrier can control air currents and blowing soil. All of these fences are normally constructed of wood and they prevent erosion by obstructing the wind near the ground and preventing the soil from blowing offsite.

Barriers can be part of long-term dust control strategy in arid and semiarid areas; however, they are not a substitute for permanent stabilization. A wind barrier generally protects soil downward for a distance of 10 times the height of the barrier. Perennial grass and stands of existing trees may also serve as wind barriers.

When and Where to Use It

The above measures for dust control should be used when open dry areas of soil are anticipated on the site. Clearing and grading activities create the opportunity for large amounts of dust to be blown, therefore, one or several dust control measures should be considered prior to clearing and grading. One should also note that many of the water erosion control measures indirectly prevent wind erosion.

As the distance across bare soil increases, wind erosion becomes more and more severe. In arid and semiarid regions where rainfall is insufficient to establish vegetative cover, mulching may be used to conserve moisture, prevent surface crusting, reduce runoff and erosion, and help establish vegetation. It is a critical treatment on sites with erosive slopes.

What to Consider

The direction of the prevailing winds and careful planning of clearing activities are important considerations. As a standard practice, any exposed area should be stabilized using vegetation to prevent both wind and water erosion. If your site is located in an arid or semiarid area, you may wish to contact the USDA Soil Conservation Service representative in your area or the appropriate State/local government agency for additional information.

Advantages of Dust Control
$ Reduces movement of soil to offsite areas
Disadvantages of Dust Control
$ Excessive sprinkling may result in non-storm water discharges from the site

3.2.2 Structural Erosion and Sediment Control Practices

Structural practices used in sediment and erosion control divert storm water flows away from exposed areas, convey runoff, prevent sediments from moving offsite, and can also reduce the erosive forces of runoff waters. The controls can either be used as permanent or temporary measures. Practices discussed include the following:

- Earth Dike
- Drainage Swale
- Interceptor Dikes and Swales
- Temporary Stream Crossing
- Temporary Storm Drain Diversion
- Pipe Slope Drains
- Subsurface Drains
- Silt Fence
- Gravel or Stone Filter Berm
- Storm Drain Inlet Protection
- Sediment Trap
- Temporary Sediment Basin
- Outlet Protection
- Check Dams
- Surface Roughening
- Gradient Terraces.

EPA BASELINE GENERAL PERMIT REQUIREMENTS
Structural Practices
Parts IV.D.2.a.(2).(a). and (b).
For common drainage locations that serve an area with 10 or more disturbed acres at one time, a temporary (or permanent) sediment basin providing 3,600 cubic feet of storage per acre drained, or equivalent control measures, shall be provided where attainable until final stabilization of the site. The 3,600 cubic feet of storage area per acre drained does not apply to flows from offsite areas and flows from onsite areas that are either undisturbed or have undergone final stabilization where such flows are diverted around the sediment basin. For drainage locations which serve 10 or more disturbed acres at one time and where a temporary sediment basin providing 3,600 cubic feet of storage per acre drained, or equivalent controls is not attainable, sediment traps should be used. At a minimum, silt fences or equivalent sediment controls are required for all sideslope and downslope boundaries of the construction area. For drainage locations serving less than 10 acres, sediment traps, silt fences or equivalent sediment controls are required for all sideslope and downslope boundaries of the construction area unless a sediment basin providing storage for 3,600 cubic feet of storage per acre drained is provided.

Earth Dike

What Is It

An earth dike is a ridge or ridge and channel combination used to protect work areas from upslope runoff and to divert sediment-laden water to appropriate traps or stable outlets. The dike consists of compacted soil and stone, riprap, or vegetation to stabilize the channel.

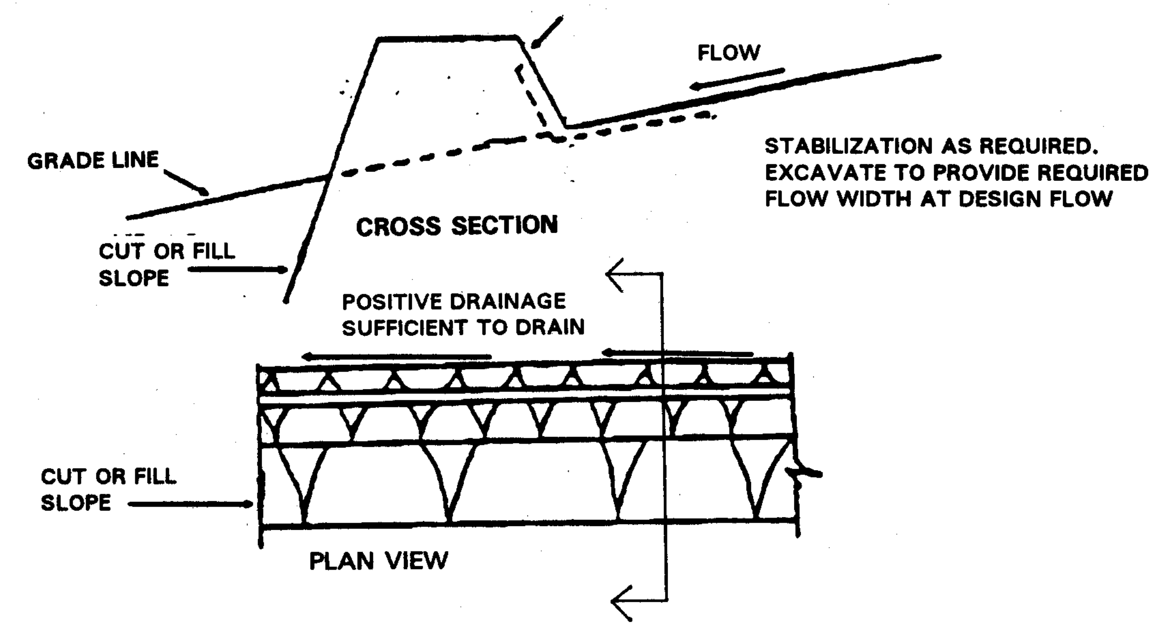


FIGURE 3.10 EARTH DIKE
(Modified from Maryland Department of the Environment, 1991)

When and Where to Use It

Earth dikes are used in construction areas to control erosion, sedimentation, or flood damage. Earth dikes can be used in the following situations:

- Above disturbed existing slopes and above cut or fill slopes to prevent runoff over the slope
- Across unprotected slopes, as slope breaks, to reduce slope length
- Below slopes to divert excess runoff to stabilized outlets
- To divert sediment laden water to sediment traps
- At or near the perimeter of the construction area to keep sediment from leaving the site

- Above disturbed areas before stabilization to prevent erosion and maintain acceptable working conditions
- Temporary diversions may also serve as sediment traps when the site has been overexcavated on a flat grade or in conjunction with a sediment fence.

What to Consider

Despite an earth dike's simplicity, improper design can limit its effectiveness; therefore, the State or local requirements should be consulted. Some general considerations include proper compaction of the earth dike, appropriate location to divert the intercepted runoff, and properly designed ridge height and thicknesses. Earth dikes should be constructed along a positive grade. There should be no dips or low points in an earth dike where the storm water will collect (other than the discharge point). Also, the intercepted runoff from disturbed areas should be diverted to a sediment-trapping device. Runoff from undisturbed areas can be channeled to an existing swale or to a level spreader. Stabilization for the dike and flow channel of the drainage swale should be accomplished as soon as possible. Stabilization materials can include vegetation or stone/riprap.

Advantages of an Earth Dike
• Can be constructed from materials and equipment which are typically already present on a construction site
Disadvantages of an Earth Dike
• Frequent inspection and maintenance required

Drainage Swale

What Is It

A drainage swale is a channel with a lining of vegetation, riprap, asphalt, concrete, or other material. It is constructed by excavating a channel and applying the appropriate stabilization.

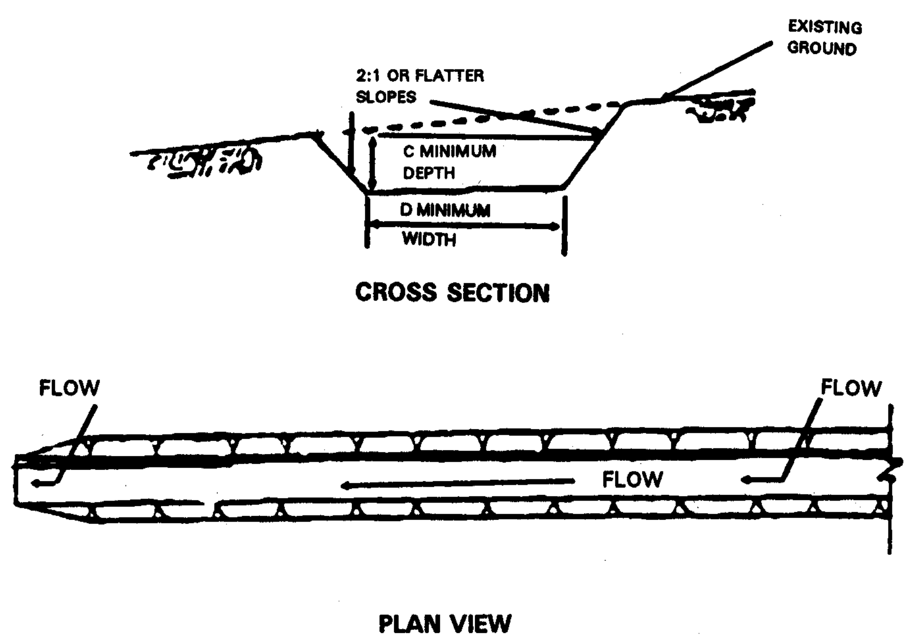


FIGURE 3.11 TEMPORARY SWALE
(Modified from Maryland Department of the Environment, 1991)

When and Where to Use It

A drainage swale applies when runoff is to be conveyed without causing erosion. Drainage swales can be used to convey runoff from the bottom or top of a slope. Drainage swales accomplish this by intercepting and diverting the flow to a suitable outlet. For swales draining a disturbed area, the outlet can be to a sediment trapping device prior to its release.

What to Consider

Since design flows, channel linings, and appropriate outlet devices will need to be considered, consult your State's requirements on such erosion control measures prior to constructing a drainage swale. General considerations include:

- Divert the intercepted runoff to an appropriate outlet.

- The swale should be lined using geotextiles, grass, sod, riprap, asphalt, or concrete. The selection of the liner is dependent upon the volume and the velocity of the anticipated runoff.
- The swale should have a positive grade. There should be no dips or low points in the swale where storm water will collect.

Advantages of a Drainage Swale
$ Excavation of swale can be easily performed with earth moving equipment
$ Can transport large volumes of runoff
Disadvantages of a Drainage Swale
$ Stabilization and design costs can make construction expensive
$ Use is restricted to areas with relatively flat slopes

Interceptor Dikes and Swales

What Are They

Interceptor dikes (ridges of compacted soil) and swales (excavated depressions) are used to keep upslope runoff from crossing areas where there is a high risk of erosion. They reduce the amount and speed of flow and then guide it to a stabilized outfall (point of discharge) or sediment trapping area (see sections on Sediment Traps and Temporary Sediment Basins). Interceptor dikes and swales divert runoff using a combination of earth dike and vegetated swale. Runoff is channeled away from locations where there is a high risk of erosion by placing a diversion dike or swale at the top of a sloping disturbed area. Dikes and swales also collect overland flow, changing it into concentrated flows. Interceptor dikes and swales can be either temporary or permanent storm water control structures.

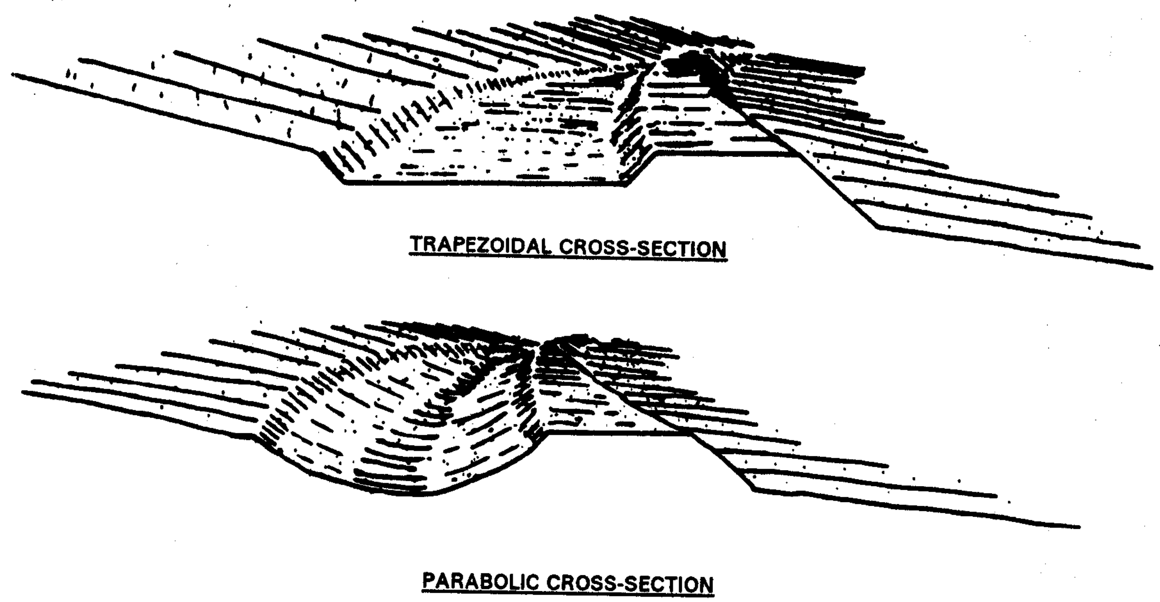


FIGURE 3.12 TYPICAL INTERCEPTOR DIKES AND SWALES
(Modified from State of Maryland, 1983)

When and Where to Use Them

Interceptor dikes and swales are generally built around the perimeter of a construction site before any major soil disturbing activity takes place. Temporary dikes or swales may also be used to protect existing buildings; areas, such as stockpiles; or other small areas that have not yet been fully stabilized. When constructed along the upslope perimeter of a disturbed or high-risk area (though not necessarily all the way around it), dikes or swales prevent runoff from uphill areas from crossing the unprotected slope. Temporary dikes or swales constructed on the down slope side of the disturbed or high-risk area will prevent runoff that contains sediment from leaving the site before sediment is removed. For short slopes, a dike or swale at the top of the slope reduces the amount of runoff

reaching the disturbed area. For longer slopes, several dikes or swales are placed across the slope at intervals. This practice reduces the amount of runoff that accumulates on the face of the slope and carries the runoff safely down the slope. In all cases, runoff is guided to a sediment trapping area or a stabilized outfall before release.

What to Consider

Temporary dikes and swales are used in areas of overland flow; if they remain in place longer than 15 days, they should be stabilized. Runoff channeled by a dike or swale should be directed to an adequate sediment trapping area or stabilized outfall. Care should be taken to provide enough slope for drainage but not too much slope to cause erosion due to high runoff flow speed. Temporary interceptor dikes and swales may remain in place as long as 12 to 18 months (with proper stabilization) or be rebuilt at the end of each day's activities. Dikes or swales should remain in place until the area they were built to protect is permanently stabilized. Interceptor dikes and swales can be permanent controls. However, permanent controls: should be designed to handle runoff after construction is complete; should be permanently stabilized; and should be inspected and maintained on a regular basis. Temporary and permanent control measures should be inspected once each week on a regular schedule and after every storm. Repairs necessary to the dike and flow channel should be made promptly.

Advantages of Interceptor Dikes and Swales
• Are simple and effective for channeling runoff away from areas subject to erosion • Can handle flows from large drainage areas • Are inexpensive because they use materials and equipment normally found onsite
Disadvantages of Interceptor Dikes and Swales
• If constructed improperly, can cause erosion and sediment transport since flows are concentrated • May cause problems to vegetation growth if water flow is too fast • Require additional maintenance, inspections, and repairs

Temporary Stream Crossing

What Is It

A temporary stream crossing is a bridge or culvert across a stream or watercourse for short-term use by construction vehicles or heavy equipment. Vehicles moving over unprotected stream banks will damage the bank, thereby releasing sediments and degrading the stream bank. A stream crossing provides a means for construction vehicles to cross streams or watercourses without moving sediment to streams, damaging the streambed or channel, or causing flooding.

When and Where to Use It

A temporary stream crossing is used when heavy equipment should be moved from one side of a stream channel to another, or where light-duty construction vehicles have to cross the stream channel frequently for a short period of time. Temporary stream crossings should be constructed only when it is necessary to cross a stream and a permanent crossing is not yet constructed.

- **BridgesC** Where available materials and designs are adequate to bear the expected loadings, bridges are preferred as a temporary stream crossing.
- **CulvertsC** Culverts are the most common type of stream crossings and are relatively easy to construct. A pipe, which is to carry the flow, is laid into the channel and covered by gravel.

What to Consider

When feasible, one should always attempt to minimize or eliminate the need to cross streams. Temporary stream crossings are a direct source of pollution; therefore, every effort should be made to use an alternate method (e.g., longer detour), when feasible. When it becomes necessary to cross a stream, a well planned approach will minimize the damage to the stream bank and reduce erosion. The design of temporary stream crossings requires knowledge of the design flows and other information; therefore, a professional engineer and specific State and local requirements should be consulted. State/local jurisdictions may require a separate permit for temporary stream crossings; contact them directly to learn about their exact requirements.

The specific loads and the stream conditions will dictate what type of stream crossing to employ. Bridges are the preferred method to cross a stream as they provide the least obstruction to flows and fish migration.

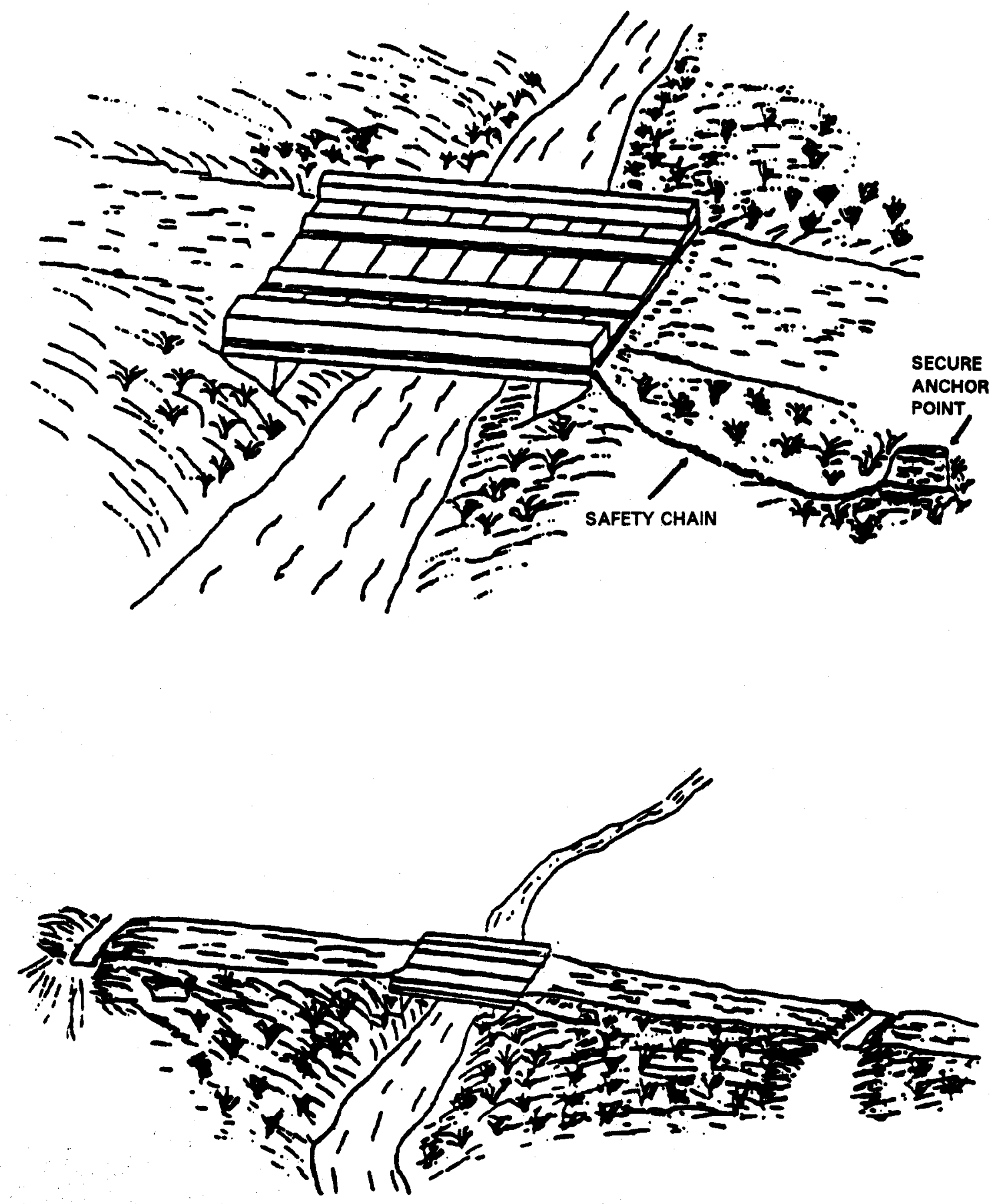


FIGURE 3.13 TEMPORARY ACCESS BRIDGE
(Modified from Maryland Department of the Environment, 1991)

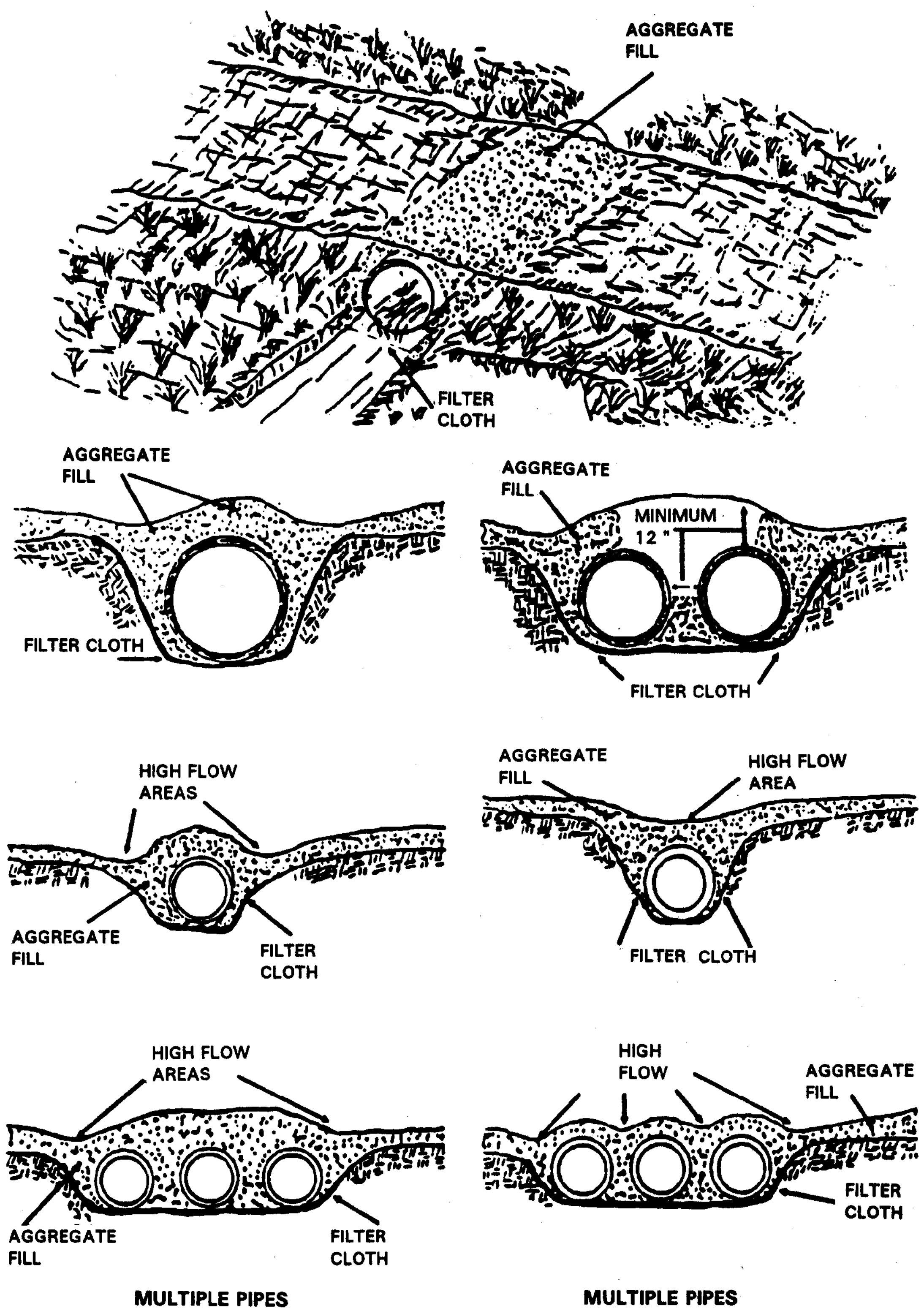


FIGURE 3.14 TEMPORARY ACCESS CULVERT
(Modified from Maryland Department of the Environment, 1991)

Advantages of a Temporary Stream Crossing
$ Bridges provide the least obstruction to flow and fish migration and the construction material can be salvaged $ Culverts are inexpensive and easily installed structures
Disadvantages of a Temporary Stream Crossing
$ Bridges are expensive to design and install $ Culverts cause greater disturbances during installation and removal

Temporary Storm Drain Diversion

What Is It

A temporary storm drain is a pipe which redirects an existing storm drain system or outfall channel to discharge into a sediment trap or basin.

When and Where to Use It

Use storm drain diversions to temporarily divert flow going to a permanent outfall. This diverted flow should be directed to a sediment-trapping device. A temporary storm drain diversion should remain in place as long as the area draining to the storm sewer remains disturbed. Another method is to delay completion of the permanent outfall and instead using temporary diversions to a sediment trapping device before discharge. Finally, a sediment trap or basin can be constructed below a permanent storm drain outfall. The basin would be designed to trap any sediment before final discharge.

What to Consider

Since the existing storm draining systems will be modified, careful consideration to piping configuration and resulting impact of installing a temporary storm drain diversion should be given. The temporary diversions will also need to be moved, once the construction has ceased and it is necessary to restore the original storm drainage systems. Therefore, appropriate restoration measures such as flushing the storm drain prior to removal of the sediment trap or basin, stabilizing the outfall, restoration of grade areas, etc. should be taken. And finally, the State or local requirements should be consulted for detailed requirements.

Advantages of a Temporary Storm Drain Diversion
§ Requires little maintenance once installed
Disadvantages of a Temporary Storm Drain Diversion
§ Disturbs existing storm drainage patterns

Pipe Slope Drains

What Are They

Pipe slope drains reduce the risk of erosion by discharging runoff to stabilized areas. Made of flexible or rigid pipe, they carry concentrated runoff from the top to the bottom of a slope that has already been damaged by erosion or is at high risk for erosion. They are also used to drain saturated slopes that have the potential for soil slides. Pipe slope drains can be either temporary or permanent depending on the method of installation and material used.

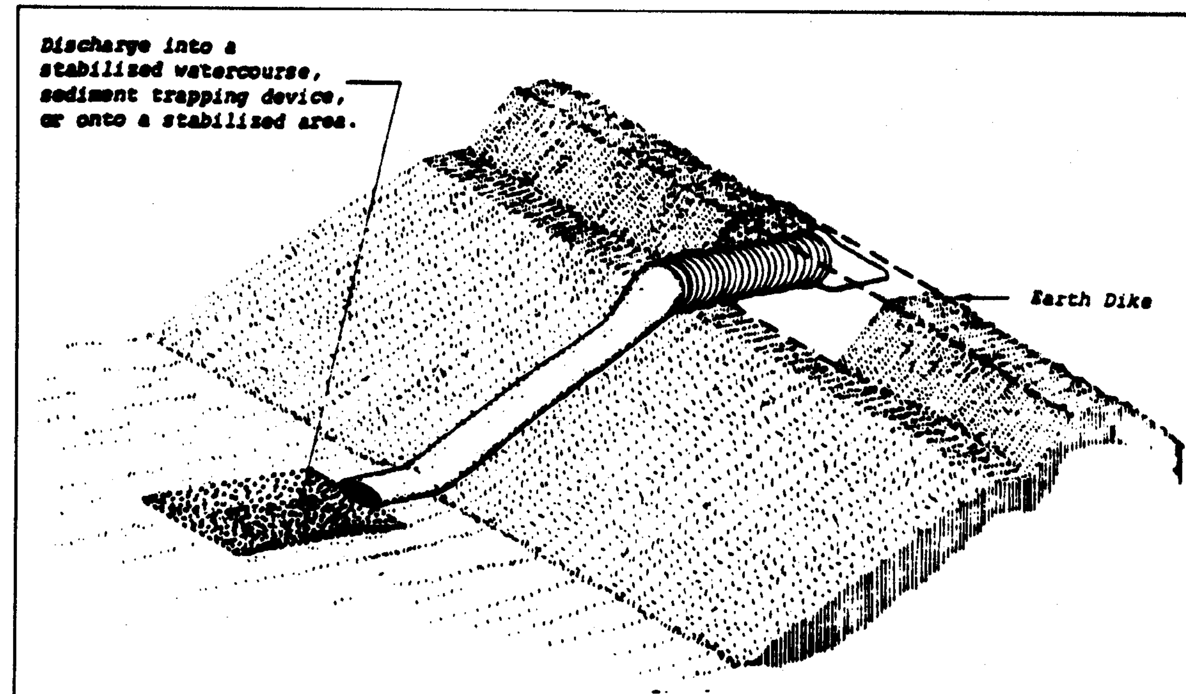


FIGURE 3.15 FLEXIBLE PIPE SLOPE DRAIN (Modified from State of Maryland, 1983)

When and Where to Use Them

Pipe slope drains are used whenever it is necessary to convey water down a slope without causing erosion. They are especially effective before a slope has been stabilized or before permanent drainage structures are ready for use. Pipe slope drains may be used with other devices, including diversion dikes or swales, sediment traps, and level spreaders (used to spread out storm water runoff uniformly over the surface of the ground). Temporary pipe slope drains, usually flexible tubing or conduit, may be installed prior to the construction of permanent drainage structures. Permanent slope drains may be placed on or beneath the ground surface; pipes, sectional downdrains, paved chutes, or clay tiles may be used.

Paved chutes may be covered with a surface of concrete or other impenetrable material. Subsurface drains can be constructed of concrete, PVC, clay tile, corrugated metal, or other permanent material.

What to Consider

The drain design should be able to handle the volume of flow. The inlets and outlets of a pipe slope drain should be stabilized. This means that a flared end section should be used at the entrance of the pipe. The soil around the pipe entrance should be fully compacted. The soil at the discharge end of the pipe should be stabilized with riprap (a combination of large stones, cobbles, and boulders). The riprap should be placed along the bottom of a swale which leads to a sediment trapping structure or another stabilized area.

Pipe slope drains should be inspected on a regular schedule and after any major storm. Be sure that the inlet from the pipe is properly installed to prevent bypassing the inlet and undercutting the structure. If necessary, install a headwall, riprap, or sandbags around the inlet. Check the outlet point for erosion and check the pipe for breaks or clogs. Install outlet protection if needed and promptly clear breaks and clogs.

Advantages of Pipe Slope Drains
- Can reduce or eliminate erosion by transporting runoff down steep slopes or by draining saturated soils - Are easy to install and require little maintenance
Disadvantages of Pipe Slope Drains
- Require that the area disturbed by the installation of the drain should be stabilized or it, too, will be subject to erosion - May clog during a large storm

Subsurface Drains

What Are They

A subsurface drain is a perforated pipe or conduit placed beneath the surface of the ground at a designed depth and grade. It is used to drain an area by lowering the water table. A high water table can saturate soils and prevent the growth of certain types of vegetation. Saturated soils on slopes will sometimes "slip" down the hill. Installing subsurface drains can help prevent these problems.

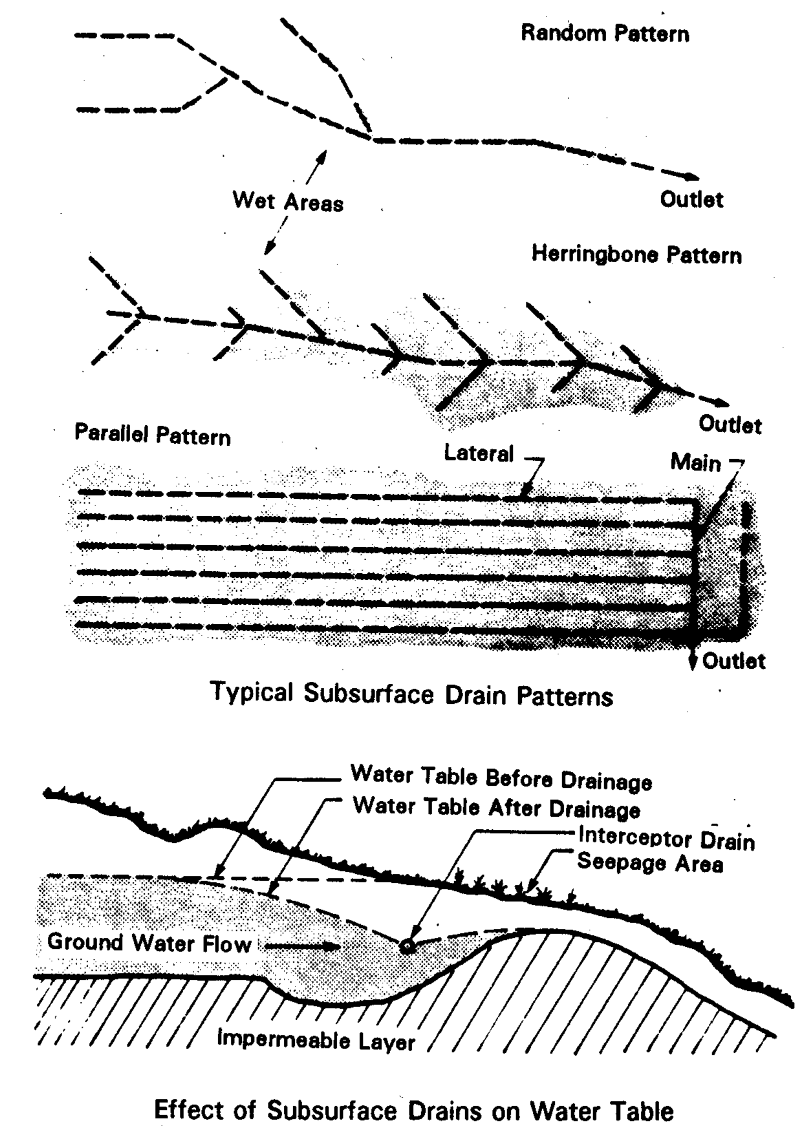


FIGURE 3.16 SUBSURFACE DRAINS
(Modified from Commonwealth of Virginia, 1980)

When and Where to Use Them

There are two types of subsurface drains: relief drains and interceptor drains. Relief drains are used to dewater an area where the water table is high. They may be placed in a gridiron, herringbone, or random pattern. Interceptor drains are used to remove water where sloping soils are excessively wet or subject to slippage. They are usually placed as single pipes instead of in patterns. Generally, subsurface drains are suitable only in areas where the soil is deep enough for proper installation. They are not recommended where they pass under heavy vehicle crossings.

What to Consider

Drains should be placed so that tree roots will not interfere with drainage pipes. The drain design should be adequate to handle the volume of flow. Areas disturbed by the installation of a drain should be stabilized or they, too, will be subject to erosion. The soil layer must be deep enough to allow proper installation.

Backfill immediately after the pipe is placed. Material used for backfill should be open granular soil that is highly permeable. The outlet should be stabilized and should direct sediment-laden storm water runoff to a sediment trapping structure or another stabilized area.

Inspect subsurface drains on a regular schedule and check for evidence of pipe breaks or clogging by sediment, debris, or tree roots. Remove blockage immediately, replace any broken sections, and restabilize the surface. If the blockage is from tree roots, it may be necessary to relocate the drain. Check inlets and outlets for sediment or debris. Remove and dispose of these materials properly.

Advantages of Subsurface Drains

- Provide an effective method for stabilizing wet sloping soils
- Are an effective way to lower the water table

Disadvantages of Subsurface Drains

- May be pierced and clogged by tree roots
- Should not be installed under heavy vehicle crossings
- Cost more than surface drains because of the expenses of excavation for installation

Silt Fence

What Is It

A silt fence, also called a "filter fence," is a temporary measure for sedimentation control. It usually consists of posts with filter fabric stretched across the posts and sometimes with a wire support fence. The lower edge of the fence is vertically trenched and covered by backfill. A silt fence is used in small drainage areas to detain sediment. These fences are most effective where there is overland flow (runoff that flows over the surface of the ground as a thin, even layer) or in minor swales or drainageways. They prevent sediment from entering receiving waters. Silt fences are also used to catch wind blown sand and to create an anchor for sand dune creation. Aside from the traditional wooden post and filter fabric method, there are several variations of silt fence installation including silt fence which can be purchased with pockets presewn to accept use of steel fence posts.

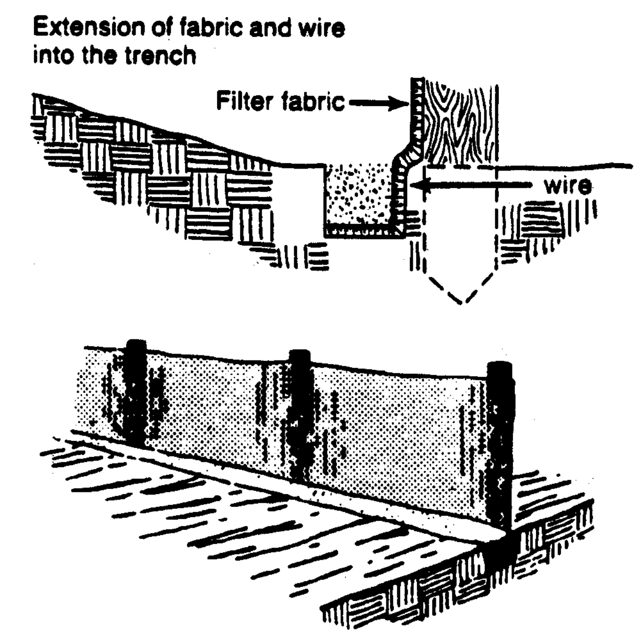


FIGURE 3.17 SILT FENCE DETAILS
(Modified from State of North Carolina, 1988; and State of Wisconsin, 1988)

When and Where to Use It

A silt fence should be installed prior to major soil disturbance in the drainage area. The fence should be placed across the bottom of a slope along a line of uniform elevation (perpendicular to the direction of flow). It can be used at the outer boundary of the work area. However, the fence does not have to surround the work area completely. In addition, a silt fence is effective where sheet and rill erosion may be a problem. Silt fences should not be constructed in streams or swales.

What to Consider

A silt fence is not appropriate for controlling runoff from a large area. This type of fence can be more effective than a straw bale barrier if properly installed and maintained. It may be used in combination with other erosion and sediment practices.

The effective life span for a silt fence depends upon the material of construction and maintenance. The fence requires frequent inspection and prompt maintenance to maintain its effectiveness. Inspect the fence after each rainfall. Check for areas where runoff eroded a channel beneath the fence, or where the fence was caused to sag or collapse by runoff flowing over the top. Remove and properly dispose of sediment when it is one-third to one-half the height of the fence or after each storm.

Advantages of a Silt Fence

- Removes sediments and prevents downstream damage from sediment deposits
- Reduces the speed of runoff flow
- Minimal clearing and grubbing required for installation
- Inexpensive

Disadvantages of a Silt Fence

- May result in failure from improper choice of pore size in the filter fabric or improper installation
- Should not be used in streams
- Is only appropriate for small drainage areas with overland flow
- Frequent inspection and maintenance is necessary to ensure effectiveness

Gravel or Stone Filter Berm

What Is It

A gravel or stone filter berm is a temporary ridge constructed of loose gravel, stone, or crushed rock. It slows and filters flow, diverting it from an exposed traffic area. Diversions constructed of compacted soil may be used where there will be little or no construction traffic within the right-of way. They are also used for directing runoff from the right-of-way to a stabilized outlet.

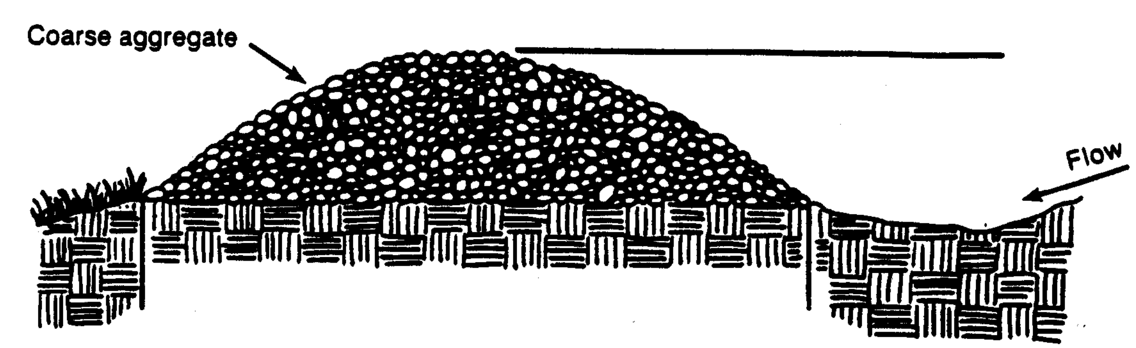


FIGURE 3.18 TYPICAL GRAVEL FILTER BERM
(Modified from Commonwealth of Virginia, 1980)

When and Where to Use It

This method is appropriate where roads and other rights-of-way under construction should accommodate vehicular traffic. Berms are meant for use in areas with gentle slopes. They may also be used at traffic areas within the construction site.

What to Consider

Berm material should be well graded gravel or crushed rock. The spacing of the berms will depend on the steepness of the slope: berms should be placed closer together as the slope increases. The diversion should be inspected regularly after each rainfall, or if breached by construction or other vehicles. All needed repairs should be performed immediately. Accumulated sediment should be removed and properly disposed of and the filter material replaced, as necessary.

Advantages of a Gravel or Stone Filter Berm
$ Is a very efficient method of sediment control $ Reduces the speed of runoff flow

Disadvantages of a Gravel or Stone Filter Berm
$ Is more expensive than methods that use onsite materials $ Has a very limited life span $ Can be difficult to maintain because of clogging from mud and soil on vehicle tires

Storm Drain Inlet Protection

What Is It

Storm drain inlet protection is a filtering measure placed around any inlet or drain to trap sediment. This mechanism prevents the sediment from entering inlet structures. Additionally, it serves to prevent the silting-in of inlets, storm drainage systems, or receiving channels. Inlet protection may be composed of gravel and stone with a wire mesh filter, block and gravel, filter fabric, or sod.

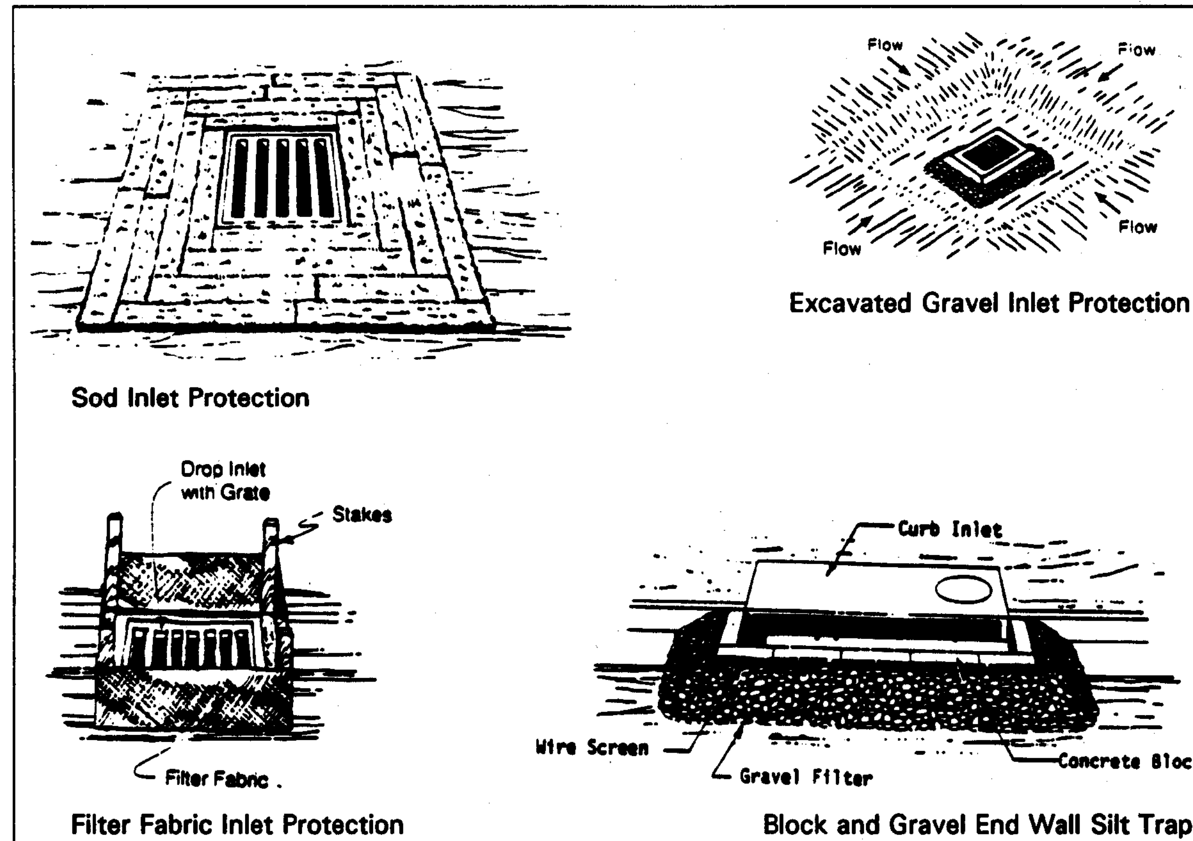


FIGURE 3.19 EXAMPLES OF STORM DRAIN INLET PROTECTION
(Modified from State of North Carolina, 1988; Washington State, 1992; and County of Fairfax, 1987)

When and Where to Use It

This type of protection is appropriate for small drainage areas where storm drain inlets will be ready for use before final stabilization. Storm drain inlet protection is also used where a permanent storm drain structure is being constructed onsite. Straw bales are not recommended for this purpose. Filter fabric is used for inlet protection when storm water flows are relatively small with low velocities. This practice cannot be used where inlets are paved because the filter fabric should be staked. Block and gravel filters can be used where velocities are higher. Gravel and mesh filters can be used where flows are higher and subject to disturbance by site traffic. Sod inlet filters are generally used where sediments in the storm water runoff are low.

What to Consider

Storm drain inlet protection is not meant for use in drainage areas exceeding 1 acre or for large concentrated storm water flows. Installation of this measure should take place before any soil disturbance in the drainage area. The type of material used will depend on site conditions and the size of the drainage area. Inlet protection should be used in combination with other measures, such as small impoundments or sediment traps, to provide more effective sediment removal. Inlet protection structures should be inspected regularly, especially after a rainstorm. Repairs and silt removal should be performed as necessary. Storm drain inlet protection structures should be removed only after the disturbed areas are completely stabilized.

Advantages of Storm Drain Inlet Protection
$ Prevents clogging of existing storm drainage systems and the siltation of receiving waters $ Reduces the amount of sediment leaving the site
Disadvantages of Storm Drain Inlet Protection
$ May be difficult to remove collected sediment $ May cause erosion elsewhere if clogging occurs $ Is practical only for low sediment, low volume flows (disturbed areas less than one acre)

Sediment Trap

What Is It

A sediment trap is formed by excavating a pond or by placing an earthen embankment across a low area or drainage swale. An outlet or spillway is constructed using large stones or aggregate to slow the release of runoff. The trap retains the runoff long enough to allow most of the silt to settle out.

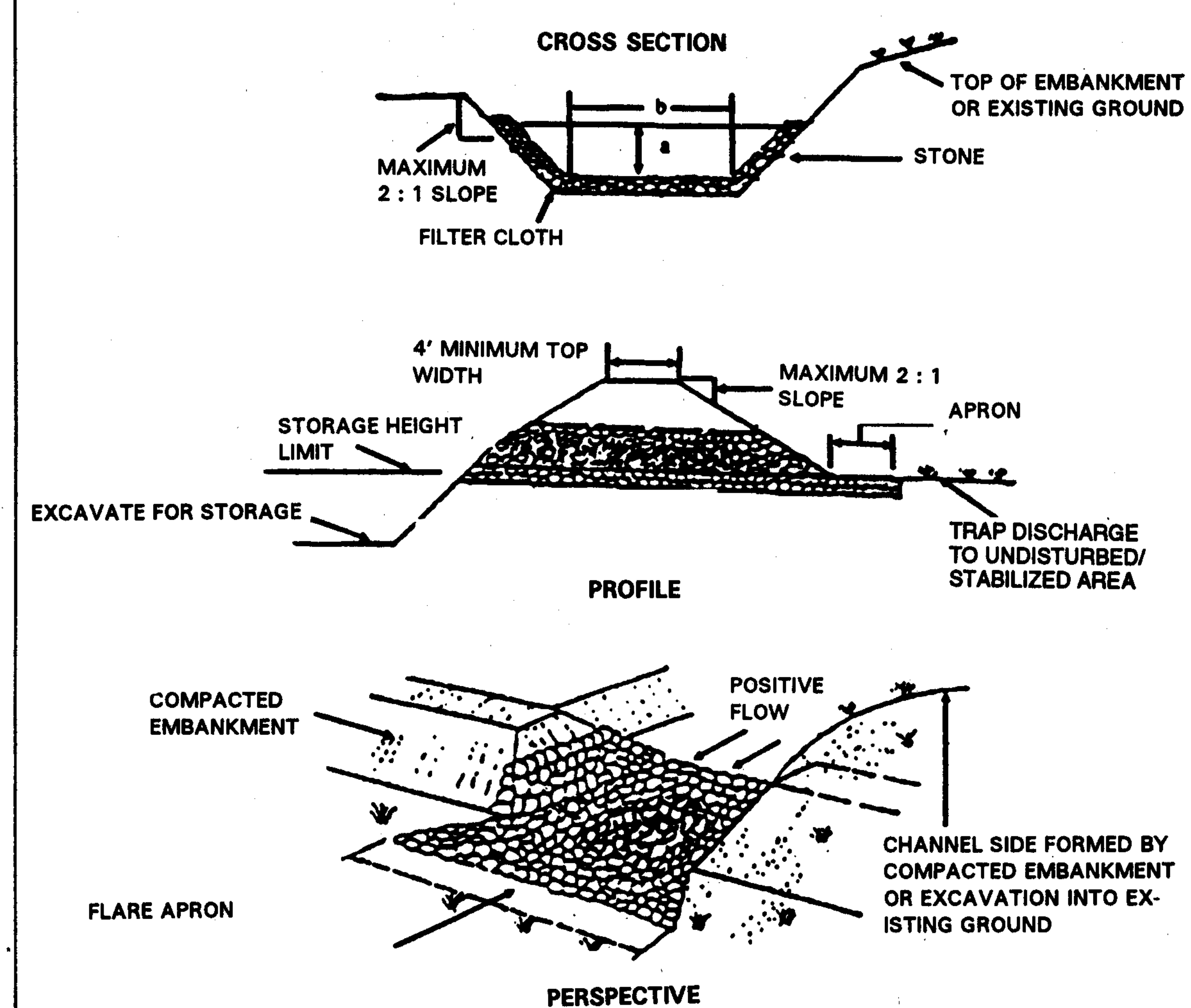


FIGURE 3.20 TYPICAL SEDIMENT TRAP
(Modified from State of Maryland, 1991)

When and Where to Use It

A temporary sediment trap may be used in conjunction with other temporary measures, such as gravel construction entrances, vehicle wash areas, slope drains, diversion dikes and swales, or diversion channels.

What to Consider

Sediment traps are suitable for small drainage areas, usually no more than 10 acres. The trap should be large enough to allow the sediments to settle and should have a capacity to store the collected sediment until it is removed. The volume of storage required depends upon the amount and intensity of expected rainfall and on estimated quantities of sediment in the storm water runoff. Check your Permit to see if it specifies a minimum storage volume for sediment traps.

The effective life of a sediment trap depends upon adequate maintenance. The trap should be readily accessible for periodic maintenance and sediment removal. Traps should be inspected after each rainfall and cleaned when no more than half the design volume has been filled with collected sediment. The trap should remain in operation and be properly maintained until the site area is permanently stabilized by vegetation and/or when permanent structures are in place.

Advantages of a Temporary Sediment Trap
$ Protects downstream areas from clogging or damage due to sediment deposits
$ Is inexpensive and simple to install
$ Can simplify the design process by trapping sediment at specific spots onsite
Disadvantages of a Temporary Sediment Trap
$ Is suitable only for a limited area
$ Is effective only if properly maintained
$ Will not remove very fine silts and clays

Temporary Sediment Basin

What Is It

A temporary sediment basin is a settling pond with a controlled storm water release structure used to collect and store sediment produced by construction activities. A sediment basin can be constructed by excavation and/or by placing an earthen embankment across a low area or drainage swale. Sediment basins can be designed to maintain a permanent pool or to drain completely dry. The basin detains sediment-laden runoff from larger drainage areas long enough to allow most of the sediment to settle out.

The pond has a riser and pipe outlet with a gravel outlet or spillway to slow the release of runoff and provide some sediment filtration. By removing sediment, the basin helps prevent clogging of offsite conveyance systems and sediment-loading of receiving waterways. In this way, the basin helps prevent destruction of waterway habitats.

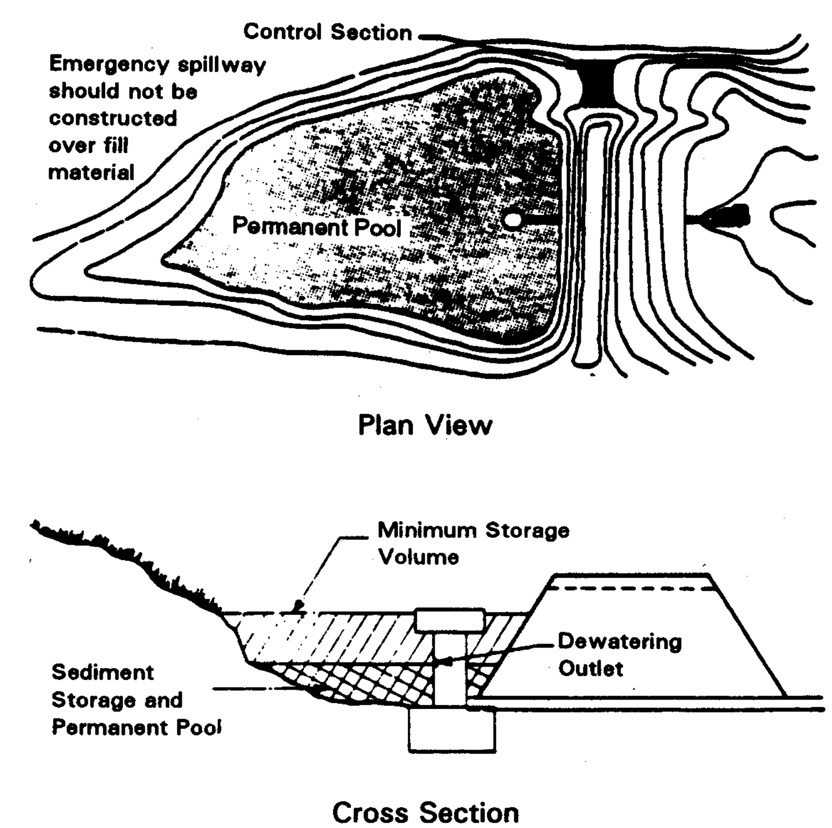


FIGURE 3.21 TEMPORARY SEDIMENT BASIN (Modified from Commonwealth of Virginia, 1980)

When and Where to Use It

A temporary sediment basin should be installed before clearing and grading is undertaken. It should not be built on an embankment in an active stream. The creation of a dam in such a site may result in the destruction of aquatic habitats. Dam failure can also result in flooding. A temporary sediment basin should be located only if there is sufficient space and appropriate topography. The basin should be made large enough to handle the maximum expected amount of site drainage. Fencing around the basin may be necessary for safety or vandalism reasons.

A temporary sediment basin used in combination with other control measures, such as seeding or mulching, is especially effective for removing sediments.

What to Consider

Temporary sediment basins are usually designed for disturbed areas larger than 5 acres. The pond should be large enough to hold runoff long enough for sediment to settle. Sufficient space should be allowed for collected sediments. Check the requirements of your permit to see if there is a minimum storage requirement for sediment basins. The useful life of a temporary sediment basin is dependent upon adequate maintenance.

Sediment trapping efficiency is improved by providing the maximum surface area possible. Because finer silts may not settle out completely, additional erosion control measures should be used to minimize release of fine silt. Runoff should enter the basin as far from the outlet as possible to provide maximum retention time.

Sediment basins should be readily accessible for maintenance and sediment removal. They should be inspected after each rainfall and be cleaned out when about half the volume has been filled with sediment. The sediment basin should remain in operation and be properly maintained until the site area is permanently stabilized by vegetation and/or when permanent structures are in place. The embankment forming the sedimentation pool should be well compacted and stabilized with vegetation. If the pond is located near a residential area, it is recommended for safety reasons that a sign be posted and that the area be secured by a fence. A well built temporary sediment basin that is large enough to handle the post construction runoff volume may later be converted to use as a permanent storm water management structure.

The sediment basins outlet pipe and spill way should be designed by an engineer based upon an analysis of the expected runoff flow rates from the site. Consult your state/local requirements to determine the frequency of the storm for which the outlet must be designed.

EPA BASELINE GENERAL PERMIT REQUIREMENTS
Sediment Basin Requirements
Part IV.D.2.a.(2).(a).
For common drainage locations that serve an area with 10 or more disturbed acres at one time, a temporary (or permanent) sediment basin providing 3,600 cubic feet of storage per acre drained, or equivalent control measures, shall be provided where attainable until final stabilization of the site. The 3,600 cubic feet of storage area per acre drained does not apply to flows from offsite areas and flows from onsite areas that are either undisturbed or have undergone final stabilization where such flows are diverted around the sediment basin. For drainage locations which serve 10 or more disturbed acres at one time and where a temporary sediment basin providing 3,600 cubic feet of storage per acre drained, or equivalent controls is not attainable, sediment traps, silt fences, or equivalent sediment controls are required for all sideslope and downslope boundaries of the construction area.

Advantages of a Temporary Sediment Basin

$ Protects downstream areas from clogging or damage due to sediment deposits generated during construction activities

$ Can trap smaller sediment particles than sediment traps can because of the longer detention time

$ Can be converted to a permanent storm water detention structure, once construction is complete

Disadvantages of a Temporary Sediment Basin

$ Is generally suitable for small areas

$ Requires regular maintenance and cleaning

$ Will not remove very fine silts and clays unless used in conjunction with other measures

$ Is a more expensive way to remove sediment than several other methods

$ Requires careful adherence to safety practices since ponds are attractive to children

Outlet Protection

What Is It

Outlet protection reduces the speed of concentrated storm water flows and therefore it reduces erosion or scouring at storm water outlets and paved channel sections. In addition, outlet protection lowers the potential for downstream erosion. This type of protection can be achieved through a variety of techniques, including stone or riprap, concrete aprons, paved sections and settling basins installed below the storm drain outlet.

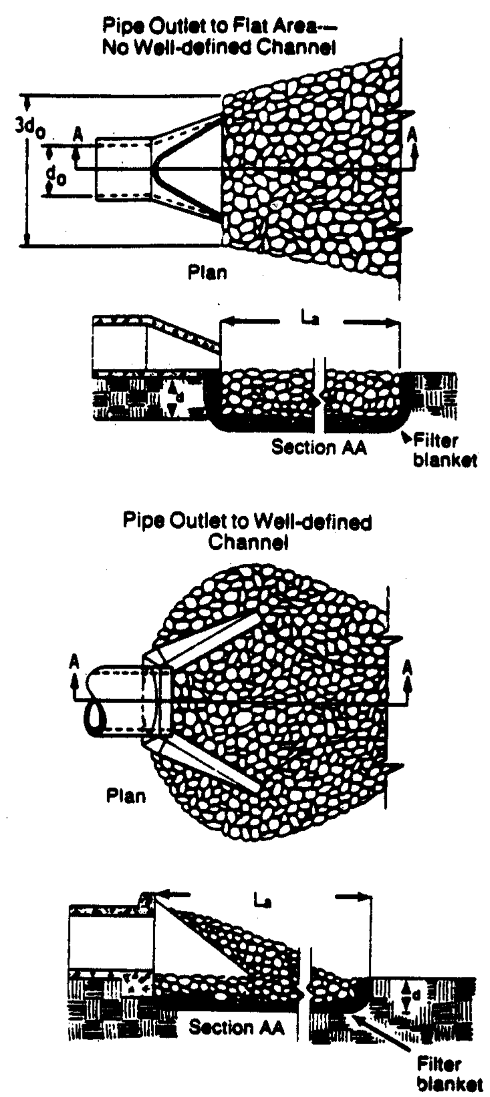


FIGURE 3.22 TYPICAL DETAILS FOR ROCK OUTLET PROTECTION
(Modified from State of North Carolina, 1988)

When and Where to Use It

Outlet protection should be installed at all pipe, interceptor dike, swale, or channel section outlets where the velocity of flow may cause erosion at the pipe outlet and in the receiving channel. Outlet protection should also be used at outlets where the velocity of flow at the design capacity may result in plunge pools (small permanent pools located at the inlet to or the outfall from BMPs). Outlet protection should be installed early during construction activities, but may be added at any time, as necessary.

What to Consider

The exit velocity of the runoff as it leaves the outlet protection structure should be reduced to levels that minimize erosion. Outlet protection should be inspected on a regular schedule to look for erosion and scouring. Repairs should be made promptly.

Advantages of Outlet Protection
$ Provides, with riprap-line apron (the most common outlet protection), a relatively low cost method that can be installed easily on most sites $ Removes sediment in addition to reducing flow speed $ Can be used at most outlets where the flow speed is high $ Is an inexpensive but effective measure $ Requires less maintenance than many other measures
Disadvantages of Outlet Protection
$ May be unsightly $ May cause problems in removing sediment (without removing and replacing the outlet protection structure itself) $ May require frequent maintenance for rock outlets with high velocity flows

Check Dams

What Are They

A check dam is a small, temporary or permanent dam constructed across a drainage ditch, swale, or channel to lower the speed of concentrated flows. Reduced runoff speed reduces erosion and gullying in the channel and allows sediments to settle out.

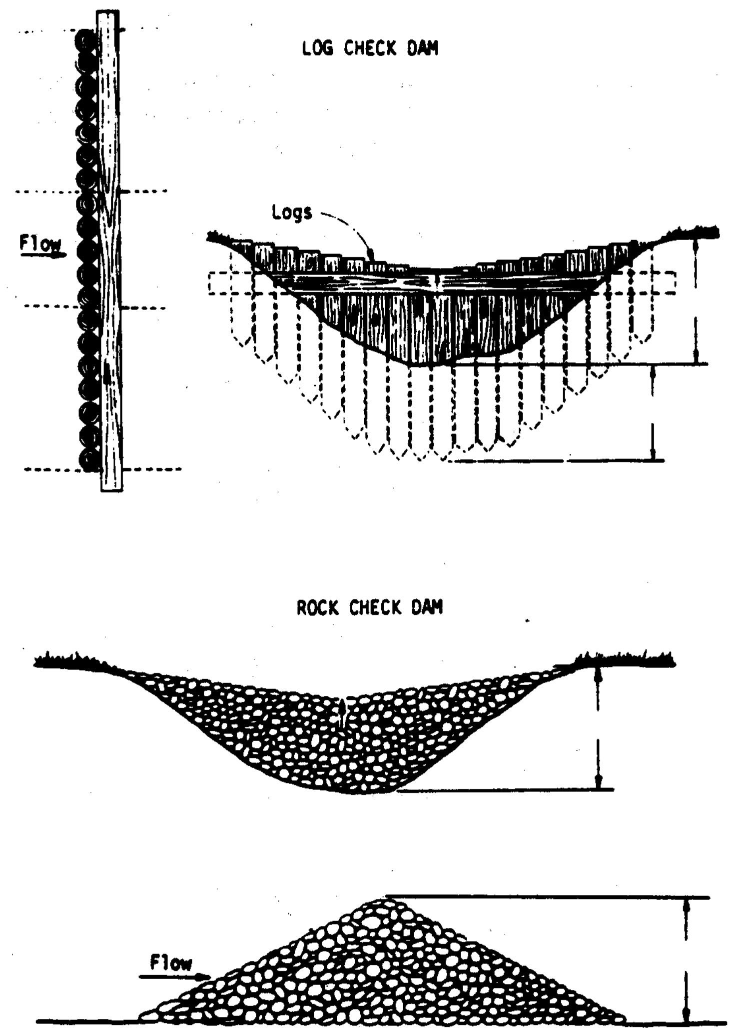


FIGURE 3.23 TYPICAL CHECK DAMS
(Modified from Commonwealth of Virginia, 1980)

When and Where to Use Them

A check dam should be installed in steeply sloped swales, or in swales where adequate vegetation cannot be established. A check dam may be built from logs, stone, or pea gravel-filled sandbags.

What to Consider

Check dams should be used only in small open channels which will not be overtopped by flow once the dams are constructed. The dams should not be placed in streams (unless approved by appropriate State authorities). The center section of the check dam should be lower than the edges. Dams should be spaced so that the toe of the upstream dam is at the same elevation as the top of the downstream dam.

After each significant rainfall, check dams should be inspected for sediment and debris accumulation. Sediment should be removed when it reaches one half the original dam height. Check for erosion at edges and repair promptly as required. After construction is complete, all stone and riprap should be removed if vegetative erosion controls will be used as a permanent erosion control measure. It will be important to know the expected erosion rates and runoff flow rate for the swale in which this measure is to be installed. Contact the State/local storm water program agency or a licensed engineer for assistance in designing this measure.

Advantages of Check Dams
$ Are inexpensive and easy to install
$ May be used permanently if designed properly
$ Allow a high proportion of sediment in the runoff to settle out
$ Reduce velocity and may provide aeration of the water
$ May be used where it is not possible to divert the flow or otherwise stabilize the channel
Disadvantages of Check Dams
$ May kill grass linings in channels if the water level remains high after it rains or if there is significant sedimentation
$ Reduce the hydraulic capacity of the channel
$ May create turbulence which erodes the channel banks

Surface Roughening

What Is It

Surface roughening is a temporary erosion control practice. The soil surface is roughened by the creation of horizontal grooves, depressions, or steps that run parallel to the contour of the land. Slopes that are not fine-graded and that are left in a roughened condition can also control erosion. Surface roughening reduces the speed of runoff, increases infiltration, and traps sediment. Surface roughening also helps establish vegetative cover by reducing runoff velocity and giving seed an opportunity to take hold and grow.

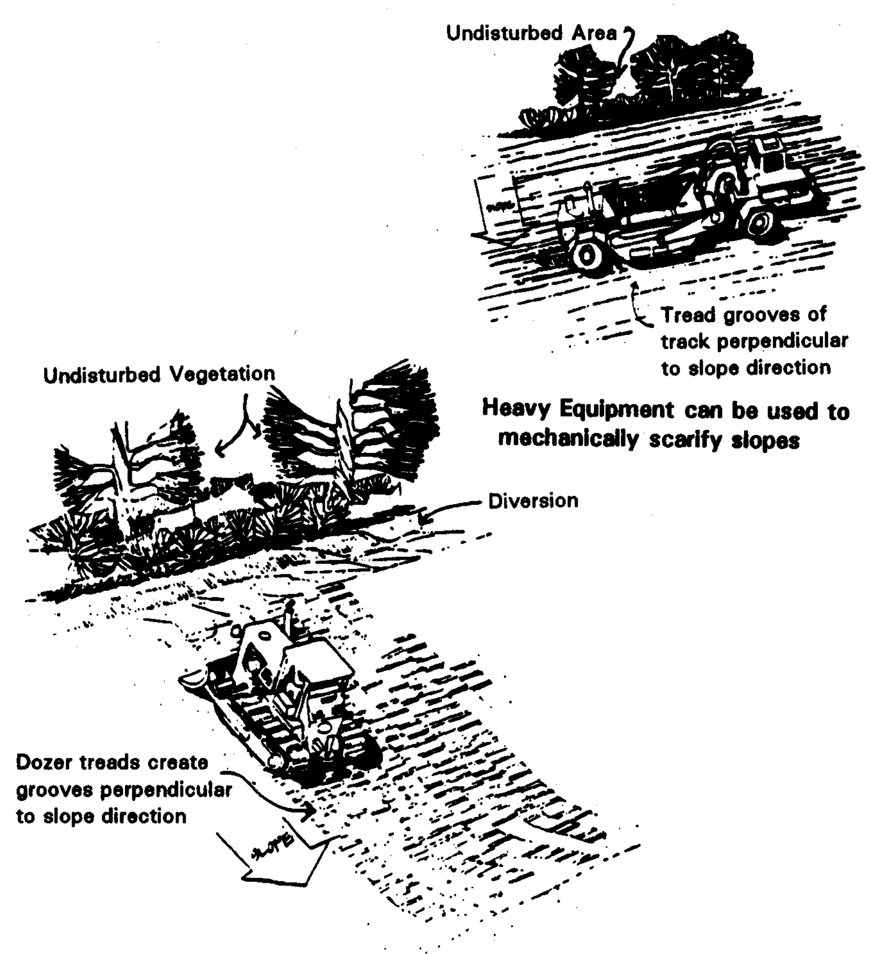


FIGURE 3.24 SURFACE ROUGHENING
(Modified from Washington State, 1992)

When and Where to Use It

Surface roughening is appropriate for all slopes. To slow erosion, roughening should be done as soon as possible after the vegetation has been removed from the slope. Roughening can be used with both seeding and planting and temporary mulching to stabilize an area. For steeper slopes and slopes that will be left roughened for longer periods of time, a combination of surface roughening and vegetation is appropriate. Surface roughening should be performed immediately after grading activities have ceased (temporarily or permanently) in an area.

What to Consider

Different methods can be used to roughen the soil surface on slopes. They include stair-step grading, grooving (using disks, spring harrows, or teeth on a front-end loader), and tracking (driving a crawler tractor up and down a slope, leaving the cleat imprints parallel to the slope contour). The selection of an appropriate method depends on the grade of the slope, mowing requirements after vegetative cover is established, whether the slope was formed by cutting or filling, and type of equipment available.

Cut slopes with a gradient steeper than 3:1 but less than 2:1 should be stair-step graded or groove cut. Stair-step grading works well with soils containing large amounts of small rock. Each step catches material discarded from above and provides a level site where vegetation can grow. Stairs should be wide enough to work with standard earth moving equipment. Grooving can be done by any implement that can be safely operated on the slope, including those described above. Grooves should not be less than 3 inches deep nor more than 15 inches apart. Fill slopes with a gradient steeper than 3:1 but less than 2:1 should be compacted every 9 inches of depth. The face of the slope should consist of loose, uncompacted fill 4 to 6 inches deep that can be left rough or can be grooved as described above, if necessary.

Any cut or filled slope that will be mowed should have a gradient less than 3:1. Such a slope can be roughened with shallow grooves parallel to the slope contour by using normal tilling. Grooves should be close together (less than 10 inches) and not less than 1 inch deep. Any gradient with a slope greater than 2:1 should be stair-stepped.

It is important to avoid excessive compacting of the soil surface, especially when tracking, because soil compaction inhibits vegetation growth and causes higher runoff speed. Therefore, it is best to limit roughening with tracked machinery to sandy soils that do not compact easily and to avoid tracking on clay soils. Surface roughened areas should be seeded as quickly as possible. Also, regular inspections should be made of all surface roughened areas, especially after storms. If rills (small watercourses that have steep sides and are usually only a few inches deep) appear, they should be filled, graded again, and reseeded immediately. Proper dust control procedures should be followed when surface roughening.

Advantages of Surface Roughening
$ Provides a degree of instant erosion protection for bare soil while vegetative cover is being established $ Is inexpensive and simple for short-term erosion control
Disadvantages of Surface Roughening
$ Is of limited effectiveness in anything more than a gentle rain $ Is only temporary; if roughening is washed away in a heavy storm, the surface will have to be re-roughened and new seed laid

Gradient Terraces

What Are They

Gradient terraces are earth embankments or ridge-and-channels constructed along the face of a slope at regular intervals. Gradient terraces are constructed at a positive grade. They reduce erosion damage by capturing surface runoff and directing it to a stable outlet at a speed that minimizes erosion.

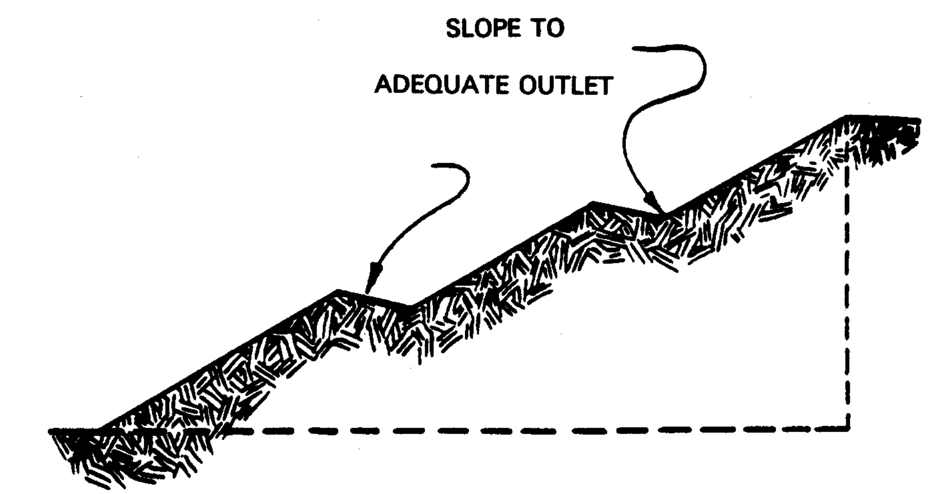


FIGURE 3.25 GRADIENT TERRACE (Washington State, 1992)

When and Where to Use Them

Gradient terraces are usually limited to use on long, steep slopes with a water erosion problem, or where it is anticipated that water erosion will be a problem. Gradient terraces should not be constructed on slopes with sandy or rocky soils. They will be effective only where suitable runoff outlets are or will be made available.

What to Consider

Gradient terraces should be designed and installed according to a plan determined by an engineering survey and layout. It is important that gradient terraces are designed with adequate outlets, such as a grassed waterway, vegetated area, or tile outlet. In all cases, the outlet should direct the runoff from the terrace system to a point where the outflow will not cause erosion or other damage. Vegetative cover should be used in the outlet where possible. The design elevation of the water surface of the terrace should not be lower than the design elevation of the water surface in the outlet at their junction, when both are operating at design flow. Terraces should be inspected regularly at least once a year and after major storms. Proper vegetation/stabilization practices should be followed while constructing these features.

Advantages of Gradient Terraces
$ Reduce runoff speed and increase the distance of overland runoff flow $ Hold moisture better than do smooth slopes and minimize sediment loading of surface runoff
Disadvantages of Gradient Terraces
$ May significantly increase cut and fill costs and cause sloughing if excessive water infiltrates the soil $ Are not practical for sandy, steep, or shallow soils

3.3 SUMMARY

Erosion of disturbed soils on construction sites can be prevented in many cases. When it is not possible to prevent the erosion, then the sediment can be trapped onsite. This chapter describes the measures used for erosion and sediment control and provides guidance for selecting the most appropriate measure for a particular site. The descriptions of the measures contained in this chapter are intended to provide general understanding of the measures rather than detailed design information. Check with your State or local erosion and sediment control agency to obtain a copy of their design standards or guidance. If your State or local agency does not have design standards or guidance, then refer to the design "Fact Sheets" contained in Appendix B of this manual.

Erosion and sediment control measures are a critical component of a Storm Water Pollution Prevention Plan and of a construction project. These measures should be designed and constructed in the most effective manner.

APPENDIX B

BMP FACT SHEETS

SILT FENCE

September 1992

Design Criteria

- Silt fences are appropriate at the following general locations:
  - Immediately upstream of the point(s) of runoff discharge from a site before flow becomes concentrated (maximum design flow rate should not exceed 0.5 cubic feet per second).
  - Below disturbed areas where runoff may occur in the form of overland flow.
- Ponding should not be allowed behind silt fences since they will collapse under high pressure; the design should provide sufficient outlets to prevent overtopping.
- The drainage area should not exceed 0.25 acre per 100 feet of fence length.
- For slopes between 50:1 and 5:1, the maximum allowable upstream flow path length to the fence is 100 feet; for slopes of 2:1 and steeper, the maximum is 20 feet.
- The maximum upslope grade perpendicular to the fence line should not exceed 1:1.
- Synthetic silt fences should be designed for 6 months of service; burlap is only acceptable for periods of up to 60 days.

Materials

- Synthetic filter fabric should be a pervious sheet of polypropylene, nylon, polyester, or polyethylene yarn conforming to the requirements in Table 1 below.

TABLE 1. SYNTHETIC FILTER FABRIC REQUIREMENTS

Physical Property	Requirements
Filtering Efficiency	75% - 85% (minimum)
Tensile Strength at 20% (maximum) Elongation	Standard Strength - 30 lb/linear inch (minimum)
	Extra Strength - 50 lb/linear inch (minimum)
Slurry Flow Rate	0.3 gal/ft^2/min (minimum)

- Synthetic filter fabric should contain ultraviolet ray inhibitors and stabilizers to provide a minimum of 6 months of expected usable construction life at a temperature range of 0 to 120°F.
- Burlap of 10 ounces per square yard of fabric can also be used.
- The filter fabric should be purchased in a continuous roll to avoid joints.
- While not required, wire fencing may be used as a backing to reinforce standard strength filter fabric. The wire fence (14 gauge minimum) should be at 22-48 inches wide and should have a maximum mesh spacing of 6 inches.
- Posts should be 2-4 feet long and should be composed of either 2" x 2-4" pine (or equivalent) or 1.00 to 1.33 lb/linear ft steel. Steel posts should have projections for fastening wire and fabric to them.

Construction Specifications

- The maximum height of the filter fence should range between 18 and 36 inches above the ground surface (depending on the amount of upslope ponding expected).

SILT FENCE

- Posts should be spaced 8 to 10 feet apart when a wire mesh support fence is used and no more than 6 feet apart when extra strength filter fabric (without a wire fence) is used. The posts should extend 12 to 30 inches into the ground.
- A trench should be excavated 4 to 8 inches wide and 4 to 12 inches deep along the upslope side of the line of posts.
- If standard strength filter fabric is to be used, the optional wire mesh support fence may be fastened to the upslope side of the posts using 1 inch heavy duty wire staples, tie wires, or hog rings. Extend the wire mesh support to the bottom of the trench. The filter fabric should then be stapled or wired to the fence, and 8 to 20 inches of the fabric should extend into the trench (Figure 1).
- Extra strength filter fabric does not require a wire mesh support fence. Staple or wire the filter fabric directly to the posts and extend 8 to 20 inches of the fabric into the trench (Figure 1).
- Where joints in the fabric are required, the filter cloth should be spliced together only at a support post, with a minimum 6-inch overlap, and securely sealed.
- Do not attach filter fabric to trees.
- Backfill the trench with compacted soil or 0.75 inch minimum diameter gravel placed over the filter fabric.

Maintenance

- Inspect filter fences daily during periods of prolonged rainfall, immediately after each rainfall event, and weekly during periods of no rainfall. Make any required repairs immediately.
- Sediment must be removed when it reaches one-third to one-half the height of the filter fence. Take care to avoid damaging the fence during cleanout.
- Filter fences should not be removed until the upslope area has been permanently stabilized. Any sediment deposits remaining in place after the filter fence has been removed should be dressed to conform with the existing grade, prepared, and seeded.

Cost

- Silt fence installation costs approximately $6.00 per linear foot.

Sources

- Commonwealth of Virginia - County of Fairfax, 1987. 1987 Check List For Erosion And Sediment Control - Fairfax County, Virginia.
- State of North Carolina, 1988. Erosion and Sediment Control Planning and Design Manual. North Carolina Sedimentation Control Commission, Department of Natural Resources and Community Development.
- Maryland Department of the Environment, 1991. 1991 Maryland Standards And Specifications For Soil Erosion And Sediment Control - Draft.

PIPE SLOPE DRAIN

September 1992

Design Criteria

- Pipe Slope Drains (PSD) are appropriate in the following general locations:
  - On cut or fill slopes before permanent storm water drainage structures have been installed.
  - Where earth dikes or other diversion measures have been used to concentrate flows.
  - On any slope where concentrated runoff crossing the face of the slope may cause gullies, channel erosion, or saturation of slide-prone soils.
  - As an outlet for a natural drainageway.
- The drainage area may be up to 10 acres; however, many jurisdictions consider 5 acres the recommended maximum.
- The PSD design should handle the peak runoff for the 10-year storm. Typical relationships between area and pipe diameter are shown in Table 2 below.

TABLE 2. RELATIONSHIP BETWEEN AREA AND PIPE DIAMETER

Maximum Drainage Area (Acres)	Pipe Diameter (D) (Inches)
0.5	12
0.75	15
1.0	18

Materials

- Pipe may be heavy duty flexible tubing designed for this purpose, e.g., nonperforated, corrugated plastic pipe, corrugated metal pipe, bituminous fiber pipe, or specially designed flexible tubing.
- A standard flared end section secured with a watertight fitting should be use for the inlet. A standard T-section fitting may also be used.
- Extension collars should be 12-inch long sections of corrugated pipe. All fittings must be watertight.

Construction Specifications

- Place the pipe slope drain on undisturbed or well-compacted soil.
- Soil around and under the entrance section must be hand-tamped in 4-inch to 8-inch lifts to the top of the dike to prevent piping failure around the inlet.
- Place filter cloth under the inlet and extend 5 feet in front of the inlet and be keyed in 6-inches on all sides to prevent erosion. A 6-inch metal toe plate may also be used for this purpose.
- Ensure firm contact between the pipe and the soil at all points by backfilling around and under the pipe with stable soil material hand compacted in lifts of 4-inches to 8-inches.
- Securely stake the PSD to the slope using grommets provided for this purpose at intervals of 10 feet or less.
- Ensure that all slope drain sections are securely fastened together and have watertight fittings.

PIPE SLOPE DRAIN

- Extend the pipe beyond the toe of the slope and discharge at a nonerosive velocity into a stabilized area (e.g., rock outlet protection may be used) or to a sedimentation trap or pond.
- The PSD should have a minimum slope of 3 percent or steeper.
- The height at the centerline of the earth dike should range from a minimum of 1.0 foot over the pipe to twice the diameter of the pipe measured from the invert of the pipe. It should also be at least 6 inches higher than the adjoining ridge on either side.
- At no point along the dike will the elevation of the top of the dike be less than 6 inches higher than the top of the pipe.
- Immediately stabilize all areas disturbed by installation or removal of the PSD.

Maintenance

- Inspect regularly and after every storm. Make any necessary repairs.
- Check to see that water is not bypassing the inlet and undercutting the inlet or pipe. If necessary, install headwall or sandbags.
- Check for erosion at the outlet point and check the pipe for breaks or clogs. Install additional outlet protection if needed and immediately repair the breaks and clean any clogs.
- Do not allow construction traffic to cross the PSD and do not place any material on it.
- If a sediment trap has been provided, clean it out when the sediment level reaches 1/3 to 1/2 the design volume.
- The PSD should remain in place until the slope has been completely stabilized or up to 30 days after permanent slope stabilization.

Cost

- Pipe slope drain costs are generally based upon the pipe type and size (generally, flexible PVC at $5.00 per linear foot). Also adding to this cost are any expenses associated with inlet and outlet structures.

Sources

- Commonwealth of Virginia - County of Fairfax, 1987. 1987 Check List For Erosion And Sediment Control - Fairfax County, Virginia.
- State of North Carolina, 1988. Erosion and Sediment Control Planning and Design Manual. North Carolina Sedimentation Control Commission, Department of Natural Resources and Community Development.
- Maryland Department of the Environment, 1991. 1991 Maryland Standards And Specifications For Soil Erosion And Sediment Control - Draft.
- Storm Water Management Manual for the Puget Sound Basin. State of Washington, Department of Ecology, 1991.
- Cost Data:
- Draft Sediment and Erosion Control, An Inventory of Current Practices, April 20, 1990. Prepared by Kamber Engineering for the U.S. Environmental Protection Agency, Office of Water Enforcement and Permits, Washington, D.C. 20460.

STABILIZED CONSTRUCTION ENTRANCE

September 1992

Design Criteria

- A Stabilized Construction Entrance (SCE) is appropriate in the following locations:
  - Wherever vehicles are leaving a construction site and enter onto a public road
  - At any unpaved entrance/exit location where there is risk of transporting mud or sediment onto paved roads.
- The width should be at least 10 feet to 12 feet or the as wide as the entire width of the access. At sites where traffic volume is high the entrance should be wide enough for two vehicles to pass safely.
- The length should be between 50 to 75 feet in length.
- Flare the entrance where it meets the existing road to provide a turning radius.
- Runoff from a stabilized construction entrance should drain to a sediment trap or sediment basin.
- Pipe placed under the entrance to handle runoff should be protected with a mountable berm.
- Dust control should be provided in accordance with Section 3.2.1.

Materials

- Crushed stone 2-inches-4-inches in diameter
- Geotextile (filter fabric) with the properties listed in Table 3 below.

TABLE 3. GEOTEXTILE REQUIREMENTS

Physical Property	Requirements
Grab Tensile Strength	220 lbs. (ASTM D1682)
Elongation Failure	60 % (ASTM D1682)
Mullen Burst Strength	430 lbs. (ASTM D3768)
Puncture Strength	125 lbs. (ASTM D751) (modified)
Equivalent Opening	Size 40-80 (US std Sieve) (CW-02215)

Construction Specifications

- Clear all vegetation, roots and all other obstructions in preparation for grading.
- Prior to placing geotextile (filter fabric) make sure that the entrance is properly graded and compacted.

STABILIZED CONSTRUCTION ENTRANCE

- To reduce maintenance and loss of aggregate place geotextile fabric (filter cloth) over the existing ground before placing the stone for the entrance.
- Stone should be placed to a depth of 6-inches or greater for the entire width and length of the SCE.

Maintenance

- Inspect the measure on a regular basis and after there has been a high volume of traffic or storm event.
- Apply additional stone periodically and when repair is required.
- Immediately remove sediments or any other materials tracked onto the public roadway.
- Ensure that associated sediment control measures are in good working condition.

Cost

- Stabilized construction entrances cost ranges from $1,500 to $5,000 to install.

Sources

- Commonwealth of Virginia - County of Fairfax, 1987. 1987 Check List For Erosion And Sediment Control - Fairfax County, Virginia.
- State of North Carolina, 1988. Erosion and Sediment Control Planning and Design Manual. North Carolina Sedimentation Control Commission, Department of Natural Resources and Community Development.
- Maryland Department of the Environment, 1991. 1991 Maryland Standards And Specifications For Soil Erosion And Sediment Control - Draft.
- Storm Water Management Manual for the Puget Sound Basin. State of Washington, Department of Ecology, 1991.
- Cost Data:
  - Draft Sediment and Erosion Control, An Inventory of Current Practices, April 20, 1990. Prepared by Kamber Engineering for the U.S. Environmental Protection Agency, Office of Water Enforcement and Permits, Washington, D.C. 20460.

FILTER FABRIC INLET PROTECTION

September 1992

Design Criteria

- Inlet protection is appropriate in the following locations:
  - In small drainage areas (less than 1 acre) where the storm drain inlet is functional before the drainage area has been permanently stabilized.
  - Where there is danger of sediment silting in an inlet which is in place prior to permanent stabilization.
- Filter fabric inlet protection is appropriate for most types of inlets where the drainage area is one acre or less.
- The drainage area should be fairly flat with slopes of 5% or less and the area immediately surrounding the inlet should not exceed a slope of 1%.
- Overland flow to the inlet should be no greater than 0.5 cfs.
- This type of inlet protection is not appropriate for use in paved areas because the filter fabric requires staking.
- To avoid failure caused by pressure against the fabric when overtopping occurs, it is recommended that the height of the filter fabric be limited to 1.5 feet above the crest of the drop inlet.
- It is recommended that a sediment trapping sump of 1 to 2 feet in depth with side slopes of 2:1 be provided.

Materials

- Filter fabric (see the fabric specifications for silt fence).
- Wooden stakes 2" x 2" or 2"x 4" with a minimum length of 3 feet.
- Heavy-duty wire staples at least inch in length.
- Washed gravel inches in diameter.

Construction Specifications

- Place a stake at each corner of the inlet and around the edges at no more than 3 feet apart. Stakes should be driven into the ground 18 inches or at a minimum 8 inches.
- For stability a framework of wood strips should be installed around the stakes at the crest of the overflow area 1.5 feet above the crest of the drop inlet.
- Excavate a trench of 8 inches to 12 inches in depth around the outside perimeter of the stakes. If a sediment trapping sump is being provided then the excavation may be as deep as 2 feet.
- Staple the filter fabric to the wooden stakes with heavy-duty staples, overlapping the joints to the next stake. Ensure that between 12 inches to 32 inches of filter fabric extends at the bottom so it can be formed into the trench.
- Place the bottom of the fabric in the trench and backfill the trench all the way around using washed gravel to a minimum depth of 4 inches.

FILTER FABRIC INLET PROTECTION

Maintenance

- Inspect regularly and after every storm. Make any repairs necessary to ensure the measure is in good working order.
- Sediment should be removed and the trap restored to its original dimensions when sediment has accumulated to the design depth of the trap.
- If the filter fabric becomes clogged it should be replaced immediately.
- Make sure that the stakes are firmly in the ground and that the filter fabric continues to be securely anchored.
- All sediments removed should be properly disposed.
- Inlet protection should remain in place and operational until the drainage area is completely stabilized or up to 30 days after the permanent site stabilization is achieved.

Cost

- The cost of storm drain inlet protection varies dependent upon the size and type of inlet to be protected but generally is about $300.00 per inlet.

Sources

- Commonwealth of Virginia - County of Fairfax, 1987. 1987 Check List For Erosion And Sediment Control - Fairfax County, Virginia.
- State of North Carolina, 1988. Erosion and Sediment Control Planning and Design Manual. North Carolina Sedimentation Control Commission, Department of Natural Resources and Community Development.
- Maryland Department of the Environment, 1991. 1991 Maryland Standards And Specifications For Soil Erosion And Sediment Control - Draft.
- Storm Water Management Manual for the Puget Sound Basin. State of Washington, Department of Ecology, 1991.
- Cost Data:
  - Draft Sediment and Erosion Control, An Inventory of Current Practices, April 20, 1990. Prepared by Kamber Engineering for the U.S. Environmental Protection Agency, Office of Water Enforcement and Permits, Washington, D.C. 20460.

EXCAVATED GRAVEL INLET PROTECTION

September 1992

Design Criteria

- Inlet protection is appropriate in the following locations:
  - In small drainage areas (less than 1 acre) where the storm drain inlet is functional before the drainage area has been permanently stabilized.
  - Where there is danger of sediment silting in an inlet which is in place prior to permanent stabilization.
  - Where ponding around the inlet structure could be a problem to traffic on site.
- Excavated gravel and mesh inlet protection may be used with most inlets where overflow capability is needed and in areas of heavy flows, 0.5 cfs or greater.
- The drainage area should not exceed 1 acre.
- The drainage area should be fairly flat with slopes of 5% or less.
- The trap should have a sediment trapping sump of 1 to 2 feet measured from the crest of the inlet. Side slopes should be 2:1. The recommended volume of excavation is 35 yd /acre disturbed.
- To achieve maximum trapping efficiency the longest dimension of the basin should be oriented toward the longest inflow area.

Materials

- Hardware cloth or wire mesh with inch openings.
- Filter fabric (see the fabric specifications for silt fence).
- Washed gravel inches to 4 inches in diameter.

Construction Specifications

- Remove any obstructions to excavating and grading. Excavate sump area, grade slopes and properly dispose of soil.
- The inlet grate should be secured to prevent seepage of sediment laden water.
- Place wire mesh over the drop inlet so that the wire extends a minimum of 1 foot beyond each side of the inlet structure. Overlap the strips of mesh if more than one is necessary.
- Place filter fabric over the mesh extending it at least 18 inches beyond the inlet opening on all sides. Ensure that weep holes in the inlet structure are protected by filter fabric and gravel.
- Place stone/gravel over the fabric/wire mesh to a depth of at least 1 foot.

EXCAVATED GRAVEL INLET PROTECTION

Maintenance

- Inspect regularly and after every storm. Make any repairs necessary to ensure the measure is in good working order.
- Sediment should be removed and the trap restored to its original dimensions when sediment has accumulated to the design depth of the trap.
- Clean or remove and replace the stone filter or filter fabric if they become clogged.
- Inlet protection should remain in place and operational until the drainage area is completely stabilized or up to 30 days after the permanent site stabilization is achieved.

Cost

- The cost of storm drain inlet protection varies dependent upon the size and type of inlet to be protected but generally is about $300.00 per inlet.

Sources

- Commonwealth of Virginia - County of Fairfax, 1987. 1987 Check List For Erosion And Sediment Control - Fairfax County, Virginia.
- State of North Carolina, 1988. Erosion and Sediment Control Planning and Design Manual. North Carolina Sedimentation Control Commission, Department of Natural Resources and Community Development.
- Maryland Department of the Environment, 1991. 1991 Maryland Standards And Specifications For Soil Erosion And Sediment Control - Draft.
- Storm Water Management Manual for the Puget Sound Basin. State of Washington, Department of Ecology, 1991.
- Cost Data:
  - Draft Sediment and Erosion Control, An Inventory of Current Practices, April 20, 1990. Prepared by Kamber Engineering for the U.S. Environmental Protection Agency, Office of Water Enforcement and Permits, Washington, D.C. 20460.

BLOCK AND GRAVEL INLET PROTECTION

September 1992

Design Criteria

- Inlet protection is appropriate in the following locations:
  - In drainage areas (less than 1 acre) where the storm drain inlet is functional before the drainage area has been permanently stabilized.
  - Where there is danger of sediment silting in an inlet which is in place prior to permanent stabilization.
- Block and gravel inlet protection may be used with most types of inlets where overflow capability is needed and in areas of heavy flows 0.5 cfs or greater.
- The drainage area should not exceed 1 acre.
- The drainage area should be fairly flat with slopes of 5% or less.
- To achieve maximum trapping efficiency the longest dimension of the basin should be oriented toward the longest inflow area.
- Where possible the trap should have sediment trapping sump of 1 to 2 feet in depth with side slopes of 2:1.
- There are several other types of inlet protection also used to prevent siltation of storm drainage systems and structures during construction, they are:
  - Filter Fabric Inlet Protection
  - Excavated Gravel Inlet Protection

Materials

- Hardware cloth or wire mesh with inch openings
- Filter fabric (see the fabric specifications for silt fence)
- Concrete block 4 inches to 12 inches wide.
- Washed gravel inches to 4 inches in diameter

Construction Specifications

- The inlet grate should be secured to prevent seepage of sediment laden water.
- Place wire mesh over the drop inlet so that the wire extends a minimum of 12 inches to 18 inches beyond each side of the inlet structure. Overlap the strips of mesh if more than one is necessary.
- Place filter fabric (optional) over the mesh and extend it at least 18 inches beyond the inlet structure.
- Place concrete blocks over the filter fabric in a single row lengthwise on their sides along the sides of the inlet. The foundation should be excavated a minimum of 2 inches below the crest of the inlet and the bottom row of blocks should be against the edge of the structure for lateral support.
- The open ends of the block should face outward not upward and the ends of adjacent blocks should abut. Lay one block on each side of the structure on its side to allow for dewatering of the pool.
- The block barrier should be at least 12 inches high and may be up to a maximum of 24 inches high and may be from 4 inches to 12 inches in depth depending on the size of block used.
- Prior to backfilling, place wire mesh over the outside vertical end of the blocks so that stone does not wash down the inlet.
- Place gravel against the wire mesh to the top of the blocks.

BLOCK AND GRAVEL INLET PROTECTION

Maintenance

- Inspect regularly and after every storm. Make any repairs necessary to ensure the measure is in good working order.
- Sediment should be removed and the trap restored to its original dimensions when sediment has accumulated to the design depth of the trap.
- All sediments removed should be properly disposed of.
- Inlet protection should remain in place and operational until the drainage area is completely stabilized or up to 30 days after the permanent site stabilization is achieved.

Cost

- The cost of storm drain inlet protection varies dependent upon the size and type of inlet to be protected but generally is about $300.00 per inlet.

Sources

- Commonwealth of Virginia - County of Fairfax, 1987. 1987 Check List For Erosion And Sediment Control - Fairfax County, Virginia.
- State of North Carolina, 1988. Erosion and Sediment Control Planning and Design Manual. North Carolina Sedimentation Control Commission, Department of Natural Resources and Community Development.
- Maryland Department of the Environment, 1991. 1991 Maryland Standards And Specifications For Soil Erosion And Sediment Control - Draft.
- Storm Water Management Manual for the Puget Sound Basin. State of Washington, Department of Ecology, 1991.
- Cost Data:
  - Draft Sediment and Erosion Control, An Inventory of Current Practices, April 20, 1990. Prepared by Kamber Engineering for the U.S. Environmental Protection Agency, Office of Water Enforcement and Permits, Washington, D.C. 20460.

CHECK DAMS

September 1992

Design Criteria

- Check dams are appropriate for use in the following locations:
  - Across swales or drainage ditches to reduce the velocity of flow.
  - Where velocity must be reduced because a vegetated channel lining has not yet been established.
- Check dams may never be used in a live stream unless approved by the appropriate government agency.
- The drainage area above the check dam should be between 2 acres and 10 acres.
- The dams must be spaced so that the toe of the upstream dam is never any higher than the top of the downstream dam.
- The center of the dam must be 6 inches to 9 inches lower than either edge, and the maximum height of the dam should be 24 inches.
- The check dam should be as much as 18 inches wider than the banks of the channel to prevent undercutting as overflow water re-enters the channel.
- Excavating a sump immediately upstream from the check dam improves its effectiveness.
- Provide outlet stabilization below the lowest check dam where the risk of erosion is greatest.
- Consider the use of channel linings or protection such as plastic sheeting or riprap where there may be significant erosion or prolonged submergence.

Materials

- Stone 2 inches to 15 inches in diameter
- Logs 6 inches to 8 inches in diameter
- Sandbags filled with pea gravel
- Filter fabric (see the fabric specifications for silt fence)

Construction Specifications

- Rock Check Dams
  - Place the stones on the filter fabric either by hand or using appropriate machinery; do not simply dump them in place.
  - Extend the stone 18 inches beyond the banks and keep the side slopes 2:1 or flatter.
  - Lining the upstream side of the dam with inch to 1 inch gravel 1 foot in depth is a suggested option.
- Log Check Dams
  - Logs must be firmly embedded in the ground; 18 inches is the recommended minimum depth.
- Sand Bag Check Dams
  - Be sure that bags are all securely sealed.
- Place bags by hand or use appropriate machinery.

CHECK DAMS

Maintenance

- Inspect regularly and after every storm. Make any repairs necessary to ensure the measure is in good working order.
- Accumulated sediment and leaves should be removed from behind the dams and erosive damage to the channel restored after each storm or when the original height of the dam is reached.
- All accumulated material removed from the dam shall be properly disposed.
- Replace stone as necessary for the dams to maintain their correct height.
- If sand bags are used, the fabric of the bags should be inspected for signs of deterioration.
- Remove stone or riprap if grass lined channel requires mowing.
- Check dams should remain in place and operational until the drainage area and channel are completely stabilized or up to 30 days after the permanent site stabilization is achieved.
- Restore the channel lining or establish vegetation when each check dam is removed.

Cost

- The costs for the construction of check dams varies with the material used. Rock costs about $100 per dam. Log check dams are usually slightly less expensive than rock check dams. All costs vary depending on the width of channel to be checked.

Sources

- Commonwealth of Virginia - County of Fairfax, 1987. 1987 Check List For Erosion And Sediment Control - Fairfax County, Virginia.
- State of North Carolina, 1988. Erosion and Sediment Control Planning and Design Manual. North Carolina Sedimentation Control Commission, Department of Natural Resources and Community Development.
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EARTH DIKE

September 1992

Design Criteria

- Earth dikes are appropriate in the following situations:
  - To divert upslope flows away from disturbed areas such as cut or fill slopes and to divert runoff to a stabilized outlet
  - To reduce the length of the slope runoff will cross
  - At the perimeter of the construction site to prevent sediment-laden runoff from leaving the site
  - To direct sediment-laden runoff to a sediment trapping device.
- When the drainage area to the earth dike is greater than 10 acres, the United States Department of Agriculture - Soil Conservation Service (USDA - SCS) standards and specification for diversions should be consulted.
- Table 4 contains suggested dike design criteria.

TABLE 4. SUGGESTED DIKE DESIGN CRITERIA

Drainage Area	Under 5 Acres	Between 5-10 Acres
Dike Height	18 inches	30 inches
Dike Width	24 inches	36 inches
Flow Width	4 feet	6 feet
Flow Depth	12 inches	24 inches
Side Slopes	2:1 or less	2:1 or less
Grade	0.5% - 10%	0.5% - 10%

- The base for a dike 18 inches high and 24 wide at the top should be between 6 feet - 8 feet. The height of the dike is measured on the upslope side.
- If the dike is constructed using coarse aggregate the side slopes should be 3:1 or flatter.
- The channel formed behind the dike should have a positive grade to a stabilized outlet. The channel should be stabilized with vegetative or other stabilization measures.
- Grades over 10% may require an engineering design.
- Construct the dike where it will not interfere with major areas of construction traffic so that vehicle damage to the dike will be kept to the minimum.
- Diversion dikes should be installed prior to the majority of soil disturbing activity, and may be removed when stabilization of the drainage area and outlet are complete.

Materials

- Compacted Soil
- Coarse Aggregate

EARTH DIKE

Construction Specifications

- Clear the area of all trees, brush, stumps or other obstructions.
- Construct the dike to the designed cross-section, line and grade making sure that there are no irregularities or bank projections to impede the flow.
- The dike should be compacted using earth moving equipment to prevent failure of the dike.
- The dike must be stabilized as soon as possible after installation.

Maintenance

- Inspect regularly and after every storm, make any repairs necessary to ensure the measure is in good working order.
- Inspect the dike, flow channel and outlet for deficiencies or signs of erosion.
- If material must be added to the dike be sure it is properly compacted.
- Reseed or stabilize the dike as needed to maintain its stability regardless if there has been a storm event or not.

Cost

- The cost associated with earth dike construction is roughly $4.50 per linear foot which covers the earthwork involved in preparing the dike. Also added to this cost is approximately $1.00 per linear foot for stabilization practices. It should be noted that for most construction projects, the cost of earth dike construction is insignificant compared to the overall earthwork project costs.

Sources

- Commonwealth of Virginia - County of Fairfax, 1987. 1987 Check List For Erosion And Sediment Control - Fairfax County, Virginia.

- State of North Carolina, 1988. Erosion and Sediment Control Planning and Design Manual. North Carolina Sedimentation Control Commission, Department of Natural Resources and Community Development.
- Maryland Department of the Environment, 1991. 1991 Maryland Standards And Specifications For Soil Erosion And Sediment Control - Draft.
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DRAINAGE SWALE

September 1992

Design Criteria

- Temporary drainage swales are appropriate in the following situations:

  - To divert upslope flows away from disturbed areas such as cut or fill slopes and to divert runoff to a stabilized outlet
  - To reduce the length of the slope runoff will cross
  - At the perimeter of the construction site to prevent sediment-laden runoff from leaving the site
  - To direct sediment-laden runoff to a sediment trapping device.

- When the drainage area is greater than 10 acres the United States Department of Agriculture - Soil Conservation Service (USDA - SCS) standards and specifications for diversions should be consulted.
- Swales may have side slopes ranging from 3:1 to 2:1.
- The minimum channel depth should be between 12 inches and 18 inches.
- The minimum width at the bottom of the channel should be 24 inches and the bottom should be level.
- The channel should have a uniform positive grade between 2% and 5%, with no sudden decreases where sediments may accumulate and cause overtopping.
- The channel should be stabilized with temporary or permanent stabilization measures.
- Grades over 10% may require an engineering design.
- Construct the swale away from areas of major construction traffic.
- Runoff must discharge to a stabilized outlet.

Materials

- Grass seed for temporary or permanent stabilization
- Sod
- Coarse aggregate or riprap

Construction Specifications

- Clear the area of all trees, brush, stumps or other obstructions.

- Construct the swale to the designed cross-section, line and grade making sure that there are no irregularities or bank projections to impede the flow.
- The lining should be well compacted using earth moving equipment and stabilization initiated as soon as possible.
- Stabilize lining with grass seed, sod, or riprap.
- Surplus material should be properly distributed or disposed of so that it does not interfere with the functioning of the swale.
- Outlet dissipation measures should be used to avoid the risk of erosion.

Maintenance

- Inspect regularly and after every storm, make any repairs necessary to ensure the measure is in good working order.
- Inspect the flow channel and outlet for deficiencies or signs of erosion.
- If surface of the channel requires material to be added be sure it is properly compacted.
- Reseed or stabilize the channel as needed to prevent erosion during a storm event.

DRAINAGE SWALE

Cost

- Drainage swale can vary widely depending on the geometry of the swale and the type of lining material:

  - Grass $3.00/square yard
  - Sod $4.00/square year
  - Riprap $45.00/square year

- No matter which liner type is used, the entire swale must be stabilized (i.e., seeded and mulched at a cost of $1.25/square yard).

Sources

- Commonwealth of Virginia - County of Fairfax, 1987. 1987 Check List For Erosion And Sediment Control - Fairfax County, Virginia.
- State of North Carolina, 1988. Erosion and Sediment Control Planning and Design Manual. North Carolina Sedimentation Control Commission, Department of Natural Resources and Community Development.
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TEMPORARY SEDIMENT TRAP

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Design Criteria

- Temporary sediment traps are appropriate in the following locations:

  - At the outlet of the perimeter controls installed during the first stage of construction.
  - At the outlet of any structure which concentrates sediment-laden runoff, e.g. at the discharge point of diversions, channels, slope drains, or other runoff conveyances.
  - Above a storm water inlet that is in line to receive sediment-laden runoff.

- Temporary sediment traps may be constructed by excavation alone or by excavation in combination with an embankment.
- Temporary sediment traps are often used in conjunction with a diversion dike or swale.
- The drainage area for the sediment trap should not exceed 5 disturbed acres.
- The trap must be accessible for ease of regular maintenance which is critical to its functioning properly.
- Sediment traps are temporary measures and should not be planned to remain in place longer than between 18 and 24 months.
- The capacity of the sedimentation pool should provide storage volume for 3,600 cubic feet/acre drainage area.
- The outlet should be designed to provide a 2 foot settling depth and an additional sediment storage area 1 feet deep at the bottom of the trap.
- The embankment may not exceed 5 feet in height.
- The recommended minimum width at the top of the embankment is between 2 feet and 5 feet.
- The minimum recommended length of the weir is between 3 feet and 4 feet, and the maximum is 12 feet in length.
- Table 5 illustrates the typical relationship between the embankment height, the height of the outlet (H_o), and the width (W) at the top of the embankment.

TABLE 5. EMBANKMENT HEIGHT vs. OUTLET HEIGHT AND WIDTH

H	H_o	W
1.5	0.5	2.0
2.0	1.0	2.0
2.5	1.5	2.5
3.0	2.0	2.5
3.5	2.5	3.0
4.0	3.0	3.0
4.5	3.5	4.0
5.0	4.0	4.5

Materials

- Filter fabric (see fabric requirement for silt fence)
- Coarse aggregate or riprap 2 inches to 14 inches in diameter
- Washed gravel to 1 inches in diameter
- Seed and mulch for stabilization

TEMPORARY SEDIMENT TRAP

Construction Specifications

- Clear the area of all trees, brush, stumps or other obstructions.
- Construct the embankment in 8 inch lifts compacting each lift with the appropriate earth moving equipment. Fill material must be free of woody vegetation, roots, or large stones.
- Keep cut and fill slopes between 3:1 and 2:1 or flatter.
- Line the outlet area with filter fabric prior to placing stone or gravel.
- Construct the gravel outlet using heavy stones between 6 inches and 14 inches in diameter and face the upstream side with a 12 inch layer of inch to 1 inch washed gravel on the upstream side.
- Seed and mulch the embankment as soon as possible to ensure stabilization.

Maintenance

- Inspect regularly and after every storm. Make any repairs necessary to ensure the measure is in good working order.
- Frequent removal of sediment is critical to the functioning of this measure. At a minimum sediment should be removed and the trap restored to its original volume when sediment reaches of the original volume.
- Sediment removed from the trap must be properly disposed.
- Check the embankment regularly to make sure it is structurally sound.

Cost

- Costs for a sediment trap vary widely based upon their size and the amount of excavation and stone required, they usually can be installed for $500 to $7,000.

Sources

- Commonwealth of Virginia - County of Fairfax, 1987. 1987 Check List For Erosion And Sediment Control - Fairfax County, Virginia.
- State of North Carolina, 1988. Erosion and Sediment Control Planning and Design Manual. North Carolina Sedimentation Control Commission, Department of Natural Resources and Community Development.
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Bioengineering for Hill slope, Stream bank, and Lakeshore Erosion Control

Bioengineering techniques for hill slope, stream bank, and lakeshore erosion control are described, as are tips for a successful bioengineering installation and demonstration project.

Thomas G. Franti, Extension Surface Water Management Specialist

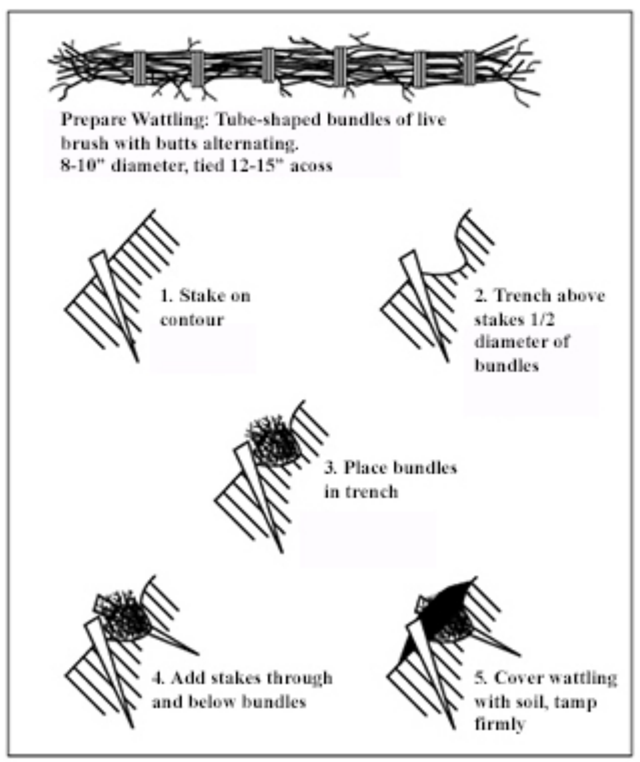


Figure 1. Preparation of wattling and installation procedure. Installation starts at the bottom of the cut or fill and proceeds upslope. Numbered sequence of operations is shown schematically. (From Gray and Leiser, 1982)

Soil erosion occurs whenever water meets land with enough force to move soil. Often this occurs along stream banks and lakeshores or where excess water flows over hill slopes. Stream bank and hill slope erosion can be dramatic, especially after large rainfalls or floods. However, normal stream flows, excess runoff from urbanized areas, and wave action along lakeshores continually erode soil. Erosion can be severe, as is the case in many man-made lakes, where shorelines are composed of easily erodible soil. Traditional methods of controlling stream flow and wave-induced erosion have relied on structural practices like rip rap, retaining walls, and sheet piles. In many cases, these methods are expensive, ineffective, or socially unacceptable. An alternative approach is bioengineering, a method of construction using live plants alone or combined with dead or inorganic materials, to produce living, functioning systems to prevent erosion, control sediment, and provide habitat. Bioengineering uses combinations of structural practices and live vegetation to provide erosion protection for hill slopes, stream banks, and lakeshores. Bioengineering is a diverse and multidisciplinary field, requiring the knowledge of engineers, botanists, horticulturalists, hydrologists, soil scientists, and construction contractors. It is a rapidly growing field, subject to innovations and changing design specifications. Terms such as biotechnical erosion control, bio-stabilization, or soil-bioengineering often are used synonymously with bioengineering.

History

The use of bioengineering methods dates back to 12th century China, when brush bundles were used to stabilize slopes. In the early 20th century, similar techniques were used in China to control flooding and erosion along the Yellow River. In Europe, especially Germany, bioengineering methods have been used for over 150 years. Documented use of bioengineering in the United States dates to the 1920s and ’30s. Stream bank stabilization, timber access road stabilization, and slope restoration were common applications. After World War II, with increased access to earth-moving equipment and the development of new structural slope stabilization, and erosion control methods, bioengineering practices all but disappeared. In the last 20 years, bioengineering has been recognized as a re-emerging technique to provide erosion control, environmentally sound design, and aesthetically pleasing structures. Gray and Leiser (1982) published the first U.S. textbook on bioengineering: *Biotechnical Slope Protection and Erosion Control*.

Applications, Advantages, Limitations

Bioengineering solutions can be adopted in many soil stabilization and erosion control situations, from stream bank and lakeshore protection to upland gully restoration and slope stabilization. Bioengineered restoration of flood or high water damage to streams and lakes provides a more natural-looking solution than traditional rip rap or concrete structures.

Advantages of bioengineering solutions are: 1) low cost and lower long-term maintenance cost than traditional methods; 2) low maintenance of live plants after they are established; 3) environmental benefits of wildlife habitat, water quality improvement, and aesthetics; 4) improved strength over time as root systems develop and increase structural stability; and 5) compatibility with environmentally sensitive sites or sites with limited access.

Limitations to bioengineering methods include: 1) installation season often is limited to plant dormant seasons, when site access may be limited; 2) availability of locally adapted plants may be limited; 3) labor needs are intensive and skilled, and experienced labor may be unavailable; 4) installers may be unfamiliar with bioengineering principles and designs, so upfront training may be required; and 5) alternative practices are aggressively marketed and often more widely accepted by society and contractors.

Bioengineering Techniques

Homeowners who have streamside or lakeside property, contractors required to work in difficult environmental circumstances, or professionals interested in natural restoration of landscapes will find bioengineering techniques useful. New methods of application and materials being developed will result in new and improved bioengineering design.

Contour Wattling — This method is used to control surface erosion by breaking long slopes into shorter slopes. Bundles of branches, called wattles or fascines, are placed in shallow trenches along the slope or stream bank contour *(Figure 1)*. Trenches are excavated by hand to half the diameter of the bundles. Wattles are typically 8 to 10 inches in diameter and branches secured with twine. After the wattle is staked in place, the trench is backfilled until only the top of the bundle is exposed. Wattles can be used for hill slope restoration, road embankments, wide gullies, or slump areas.

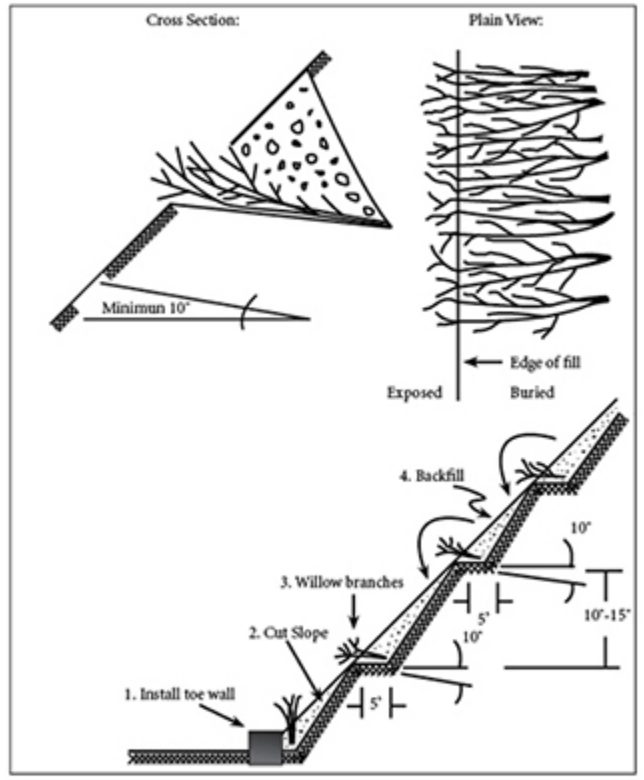


Figure 2. Installation of brush layering. Numbered sequence of operations is shown. Vertical spacing depends on slope angle. (From Gray and Leiser, 1982)

Brush Layering — This method is used to restore slopes by constructing a fill-slope consisting of alternating layers of live branches and soil, creating a series of reinforced benches *(Figure 2)*. Large quantities of dormant willow branches often are used. While about 75 percent to 80 percent of the branch is buried, the tips are left exposed. The layers of branches help reinforce the fill, which improves as the branches develop roots throughout the fill area. Brush layering can be used to place new fill or repair old fill areas, restore shallow slumps, repair narrow gullies, and stabilize loose soil slopes.

Trench Packing — This method is used to slow or spread water by placing live plants in a trench perpendicular to the flow. To reduce wave impact, live plants are placed in trenches running parallel to the shoreline. Several trenches may be used with different plants in each, depending on the distance to water. Generally, a wide planting area is needed to dissipate wave energy. In upland areas, trench packing serves to slow water and spread it over the soil surface, reducing its erosion potential. Trench packing also can be used to control shallow seeps, protect wetland construction and renovation, and protect abandoned roads.

Brush Matting — This method protects stream banks by placing a mattress-like layer of branches over it to protect soil and slow water velocity. The mat is composed of interwoven, usually dead, branches secured to the soil by live stakes, wire, twine, or live branches. Live stakes often are cut from dormant willow. Brush matting helps collect sediment and enables establishment of vegetation on banks. Like brush layering, this method requires large quantities of branches.

Live Cuttings — Live cuttings can be used to secure materials in place and to increase plantings on a slope. Live cuttings can be from 18 inches to 4 feet in length. Longer cuttings are used for live staking of wattles, while shorter cuttings are used for plantings.

Coir Fascines — Coir fascines are wattles made from the fibrous outer husk of coconuts. Coir is denser than water so it won't float and is very slow to decay. Coir fascines are a readily available manufactured product and are popular for stream bank and wetland restoration where a natural look is desired *(Figure 3)*. Coir fascines are placed with their tops at the water surface. Live plants can be placed into coir fascines to create a natural look.

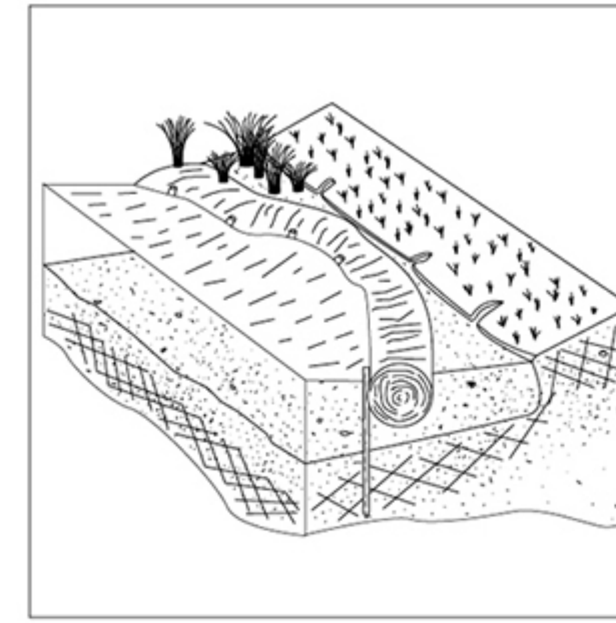


Figure 3. Coir fascines stabilize banks and help establishment of wetland plants. The coconut fiber accumulates sediment and biodegrades as plant roots develop and become a stabilizing system. (From Bestmann-Green Systems)

Pre-vegetated Mats — Pre-vegetated mats are live plants grown on a movable mat of organic material. They come in many sizes and materials and are moved and installed in one piece. They are generally 4- by 8-feet in size for easy handling. Mats are grown in nurseries for up to a year or more to provide a good plant stand. Thin mats can be rolled up and shipped without special packing. Thick mats are handled with heavy equipment because of their weight. Pre-vegetated mats are made of coir or other slowly degradable material and can use many types of plants. Mats usually are used in wetland or lakeshore environments so wetland plants are the most common. Currently, most pre-vegetated mats are custom ordered one to two years in advance.

Inter planting Rip Rap — Rip rap often is used to protect stream banks and lakeshores. Rip rap is composed of various size large stones placed on the soil surface where the water contacts the soil. Live cuttings can be inter planted in rip rap to provide additional slope stability. Root growth below the rip rap will improve soil strength and live vegetation will hide the rocks, presenting a more natural look.

Staking — Staking is used extensively in bioengineering practice. Stakes can be live or dead. Live staking often is done with willows to stabilize soil or to stake other materials in place. Manufactured timber stakes, 2 to 3 feet long, are used to secure wattles and coir fascines. Timber stakes for upland application need to have a bias, or angle, cut, making them easier to install. For wetland or streamside applications, stakes need straight parallel sides to prevent heaving from water pressure.

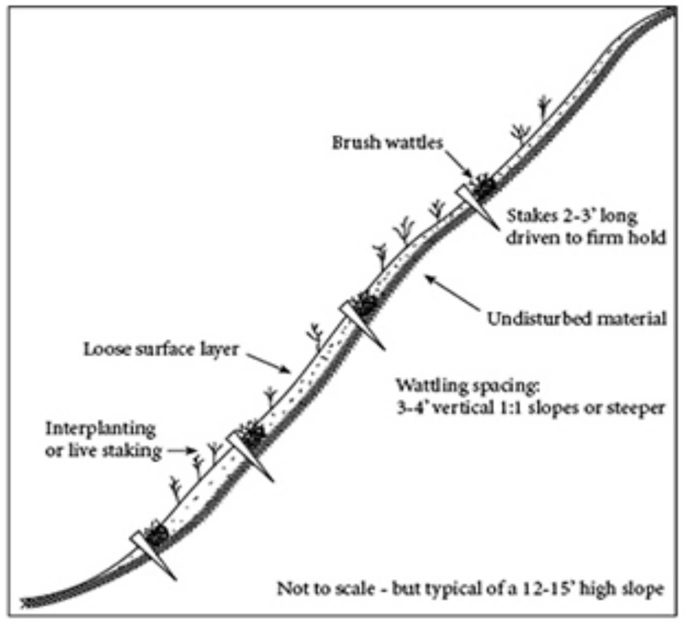
Combinations — Combinations of the above practices are usually used for most bioengineering designs. For example, brush wattles and live staking is a common combination used to stabilize slopes *(Figure 4)*. A coir fascine can be used with live plantings, brush matting, and trench packing to restore wetlands or stream channels *(Figure 5)*. New combinations of existing methods, and the use of new materials, will provide creative applications of bioengineering techniques.

Plantings

Bioengineering involves the use of live plants to add structural strength to soil. Many different plant materials are used. Live cuttings should be soaked in cold water for at least 24 hours before they are used. This not only provides the cuttings with needed moisture but also improves rooting. Live potted plants often are used. Care of live plants before and during planting is critical for success. Live plants raised indoors need to be acclimatized to the outdoor environment before planting.

Plants can be planted directly into coir fascines, coir pots, or mats. Pre-vegetated mats, as described earlier, are another method used to transplant live plants. A plant roll can be developed by wrapping several live plants in a roll of degradable material and placing the roll in the ground like a wattle. This method also can be used for trench packing.

Seeding can be used where appropriate. Seeding and mulching are not appropriate in areas of flooding, high water flow, or rapid changes in water depth, as the mulch and seed will be washed away. Proper seedbed preparation, fertilization, and irrigation may be needed to assure seedling survival. **Figure 4. Slope treatment using wattles and live plants or stakes. Use for loose surface soils with sheet, rill, or small gully erosion. (From A.T. Leiser)**



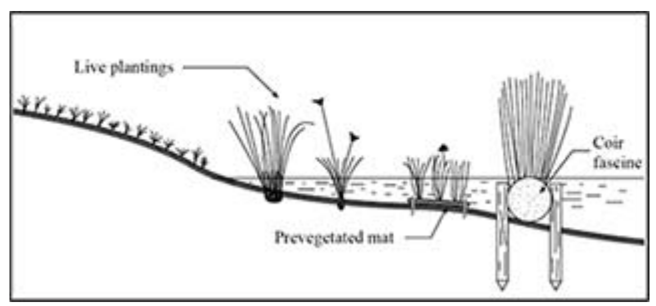


Figure 5. Lakeshore erosion control using a combination design of coir fascine and wetland plantings, pre-vegetated mat and live plantings. (From A.T. Leiser)

Expect some failure of plantings in all bioengineering applications. A 75 percent to 80 percent survival rate is considered very good. Replanting generally is inexpensive and often the plants will reestablish themselves in time. Some loss of vegetation does not seriously impact a project as long as most of the soil stays in place and the structural features of the design are sound.

Protect Plantings — Protect live plantings from animals, especially ducks and geese along lakeshores and stream sides. Deer, muskrats, beaver, dogs, and humans also can pose a threat. Signs may keep people away, but fencing may be needed if animals are a problem. For lakeshore or stream sides, an enclosed fencing layout is best to keep waterfowl away. One fence should be placed 1 to 2 feet into the water away from the shoreline plantings with a parallel fence 2 to 3 feet upslope from the plantings. Also, protection from flooding or excess water flowing across the planting is important to establish all bioengineering plantings. Be sure surface drainage and water flow is directed away from the new plantings or protected slope.

Vegetation Type — Selection, procurement, and installation of the proper plant material is essential for a successful design. In the case of lakeshore and stream bank protection, both herbaceous and woody plants are needed. Herbaceous plants, or wetland plants, will be needed at and near the water's edge. These plants can grow with their roots underwater. This root growth adds considerable strength to the soil. Generally, using several different wetland plant species increases the chance of a successful planting. However, woody plants placed too near the water or water table will not provide good structural strength and may not survive. Woody plants should be used on the upper slope and upland areas where their roots can grow in soil above the water table.

Native vegetation existing at or near the site will give good guidance concerning plant selection. As mentioned, willow cuttings often are used for wattles and live cuttings. Proper species selection is important. Willows need not be native, but should be well-adapted to the region. The use of introduced species allows the potential for increasing the number of different species available.

The availability of plant species, in the appropriate size and quantity, often is a limiting factor in the final selection process. Local nurseries may not carry the types of wetland plants needed. They may be able to propagate the species needed, but this will take 12 to 18 months. A compromise between use of native species and what may be locally or regionally available will be needed to develop a successful design. Consult horticulturalists and botanists for plant selection assistance. The International Erosion Control Association (IECA) publishes a products and services directory listing sources of plant material and professional assistance (see resource listing).

Improving Success with Bioengineering

Bioengineering can be effective in many stream bank, lakeshore, and hill slope erosion situations, but it will not solve all soil erosion or slope failure problems. The success of a project hinges on many factors, including proper design, plant selection, proper installation, weather conditions, and outside factors like animal damage. Site evaluation is important to determine whether there is adequate sunlight, soil type, and water quality to support vigorous plant growth. Do not expect bioengineering solutions to stop slope failure caused by high water tables or landslides. Nor are they ideal for high stress areas with severe wave action, rapid or long-term water level fluctuations, or fast water flows. The following list includes tips that may help ensure a successful bioengineering project.

1. Do not attempt bioengineering solutions in situations where: 1) there is severe soil or water contamination; 2) the stream bottom is degrading; 3) human or animal traffic cannot be controlled at the site; or 4) there is too much shade for selected plant species to thrive.

2. Check with local, state, and federal regulatory agencies before beginning the project. Do not alter a wetland area without proper permits. In Nebraska, check with the local Natural Resources District or the Natural Resources Conservation Service to inquire about permits.

3. Water elevation is the most critical element in a successful installation. Be sure to know the normal, high, and low water elevations for the site. Know the seasonal changes in water elevation and how rapidly these changes occur.

4. Be sure to fence out animals and people, if needed. If damage occurs, supplemental planting may be necessary.

5. Be aware of flood or drought conditions that could impact installation. Severe weather will reduce seedling survival. Supplemental planting may be needed.

6. Provide regular monitoring and maintenance, especially in the first year, to assure adequate plant survival.

7. Plan ahead. Involve the proper design professionals and experts to provide information on hydrology, plantings, and structural design. A multidisciplinary approach will assure success.

When to Seek Expert Help

Bioengineering consultants are available to help with all aspects of site assessment, design, and installation. Their input could make the difference between success or failure. Use the IECA Products & Services Directory to seek out professional assistance (see resource listing). Many bioengineering techniques can be used successfully without input from consultants; however, it is best to consider expert help if characteristics of your site are such that: 1) stream velocities are greater than 3 to 5 feet per second; 2) stream bank heights are greater than 3 feet; or 3) wave impacts are from waves greater than 1 foot high.

Tips for a Successful Demonstration

Demonstration projects can help show the advantages and benefits of bioengineering solutions. Keep demonstration projects small, from 100 to 500 feet in length, for most situations. A smaller project puts less property and dollars at risk. A demonstration helps evaluate what methods or plant species perform best under similar conditions. Incorporate some variety into the project so you can compare differences. To start, choose a simple project, in a low impact area, with a low profile or incorporate some bioengineering methods into larger projects and collect data to evaluate their success. Provide adequate maintenance and keep good monitoring records. Schedule agency personnel and public visits to the site to maximize public relations. Plan to hold these visits during installation and again after one growing season.

Resources

Gray, D.H. and A.T. Leiser. 1982. Biotechnical slope protection and erosion control. Van Nostrand Reinhold Company Inc., New York, 271 pp.

International Erosion Control Association, *www.ieca.org*

E - Invaisive Plants/Native Plant Community Information

LANDOWNERS FOR WILDLIFE

Landowners for Wildlife
Private Lands Program

INVASIVE PLANTS

By Jimmy Ernst, Wildlife Biologist

One of the greatest threats to wildlife habitat today is the spread of exotic, invasive plants. Exotic and invasive plants are not native to Louisiana and may rapidly dominate the beneficial plants that have evolved in our native habitats. These invaders out-compete native species, are very prolific, are not usually affected by native insects or diseases, and grow very rapidly. The long lists of exotic invasive species that have invaded terrestrial Louisiana habitats include Chinese tallow trees, Chinese privet and cogongrass. Aquatic invasive species include hydrilla, salvinia and water hyacinth - all of which clog waterways and completely replace beneficial aquatic plants. As they grow, they block sunlight penetration into the water, and when they die, their decomposition removes dissolved oxygen from the water column, oftentimes killing fish and aquatic animals.

Control measures must be an ongoing part of any land management plan if native habitat maintenance is the objective. Landowners and land managers will most likely be faced with invasive plant problems at some point. Many times, chemical control is the only effective solution to eradicating these nuisance species, and it can be an expensive and time-consuming process that requires professional assistance. This pamphlet offers descriptions and control recommendations for Chinese tallow trees, Chinese privet and cogongrass.

Chinese tallowtree
Photo by Thomas Ellis, Jr., Baldwin County, Alabama Planning Committee, *forestryimages.org*

CHINESE TALLOW TREES

Chinese tallow trees (*Triadica sebifera*) are known by several common names including popcorn tree, chicken tree and cancer tree. These are small deciduous trees, rarely reaching 60 feet. The distinctive leaves are alternately arranged and have smooth margins and long, pointed tips. They are well known for their fast growth and fall color. The young trees have smooth bark that becomes thicker and more furrowed as tree diameter increases. They rapidly appear in disturbed soil, and may completely dominate levees and berms after dirt work projects.

Tallow trees are very difficult to eradicate. Cutting them produces multiple, fast-growing stump sprouts. Frequent mowing or prescribed burning of fields can keep them under control, but if left alone, they will grow rapidly and spread quickly. They readily sprout from cut roots, so disking or plowing are not long-term solutions.

Chinese tallowtree infestation
Photo by Charles T. Bryson, USDA Agricultural Research Service, *forestryimages.org*

CHINESE TALLOW TREE CONTROL

Herbicides are the most effective means of controlling tallow trees. Small trees can be killed using a foliar or basal spray treatment while larger trees are killed using a basal spray or injection. Foliar treatments may be made with a small garden sprayer, a backpack sprayer, or an ATV or tractor mounted tank sprayer. Aerial applications with aircraft may be required to control excessively large acreages. Basal treatments are usually done manually, normally requiring the use of a backpack sprayer. Injection may be done with a machete and a squirt bottle, a very labor-intensive method. A specialized forestry tree injector may be necessary to treat large acreages or high numbers of stems. The herbicides used to kill tallow trees are usually non-selective and will readily kill non-target vegetation so caution must be used to protect non-target species. A common selective broadleaf herbicide used as a foliar application or by injection to control tallow trees is 2,4-D. A list of effective chemicals, listed by application method, along with generic names and common trade names are listed in *Figure 1*.

Chinese Tallowtree Pods
Photo by Chris Evans, River to River CWMA, *forestryimages.org*

Chinese Tallowtree Leaves
Photo by Chris Evans, River to River CWMA, *forestryimages.org*

Tallowtree Flowers
Photo by Chuck Bargeron, University of Georgia, *forestryimages.org*

Foliar Application:

Imazapyr	(Arsenal AC)
Triclopyr 2%	(Remedy*, Garlon 4*, Tahoe 4E*)
2-4,D	

Basal Spray:

Triclopyr	(Remedy*, Garlon 4*, Tahoe 4E*)
10-20%	(Pathfinder II - ready to use)

Injection:

Imazapyr	(Arsenal AC)
Triclopyr	(Remedy, Garlon 3A, Tahoe 3A)
Picloram	(Pathway)
& 2,4-D in combination	
2,4-D	

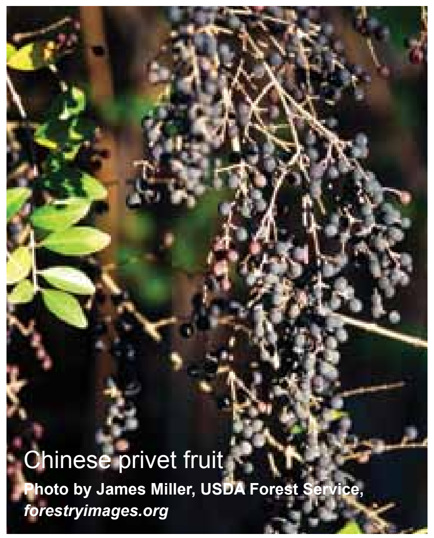
** Mixed with diesel*

Figure 1

Hack and squirt control method
Photo by James H. Miller, USDA Forest Service, *forestryimages.org*

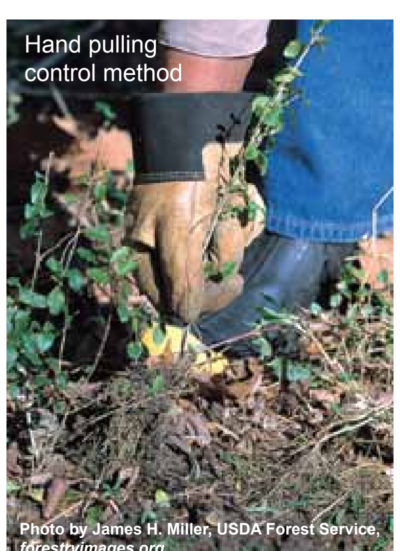
Chinese privet hedge
Photo by James H. Miller, USDA Forest Service, forestryimages.org

Chinese privet stems
Photo by Nancy Loewenstein, Auburn University, *forestryimages.org*



Chinese privet fruit
Photo by James Miller, USDA Forest Service, *forestryimages.org*

Privet Branch and leaves
John Tann, Wikimedia Commons



Hand pulling control method
Photo by James H. Miller, USDA Forest Service, *forestryimages.org*

Privet removal with gyro-trac machine
Photo by Scott Horn, USDA Forest Service, *forestryimages.org*

CHINESE PRIVET

Chinese privet (*Ligustrum sinense*), often called privet hedge, was introduced into the United States from China in the mid 1800s for ornamental use. Since then, it has escaped into the wild to become a highly invasive species, forming dense evergreen shrub thickets along roadsides, ditches, fencerows, forested areas and old home sites. These thickets out-compete and displace native vegetation. The result is severely degraded wildlife habitat and loss of aesthetic value of the forest or field. It reduces access for recreational purposes and increases maintenance costs of fences and rights-of-way.

Privet is an evergreen shrub that grows up to 30 feet tall, and is typically very dense with multiple stems showing thin, pale gray bark. The leaves grow opposite each other on long, thin stems and are 1 to 1.5 inches long and 0.5 to 1 inch wide. In the spring, privet produces numerous clusters of small, fragrant white flowers. The flowers give way to numerous clusters of small, berry-like fruits (drupes) that remain green throughout summer and fall until they ripen and turn dark purple or almost black in winter.

CHINESE PRIVET CONTROL

Physical removal of the plant is one method of control, but because it can re-sprout from the roots, complete control of the plant by removal is largely impractical. Heavy equipment can be used to clear large areas of above-ground privet, but this process is expensive and will usually cause considerable soil disturbance and erosion problems. Any root sprouts that appear after clearing must be treated with a herbicide or the plant will quickly reestablish itself.

Herbicides are highly effective against privet when properly used. Foliar applications of glyphosate herbicides (Roundup®, Accord® , and Rodeo®) are effective when applied at 2 percent rates with ½ percent of a non-ionic surfactant.** Privet can be treated during the winter when more desirable species are dormant, but not during below-freezing temperatures. Injection and basal spray are two other methods of herbicide application that are effective against privet.

*** Always follow label directions.*

Photo by Ted Bodner, Southern Weed Science Society, *forestryimages.org*

COGONGRASS

Cogongrass (*Imperata cylindrica*) has become a serious problem for many Louisiana landowners and land managers. It was accidentally introduced into the United States in south Alabama around 1911 when it was used as packing material in Japanese imports. Since its escape, it has spread throughout many southeastern states.

Cogongrass is often found as a circular patch of yellow-green grass, 1 to 4 feet tall. The leaves are ½ to 1 inch wide and the midrib is offset to one side. The midrib of most native grasses is located in the center of the leaf. The edges, or margins, of the leaves are serrated, rough to the touch and may turn a reddish color in the fall. The serrated margins and extremely high silica content make the plant undesirable as an animal forage crop. In the spring, cogongrass produces white, fluffy seed heads approximately 2 to 8 inches long, and each seed head may contain 3,000 seeds. Cogongrass can form extremely dense stands that eliminate nearly all other plants. In addition, stands of cogongrass burn extremely hot and can cause mortality in normally fire tolerant plants such as longleaf and loblolly pine.

CONGONGRASS CONTROL

Small patches of cogongrass in open areas may be eliminated by frequent disking during the growing season. Disking should reach a depth of 6 inches with repeated disking every six weeks from early spring through fall. If the area cannot be disked, chemical control is necessary. Herbicides containing the active ingredient glyphosate (Roundup®) or imazapyr (Arsenal® or Arsenal AC®) are very effective, but will likely require multiple applications for full control. Initial applications in the late summer or fall will usually kill the leaves and stems. Springtime re-growth should be treated before the plant flowers. A third treatment in the fall may be necessary for complete eradication.

Photo by Charles T. Bryson, USDA Agricultural Research Service, *forestryimages.org*

Mowing or prescribed burning the dead growth in winter will increase the efficiency of subsequent chemical applications. Allowing the plant to re-sprout before spraying herbicide will provide a more effective control of cogongrass.

Great care should be taken to clean equipment such as disks, mowers and tractors to avoid spreading cogon grass seed or rhizomes to new areas.

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Louisiana Department of Wildlife & Fisheries Wildlife Division - Private Lands Program

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Louisiana Forest Stewardship Program

for more information:
www.wlf.louisiana.gov or contact a local LDWF office

Baton Rouge	225.765.2354
Minden	318.371.3050
Monroe	318.343.4044
Pineville	318.487.5885
Lake Charles	337.491.2575
Opelousas	337.948.0255
Hammond	985.543.4777

The Problem of Introduced Species

Invasive species threaten not only Louisiana's economy and environment, but also its unique cultural identity in America—one based on our bayous and backswamps, our rich history and famous cuisine, and our core industries. In recent years, aquatic plants from around the world—hydrilla, water hyacinth and salvinia—have clogged the waterways that make Louisiana a "sportsman's paradise." Henderson Lake near Lafayette had to be drained to eliminate a mat of hydrilla so thick that marinas, swamp tour operators, and fishermen could no longer use the lake. Muskrat, once trapped for their valuable fur throughout Cajun country, have been crowded out by South American nutria. In New Orleans, Formosan termites have weakened thousands of historical structures and hollowed the city's graceful live oaks. And in the summer of 2000, masses of Australian spotted jellyfish along the Louisiana coast raised the possibility that the gulf shrimp industry may be disrupted by a species from half-a-world away.

From places like China, Brazil, and the South Pacific, these species are "introduced" to Louisiana, having evolved outside our natural ecosystems. Some introduced species (also called *exotic*, *alien*, or *nonindigenous species*) prove to be beneficial, such as sugarcane and cotton, our biggest crops. Others are benign, such as azaleas and crape myrtles, our favorite ornamentals. But other introduced species—called *invasive species*—prove to be astonishingly problematic and costly. Brought here accidentally or intentionally, through trade and transport, they have multiplied rapidly and disrupted local environments and economies. Who are these uninvited guests, how did they arrive and spread, what impact are they having on Louisiana, and how can this problem be addressed? The purpose of this map, created by the Center for Bioenvironmental Research at Tulane and Xavier Universities with support from The Coypu Foundation, is to answer these questions.

North America has already been transformed by the plants, animals and pathogens of faraway continents, at times with devastating consequences. Colonization brought not just people but new domestic animals, crops, weeds and diseases. One could argue that smallpox was the continent's first invasive species, moving into Indian communities in the interior far faster than the Europeans who first brought it. Perhaps the greatest human health crises to afflict our state, the yellow-fever epidemics of the nineteenth century that killed well over 100,000 Louisianians, was caused by an introduced virus carried by the *Aedes aegypti* mosquito brought over from Africa. Today, globalization has increased the opportunities for species to move into new environments: from 1950-1998, exports have increased from $311 billion to $5.4 trillion, while international travel has grown from 25 million to 635 million border crossings annually. Introduced species can tag along in packaging, ride in a ship's ballast water, travel in the baggage of returning passengers, or be shipped and sold as products. This map shows how invasive species have entered ("portals") and moved ("pathways") through Louisiana, and why the Bayou State is especially vulnerable to species invasions.

The phenomenal diffusion of species in new environments has many ecologists contemplating the possibility of a "global McEcosystem." Just as franchised fast food has homogenized local cuisines, species introduction may homogenize the world's biodiversity. Invasive species are a major cause of the extinction of native species (second only to habitat loss), and the arrival of a single alien species can alter an entire ecosystem. Cogon grass, which is entering Louisiana along roadways, increases the amount of fuel in forests, so that fires burn hotter and kill native longleaf pines. Southern Louisiana is already losing 25 square miles of coastal lands each year; a crisis exacerbated by the nutria, a large South American rodent that eats the roots and stems of marsh plants.

An early study of invasive species in the United States estimated that damage and control efforts cost $137 billion annually. Formosan termites alone cause $1 billion in damage nationally each year, with $300 million spent in the New Orleans area alone. One may argue that invasive species are simply one of the costs that accompany the many benefits of a modern, industrialized society. But, as in any endeavor, costs can and must be minimized. The problem of invasive species is especially daunting in Louisiana, but is not beyond the power of Louisianians to solve it. Various solutions are underway and others are planned. With knowledge of the geography of species introduction, we can better design strategies of prevention. On another level, the problem of invasive species in Louisiana calls for recovering a particular kind of environmental knowledge: simply knowing and appreciating the native plants and animals with which we share this place. Even as we develop effective policies and technologies for preventing and slowing the spread of introduced species, we need to learn enough about our local ecosystems to recognize new species that may create problems.

Louisiana: A Hotspot for Species Introduction

Most large rivers host extraordinary communities near their mouths. Human societies tend to be more culturally diverse at these strategic positions; their economies and histories tend to be more far-reaching and tumultuous. The meeting point of vast interior hinterlands with large exterior water bodies—where *rio* joins *mar* at the brink of continents—also creates rich, productive natural ecosystems; in Louisiana, these environments include our inland wetlands and swamps as well as the estuaries where fresh and salt water mix. To scientists, urbanists, poets, and engineers, these port cities and their environs comprise arguably the most fascinating places on Earth. But communities at the mouths of great rivers are also more vulnerable to invasion by species that did not evolve under these specialized conditions. Centuries of shipping merchandise and raw materials from suppliers in one part of the world, through ports and waterways to consumers in other parts of the world, have seen the accidental relocation of thousands of species to new environs.

Louisiana, especially the porous netherlands of the southeast, forms an especially vulnerable site for species introduction. Port activity accounts for much accidental introduction, and Louisiana is home to one of the world's great ports, New Orleans, the gatekeeper of the Mississippi River and entry point to the richest valley of the richest country on Earth. It is neighbored by dozens of smaller ports, perched on nearly every waterway that penetrates the Deep South, as well as larger facilities in nearby Houston, Gulfport, and Mobile. Louisiana's mild, humid subtropical climate allows many incoming species to survive upon arrival; of these, some thrive by exploiting niches in the state's diverse ecosystems (made vulnerable by the large quantity of disturbed land) and then spreading. Railroads, canals, roads, and interstates crisscross the region, performing critical economic functions but also serving as conduits for this diffusion. Even the waters of the Mississippi carry species introduced in northern ports to Louisiana's waterways and estuaries downstream.

As a link between the American heartland and world beyond the Gulf of Mexico, Louisiana is a hotspot for invasive species. Consider these figures:

Of the world's 100 worst invasive species identified by the *Fondation d'Entreprise*, at least 13 occur in southern Louisiana. Those species are the Asian tiger mosquito,

- Formosan termite, zebra mussel, water hyacinth, feral cat, cogon grass, house mouse, nutria, rabbit, kudzu, rat, red imported fire ant, and feral pig.
- According to the US Geological Survey's database of nonindigenous aquatic species, Louisiana has more introduced aquatic plants (32) than any other state save Florida, which has 45. Louisiana has almost 2_ times the average number of introduced aquatic plants per state.
- The Nature Conservancy's "Dirty Dozen" list of most destructive invasive species in the US cites four (33%) occurring in Louisiana, a state that comprises 1.4% of the conterminous US land area. Those species are the zebra mussel, tamarisk, hydrilla, and Chinese tallow.

Louisiana bears a disproportionate share of the ecological and economic burden imparted by invasive species, in a natural and built environment that offers so many unique aspects to the nation and world.

The Geography of Species Introduction in Louisiana

How did these alien species arrive? *Pathways* are the geographical features or patterns that species follow into new areas. Pathways may include shipping lanes, interstate rights-of-way, rivers, ocean currents, or transportation corridors. *Media* are the materials and physical objects on which the species "hitch a ride," and may include ballast water, packing material, water trapped in used tires, or outboard motors. Pathways and media together are sometimes known as *vectors*. *Portal* is a term used here to describe the point of original introduction, which applies to both intentionally and accidentally introduced species. Once introduced, species may perish or persist in their new environment; those that persist may spread by (1) expansion diffusion, in which they expand contiguously into adjacent areas (for example, nutria); (2) by hierarchical diffusion, where they jump from place to place in a non-contiguous manner (for example, Formosan termites relocated by trucks hauling wood to new cities), or (3) by contagious diffusion (such as a virus, spreading from one to many). Considering only those species that have been *accidentally* introduced to our land, there are a number of common pathways of arrival and/or dispersion in Louisiana.

Port / Shipping Activity A premier pathway of species introduction to the Gulf Coast is also one of the region's most important industries. Ships from distant lands have been importing cargo to our shores since 1699; today, 6000 ocean-going vessels carry over 11,000,000 tons of cargo annually through the Port of New Orleans alone. The 2,340-mile-long Mississippi River accesses 14,500 miles of connecting waterways throughout the North American interior, and provides the entire world with access to that million square mile basin once it passes through southeastern Louisiana and joins the Gulf of Mexico. Species accidentally introduced by ocean-going vessels into ports in Louisiana, Texas, Alabama, and Mississippi have subsequently spread to surrounding areas. Among them:

- Formosan termites originated in Asia and arrived probably first in Houston in the 1940s by means of wooden pallets used to stack freight.
- Red and black imported fire ants arrived in Mobile from South America during 1910s-1940s by way of soil and shipping dunnage (packing materials).
- Asian tiger mosquitoes arrived in Houston during the 1980s as larvae residing in water trapped in used tires.
- Mediterranean geckos arrived to New Orleans as "stowaways."

Transportation Corridors Trucks and trains, like ships, may relocate cargo bearing invasive species. The corridors they use also have been documented as pathways; for example, there is evidence that Formosan termites may spread by infesting consecutive ties along railroad tracks.

Waterways Once introduced to a particular site, the labyrinth of natural and manmade waterways intersecting Louisiana often serve as pathways themselves, allowing aquatic species to proliferate throughout an entire drainage basin. The waters of the Mississippi have brought to Louisiana the zebra mussel, introduced via ballast water dumped in the Great Lakes region, and the rainbow smelt, stocked in northern lakes. Asian clams and Australian spotted jellyfish may spread by water currents, eddies, and phenomena such as the "dead zone" in the Gulf of Mexico.

Equipment / Object / Water Relocation The relocation of equipment, oil rigs, and boats along terrestrial or marine transportation corridors may disperse aquatic plants, crustaceans, and other creatures over long distances to new habitats or into new drainage basins just a few miles from prior infested areas. The transportation of lumber, firewood, and railroad ties (used for landscaping) has spread Formosan termites to new areas. Dumping of water into waterways also accounts for species introduction. On a regional scale, this phenomenon has been observed in ballast water, as previously mentioned; at the local scale, the disposal of aquarium or bait water into the ecosystem has spread hydrilla, goldfish, dotted duckweed, and Asian clams.

Animal Routes Native birds and animals are unlikely to introduce species from afar because of their relatively restricted ranges, but they may assist in spreading introduced species throughout the new habitat. Birds, for example, may have helped spread giant salvinia throughout the wetlands of southern Louisiana. When infected by the introduced viruses that cause encephalitis, crows and other birds do not necessarily die immediately, creating the possibility that infected birds' flight paths and migrations become pathways.

Monocultural Croplands Vast expanses of a single agricultural or silvicultural species have served as pathways spreading pests into previously uninfested regions. Boll weevils diffused from Central America into Mexico and thence into the American South a century ago by infesting contiguous plantations across the cotton belt, causing billions of dollars in damage.

Ecological Niches If an ecological niche opens up through the eradication of a native species, such as the wolf, that open niche may be viewed as a pathway if it attracts species from neighboring regions. Coyotes arrived to Louisiana from the American West in this manner. Open ecological niches may also help establish introduced species that otherwise would have perished.

Disturbed Ecosystems Expansive areas of overgrazed grasslands, clear-cut forests, or other disturbed ecosystems enable invasive grasses and other plants to spread. Cogon grass spreads along stressed area paralleling interstates and other rights-of-way in southern Alabama and Mississippi, into Louisiana.

Pathways of the Future In the near future, we may see new pathways of species introduction develop in Louisiana. Freshwater-diversion projects designed to reverse salt-water intrusion and to slow wetlands erosion may carry zebra mussels and rainbow smelt into the wetlands. Global climate change may expand regions of subtropical or tropical climatic conditions, allowing exotic species to survive which otherwise would have perished. Deliberate introductions may increase as immigrant communities attempt to grow traditional foods locally. Globalization of economic activity, while not a pathway *per se*, will likely increase the rate at which pathways accidentally deliver new species to our shores, expand the geographical range from which these species come, and speed their spread once they are established.

So What To Do?
Most people agree that invasive species threaten our biodiversity and cost us billions of dollars, but few agree on what we can do. The challenge posed by the continuous stream of alien species entering Louisiana through various portals and spreading via numerous pathways cannot be met through a single "silver bullet" solution. Rather, solutions are as varied as the dimensions of this problem, and they all depend on *people*.

People minimize the spread of certain invasive species in their domestic and recreational activities. This is achieved when:

Old wood and railroad ties are inspected carefully for Formosan termite infestation before they are transported, and treated or burned if an infestation is found.
Aquatic plants are removed from hulls and outboard motors before recreational boats are launched in new water bodies.
Exotic fish in aquariums and aquatic plants in ponds are carefully controlled and not released into the environment.

People make laws more effective. Federal and state laws prohibit known invasive species to be carried in air, rail, and ship cargo. Animals or plants not specifically excluded by law may be quarantined for a period by the USDA Animal and Plant Health Inspection Service (APHIS) to assure that they are free of diseases or pests. These laws are supported when:

Gardeners purchase native rather than alien species from nurseries and catalogs.
Pet wholesalers and retailers stock native rather than exotic species.
Returning vacationers leave exotic plants and animals behind.

People reduce the gamble of biocontrol—that is, the introduction of species to control invasive species, a sometimes-risky venture. Before introduction, scientists try to predict whether the biocontrol species will also become a pest. More wins than losses result when:

Farmers and gardeners use only carefully studied biocontrol species that are either native or unlikely to become invasive.
Hunters and anglers allow wildlife agencies the time and resources to study the impacts of stocking new species.

People minimize risks of introduced food species. Alien species may be introduced as seed to develop a food resource or to improve recreational hunting and fishing, but these species may eventually cost more than they benefit. Risk is reduced when:

Gardeners, especially in recently arrived immigrant communities, are discouraged from planting homeland species around their new homes.
Hunting and angling clubs stock private recreational areas with native species.
Seed species are quarantined and studied before use.
Aquaculture entrepreneurs isolate their equipment and processes from the natural environment, with proper disposal and treatment of wastewater.

People control "late blooming" invasives. Some alien species, like nutria, Chinese tallow, or salvinia, did not become invasive (harmful) until years after introduction. Late bloomers can be controlled when:

Hunters and trappers pursue invasive animals such as nutria and wild hogs.
Home and camp owners control invasive water plants through removal or use of approved herbicides.
Property owners remove invasive trees and shrubs and replant with natives.
Fishermen empty bait buckets and bilges before proceeding to another location.

People enforce controls in industry and commerce. The US Coast Guard depends upon the cooperation of global commercial shippers to prevent accidental species introduction through ballast water. However, ships moving freely between Louisiana, the Caribbean, and Latin America are not covered by this process, nor are invaders riding in a plane's wheel well, a ship's hull, or elsewhere. Gaps can be filled when:

Rail, air, and towboat crews clean equipment and transportation corridors that possibly harbor invasive species.
Gulf and Caribbean shippers or ports initiate local ballast water management programs.
Importers and exporters inspect and, if necessary, destroy cargo containers and packing materials that possibly harbor invasive species.
Consumers buy domestic or local products whenever possible.

Together, every Louisianian, government agencies at all levels, every wildlife, recreation and conservation organization, and all businesses and universities can help control invasive and potentially invasive species through these routine activities. Biodiversity *can be lost* imperceptibly, but invasive species *can be controlled* just as imperceptibly, with a little bit of effort from everyone.

For More Information

General Information

Center for Bioenvironmental Research. http://www.cbr.tulane.edu

Louisiana Department of Natural Resources, Office of Coastal Restoration and Management. http://www.savelawetlands.org

Louisiana Department of Agriculture and Forestry. http://www.ldaf.state.la.us

Louisiana Department of Wildlife and Fisheries. http://www.wlf.state.la.us

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3.B Species

Aquatic species are organisms living primarily in a water environment. Usage commonly refers to aquatic plants such as water hyacinth and salvinia, fish, and invertebrates, but also includes mammals such as nutria. The definition of "aquatic species" has been expanded for this management plan to include species that arrived through aquatic pathways. Therefore, the Louisiana Aquatic Invasive Species Management Plan will address some species that are not traditionally considered aquatic, such as cogongrass and Formosan termites.

3.B.1 Aquatic Plants

Aquatic invasive plants of Louisiana are categorized in this management plan as Extensively Established Species, Locally Established Species, and Potential Arrivals, based on range data from the USGS Nonindigenous Aquatic Species Program. Aquatic invasive plants found in eight or more of the 13 drainage basins spanning Louisiana and adjacent area were categorized as "Extensively Established Species." Those that occur in three to seven drainages were categorized as "Locally Established Species," and plants found in two or fewer drainages were listed as "Potential Arrivals."

It is important to note that this method of categorization emphasizes distribution in the state rather than density in a particular location. One plant species sparsely distributed throughout eight drainages may be listed as "extensively established", whereas another species could be extensively established in only one drainage basin but listed only as a "locally established species".

Also, note that not all non-native plants listed by USGS as present in Louisiana appear in this section. Only those plants generally recognized as the most problematic, regardless of establishment, are described below. (Please see Appendix B for a complete list of all aquatic invasive plants in Louisiana.)

3.B.1.a Extensively Established Species

According to USGS, the following aquatic plants occur in eight or more drainage basins in Louisiana:

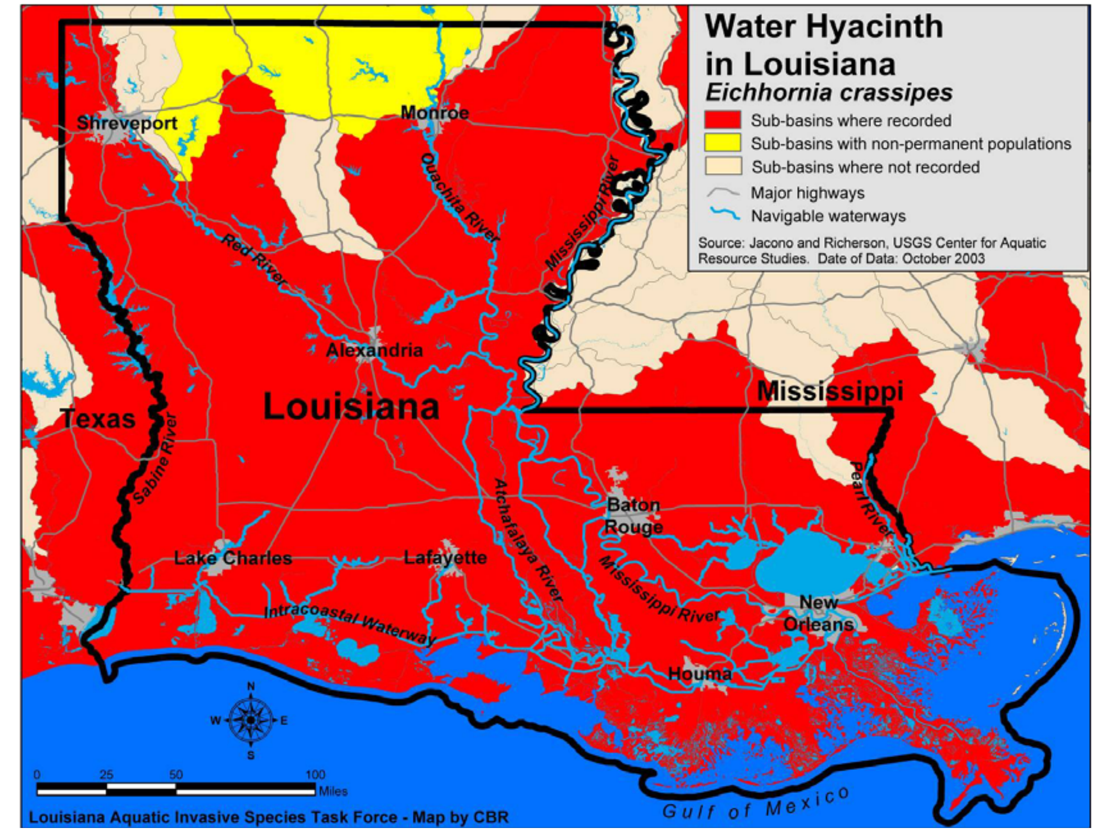
3.B.1.a.i Water Hyacinth (*Eichhornia crassipes*)

Water hyacinth was first introduced to the United States as an ornamental plant at the World's Industrial and Cotton Centennial Exposition in New Orleans in 1884-1885. A South American native, water hyacinth frequently clogs bayous and canals, impedes boat traffic, slows water currents, and blocks light to native submerged aquatic vegetation (SAV) which degrades water quality and harms wildlife. Known for its beautiful flowers, hyacinth can be found in almost every drainage basin in Louisiana.[68]

3.B.1.a.ii Chinese Tallow Tree (*Sapium sebiferum*)

Benjamin Franklin first introduced Chinese tallow trees to the United States in 1772 as ornamentals.[69] Widely sold by nurseries and promoted by landscapers for its attractive red and green foliage, the hardy Chinese tallow — a source of tallow oil and wax — was also planted throughout the Gulf South in the early 20th century in hopes of establishing a local soap industry.[70] Tallow trees escaped tree farms when natural processes (animal interaction, bird consumption, wind, etc.) spread the seeds over long distances. Today, these trees are considered nuisances in many Louisiana prairies, parks, and wetlands.

[68] Jacono and Richerson 2003.
[69] McQuaid 1998.
[70] USGS 2000a.



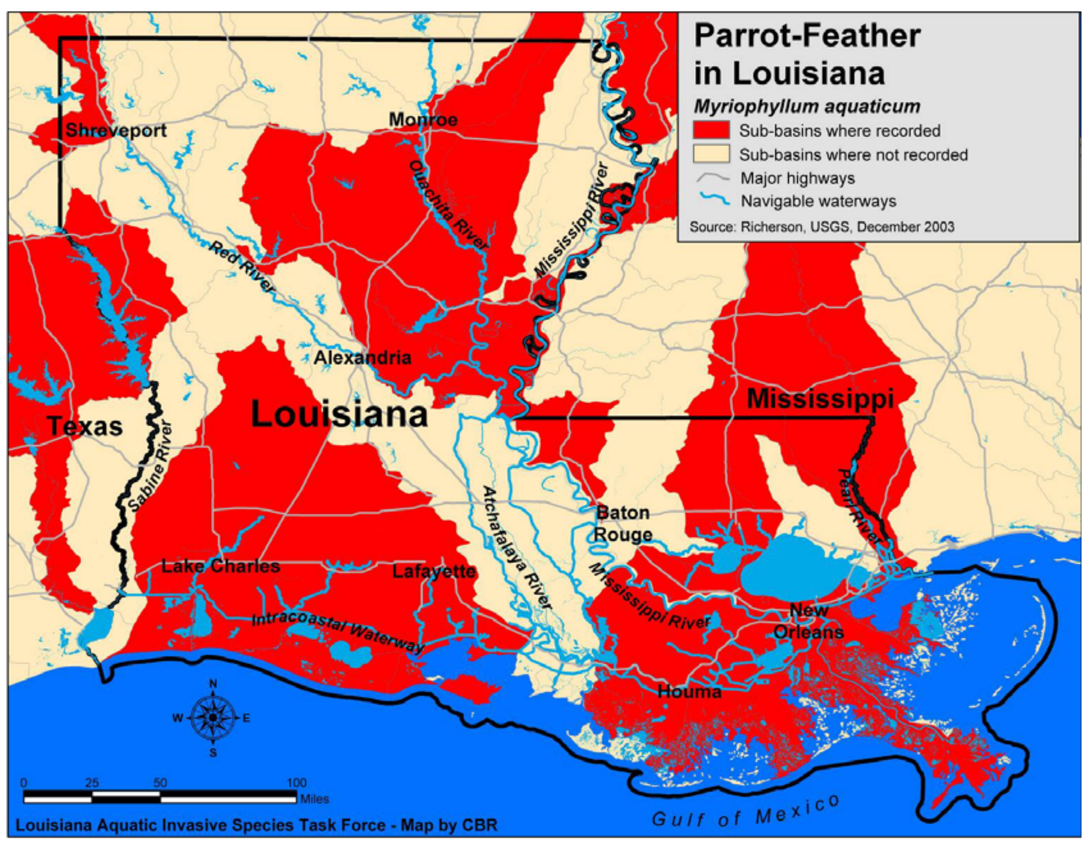
Distribution of water hyacinth in Louisiana (map, top), aggregated by drainage basin. First introduced to the U.S. as an ornamental plant at an exposition in New Orleans in 1884-1885, this South American native frequently clogs waterways, impedes boat traffic, slows water currents, and blocks light to submerged vegetation, which degrades water quality and harms wildlife. Because of its attractive purple flowers, water hyacinth quickly became popular among gardeners and landscapers. Many invasive species are aesthetically appealing, which aids their spread and exacerbates their ecological and economic harm. This invasive plant infests nearly 200,000 acres of Louisiana's waters. *Map and photos by CBR, 2003-2004.*

Chinese Tallow

Chinese tallow trees can reach up to 30 feet in height and form dense monocultures in wooded areas, affecting the growth of native trees and shrubs. *Photo by CBR, 2004.*

Parrot Feather

Distribution of parrot feather in Louisiana (map, below), aggregated by drainage basin. A popular plant in aquatic gardens and aquariums, parrot feather probably escaped through aquarium releases into open water bodies. It can reproduce vegetatively, so boat traffic or the natural flow of water may serve as a pathway. Parrot feather is also known as Brazilian watermilfoil and is sometimes mistaken for Eurasian watermilfoil. *Map by CBR, 2004.*



Still sold by some plant nurseries, Chinese tallow trees grow quickly and resist many pests. Sometimes called "popcorn trees," they can grow to a height of 30 feet, tend to form thick stands, and can easily shade-out native plants. Chinese tallow trees are dispersed throughout almost every Louisiana parish. [71]

The Louisiana Department of Agriculture and Forestry runs a state-wide cost-share program with private landowners to combat Chinese tallow trees. Tallow trees can be controlled with fire and some chemical spraying in pine stands, but these methods are not effective in bottomland hardwood forests because fire and chemicals kill deciduous trees.[72]

3.B.1.a.iii Parrot feather (*Myriophyllum aquaticum*)

Parrot feather is a submerged aquatic plant that can grow in riparian areas and at water surfaces. Sold at gardening centers, and frequently under an incorrect name,[73] parrot feather is also known as Brazilian watermilfoil and is sometimes mistaken for its "cousin", Eurasian watermilfoil (*Myriophyllum spicatum*).

This aquatic weed is a native of the Amazon River basin in South America, but is now found worldwide. Its exact date of introduction to the U.S. is unknown, but it was first discovered here in a Washington, D.C., pond in 1890. A popular plant in aquatic gardens and indoor and outdoor aquariums, parrot feather probably escaped cultivation through aquarium releases into open water bodies. It can reproduce vegetatively, so boat traffic or the natural flow of water may serve as a pathway in spreading it.

Brazilian watermilfoil shades out native submerged aquatic vegetation and seriously disrupts the aquatic food chain. This aquatic weed can block waterways, suspending boat traffic and fishing, and could potentially clog irrigation and drainage canals. Thick growth at the water surface can also provide ideal mosquito breeding habitat.[74]

3.B.1.a.iv Hydrilla (*Hydrilla verticillata*)

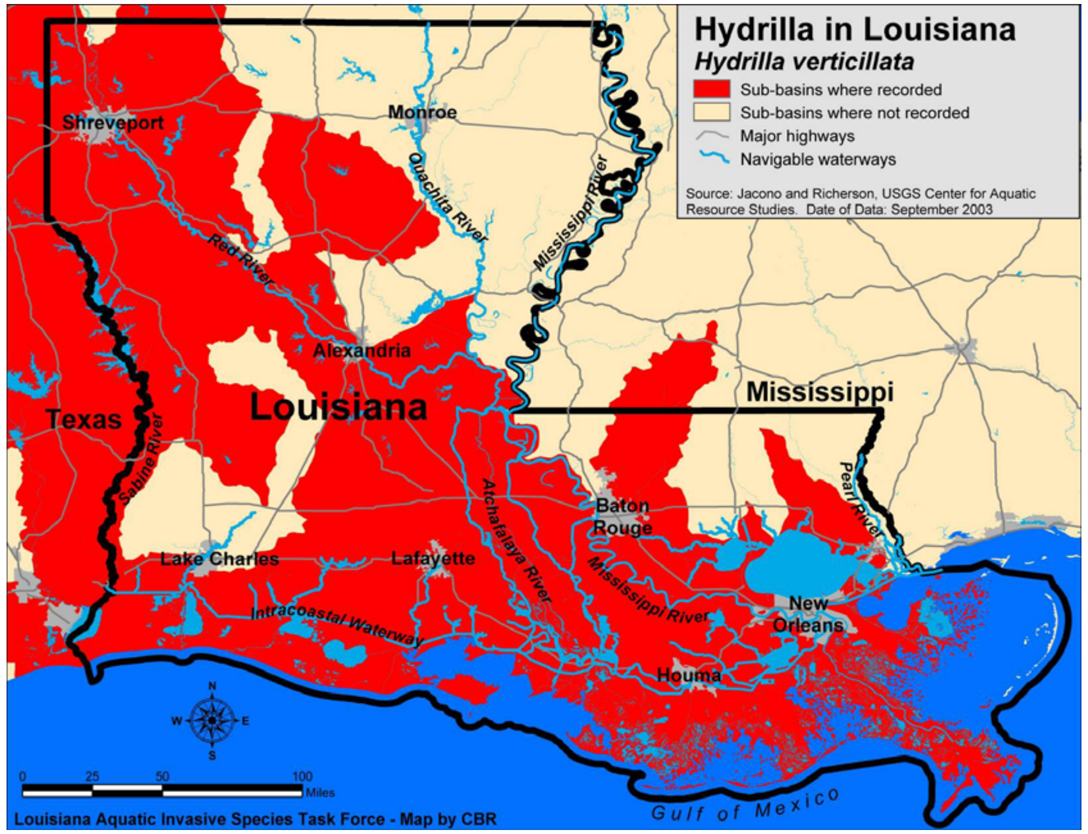
Originally from Asia, hydrilla is a rooted, aquatic weed that inhabits both deep and shallow waters. In shallower areas, hydrilla forms thick mats that impede boat traffic and swimming. It adversely affects water quality by shading out native vegetation, lowering dissolved oxygen concentrations, and can result in fish kills.[75]

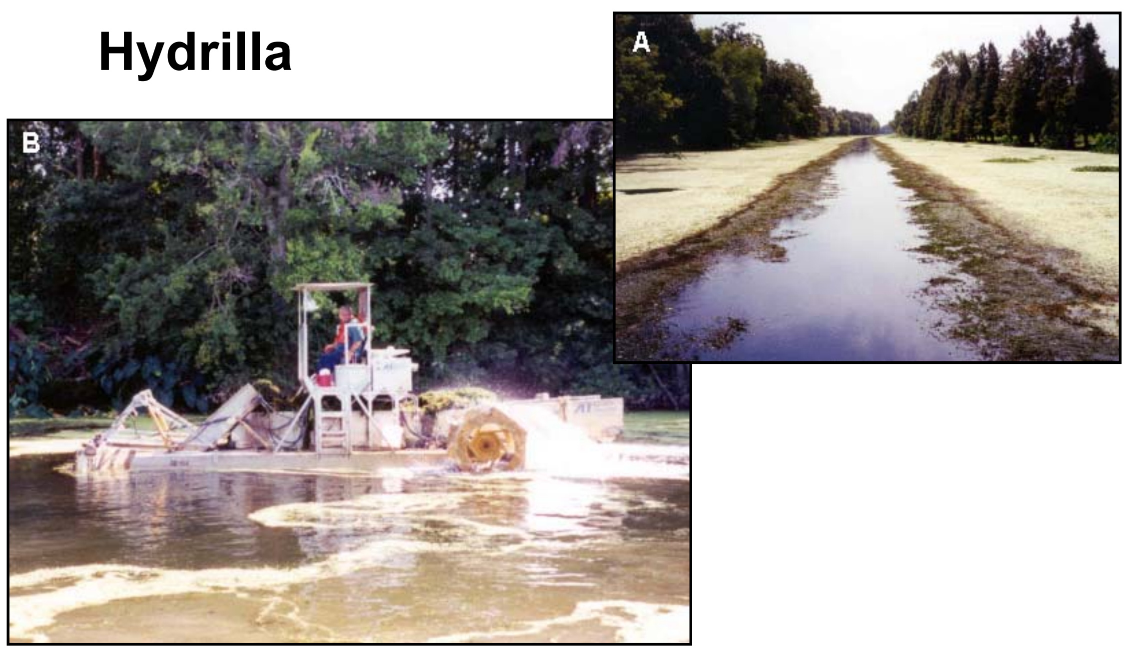
It is believed that hydrilla was first discarded from a home aquarium or possibly was planted in canals in Miami and Tampa, Florida. Accidental introduction through boating, usually when attached to a boat or boat trailer, is the primary pathway spreading hydrilla into new areas. Hydrilla is appearing more frequently in Louisiana drainages, particularly in the Atchafalaya Basin and along Highway 1. In Bayou Lafourche, Louisiana, hydrilla clogged an intake pipe for a drinking water treatment plant, causing public health concerns. At times, it made several water bodies virtually unusable for aquatic recreation, in particular the Spring Bayou Wildlife Management Area and Henderson Lake in the Atchafalaya Basin.[76]

3.B.1.a.v Wild Taro (*Colocasia esculenta*)

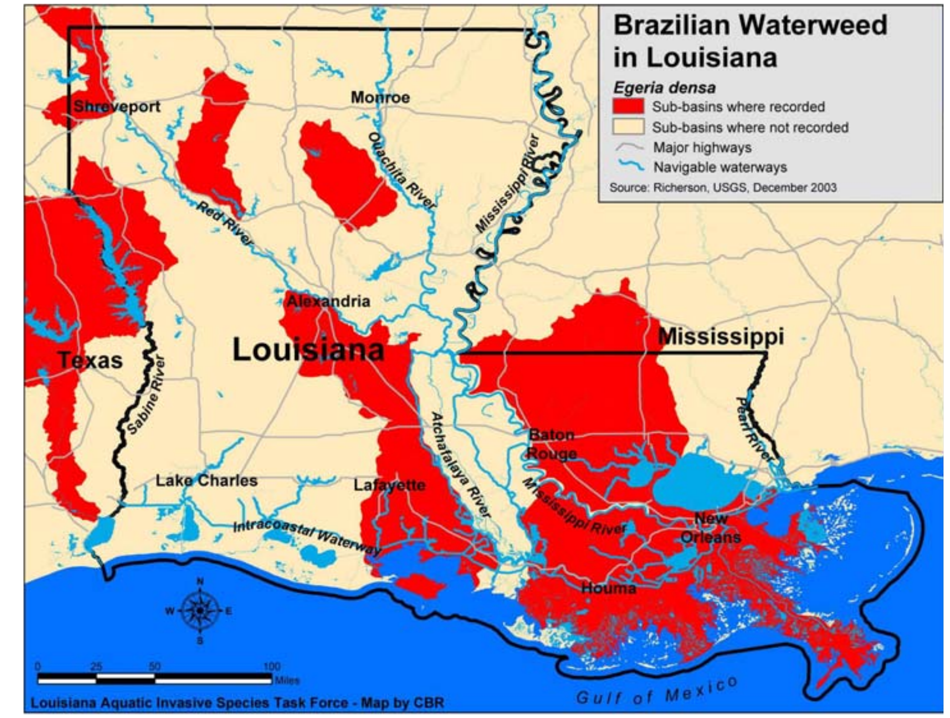
Wild taro was initially introduced to North America in association with the slave trade, but spread when the U.S. Department of Agriculture promoted it as a substitute for potatoes in the early 1900s. Wild taro forms dense growth stands in riparian zones and displaces native vegetation.[77] Many types of taro are sold at garden stores as ornamental plants.

[71] University of Florida Center for Aquatic and Invasive Plants 2001a.
[72] Frey 2003.
[73] University of Florida Center for Aquatic and Invasive Plants 2001b.
[74] Washington State Department of Ecology 2003.
[75] Jacono 2002a.
[76] Jacono 2002a; Lovell and Bahlinger 2002.
[77] University of Florida Center for Aquatic and Invasive Plants (no date).

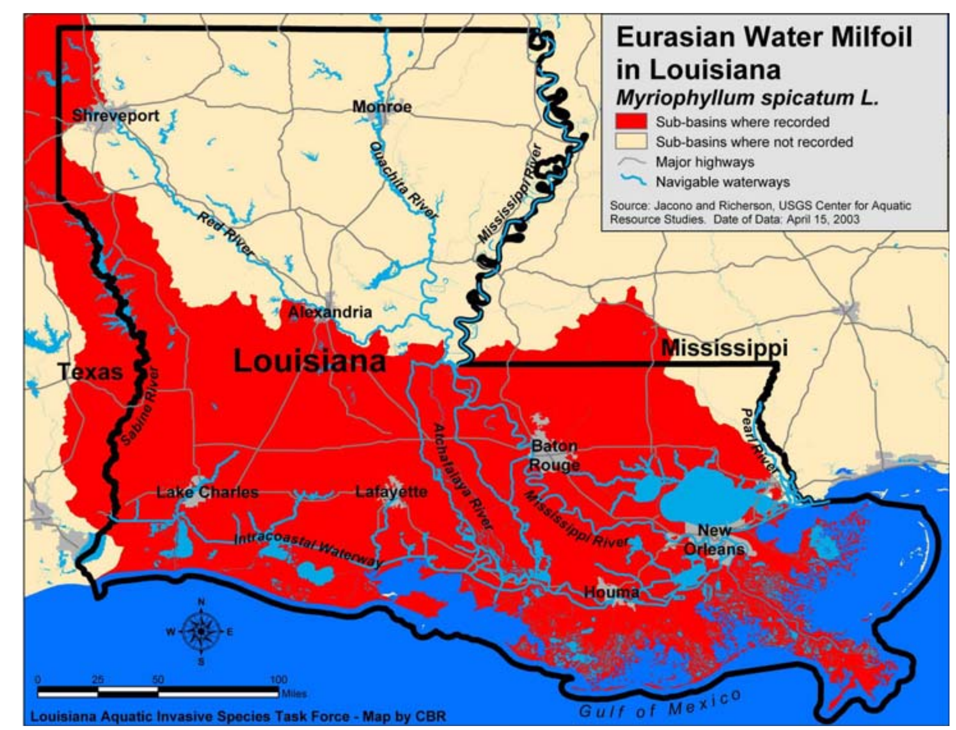




Distribution of hydrilla in Louisiana, aggregated by drainage basin. This rooted aquatic weed from Asia forms thick mats which can impede boat traffic and swimming, diminish water quality, and kill fish. In Bayou Lafourche, hydrilla clogged an intake pipe for a drinking water treatment plant (A), causing public health concerns. To alleviate the infestation, a hydrilla mower clears a mat on Bayou Lafourche (B). *Map by CBR, 2003-2004. Photos by BTNEP, 2003.*



Distribution of Brazilian water weed in Louisiana, aggregated by drainage basin. Deliberately introduced by the aquarium trade, this aquatic weed became established in the wild most likely through aquarium releases. It may also have been planted for malaria eradication, as its oxygenating properties led researchers to believe it could control mosquito larvae. *Map by CBR, 2004.*



Distribution of Eurasian water milfoil in Louisiana, aggregated by drainage basin. Eurasian watermilfoil was first recorded in the U.S. in Washington, D.C. in 1942, possibly introduced intentionally by federal authorities. It has since spread throughout the U.S. as a disposed packing material for baitworms, and as vegetative debris attached to boats and boat trailers. It is still sold by some pet stores and on the Internet as an aquarium plant. *Map by CBR, 2004.*

3.B.1.a.vi Brazilian Waterweed (*Egeria densa*)

Since as early as 1915, Brazilian waterweed has been a popular aquarium plant for its rapid growth and oxygenating properties. Pet and aquarium stores sometimes sell this plant under the name "Anacharis". To date, it is one of the most widely distributed and utilized aquarium oxygenator plants. Also known as common waterweed and Brazilian elodea, *Egeria densa* prefers the slow-moving waters of streams, ponds, and lakes.

The aquarium trade deliberately introduced this aquatic weed, but its establishment in natural ecosystems is likely due to aquarium releases. It may also have been planted for malaria eradication: its oxygenating properties led researchers to believe it could control mosquito larvae.[78]

Brazilian waterweed forms thick mats at the water surface, impeding recreational activities such as swimming, boating, and fishing. The weed chokes out native vegetation and degrades water quality and fish habitat. *Egeria densa* can reproduce vegetatively and is therefore prone to spreading through boat traffic and water currents.[79]

3.B.1.a.vii Eurasian Watermilfoil (*Myriophyllum spicatum*)

Eurasian watermilfoil, also called spike watermilfoil, aggressively outcompetes native vegetation and degrades water quality for fish and birds. *Myriophyllum spicatum* prefers slow moving waters, such as ponds, lakes, bayous, shallow reservoirs, streams, and low-energy rivers, but can tolerate brackish waters. It forms thick, dense mats at the water surface and impedes recreational activities, such as boating and swimming.[80]

Myriophyllum spicatum was first recorded in the United States in Washington, D.C., in 1942, possibly an intentional introduction by federal authorities. Its rapid spread throughout the country may derive from its use as packing material for baitworms sold to fishermen. Today, the most common pathway is vegetative fragments attached to boats and boat trailers. Eurasian watermilfoil is still sold by some pet stores and on the Internet as an aquarium plant. Some introductions may be due to aquarium releases.[81]

3.B.1.a.viii Water Lettuce (*Pistia stratiotes*)

Water lettuce is a floating plant resembling a head of lettuce with thick green leaves. A perennial, water lettuce infestations impede boat traffic, swimming, fishing, and other recreational activities. It degrades water quality for native vegetation and adversely affects fish and bird populations.

Some experts believe the plant is native to Africa and was introduced in ballast water by early explorers (there are records of *Pistia stratiotes* in Florida as early as 1765). Though this plant is on the Federal Noxious Weed List, water lettuce is still available through aquarium suppliers and on the Internet.[82]

3.B.1.a.ix Common Salvinia (*Salvinia minima*)

A floating fern, common salvinia is also sometimes called "water spangles" or "water fern." *Salvinia minima* prefers slow-moving freshwaters such as bayous, cypress swamps, marshes, and ponds and lakes. Common salvinia forms thick mats on the water surface, up to almost 25 centimeters (10 inches) deep in some instances. These mats shade and crowd-out native plants, degrading habitat for fish and birds and negatively affecting water quality.[83]

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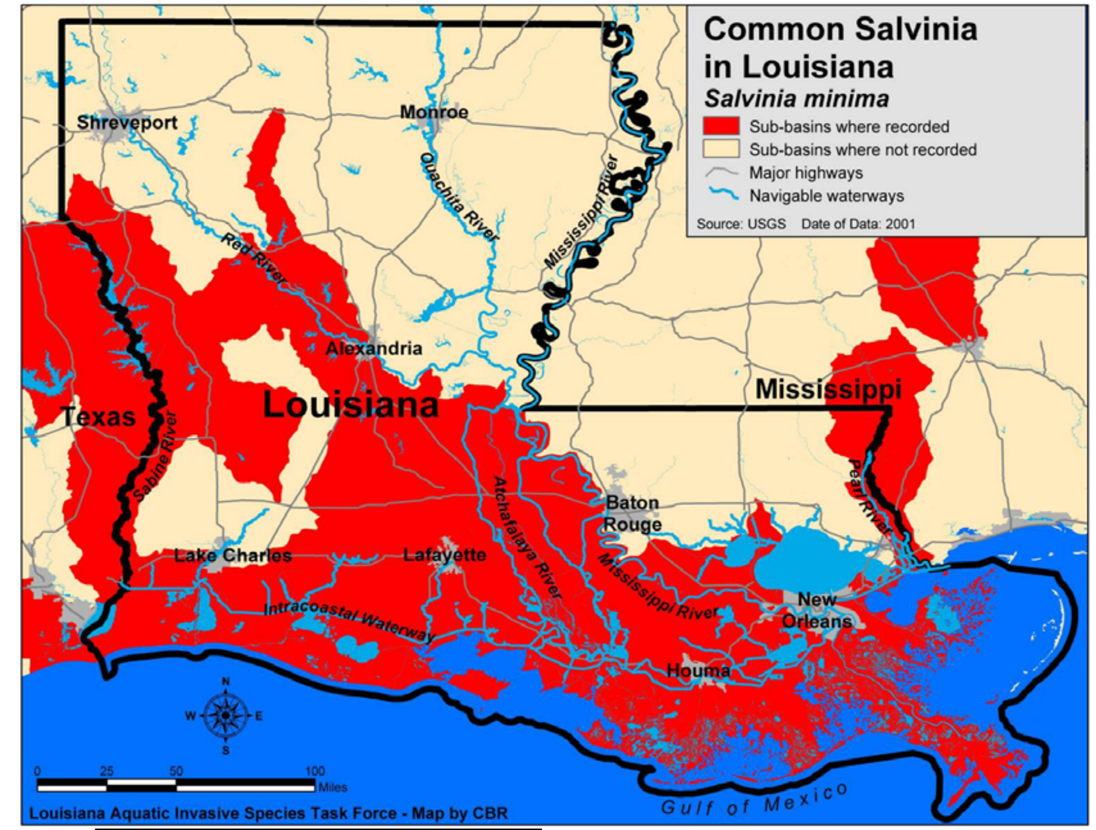
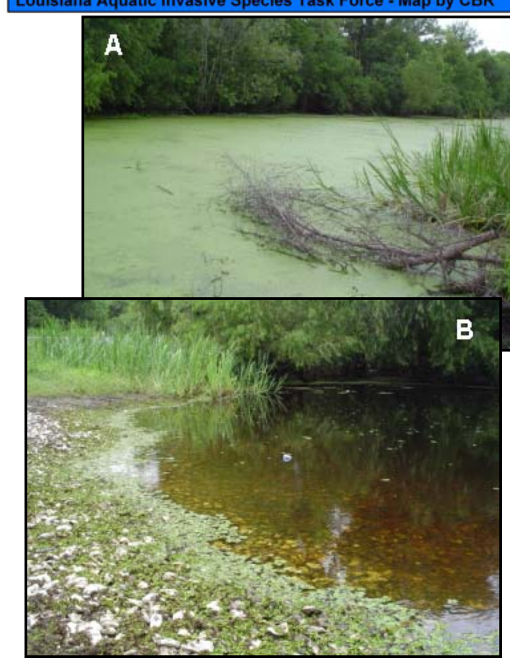
[78] University of Florida Center for Aquatic and Invasive Plants 1996.
[79] Washington State Department of Ecology (no date)a.
[80] Jacono 2002b; University of Florida Center for Aquatic and Invasive Plants 2001c.
[81] University of Florida Center for Aquatic and Invasive Plants 2001c; Jacono 2002b.
[82] Ramey 2001.
[83] Jacono 2002c.



Common Salvinia



Distribution of common salvinia in Louisiana, aggregated by drainage basin. This Central and South American native has been cultivated in water gardens in the United States since the 1880s. First recorded in Louisiana in 1980 in the Bayou Teche area of St. Mary Parish, common salvinia has since spread into rice and crawfish farms via irrigation systems and is now considered a nuisance throughout the state. Common salvinia frequently spreads when boaters fail to wash their boats and trailers before launching at new ramps. In photo A, taken in St. John the Baptist Parish, salvinia covers the surface of a canal, hindering boat traffic; in photo B, it lines the edge of a boat ramp. Photo C shows common salvinia in swamp waters of Tangipahoa Parish. Salvinia and other aquatic weed mats provide ideal habitat for mosquitoes and other disease-carrying organisms. *Map and photos by CBR, 2004.*

LSU researchers release Florida-strain salvinia weevils in an experiment to control common salvinia at Cypress Lake. Biocontrol can be an effective method for curbing the spread of invasive species, but risks introducing new species which can prove even more harmful. *Photo by LSU Agricultural Center.*

This Central and South American native has been cultivated in the United States since the 1880s for water gardens. Researchers believe *Salvinia minima* escaped from cultivation into Florida's St. Johns River in 1928, probably when a water garden flooded, but possibly from an intentional release. It was first recorded in Louisiana in 1980 in the Bayou Teche area of St. Mary Parish, and is now considered a nuisance throughout the state. Introduction into rice and crawfish farms via irrigation practices has caused problems for farmers. One of the most common *Salvinia minima* pathways is boat traffic traversing Louisiana's waterways.[84]

The USDA Agricultural Research Service, in cooperation with the National Park Service, is experimenting with the Florida salvinia weevils (*Cyrtobagous salviniae*) as a form of biocontrol for common salvinia. Tests began in June 2002 at Jean Lafitte National Historical Park and Preserve. The sites are monitored regularly for survival of the weevils and for salvinia damage. Despite additional weevil releases in August and December 2002, the March 2003 surveys did not find any adult weevils. However, a July 2003 survey resulted in the discovery of one adult. It is believed that this weevil, though solitary, is part of a new generation from a reproducing population. An additional 1,000 salvinia weevils were released at the experiment sites in June and July 2003.[85]

3.B.1.b Locally Established Species

According to USGS, the following aquatic invasive plants occur in three to seven drainage basins in Louisiana:

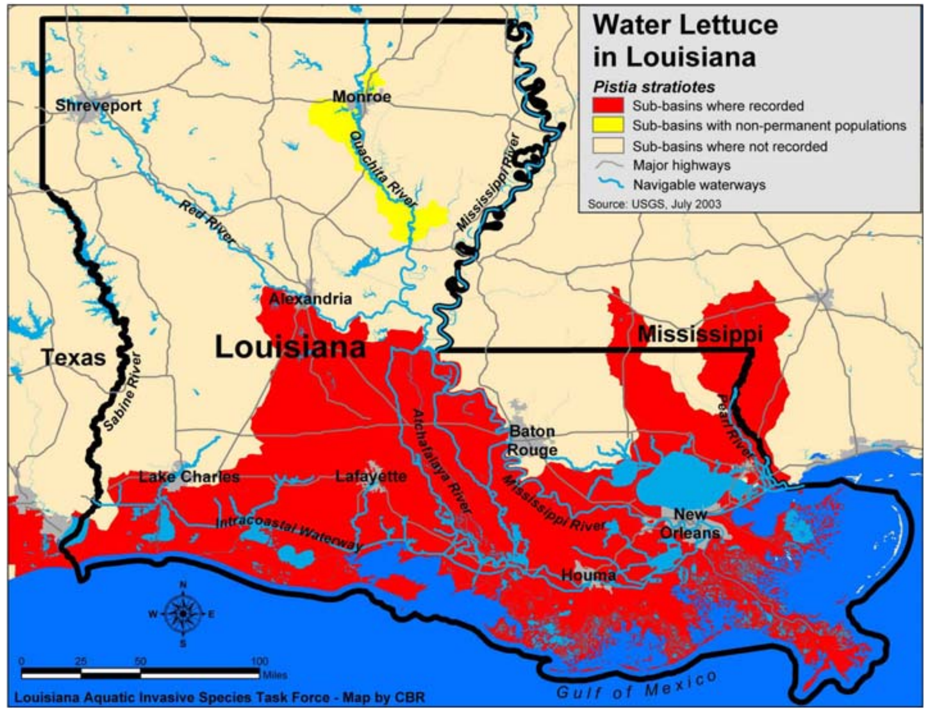
3.B.1.b.i Giant Salvinia (*Salvinia molesta*)

Salvinia molesta was probably intentionally introduced to the United States as an aquarium plant, and, in fact, has been linked to several aquatic plant nurseries. The plant was probably kept in an aquarium until overgrowth occurred, at which point the aquarium contents were dumped into a local stream or pond.[86] Giant salvinia expands its range through reproduction, wind transport, and boaters and fishermen who do not rinse their gear.

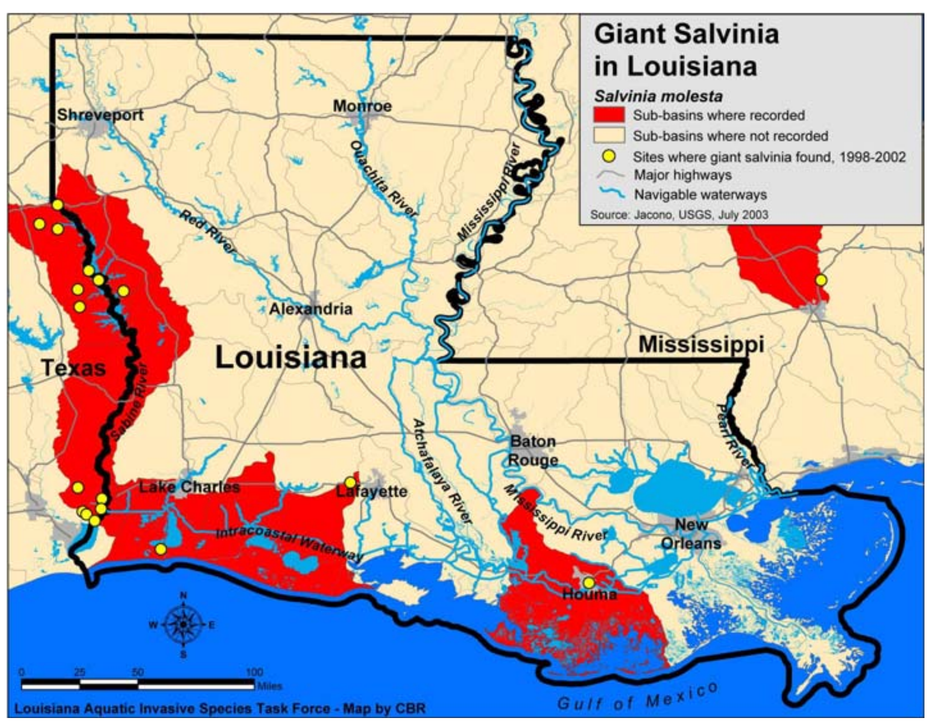
Giant salvinia first appeared in Louisiana in 1998 in the Toledo Bend Reservoir on the Texas-Louisiana border. Since then, it expanded into at least 15 locations throughout southern Louisiana. It is a free-floating, rootless plant that reproduces quickly; under ideal conditions, *Salvinia molesta* can double its biomass every seven to ten days. It chokes bayous and canals, and can cover large portions of lakes and reservoirs, degrading water quality, harming wildlife, and impeding boat traffic. In Cameron Parish, Louisiana, giant salvinia posed a public health threat because it blocked the operation of floodgates.[87]

The USDA Agricultural Research Service is working with Texas Parks and Wildlife to determine the success of the Florida salvinia weevil (*Cyrtobagous salviniae*) as a biocontrol for *Salvinia molesta*. Experiments begun in 2001 are ongoing. March 2003 surveys found the adult weevils over-wintered at all release sites, and numbers of weevils appeared larger than in 2002. Biomass of *Salvinia molesta* appeared to be decreasing. In June 2003, surveys found adult weevils at all sites, but in smaller numbers than were found in March. Researchers state, "The reason for this is simple and very exciting: much of the giant salvinia is no longer suitable for feeding."[88] Researchers observed rotting and sinking mats of *Salvinia molesta* vegetation, and no healthy, undamaged buds were found. Overall, water coverage was down from 100 percent in March to 60 percent in June.

[84] Jacono 2002c.
[85] Tipping, Center, Hulslander, and Muth 2003.
[86] Jacono 2002d.
[87] Jacono 2002d; Louisiana Aquatic Invasive Species Task Force 18 September 2002.
[88] Tipping, Center, Helton, and Findeisen 2003.



Distribution of water lettuce in Louisiana, aggregated by drainage basin. Water lettuce infestations impede boat traffic, swimming, fishing, and other recreational activities. Some experts believe this perennial is native to Africa and was introduced in ballast water by early explorers. Though on the Federal Noxious Weed List, water lettuce is still available through aquarium suppliers and on the Internet. *Map by CBR, 2004.*



Distribution of giant salvinia in Louisiana, aggregated by drainage (red) as well as individual sites (yellow). Giant salvinia first appeared in Louisiana in 1998 in the Toledo Bend Reservoir on the Texas-Louisiana border. Since then, it expanded into at least 15 locations throughout southern Louisiana. It chokes bayous and canals, and can cover large portions of lakes and reservoirs, degrading water quality, harming wildlife, and impeding boat traffic. *Map by CBR, 2004.*

In Cameron Parish, control efforts included introducing saltwater from the Gulf Intracoastal Waterway into the infested water body located on private property. This method appears to have been successful, as the giant salvinia has not reappeared in the marsh where saltwater was introduced.[89]

3.B.1.b.ii Cogongrass (*Imperata cylindrica*) [90]

Cogongrass is a hardy species tolerant of shade, drought, and high salinities, which tends to invade disturbed ecosystems such as roadway shoulders. Its dense growth pattern creates unsuitable habitat for native plants, insects, mammals, and birds. Johnson and Shilling (1998) report that "large infestations of cogongrass can alter the normal fire regime of a fire-driven ecosystem by causing more frequent and intense fires that injure or destroy native plants."[91]

Cogongrass was accidentally introduced to the United States in Mobile, Alabama, as a packing material in shipping crates. The USDA also intentionally introduced it for controlling soil erosion and as a foraging grass. Its hardiness and attractive leaves have made it a popular grass sold by plant nurseries.[92]

In Louisiana, cogongrass is rapidly spreading along roads and right-of-ways through the relocation of soil containing cogongrass rhizomes. Sometimes called "Red Baron" or "Blood Grass" for its striking red foliage, cogongrass is becoming prominent in the Florida parishes (West Feliciana, East Feliciana, East Baton Rouge, St. Helena, Livingston, Tangipahoa, Washington, and St. Tammany).[93]

3.B.1.c Potential Arrivals

According to USGS, the following aquatic plants occur in fewer than three drainage basins in Louisiana:

3.B.1.c.i Purple Loosestrife (*Lythrum salicaria*)

Purple loosestrife is an invasive plant introduced from Europe in the 1800s as an ornamental plant. It also may have arrived in the northeastern United States in ships' ballast. Loosestrife stalks can grow up to nine feet tall, and just one mature loosestrife plant can produce an estimated 3 million seeds annually. Seeds are prone to wind, animal, and water dispersal. Purple loosestrife stands disrupt wetland ecosystems by displacing native wildlife, and affect agriculture by clogging irrigation systems or destroying grazing pastures by replacing range grasses.[94]

An easy-to-grow plant with attractive purplish-magenta flowers, purple loosestrife can be purchased in many plant nurseries, garden stores, and over the Internet. Some nurseries claim to sell only sterile loosestrife plants, but these claims have often proven false.[95]

While the U.S. Fish and Wildlife Service reports that purple loosestrife is present in every state except Florida, the USDA and USGS have no record of purple loosestrife Louisiana.[96] Conflicting reports about the presence of *Lythrum salicaria* in Louisiana may be due to two native loosestrife species, *Lythrum lineare* and *Lythrum alatum*.

[89] Savoie 2003.
[90] Cogongrass is not listed by USGS as an aquatic invasive plant. The LAIS Task Force, however, has chosen to classify cogongrass as an aquatic invasive because it occurs in areas that experience some flooding, and it was introduced through an aquatic pathway.
[91] Johnson and Shilling 1998.
[92] University of Florida Center for Aquatic and Invasive Plants 2001d; Johnson and Shilling 1998.
[93] Frey 2003.
[94] Swearingen 1997; Thompson, Stuckey, and Thompson 1987; Washington State Department of Ecology (no date)b.
[95] Urbatsch and Skinner 2000.
[96] Swearingen 1997; USDA Natural Resources Conservation Service 2002; USGS 2001.

Invasive Species in Disturbed Habitats

Invasive species often thrive in disturbed habitats, thus further altering the area and possibly "enabling" the establishment of additional invasives. Multiple invasive plant species often grow together in disturbed habitats, such as in A and B, where alligator weed and common salvinia clog a bayou in St. John the Baptist Parish, and C, where common salvinia, wild taro (heart-shaped leaves), and alligator weed (narrow leaves; center right) co-exist in Jean Lafitte National Historical Park and Preserve. *Photos by CBR, 2004.*

Records from Tulane University's Herbarium in New Orleans indicate two *Lythrum salicaria* samples were collected and identified in the mid- to late-1980s. The first sample was collected in 1986 from Plaquemines Parish, approximately eight miles south of Venice, Louisiana, and about two miles east of the Mississippi River. The second specimen was collected from a cultivated garden at Longue Vue House and Gardens in 1988 in New Orleans.[97]

3.B.1.c.ii A Blue-Green Algae, *Cylindrospermopsis raciborskii* ("Cylindro")

Cylindrospermopsis raciborskii, or "Cylindro" for short, is an invasive, subtropical, microscopic blue-green alga. Researchers believe it was introduced to Florida about 30 years ago and has spread rapidly across North America over the last 10-15 years. It is likely that this alga occurs in a wide range of North American water bodies, but, due to its size, it is difficult to identify and easily confused with other blue-green algae. It is unclear how this species arrived in the United States, but it is probably spreading to new U.S. water bodies by boats, boat trailers, and waterfowl. According to St. Amand (2002), this species has been identified in water bodies throughout Florida, parts of Alabama, and central Texas. Unconfirmed reports indicate that this species was found in waters near the Caernarvon Freshwater Diversion in summer 2002.[98]

Like most blue-green algae, Cylindro has no serious adverse effect on water quality or wildlife when found in small concentrations. In fact, blue-green algae are beneficial in small concentrations because they fix nitrogen and add nutrients to the water. However, in higher concentrations, Cylindro can be very detrimental. In some Florida lakes, Cylindro outcompeted other blue-green algae species and now comprises 95 percent of the total algal biomass. When an alga species reaches high concentrations, it is called an algae bloom. Cylindro blooms in Florida can last for months at a time, although sometimes they are difficult to identify. Unlike other blue-green algae species, *Cylindrospermopsis* does not form scum on the water surface. St. Amand says Cylindro "often stays well-distributed throughout the water column and has the highest concentrations below the surface. In fact, other than a deep green-brown color, it's often difficult to determine that a serious blue-green bloom is occurring at all."[99]

Cylindro is known to produce at least three toxins — cylindrospermopsin, anatoxin-a, and saxitoxin, of which the first is the best documented. Cylindrospermopsin is a hepatotoxin which harms the liver and kidneys. Anatoxin-a and saxitoxin are neurotoxins which cause lethargy, muscle aches, confusion, memory impairment, and, at sufficiently high concentrations, death.[100] During Cylindro algae blooms, the concentration of these toxins can reach high levels and adversely impact the ecosystem, agriculture, and human health. For example, researchers suspect that *Cylindrospermopsis* may be linked to the deaths of more than 200 alligators in Lake Griffin, Florida, between 1998 and 2000. Cylindro comprises 90 percent of all microscopic algae in Lake Griffin, and researchers observed the Lake Griffin alligators behaving erratically and sluggishly, a symptom consistent with neurotoxicity.[101]

In 1997, three cows and 10 calves were found dead near a dam on a cattle farm in Queensland, Australia. Cyanobacteria blooms near the dam consisted of "a virtual monoculture of the cyanobacterium *Cylindrospermopsis raciborskii*."[102] An autopsy on one of the calves and an examination of several of the calf's organs showed damage consistent with hepatotoxin poisoning.[103]

In 1979, 150 people (mostly children) were hospitalized after ingesting from a drinking water reservoir in Australia. The water had been treated with copper sulfate to remove cyanobacteria that were blooming in the reservoir at the time, but this caused *Cylindrospermopsis*, the dominant

97 White 1986; Darwin and Wolf 1988.
98 St. Amand 2002; Chronic Neurotoxins 2002; St. Amand 2002, page 36; Rick 2003.
99 Chronic Neurotoxins 2002; St. Amand 2002, page 37.
100 St. Amand 2002, page 36; Chronic Neurotoxins 2002.
101 Hunter 2000; Chronic Neurotoxins 2002.
102 Saker, Thomas, and Norton 1999.
103 Saker, Thomas, and Norton 1999, page 179.

cyanobacterial species in the reservoir, to release even more cylindrospermopsin toxin into the water. Symptoms of the cylindrospermopsin poisoning included liver enlargement, constipation, bloody diarrhea, kidney damage, and dehydration.[104]

In Brazil, a water reservoir was treated with chlorine to kill blooming cyanobacteria, but when the algae cells died, they released more toxin into the water. More than 50 patients at a dialysis clinic died from hepatotoxin poisoning, and more than 50 more became severely ill with liver and nerve damage.

In Florida, the Cylindro seems to be resistant to copper sulfate and benomyl, a fungicide, and is non-responsive to other algae poisons.[105]

3.B.2 Finfish

The categories of "extensively established species" and "locally established species" were combined for the Finfish section of the management plan. Mobility of fish blurs the distinction between "extensively established" and "locally established." Also, the network of interconnected waterways within the state makes it easy for fish to relocate, constantly changing their ranges.

3.B.2.a Extensively Established Species

3.B.2.a.i Rio Grande Cichlid (*Cichlasoma cyanoguttatum*)

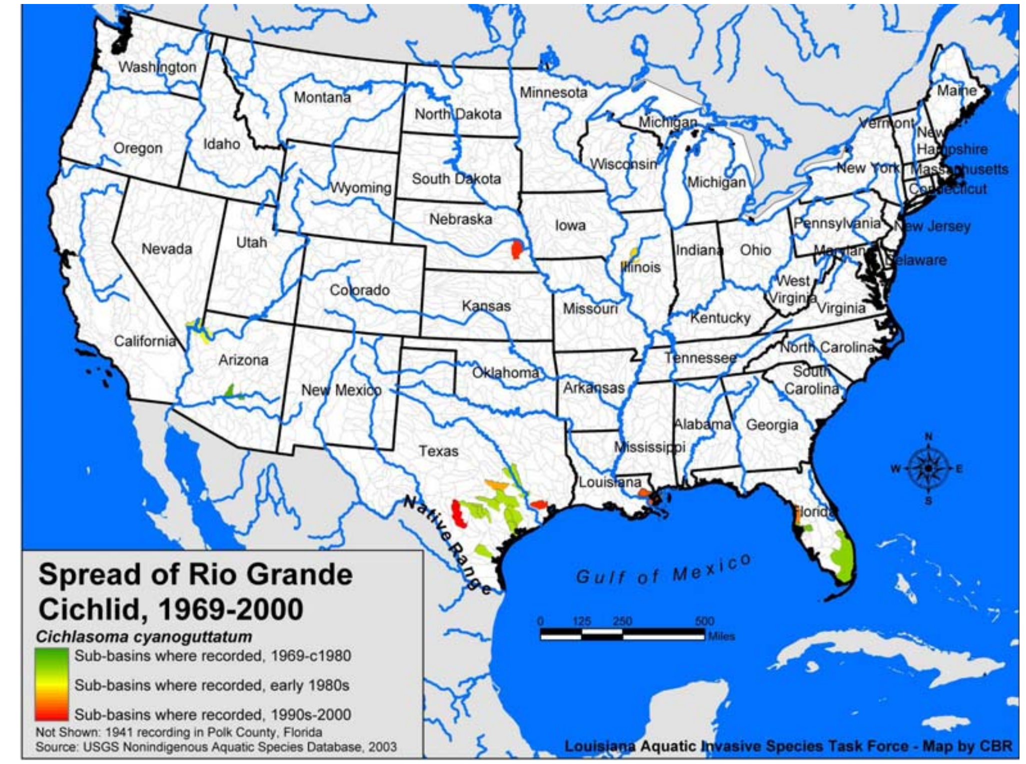
The Rio Grande cichlid, also sometimes called the Rio Grande perch or the Texas cichlid, is native to parts of southern Texas and northeastern Mexico, but its range is expanding due to human activities. Researchers speculate that the Rio Grande cichlid was introduced to Louisiana in the late 1980s or early 1990s through aquarium releases into freshwater bayous and canals on the south shore of Lake Pontchartrain. Less than 20 years after its initial introduction, this fish has been collected in numerous habitats surrounding greater New Orleans, including urban canals, freshwater marshes and bayous, and the Lake Pontchartrain estuary. Reproductive populations have been observed in many of these locations, so clearly aquarium releases are no longer the main cause of range expansion.[106]

An omnivorous fish, the Rio Grande cichlid poses a threat to aquatic vegetation and possibly commercially valuable species such as shrimp. The cichlids also may harbor parasites or diseases that can harm native fish. Recent collection locations indicate this freshwater fish is becoming tolerant of salinities of at least 5 ppt, causing concern that increased salinity tolerance will enable the Rio Grande cichlid to penetrate farther into the Lake Pontchartrain estuary, causing further displacement of native fish.[107]

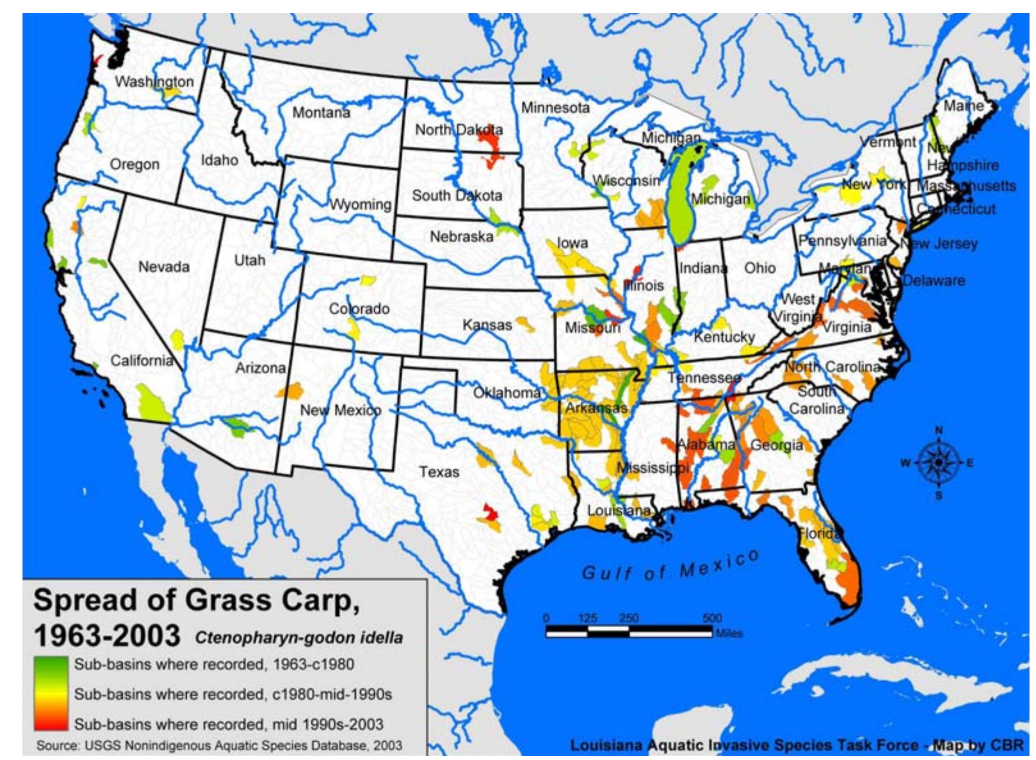
3.B.2.a.ii Common Carp (*Cyprinus carpio*)

Common carp were introduced to the United States so long ago, and are so widespread, they are commonly mistaken as an indigenous species. Records of the earliest common carp introductions are sketchy, but this freshwater fish was certainly introduced to the United States from Asia at least by 1877, and possibly as far back as the 1830s. In 1877, the U.S. Fish Commission began stocking this fish throughout the United States for food purposes. In addition to deliberate stockings, *Cyprinus carpio* escaped cultivation from fish farms and spread into wild water bodies. More recently, use of juvenile common carp as baitfish has resulted in additional introductions. Also known as German or European carp, mirror carp, leather carp, and koi, common carp have been introduced through the aquarium and water garden trade. Koi are more colorful variations of common carp that sometimes are kept as pets. It must be noted that only a small portion of common carp introductions have resulted from this pathway.[108]

[104] Falconer 1999; St. Amand 2002, page 37; Falconer 1999, page 9.
[105] Chronic Neurotoxins 2002.
[106] Nico 2000b; Cashner 2001; Aguirre and Poss 1999a; O'Connell, Cashner, and Fuentes 2002, page 16.
[107] O'Connell 2001; Cashner 2001; O'Connell, Cashner, and Fuentes 2002, page 16.
[108] Nico 1999.



Researchers suspect the Rio Grande cichlid was introduced to Louisiana around 1990 through aquarium releases into freshwater bayous and canals on the south shore of Lake Pontchartrain. An omnivore, the Rio Grande cichlid poses a threat to aquatic vegetation and possibly commercially valuable species such as shrimp. *Map by CBR, 2004.*



Grass carp were first imported to the U.S. in 1963 for Arkansas and Alabama aquaculture facilities, to control vegetation (including invasives) in fish ponds. The fish first escaped into the White River in 1966 near Stuttgart, Arkansas and were first reported in the Mississippi River in the early 1970s. Its rapid spread throughout adjacent waterways, coupled with continued deliberate stockings for biological control, allowed this fish to establish in 45 states. In Louisiana, grass carp are established in the Mississippi and Red rivers, Atchafalaya Basin, Lake Pontchartrain, and drainages on the Louisiana-Arkansas border. *Map by CBR, 2004.*

Cyprinus carpio is a freshwater fish but is able to withstand brackish waters in its native range. Its non-native range in the Gulf of Mexico is not limited by temperature; the Gulf of Mexico region's temperate waters are suitable habitat for this fish. An omnivore, *Cyprinus carpio* will consume both zoo- and phytoplankton and will frequently disturb bottom sediments while feeding. The increased turbidity and dislodging of plants disturb habitat for native species that require rooted vegetation and clear waters. Common carp also adversely impact native fishes by consuming fish eggs and larvae.[109]

Most abundant in man-made water bodies, common carp are also plentiful in waters polluted by sewage and agricultural runoff.[110] Common carp are widely distributed throughout Louisiana.

3.B.2.a.iii Grass Carp (*Ctenopharyngodon idella*)

Grass carp were first imported to the United States in 1963 for Arkansas and Alabama aquaculture facilities, where they served to control vegetation (including invasives) in fish ponds. The fish first escaped from cultivation into the White River in 1966 from the Fish Farming Experimental Station in Stuttgart, Arkansas. Grass carp were also legally and illegally stocked in many rivers, streams, and reservoirs to control unwanted submerged vegetation. Known also as white amur, grass carp were first reported in the Mississippi River in the early 1970s. Its rapid spread throughout adjacent United States waterways, coupled with continued deliberate stockings for biological control, allowed this fish to establish in 45 states. In Louisiana, grass carp are established in the Mississippi River, Red River, Atchafalaya Basin, Lake Pontchartrain, and other drainages on the Louisiana-Arkansas border.[111]

Grass carp can have serious detrimental effects on riverine, limnetic, and littoral ecosystems. They decrease available habitat and food, and change macrophyte and phytoplankton community composition, ultimately altering an ecosystem's food web. According to Nico and Fuller (2001), "although grass carp are often used to control selected aquatic weeds, these fish sometimes feed on preferred rather than on target plant species."[112] Several researchers have noted that in high numbers, grass carp can eliminate all macrophyte aquatic vegetation. Grass carp also may carry and transmit parasites and diseases to native fishes.[113]

In Louisiana, it is illegal to at any time to possess, sell, or transport live carp without written permission from LDWF.[114] This statute applies to all species of carp, including diploid and triploid grass carp. Triploid grass carp are generally sterile, but some researchers are questioning the effectiveness of triploidy as a sterilization tool. Nico and Fuller (2001) state that "techniques used to induce triploidy are not always totally effective and every individual needs to be genetically checked."[115] Other states, however, including Arkansas and Mississippi, have no restrictions.[116]

3.B.2.a.iv Silver Carp (*Hypophthalmichthys molitrix*)

Hypophthalmichthys molitrix is native to eastern Asia, particularly China, and naturally occurs in temperate and primarily freshwaters. This species was first introduced to the United States around 1973 for phytoplankton control in aquaculture ponds, and as a food fish. Earliest reports indicate that a private fish farmer imported silver carp into Arkansas in the early 1970s, but by the mid 1970s, silver carp were being stocked in private and public ponds as well as municipal sewage lagoons. By the 1980s, silver carp were found in natural water bodies.[117]

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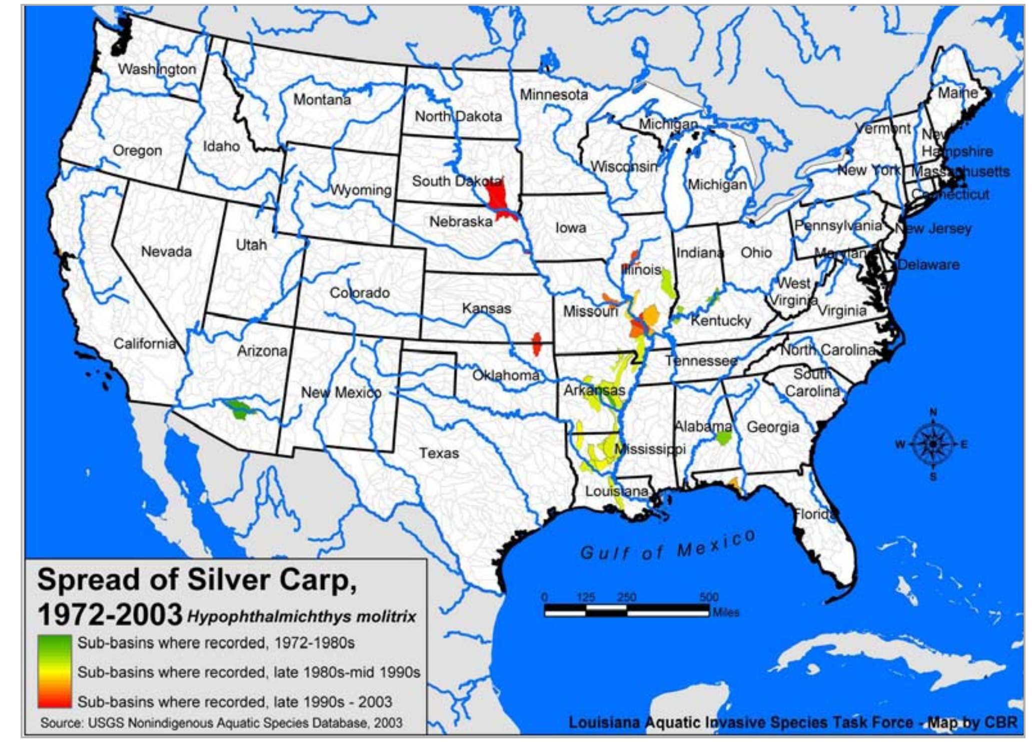
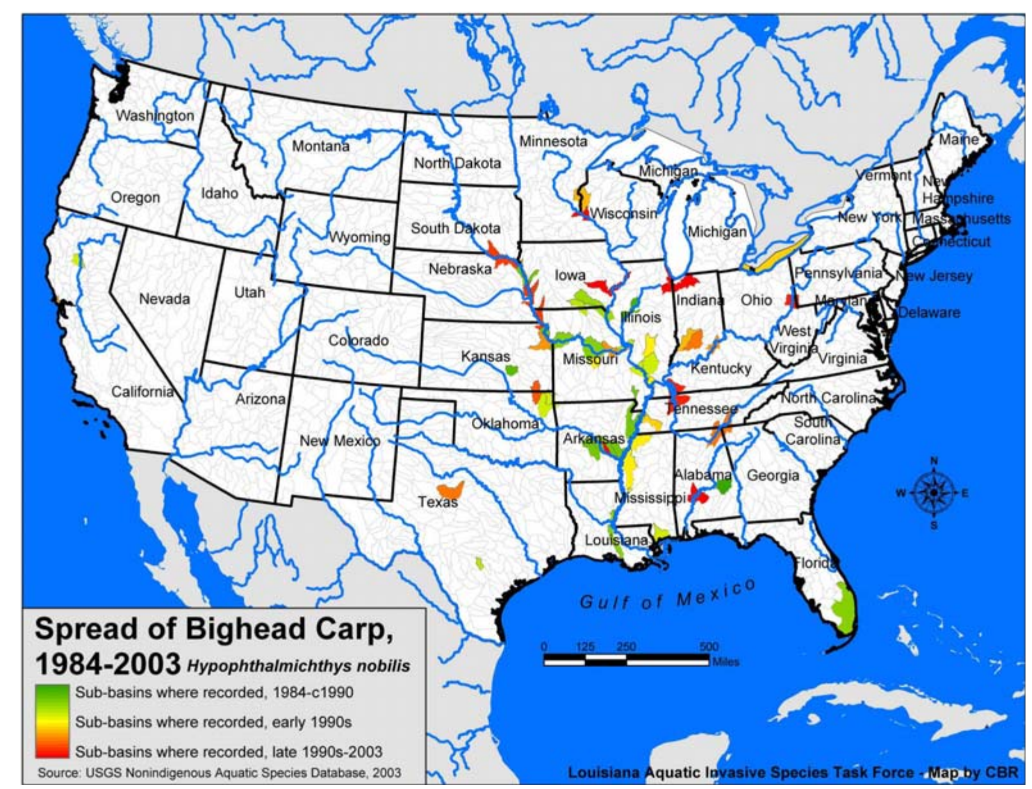
[109] Aguirre and Poss 2000a.
[110] Nico 1999.
[111] Poss and Aguirre 2000; Nico and Fuller 2001.
[112] Nico and Fuller 2001.
[113] Poss and Aguirre 2000; Nico and Fuller 2001.
[114] *Louisiana Revised Statutes, Title 56 §319* (no date).
[115] Nico and Fuller 2001.
[116] Nico and Fuller 2001.
[117] Aguirre and Poss 1998; Nico and Fuller 2000.



Native to East Asia, silver carp were first introduced to the U.S. in Arkansas in the early 1970s for phytoplankton control in aquaculture ponds and for human consumption. In Louisiana, silver carp have been reported in the Mississippi, Atchafalaya, Red, Boeuf, Ouachita, and Little rivers, plus connecting water bodies. *Map by CBR, 2004.*



Bighead carp, a zooplanktivore from Asia, was introduced by fish farmers to improve water quality and increase production in aquaculture ponds. *Map by CBR, 2004.*

In Louisiana, silver carp have been reported in the Mississippi River and its tributaries and distributaries, such as the Atchafalaya, Red, Boeuf, Ouachita, and Little rivers. Silver carp have also been collected from the Lafourche Canal, Miller Lake, and Loggy Bayou.[118]

Unlike grass carp, silver carp are planktivorous fishes that sometimes also consume detritus.[119] This could present an ecological threat to native mussels and fish larvae, organisms which are also filter-feeding planktivores. In addition to the threat to native fish and shellfish, silver carp also can be physically dangerous to fishermen and boaters. Silver carp have a tendency to leap out of the water, possibly when startled by boat motors or other noises. Flying carp land can in boats, and some significant injuries to fishermen and boaters have been documented.

3.B.2.a.v Bighead Carp (*Hypophthalmichthys nobilis*)
Similar to the silver carp, bighead carp were introduced to the United States by a private fish farmer in Arkansas in the early 1970s, who sought to use them with other herbivorous fish to improve water quality and increase production in his aquaculture ponds. Probably the result of an escape from such aquaculture facilities, bighead carp began to appear in open waters in the early 1980s. In 1994, researchers collected more than 1,600 bighead carp larvae from the Black River in Louisiana. To date, several water bodies in Louisiana have reported bighead carp sightings, including the Atchafalaya River, Turkey Creek, and the Red-Ouachita River.[120]

Both the bighead carp and the silver carp are filter feeders; bighead carp prefer zooplankton, while silver carp are primarily phytoplanktivorous. In waters with low levels of zooplankton, though, bighead carp will consume phytoplankton and detritus. In large numbers, bighead carp can deplete zooplankton populations, which could reduce native zooplanktivorous species and threaten existing food webs.[121]

3.B.2.b Locally Established Species
See fish species above.

3.B.2.c Potential Arrivals
No known established populations exist in Louisiana for the following fish species, but the LAIS Task Force identified them as species of concern in neighboring areas.

3.B.2.c.i Black Carp (*Mylopharyngodon piceus*)
Recent black carp collections from the Red River have sparked concern among fisheries managers that this species may soon become established in natural ecosystems. Also known as the snail carp, Chinese black carp, black amur, Chinese roach, or black Chinese roach, the black carp is a freshwater fish native to China, parts of eastern Russia, and possibly northern Vietnam. A bottom-dwelling mollusk eater, black carp also are known to eat freshwater shrimp, insects, and crawfish. In large numbers, black carp could threaten native shellfish and mollusks, including snails and mussels. Black carp host many parasites and flukes, not to mention bacteria and viruses, which may infect commercially valuable sportfish, food fish, or threatened and endangered species.[122]

The first introduction of black carp to the United States, in the early 1970s, was as an accidental specimen in imported grass carp stocks sent to a private fish farmer in Arkansas. The second introduction in the 1980s was deliberate: the carp were imported both as a food fish and as a biocontrol for yellow grubs at aquaculture facilities.[123] The only known introduction of black carp to open waters occurred in 1994 when high waters flooded an aquaculture facility near the Missouri River. An estimated 30 black carp, along with thousands of bighead carp, escaped into

[118] Nico and Fuller 2000.
[119] Aguirre and Poss 1998.
[120] Nico 2000c.
[121] Aguirre and Poss 2000b; Nico 2000c.
[122] U.S. Fish and Wildlife Service 2002, pages 49281 – 49282.
[123] U.S. Fish and Wildlife Service 2002, page 49281; Nico 2000a.

the Osage River.[124] According to the U.S. Fish and Wildlife Service, if black carp became established in large lakes or river systems, "eradication and/or control of black carp [would be] nearly impossible and they would likely become permanent members of the fish community."[125]

In April 2004, a 43-inch black carp was caught by a commercial fisherman in the upper Atchafalaya / lower Red rivers region of Louisiana. A second specimen was caught nearby in early May. Researchers felt that the Osage River population was too far removed from these two Louisiana specimens to explain their origin and suspected a new source. One possible explanation is that the carp escaped from a second aquaculture facility, possibly one to which LDWF had previously issued a permit to evaluate triploid black carp effectiveness for snail control. LDWF had permitted one catfish producer for this evaluation in 1996 and a second producer in 2000. Preliminary tests indicate the two black carp specimens may be diploid, indicating that they may be reproducing in open waters. The commercial fisherman who caught the carp reported that he had been catching "strange-looking grass carp in this area for over eight years."[126] LDWF is working with the fisherman to monitor the river.[127]

On March 26, 2003, Illinois fisherman Jim Beasley caught the first recorded black carp from open waters in Horseshoe Lake, Alexander County, Illinois. The carp measured 78.3 centimeters long (30.8 inches) and weighed 5.8 kilograms (12.8 pounds). Horseshoe Lake is located a few miles from the Mississippi River, which periodically floods into the lake. River floodwaters last entered Horseshoe Lake in May 2002. This particular black carp specimen was determined to be triploid (sterile), leading managers to believe it escaped from a commercial aquaculture facility. The Illinois Department of Natural Resources is working with commercial fishermen in Horseshoe Lake to determine if there are any other black carp in the lake.[128]

On July 30, 2002, the U.S. Fish and Wildlife Service published a proposed rule in the *Federal Register* which, if finalized, would add the black carp to the federally maintained list of injurious species, prohibiting "the importation of any live animal or viable egg of the black carp into the United States … live black carp or viable eggs could be imported only by permit for scientific, medical, educational, or zoological purposes, or without a permit by Federal agencies solely for their own use; permits would also be required for the interstate transportation of live black carp or viable eggs currently held in the United States for scientific, medical, educational, or zoological purposes." Furthermore, the rule would prohibit "interstate transportation of live black carp or viable eggs."[129]

3.B.2.c.ii Tilapia (*Tilapia spp., Oreochromis spp.,* and *Sarotherodon spp.*)
"Tilapia" is a general name given to many related fish species from the Genera *Tilapia*, *Oreochromis*, and *Sarotherodon*. Tilapia are increasingly common in aquaculture production in the United States, second only to carp production. Louisiana Department of Wildlife and Fisheries, the permitting agency for aquaculture fish species, allows Blue tilapia (*Tilapia aurea*), Mozambique tilapia (*Tilapia mossambica*), Nile tilapia (*Tilapia nilotica*), and Wami tilapia (*Tilapia hornorum*) in Louisiana.[130]

Though there are no known tilapia species established in the wild in Louisiana, LDWF officials are concerned that potential tilapia fish farm "escapees" could become established and degrade native fisheries. In addition to competing with natives, most tilapia species are aggressive toward other fish. Tilapia are omnivores, consuming detritus, algae, phytoplankton, zooplankton, insects,

[124] Nico 2000a; U.S. Fish and Wildlife Service 2002, page 49281.
[125] U.S. Fish and Wildlife Service 2002, page 49282.
[126] USGS 2004.
[127] McElroy 2004.
[128] Maher 2003.
[129] U.S. Fish and Wildlife Service 2002, page 49280.
[130] Lutz 1998; McElroy 2003.

vascular plant fragments, small fish, and crustaceans. Several tilapia species are established in parts of Florida, Texas, and Alabama.[131]

Others, however, question whether tilapia pose a threat to Louisiana wildlife if they escape cultivation. Though tilapia have wide salinity tolerances, they are not cold-tolerant. According to Lutz, "growth is generally limited at water temperatures below 70 degrees Fahrenheit (F), and most tilapia become severely distressed at 65 degrees F. Death begins to occur at 60 degrees F, with few surviving temperatures below 50 degrees F for any period of time."[132]

To prevent escapes from aquaculture facilities, in Louisiana, tilapia cultivation is prohibited in outdoor ponds. All water utilized in the tilapia production must be accounted for, and must be screened and / or sterilized before allowed to leave the aquaculture facility.[133]

3.B.3 Mollusks

The two known invasive mollusks in Louisiana, the zebra mussel (*Dreissena polymorpha*) and the Asian clam (*Corbicula fluminea*), are predominantly freshwater mollusks, and, in general, are confined to river drainages.

The largest rivers in Louisiana are the Mississippi, Red, and Atchafalaya; zebra mussels and Asian clams are established in all three and, therefore, are considered extensively established.

The brown mussel, *Perna perna*, is a marine species from the Gulf of Mexico near the Texas-Louisiana border. The green mussel, *Perna viridis*, is currently established in Tampa Bay, but specimens have been found in Pensacola, St. Augustine, and New Smyrna Beach, Florida, as well as on the Atlantic coast of Georgia. Louisiana waters would be suitable habitat for this species. The channeled apple snail, *Pomacea canaliculata*, is established in Texas close to Louisiana and may be here already. Unconfirmed reports indicate that this species has been found in St. Martin Parish. Pacific and Asian oysters (*Crassostrea gigas* and *Crassostrea ariakensis*, respectively) are being considered for introduction into the Chesapeake Bay to attempt to rebuild oyster stocks decimated by disease. As these potential introductions may impact Louisiana's native oyster, *Crassostrea virginica*, descriptions of the non-native oysters are provided below.

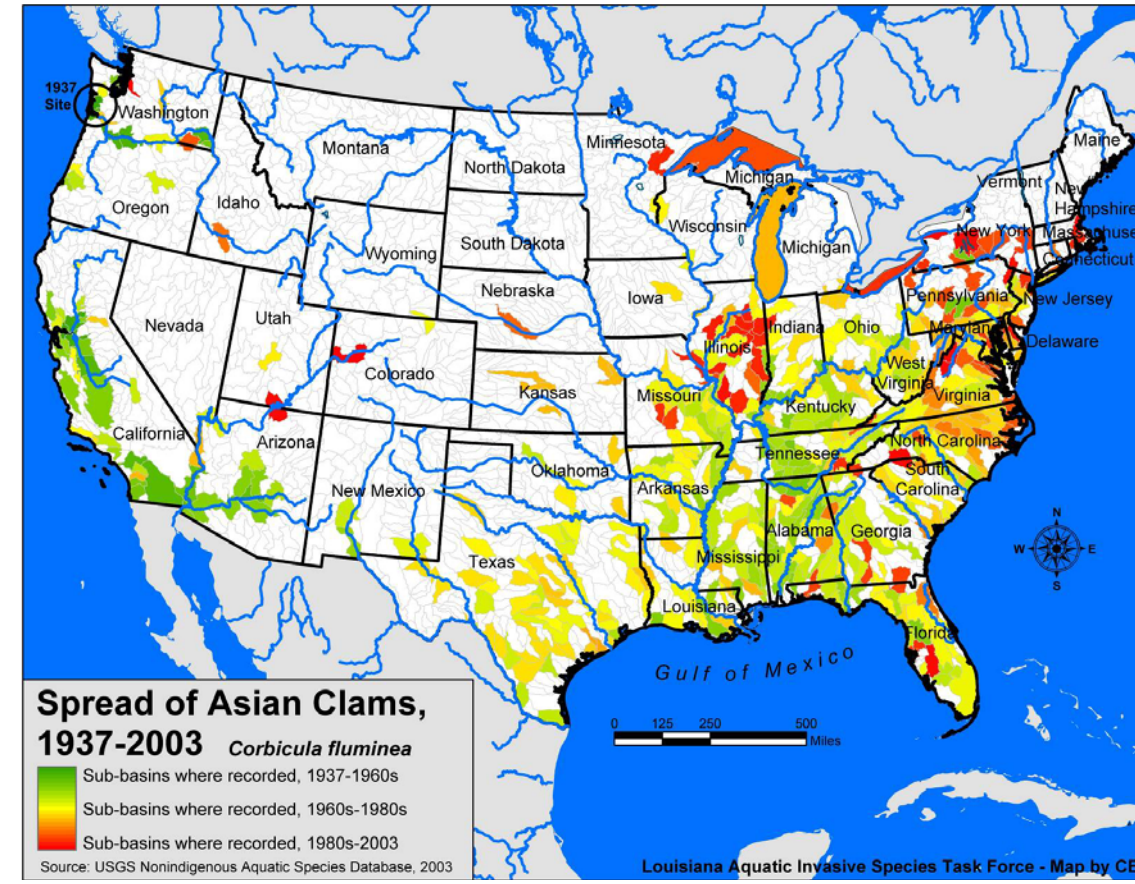
3.B.3.a Extensively Established Species

3.B.3.a.i Asian Clam (*Corbicula fluminea*)

Asian clams were likely introduced to the United States as a food source for Chinese immigrants on the West Coast, possibly as early as the mid 1800s. The clams were first discovered in Washington in 1938. Now established in at least 38 states and Washington, D.C., *Corbicula fluminea* spread mostly through human activities, such as bait bucket dumping, aquaria releases into streams or canals, and intentional releases by people who bought the clams at food markets. Asian clams may also have been a contaminant in an imported aquaculture species. Another pathway for dispersal is the passive movement of larvae in water currents. In Louisiana, *Corbicula fluminea* has been reported in 13 parishes touched by the Mississippi, Red, Pearl, and Atchafalaya rivers.[134]

The Asian clam typically measures less than 25 millimeters (one inch), although some can reach 65 millimeters (2.5 inches.) Optimum growth occurs at low salinities and in freshwater, but this species can tolerate salinities up to 24 ppt when acclimatized.[135] This may be cause for concern because the freshwater river diversions (see page 19) could serve as pathways for an Asian clam range expansion into the coastal wetlands and Lake Pontchartrain, an estuary with salinities ranging from 0 ppt to 25 ppt.

[131] McElroy 2003; Aguirre and Poss 1999b.
[132] Lutz 1998, page 1.
[133] Lutz 1998, pages 1, 4.
[134] Aguirre and Poss 1999c; Foster, Fuller, and Benson 2000.
[135] Aguirre and Poss 1999c.



Asian clams were likely introduced to the West Coast as a food source for Chinese immigrants in the mid-1800s, but were not recorded until 1938 in Washington. Now established in at least 38 states, the clams spread mostly through human activity, such as bait bucket dumping and aquaria releases. *Map by CBR, 2004.*

Ecological impacts of Asian clam infestations include the altering of benthic substrate and increased competition with native species for food and habitat resources. Asian clams also serve as a food source for many species favored by fishermen, including largemouth bass and freshwater drum. But this benefit is outweighed by the economic burden borne by industries and municipalities. Asian clams are "biofoulers" that clog power plant intake pipes and other industrial water systems. In some parts of the United States, *C. fluminea* also causes problems in irrigation canals and pipes.[136]

3.B.3.a.ii Zebra Mussel (*Dreissena polymorpha*)

The zebra mussel, native to the Black, Caspian, and Azov seas, was first discovered in North America in 1988 in Lake St. Clair, near Detroit, probably the result of a release of veligers (larvae) in ballast water. In subsequent years, zebra mussels quickly spread throughout the Great Lakes, down the Mississippi River, and up its tributaries, including the Ohio, Tennessee, Cumberland, and Arkansas rivers.[137]

In Louisiana, zebra mussels are established in the Mississippi River between Baton Rouge and New Orleans, while localized colonies exist below New Orleans near the river's mouth, and upriver near Vicksburg. In addition to the Mississippi, zebra mussels are moving northwest up the Red River toward Shreveport, while several sightings have been reported in the Atchafalaya River, Bayou Teche, Bayou Lafourche, and the Intracoastal Waterway near Houma.[138] The freshwater diversion structures and the Bonnet Carré Spillway on the Mississippi River are

[136] Foster, Fuller, and Benson 2000; Aguirre and Poss 1999c.
[137] Hard, Allen, and Poss 1999.
[138] New York Sea Grant 2003; USGS (no date)d.

potential pathways by which zebra mussels may spread to new waterways. (See section 3.A.4 on River Diversions for more information.)

In addition to other environmental problems, zebra mussels are notorious biofoulers and colonizers of water intake/outtake pipes at industrial facilities located along rivers. Entergy Corporation, the region's premier energy and gas utility, operates at least six facilities affected by zebra mussels on the Mississippi River. Entergy has implemented various monitoring and control programs. These include heating the water in a closed system to 35-36.7 degrees Celsius (95-98 degrees Fahrenheit) for several hours and chemical treatment using oxidizing and nonoxidizing chemicals. Costs associated with these treatments vary by location, but typically range from $15,000 to $100,000 per treatment.[139]

On the federal level, the U.S. Army Corps of Engineers performs periodic zebra mussel monitoring surveys at locks and other structures during dewatering or when gates are removed for maintenance. The U.S. Fish and Wildlife Service's 100th Meridian Initiative aims to prevent the westward spread of zebra mussels by trailered boats. The agency's Southeast Region Office is working with Louisiana to implement an outreach program aimed at boaters visiting the Atchafalaya and other locations of confirmed or potential zebra mussel sightings.[140]

Zebra mussel infestations, while costly to industry and public works, have not been as widespread in the lower Mississippi River as elsewhere in the United States, primarily due to current speed and water temperature. In the spring, when zebra mussel veligers are most abundant, snowmelt raises the stage of the river, which steepens its gradient and thus increases its velocity. The rapid current prevents many veligers from attaching to hard substrates in the river. Consequently, the larvae are swept to the Gulf of Mexico and die in saline waters. In the late summer and early fall, the river lowers and loses velocity, as water temperate rises. Mussels expend energy to prevent overheating, causing them to decrease their consumption and subsequently starve to death.[141]

3.B.3.b Locally Established Species

See above.

3.B.3.c Potential Arrivals

3.B.3.c.i Brown Mussel (*Perna perna*)

In 1990, for the first time in U.S. waters, two juvenile edible brown mussels were discovered on jetty rocks at Port Aransas, Texas. Native to selected coasts of the Indian and South Atlantic oceans, the *P. perna* population in Texas seems to have originated from Venezuela, according to recent DNA tracking research. The mussels were likely carried on the hulls or in the ballast water of ships calling at Venezuelan ports.[142] Brown mussels "now occur on other isolated hardshores along 1,700 km [1,056 miles] of coast from Freeport, Texas, to southern Veracruz, Mexico,"[143] and brown mussels have been found on offshore oil rigs in the Gulf of Mexico. Reports that *P. perna* are established near the Texas-Louisiana border are unconfirmed. Researchers from Texas A&M University at Corpus Christi and Texas Parks and Wildlife Department have no knowledge of *P. perna*'s existence any farther east than Freeport, Texas.[144] However, Hicks et al. (2001) suggest that, based on analyses of *P. perna* in its native ranges, the coastal Gulf of Mexico is a suitable habitat for brown mussel colonization. They predict the non-native range of *P. perna* could "spread beyond the species' present Texas/Mexico range,"[145] including the northern Gulf of Mexico coast. Probable pathways for brown mussel range expansion are ocean

[139] Stoma 2003.
[140] Saucier 2003; Carter 2003.
[141] Dietz 1995.
[142] Hicks, Tunnell, and McMahon 2001, page 181; McGrath, Hyde, and Tunnell 1999.
[143] Hicks, Tunnell, and McMahon 2001, page 181.
[144] Howells 2003; Hicks 2003.
[145] Hicks, Tunnell, and McMahon 2001, page 190.

currents or shipping routes between Texas and Louisiana ports. *P. perna* larvae in ballast water or adults attached to ship hulls could introduce this mussel to Louisiana.

The brown mussel is predominantly a marine mussel, though a colony was discovered in a bay environment in Port O'Conner, Texas. In their natural range, adult brown mussels tolerate salinities from 19 ppt to 44 ppt, and veligers (larvae) tolerate salinities of 15 ppt to 55 ppt. The Texas *P. perna* populations withstand salinities from 15 ppt to 50 ppt. However, the lowest end of this salinity range may be below their tolerance. According to Hicks (2003), *P. perna* can survive but cannot form byssal threads (strong protein "ropes" that a mussel produces to attach and anchor itself to substrate) at 15 ppt. Nevertheless, *P. perna* can survive the more saline waters of coastal Louisiana. Though no negative environmental effects have been attributed to the brown mussel in Texas, researchers believe this species can form such dense colonies that an infestation could sink navigation buoys and affect shipping safety.[146]

3.B.3.c.ii Green Mussel (*Perna viridis*)

The Asian green mussel, also sometimes called the green-lipped mussel, is native to the Indo-Pacific region, from the Persian Gulf to the South China Sea. It was introduced to the Gulf of Mexico around 1990 when larvae were transported in ballast water to Trinidad. Green mussels subsequently appeared in Venezuela in 1993, and in the United States in 1999, when underwater divers performing maintenance work at a power plant in Tampa Bay, Florida, discovered the mussels clogging the inside of cooling water intake tunnels. According to Benson et al. (2001), "phylogenetic comparisons between known *Perna* species and species collected from Tampa Bay indicated that the Tampa Bay specimens were most closely related to *Perna viridis* acquired from Trinidad."[147] As of December 2002, the range of *Perna viridis* in the United States was confined to Tampa Bay and the Gulf of Mexico between Johns Pass and Charlotte Harbor in Florida, but in February 2003, live mussels were found on the Atlantic Coast of Florida, from St. Augustine to New Smyrna Beach. In addition, the green mussel is spreading north and west. Researchers from the Smithsonian Environmental Research Center (SERC) found a *Perna viridis* specimen on a fouling plate in Pensacola, Florida. SERC believes recreational boaters probably transported the mussel.[148] Georgia Department of Natural Resources officials and researchers at the University of Georgia recently found green mussel specimens in Georgia waters, near Brunswick and Tybee Island at the mouth of the Savannah River.[149]

Green mussels prefer estuarine environments with salinities similar to Louisiana estuaries. The lower limit of *Perna viridis'* salinity tolerance is 16 ppt and researchers have shown that *P. viridis* can survive in turbid waters.[150] Researchers are concerned that as filter feeders, green mussels will impact the availability of phytoplankton for native species and increase water clarity in previously turbid waters.[151] In addition to ecological impacts, *P. viridis* is a known biofouler of boats and submerged infrastructure such as bridges, seawalls, docks, and buoys. Like the zebra mussel, the green mussel can interfere with industry and power plant activities by clogging cooling-water intakes and outflow pipes. Tampa Bay area oyster beds have recently been invaded by *Perna viridis*, which attach to and suffocate native oysters. Florida's oyster reefs consist of the species *Crassostrea virginica*, which is also commercially valuable to Louisiana's seafood industry. In the invaded Tampa Bay area oyster reefs, up to 90 percent of the dead oysters were killed recently, meaning that the oyster was still attached to the shell and normal predation was probably not a factor. Researchers suspect that the green mussel may be having a negative effect on commercially important oyster beds in Florida.[152]

[146] Crochet, Hicks, and Poss 1998; Hicks 2003.
[147] Benson, Marelli, Frischer, Danforth, and Williams 2002.
[148] Benson et al. 2002; USGS 2003; Miller 2003.
[149] Power 2003.
[150] Florida Caribbean Science Center 2001; Crochet, Hicks, and Poss 1999.
[151] Zebra mussels had a similar effect on the Great Lakes. Water clarity improved, but some areas are experiencing overgrowths of submerged aquatic vegetation, and there is less phytoplankton for native species.
[152] Benson et al. 2002; Baker, Fajans, and Bergquist 2003.

Recreational boat traffic and commercial shipping lanes between Florida (particularly Tampa Bay and Pensacola) and Louisiana could serve as a pathway for *P. viridis* into Louisiana waters. If introduced, *P. viridis* could become established in Louisiana coastal waters. According to Hicks, *P. viridis*, with its lower salinity tolerances, is probably a greater threat than *P. perna*, despite the latter's greater proximity to Louisiana.[153]

3.B.3.c.iii Channeled Apple Snail (*Pomacea canaliculata*)
Native to Central and South America, the channeled apple snail is currently established in Texas, California, Florida, and has been reported in North Carolina. This snail was first found in the Texas Gulf Coast in mid 2000 and has since spread via interconnected canals and with the help of Tropical Storm Allison in June 2001. Unconfirmed reports indicate that this species was found in St. Martin Parish, Louisiana, in 2001. Though no confirmed sightings of *Pomacea canaliculata* in Louisiana exist, its range in Texas is expanding north and east. Texas wildlife managers claim that if the snail is not already established in Louisiana, its current non-native range approaches the Texas-Louisiana border.[154]

Sold in North American pet and aquarium stores, *Pomacea canaliculata* introductions are probably the result of aquarium releases. Aquarium dealers sometimes mislabel the apple snail species; *P. canaliculata* has been sold under the names "giant Peruvian apple snail," "South American apple snail," and "mystery snail."[155]

An edible snail, *P. canaliculata* was introduced to Taiwan and other parts of Asia as a food source. The snail escaped cultivation and spread to Hong Kong, Thailand, southern China, Japan, and Indonesia, destroying rice crops in those countries. Texas rice farmers worry that a population explosion of *P. canaliculata* could have similarly devastating effects on their crops. Adults of this species are voracious eaters and prefer the soft vegetation of young rice plants.

The channeled apple snail is a hardy species that tolerates poor water quality, including pollutants or low dissolved oxygen. A shell door enables it to close itself off from harsh external conditions, so the channeled apple snail can survive droughts and can even hibernate in the mud for up to six months, reemerging when water and temperature conditions are favorable. *Pomacea canaliculata* can endure cold temperatures and a broad range of salinities. In their native environments, *P. canaliculata*'s ideal habitats include swamps, marshes, and canals, all of which are common throughout southern Louisiana.[156]

3.B.3.c.iv Pacific Oyster (*Crassostrea gigas*)
Native to Japan, this oyster was introduced to the west coast of the U.S. in the early 1900s and quickly became an important part of the aquaculture industry, particularly in Washington, where it remains the state's most valuable shellfish species. When diseases decimated the native eastern oyster (*Crassostrea virginica*) of Chesapeake Bay in the late 20th century, some researchers suggested introducing the Pacific oyster as a substitute, but it proved inadequate for reasons of growth rates, taste, and disease tolerance. Should entities suggest the introduction of the Pacific oyster into Louisiana waters, the Task Force notes that LDWF maintains jurisdiction over this matter and urges that a risk assessment be conducted on its potential impacts. Currently, the North American distribution of the Pacific oyster spans from southeast Alaska to Baja California, primarily on coastal oyster farms, though some wild populations exist in Washington, British Columbia, and Hawaii.[157]

The two diseases that devastated the native Chesapeake Bay oyster are MSX (Multinucleated sphere unknown, *Haplosporidia nelsoni*) and Dermo (*Perkinsus marinus*). Scientists believe MSX

[153] Hicks 2003.
[154] Gaudé 2002; Howells 2000.
[155] U.S. Rice Producers 2002; Howells 2000.
[156] U.S. Rice Producers 2002; Aguirre and Poss 1999d.
[157] Maryland Sea Grant 2003; Pacific States Marine Fisheries Commission 1996; USGS 2005.

arrived to the east coast via the introduction of *Crassostrea gigas* in the 1930s, which failed to establish a population.[158]

3.B.3.c.v Asian Oyster (*Crassostrea ariakensis*)
When the Pacific oyster *Crassostrea gigas* proved unsuitable for culture in the Chesapeake Bay, scientists investigated introducing the Asian (or Suminoe) oyster, *Crassostrea ariakensis*, instead. In comparative studies with the native *Crassostrea virginica*, the Asian oyster proved to be faster growing and more resistant to MSX and Dermo diseases. It was found to reach market size in only nine months, whereas native eastern oysters may require almost two years before they are large enough to harvest.[159]

Resulting pressure from the seafood industry to introduce *Crassostrea ariakensis* to the Chesapeake is causing much controversy, as scientists and natural resource managers are still unsure of the long-term ecological impacts of such introductions. Triploid (sterile) oysters are offered to control introductions, but triploids can sometimes revert to diploidy and reproduce. Ecological and economic concerns include possible adverse food web impacts, new parasites and pathogens, and a potential biofouling problem if the oysters reproduce too effectively.[160]

A final decision on the introduction has not yet been made, but the U.S. Army Corps of Engineers, Norfolk, Virginia district is currently seeking public comment on an Environmental Impact Statement. If the introduction is authorized, it may set a precedent for similar introductions in other coastal regions, including the Gulf of Mexico.

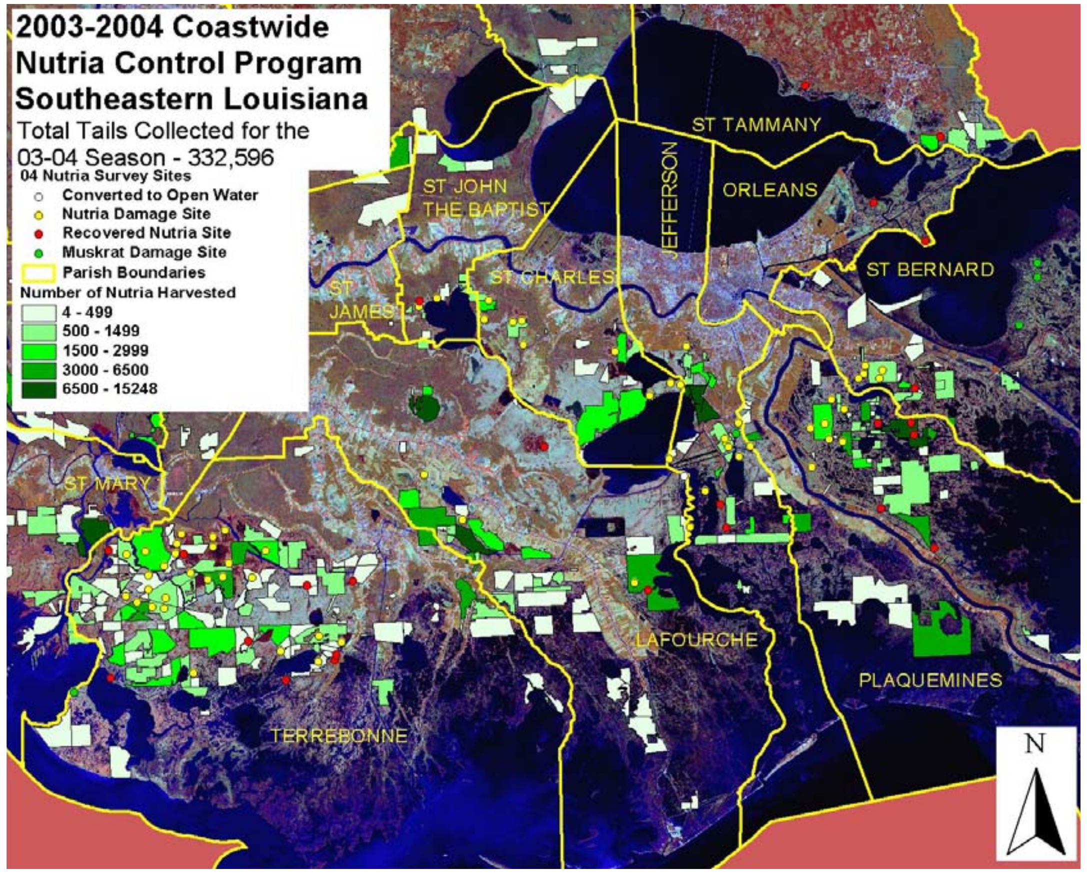
3.B.4 Mammals
Although nutria are not distributed throughout Louisiana, their numbers and environmental impact in coastal Louisiana are so great that they warrant consideration as extensively established and extremely problematic. Feral hogs (*Sus scrofa*) are established sporadically throughout the Gulf Coast and southern United States, and thus are considered extensively established for this management plan. The problems caused by feral hogs in Louisiana, however, are dwarfed by those caused by nutria. Feral hogs also provide some social and economic benefit for local hunters and trappers, whereas nutria no longer offer any benefit to Louisiana residents.

These two species are the only mammals identified as invasive in Louisiana.

3.B.4.a Extensively Established Species

3.B.4.a.i Nutria (*Myocastor coypus*)
Nutria, or coypu, are herbivorous, rodent-like aquatic mammals deliberately introduced to Louisiana from Argentina between 1900 and 1940 for fur farming. Some nutria were released into the wild, and others were used as biocontrol for invasive water hyacinth. A prolific breeder, nutria reach sexual maturity at just four months of age, and females are able to breed within 48 hours of giving birth to a litter. Nutria young are precocial (capable of a high degree of independent activity from birth,) and can swim and eat vegetation shortly after birth.[161]

[158] Chesapeake Bay Program 2004.
[159] Leffler 2002; Chesapeake Bay Program 2004.
[160] Leffler 2002; Chesapeake Bay Program 2004.
[161] LeBlanc 1994.



Coastwide Nutria Control Program

In 2002, LDWF and LDNR launched an incentive payment plan, the Coastwide Nutria Control Program, to reduce vegetative damage by increasing nutria harvest through a bounty. Registered trappers and hunters are paid $4 for every nutria taken south of the I-10/I-12 corridor. To receive payment, participants must bring well-preserved nutria tails (A) to designated collection sites, where officials tabulate them and issue vouchers (B). The program collected 308,160 and 332,596 nutria in its first two years, for which about $2.5 million was paid to participants. The above map shows number of nutria harvested by property in a portion of the program area, during the second season. *Map and photos by LDWF, 2003-2004.*

Coypu exacerbate coastal erosion by digging into thin soils and eating roots of marsh vegetation. As the vegetation dies, the fine-grained, denuded soils become more vulnerable to erosion, eventually forming expanding holes in the marsh called “eat-outs.” With the exception of alligators, nutria have no natural predators in Louisiana; populations were kept in check for decades only by fur trappers motivated by a healthy demand for nutria pelts. After the price of nutria pelts plummeted in the late 1980s, populations exploded. Wildlife managers estimate that several million nutria inhabit Louisiana today. (For more information on nutria harvests for fur, see the “Fur Industry” section under “Deliberate Introductions,” section 3.A.7.f.) By 1988, landowners complained of nutria-caused vegetative damage to coastal areas, for which the Louisiana Department of Wildlife and Fisheries began conducting vegetative surveys to document the damage.[162]

The table below, from the Louisiana Department of Wildlife and Fisheries Fur and Refuge Division, indicates the number of sites surveyed for nutria-related vegetative damage between 1998 and 2002, the number of those sites with vegetative damage, and the number of sites that showed vegetative recovery:

Year	Total Sites Surveyed	Sites with Vegetative Damage	Sites Experiencing Vegetative Recovery
1998	204	170	34
1999	184	150	34
2000	170	132	38
2001	142	123	19
2002	108	94	12

Overall, the area of coastal marsh with vegetative damage is increasing, and the numbers of sites recovering from nutria damage are decreasing. While it appears that nutria damage is decreasing overall because the number of vegetation-damaged sites is declining, many of the sites surveyed during this period in fact enlarged and merged to form the “eat-outs” mentioned earlier. Merged sites, regardless of size, were thence counted as one site instead of multiple sites.[163]

In late 2002, LDWF and the Louisiana Department of Natural Resources jointly launched an incentive payment plan called the Coastwide Nutria Control Program (CNCP). The purpose of the bounty program is to reduce vegetative damage by increasing nutria harvest. Registered trappers and hunters are paid $4 per tail (as proof of harvest) for every individual nutria taken within the project boundaries. Registered participants must obtain a valid Louisiana trapping license, complete an application, and obtain written permission from the landowner to take the nutria from his/her land. The trappers then receive a specific Nutria Control Program Registration Number. To receive the $4-per-tail bounty, trappers must bring well-preserved (fresh, frozen, salted, etc.) tails at least seven inches long to designated collection sites and must present their assigned registration numbers. As long as the nutria are taken between November and March, trappers meeting the above requirements receive vouchers for the tails, and a check is mailed to them shortly.[164]

The CNCP is funded through the Coastal Wetlands Planning, Protection, and Restoration Act for five years, for as many as 400,000 nutria per year. Program boundaries cover those coastal areas most affected by nutria, from the Interstate 10 — Interstate 12 corridor south to the coast, from the Texas border to the Mississippi border. Every year, transects along the coast are inspected from aircraft to determine nutria-caused vegetative damage. Photographs from the fly-overs will help assess the impact of the bounty program.[165]

Wildlife officials collected 308,160 and 332,596 nutria tails in the first two years of the program, for which about $2.5 million was paid to trappers.[166]

[162] USGS 2000b; Wilson 2002; Linscombe 2003a.
[163] Linscombe 2003a.
[164] Linscombe 2003a.
[165] Linscombe 2003a.
[166] Linscombe 2003b; Marshall 2004.

3.B.4.a.ii Feral Hogs (*Sus scrofa*)

Feral hogs, *Sus scrofa*, are sometimes hybrids of wild boars and domestic livestock. Domestic hogs were deliberately introduced as livestock to North America during colonial times; some escaped farms and established feral populations. In the 1940s, sportsmen deliberately introduced Russian black boars to the southeastern United States as a new game animal. Interbreeding between the boars and the feral hogs may have produced the hybrid feral hogs present in Louisiana today.[167]

Sus scrofa prefers wooded areas, flat coastal plains, swamps, marshes, and other habitats with plentiful water. Louisiana's warm and moist subtropical climate allows for reproduction almost year round, and nutrient-rich soils and diverse ecosystems abundantly produce the hogs' favorite foods: roots, leaves, nuts, tubers, snails, insects, frogs, snakes, and rats.[168]

Besides competing with deer, bears, rabbits, and other native species for habitat and food, *Sus scrofa* can pose a risk to humans. In their quest for food, feral hogs have been known to tear up hurricane protection levees with their snouts and hooves, causing scars which could erode, expand, and weaken the flood-prevention structures.[169] Feral hogs are also vectors for bovine tuberculosis and swine brucellosis, a potential human pathogen which could affect agriculture.

3.B.4.b Locally Established Species

No locally established invasive mammals currently warrant inclusion in this plan.

3.B.4.c Potential Arrivals

No potential invasive mammals are foreseen.

3.B.5 Insects

Due to the prolific nature of insects and their ability to rapidly adapt to a new environment, all insect species established in Louisiana are considered extensively established.

3.B.5.a Extensively Established Species

3.B.5.a.i Red Imported Fire Ant (*Solenopsis invicta*)

Red imported fire ants (RIFA) are thought to be native to Paraguay and the Parana river region in South America and were brought to the United States in the 1930s, probably in soil used as ballast or dunnage in commercial shipping vessels. RIFA were first detected in Mobile, Alabama but quickly spread throughout the southeastern United States, through the transport of nursery stock and earth-moving equipment. A federal quarantine was implemented in 1958 to prevent the spread of RIFA by restricting the movement of potentially infested hay, sod, soil, equipment, and nursery stock.[170]

RIFA cause a variety of adverse economic and environmental effects by outcompeting and preying on native species, feeding on agricultural crops (such as okra, cucumbers, corn, and soybeans), sometimes killing livestock, and nesting in electrical equipment such as air conditioners, traffic signal boxes, computers, airport landing lights, and telephone junctions. The estimated structural and electrical damage caused by RIFA every year is about $11.2 million, and the estimated damage to livestock, wildlife, and public health in Texas alone is $300 million per year. Medical treatment of fire ant stings costs approximately $7.9 million annually. The total cost associated with fire ants in the southern United States is estimated at $1 billion per year.[171]

[167] Aguirre and Poss 1999e; Jensen 2001.
[168] Aguirre and Poss 1999e.
[169] Jensen 2001.
[170] Morisawa 2000.
[171] Morisawa 2000.

3.B.5.a.ii Formosan Termite (*Coptotermes formosanus*)

Formosan termites were introduced to the United States during and shortly after World War II, via wooden shipping palettes on ships returning from East Asia. The termites were introduced at various ports along the Gulf Coast, including Houston, Galveston, Lake Charles, and New Orleans, as well as Charleston, South Carolina. Formosan termites were not detected at the military bases until 1966, and the extent and impact of Formosan termite populations was not fully appreciated until the 1980s. By this time, this "super termite" was well established and spreading throughout Louisiana and the Gulf Coast.[172]

Formosan termites cause an estimated $500 million in damage to Louisiana every year, with $300 million in damages to New Orleans alone. In addition to damaged houses and other buildings, particularly historical structures, Formosan termites infest and structurally weaken native trees, including live oaks and other hardwoods, rendering them more vulnerable to wind damage and other threats. Even cypress are not immune to Formosan termites.[173]

For more information on Formosan termites, visit the Louisiana Department of Agriculture and Forestry website (www.ldaf.state.la.us) or contact Operation Fullstop at the USDA Southern Regional Research Center (http://www.ars.usda.gov/is/br/fullstop).

3.B.5.a.iii Asian Tiger Mosquito (*Aedes albopictus*)

Aedes albopictus, the Asian tiger mosquito, was accidentally introduced to the United States in 1985 when used tires containing larvae-infested water were shipped from Japan to Houston, Texas. Further transport of used tires spread *Aedes albopictus* to other Southern cities. Within the first year of its introduction, the Asian tiger mosquito was reported in New Orleans, Lake Charles, Baton Rouge, and Shreveport; today it is found in almost every parish in Louisiana.[174]

Aedes albopictus breeds in stagnant water pools found in outdoor containers, especially in shady areas. For this reason, this species does particularly well in urban residential settings. This mosquito threatens public health as a known vector of the viruses that cause dengue fever, eastern equine encephalitis, and the agent that causes dog heartworm. *Aedes albopictus* is a suspected vector of other viral diseases, including West Nile virus, yellow fever, and other types of encephalitis.[175]

3.B.5.b Locally Established Species

All invasive insects are considered "Extensively Established" in this plan.

3.B.5.c Potential Arrivals

3.B.5.c.i Africanized Honeybee (*Apis mellifera scutellata*)

Nicknamed "killer bees," Africanized honeybees were imported to Brazil with the intention of genetically improving European honeybees and making them more suitable for South America. Some were accidentally released from research facilities in 1956, and they hybridized with European varieties, thus becoming "Africanized honey bees." The bees spread through South America, into Central America, and arrived in Texas in October 1990. Since their arrival in Texas, the bees have spread primarily west, into New Mexico, Arizona, and California. Currently, no known populations of Africanized honeybees exist in Louisiana, although the bees have been found as close as Houston.

Africanized honeybees grow more quickly from egg into adult, swarm more often, and are more aggressive than their European counterparts. They are known to completely abandon a colony and move on to another location. They may decrease and even replace European honeybees in parts of the United States.[176]

[172] Agricultural Research Service 2002a and b; Louisiana Formosan Termite Initiative 2003.
[173] Louisiana Formosan Termite Initiative 2003.
[174] Maryland Department of Agriculture (no date); Centers for Disease Control and Prevention 2001.
[175] Maryland Department of Agriculture (no date); Lounibos 2002.
[176] National Agricultural Pest Information System 1993, 2004.

3.B.6 Other Species

"Other species" are those that the Task Force decided are important and problematic, but do not fit into any of the above categories. These include coelenterates, crustaceans, and one cladoceran.

3.B.6.a Extensively Established Species

None to date.

3.B.6.b Locally Established Species

3.B.6.b.i Australian Spotted Jellyfish (*Phyllorhiza punctata*)

The Australian spotted jellyfish, native to the South Pacific Ocean, was introduced to the Caribbean probably between the 1950s and 1970s, but was not noticed in the northern Gulf of Mexico until June 2000. *P. punctata* was likely transported from Australia to the Caribbean through the Panama Canal, either as polyps in ballast water or attached to the hull of a ship. Transport of this species to the northern Gulf of Mexico is may have occurred when an eddy spun off of the Loop Current, which carries tropical water from the Caribbean to the Gulf of Mexico.[177]

During the *P. punctata* population explosion of 2000, researchers discovered the jellies from Mobile Bay in Alabama to the Texas-Louisiana border, with concentrations heaviest in the Mississippi Sound, the barrier islands off the coasts of Louisiana and Mississippi, and at the mouth of Lake Borgne, Louisiana.[178]

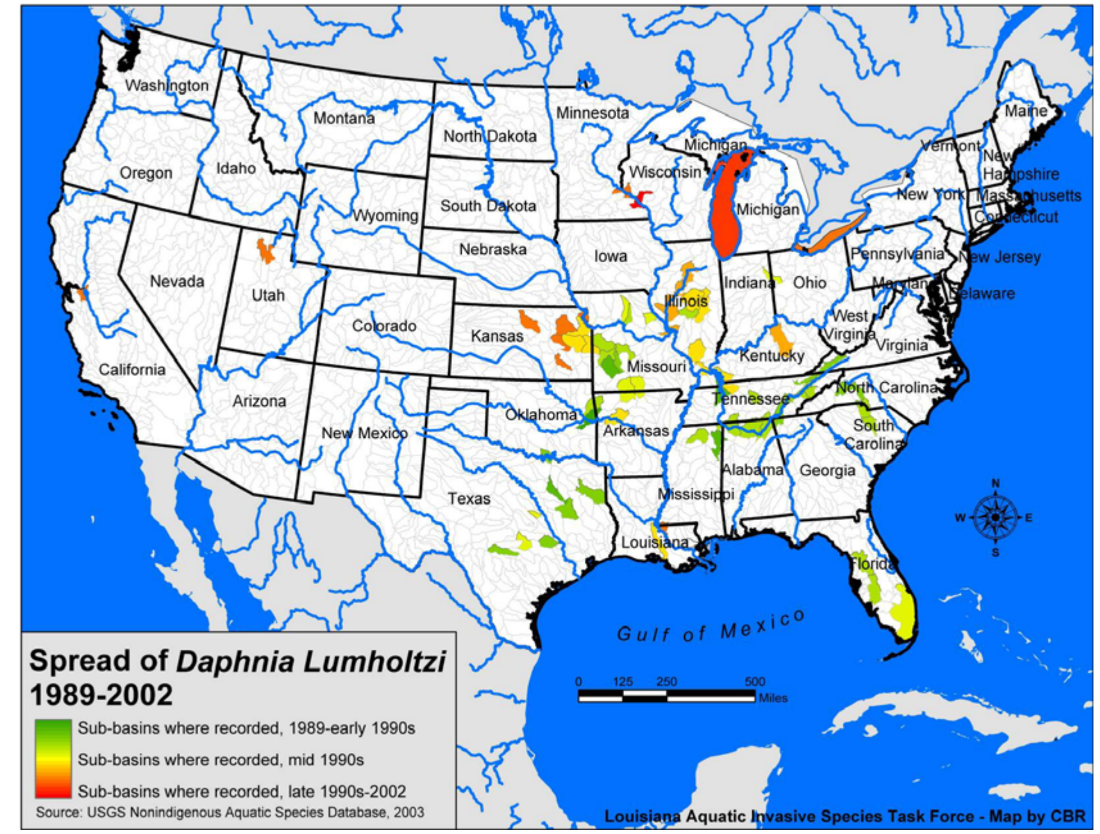
In summer 2000, when *Phyllorhiza punctata* populations were at their greatest, commercial fishermen, researchers, and environmental managers feared this species might have a significant impact on commercially valuable fisheries, specifically shrimp, menhaden, anchovies, crabs, and red snapper. Shrimpers complained that the gelatinous creatures were clogging their nets. Every summer, larval fish and eggs, particularly for the species mentioned above, are carried by tides to estuaries close to shore. The jellyfish in 2000 blocked the entrances to these estuaries. *Phyllorhiza punctata* is a filter-feeding omnivore that will consume every living organism smaller than a few millimeters across. Daily, each jellyfish can filter up to 50 cubic meters of water and eat approximately 2,400 fish and shellfish eggs.[179] According to Harriett Perry, Ph.D., director of the Fisheries Section of the Gulf Coast Research Laboratory in Mississippi, "You really have two problems in terms of commercially important fish. First, the jellies are ingesting the larvae and eggs of these commercially important species, and then the fish larvae must compete with these incredibly efficient jellies for the same food source."[180]

Though the spotted jellyfish population explosions of 2000 have not occurred since, recent evidence indicates *Phyllorhiza punctata* is established in the Gulf of Mexico, suggesting that a similar explosion could occur soon.

3.B.6.b.ii Zooplanktonic Water Flea (*Daphnia lumholtzi*)

Although several species in the Genus *Daphnia* are native to Louisiana and other parts of the United States, the water flea *Daphnia lumholtzi* is native to Africa, Asia, and Australia. It was first documented in Texas in 1990, and today can be found in Alabama, Arkansas, Florida, Illinois, Kansas, Kentucky, Louisiana, Mississippi, Missouri, North Carolina, Oklahoma, Ohio, South Carolina, Tennessee, Texas, and Utah. *D. lumholtzi* was first documented in Louisiana in 1994 when 19 zooplankton samples collected from 30 sites in the Atchafalaya Basin contained this water flea. Although its pathway is not known, scientists believe this daphnid species likely was brought to the U.S. in shipments of Nile perch from Lake Victoria in Africa. *D. lumholtzi* probably spread throughout the U.S. through contaminated water used to transport fish stocks, water

[177] Smithsonian Marine Station 2001; Dauphin Island Sea Lab (no date); Higgins 2001.
[178] Maynell 2000; Graham (no date).
[179] Raines 2000; Raines 2002.
[180] Raines 2000.



This water flea, native to Africa, Asia, and Australia, was first documented in Texas in 1990 and has since spread to at least 16 states. Although its pathway is not known, *Daphnia* was likely brought to the U.S. in shipments of Nile perch from Lake Victoria in Africa. *Map by CBR, 2004.*

drained from aquaculture ponds, and/or unwashed recreational boats trailered from one water body to another.[181]

The long-term effects of this species' introduction are currently unknown, but negative impacts are possible. Water fleas and other zooplankton are an important food source for many larval fish species, but because of *D. lumholtzi*'s head and tail spines, which are much longer and more numerous than those of native daphnid, this species of zooplankton is avoided by fish larvae, thus giving it an evolutionary advantage over natives. Stoeckel and Charlebois (1999) note "if this replacement occurs, the amount of food available to larval and juvenile fishes may be reduced."[182]

3.B.6.c Potential Arrivals

3.B.6.c.i Chinese Mitten Crab (*Eriochirus sinensis*)

Chinese mitten crabs are native to the coastal rivers and estuaries of the Yellow Sea region in China and Korea. This crab may have been introduced accidentally via ballast water discharges, or intentionally as a food source , or both. To date, there has been only one Chinese mitten crab sighting in Louisiana: in 1987, dead specimens were collected near the new St. Bernard Parish Highway-Highway 46 intersection in Bay Gardene, Louisiana.[183] Researchers believe they may have fallen off of a passing ship.

In Asia, Chinese mitten crabs are a host organism for several lung flukes (parasitic flatworms), one of which, *Paragonimus ringeri*, can affect humans. This crab species also burrows deep into

[181] Stoeckel and Charlebois 1999; USGS (no date)e.
[182] Stoeckel and Charlebois 1999.
[183] Washington Sea Grant 2000; Nates and Poss 2000.

soft river banks or levees. Burrowing could potentially weaken levees and cause ruptures, increasing flood hazards.[184]

3.B.6.c.ii Green Crab (*Carcinus maenas*)

The European green crab, *Carcinus maenas*, is native to coastal Europe and north Africa.[185] It was first introduced to the United States in the early 19th Century, primarily along the coast from New Jersey to Massachusetts and thence into Nova Scotia. *C. maenas*'s presence on the Pacific Coast of the United States was first documented in San Francisco Bay in 1998 and has since spread along coastal California, Oregon, Washington, and British Columbia. DNA tests indicate that the Pacific coast green crab population originated from the East Coast of North America, but the exact pathway of introduction is unknown.

C. maenas larvae may have been introduced to San Francisco Bay via ballast water discharges. Another likely pathway is packing material, probably seaweed containing live green crabs, used to protect live bait or live seafood during shipping from coast to coast. Improper disposal of the packing material, such as dumping it in San Francisco Bay, could have resulted in the introduction of this voracious predator.

Green crabs are a predatory species with a preference for bivalve mollusks such as clams, oysters, and mussels. They have also been observed eating polychaetes such as marine worms, and other small crustaceans. Green crabs will even prey on juvenile crabs and shellfish.[186]

If introduced to Louisiana waters, *C. maenas* could threaten Louisiana's lucrative commercial oyster, shrimp, and crab fisheries. Tolerant of wide range of temperatures and salinities—0 to 33 degrees Celsius (32-91 degrees Fahrenheit) and 4 ppt to 54 ppt—and able to live in a variety of habitats, from protected rocky shores to tidal marshes, the green crab would probably thrive in Louisiana waters.

California's Humbolt Bay experienced a 40 percent decline in its Manila clam harvest since the green crab became established there. According to the Washington Department of Fish and Wildlife, the green crab "is capable of learning and can improve its prey-handling skills while foraging."[187] This suggests that the green crab could adapt to Louisiana waters and prey on commercially important species.

3.B.7 Viruses, Bacteria, and Other Disease-Causing Microbes

West Nile Virus is one of the many examples of viruses, bacteria, and other disease-causing microbes that qualify as invasive species. Despite their acknowledged importance, the Louisiana Aquatic Invasive Species Task Force decided not to address these microorganisms in the Louisiana Aquatic Invasive Species Management Plan. The Task Force decided that few management actions that are not either planned or already in place through various other governmental health organizations, such as the Centers for Disease Control and Prevention, could address these disease-causing agents. The Task Force chooses to allocate scarce state and federal resources toward the prevention and control of invasive species that agencies focused on human health cannot address.

The LDWF would like to draw particular attention to the oyster disease MSX ("multinucleated sphere unknown"), caused by the deadly protozoan parasite *Haplosporidium nelsoni*. The origin of the disease is unknown, but it has been documented in Korean and Japanese oyster populations. In the U.S., MSX ranges from Maine to Florida on the east coast, but it is not yet present in the Gulf of Mexico. This disease devastated native oyster populations on the east coast, particularly in the mid-Atlantic region. Transfer of ballast water or estuarine animals from the east coast to the Gulf of Mexico could potentially put Louisiana's native *Crassostrea virginica* oysters at risk.[188]

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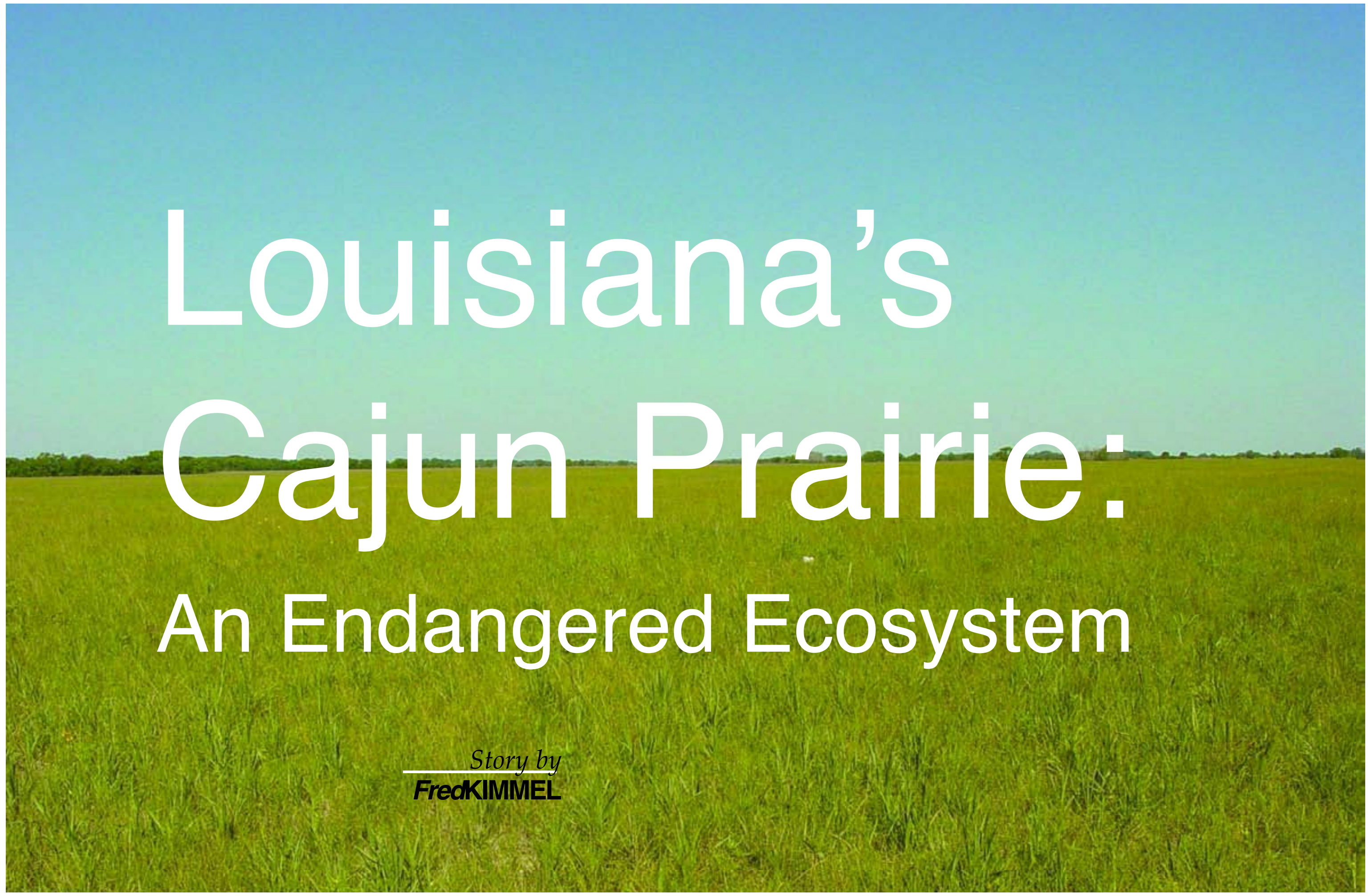
[184] Nates and Poss 2000.
[185] Copping and Smith 2001.
[186] Washington Department of Fish and Wildlife 2002; Copping and Smith 2001.
[187] Washington Department of Fish and Wildlife 2002.
[188] Virginia Institute of Marine Science (no date.)



Louisiana's Cajun Prairie:

An Endangered Ecosystem

Story by
Fred KIMMEL

Photo by John Pitre Natural Resources Conservation Service

Imagine the scene described by Samuel Lockett around 1870, "these prairies are all vast, treeless expanses, covered with a luxuriant growth of grass." It may come as a surprise that the scene described was not in Oklahoma or Kansas, but in southwest Louisiana. Until about 150 years ago, this prairie covered nearly 2.5 million acres in Louisiana and 6.5 million acres in coastal Texas. Mr. Lockett went on to say, "Altogether I look upon the prairie region as naturally the loveliest part of Louisiana." The prairie of Louisiana is known as the Gulf Coastal Prairie, or informally, as the Cajun Prairie. In Louisiana, the Cajun Prairie extended from the Sabine River to the west, the Atchafalaya bottomlands to the east, the pine woodland to the north and the coastal marshes to the south. The map of this region is dotted with names like Prairie de Femmes, Prairie Laurent, and Prairie Ronde, serving as a testament to the landscape that greeted the first settlers.

The Cajun Prairie was characterized by relatively flat terrain that was treeless except for forested areas along streams and rivers known as "gallery forests." Trees were limited to gallery forests because the soils beyond the waterways consisted of heavy clay, not favorable for tree development. Another important factor that limited tree growth on the prairies was the frequent fires ignited by lightning and native people.

Although relatively flat, the Cajun Prairie is not without interesting geological features. Unique to the Cajun Prairie are mounds of well-drained soil 3 to 7 feet high and 30-50 feet in diameter known as "pimple mounds." Pimple mounds occur only on prairie soils called alphasols, but their origin is not known. There are also low areas or depressions forming natural wetlands throughout the prairie.

Prairie phlox flower *(Plox pilosa)*

Photo by Larry Allain USGS National Wetlands Resource Center

Unfortunately, many of us are conditioned to view a landscape without trees as somehow lacking. However, when it comes to the Cajun Prairie, nothing could be further from the truth. Over 500 species of plants have been identified in the Cajun Prairie. The dominant vegetation of the prairies are grasses such as switchgrass, little bluestem, big bluestem and Indian grass. Common grasses in Cajun Prairie that don't occur in other tallgrass prairies include brownseed paspalum, Gulf Coast muhly, and slender bluestem. Among the grasses grow a diverse array of wildflowers such as prairie coneflower, blazing star, compass plant and butterfly weed.

The wildlife of the Cajun Prairie reflects its diverse vegetation. Bison, red wolves, whooping cranes and prairie chickens were once found on the prairies of Louisiana. These species are now gone, but the area remains home to a wide variety of grassland birds, waterfowl and shorebirds. In addition, over 100 species of butterflies and skippers and 86 species of dragonflies have been found in the Cajun Prairie.

The prairie landscape described by Samuel Lockett can no longer be found in Louisiana. Of the 2.5 million acres of historic Cajun Prairie, only less than 1,000, in its natural condition, can be found today. The Cajun Prairie was settled during the late 1800s and was gradually converted to pasture and agriculture uses. Today, the few remaining intact patches are found along railroad rights-of-ways and other isolated areas that were not plowed. The Gulf Coastal Prairie ecosystem is considered one of the most imperiled ecosystems not only in Louisiana, but globally as well.

For years, a few dedicated conservationists have labored in relative obscurity to preserve remnants of the Cajun Prairie. There have also been efforts to collect seed or sod from prairie remnants and use it to reestablish prairie land. However, because adequate seed was lacking and restoration was so labor intensive, efforts of large scale prairie restoration have not been attempted in Louisiana, but, that is changing.

One of the biggest obstacles to prairie restoration efforts has been the lack of suitable seed. Seeds of prairie species are available from growers in the midwestern U.S. and great plains region. However, experience has shown that plants grown from these seed sources do not persist in south Louisiana. Plants from the Midwest and Great Plains can not adapt to the humidity, rainfall, growing season, and soils found in southern Louisiana. To address this, several groups interested in prairie and grassland restoration formed the Louisiana Native Plant Initiative (LNPI). LNPI volunteers and partners collect seeds from prairie plants on remaining tracts and then grow the seeds in a nursery setting. When enough seed is grown, the seed will be released to commercial growers to produce Louisiana adapted seed for the commercial market.

Another obstacle facing prairie restoration efforts in Louisiana is the need for specialized planting equipment. Many of the prairie grasses have very fluffy seeds that cannot be effectively planted with conventional seed drills. While broadcast seeders have been effective, success requires extensive seedbed preparation that is often cost pro-

A skipper butterfly *(Thymelicus sylvestris)* resting on a rattlesnake flower *(Brazoria truncata).*

Photo by Larry Allain USGS National Wetlands Resource Center

Photo courtesy of U.S. Forest Service

Northern bobwhite quails *(Colinus virginianus)* are one of the many species that live on the Cajun Prairie.

native seeds are hard, but very small and should be planted at low seeding rates. To address this need, three drills capable of simultaneously planting fluffy seed and small hard seed at very low rates were purchased and are available for rental by land managers in Louisiana.

While prairie restoration and grassland revegetation methods are well-established in much of the nation, they are relatively new in Louisiana. As a consequence, most of the natural resource professionals that landowners traditionally seek for guidance and assistance are unfamiliar with grassland restoration. The Acadiana Grassland Restoration Initiative (AGRI) is a project now in development that will provide Louisiana's natural resource professionals training and experience in prairie and grassland planting and management. In addition the AGRI will provide "turn-key" grassland and prairie planting services to landowners.

The restoration progress will be for naught unless landowners are interested and willing to dedicate portions of their land to grassland and prairie. While a few who appreciate the intrinsic value of the Cajun Prairie will be willing and financially able to do so, many more will require financial incentives. Fortunately, there are several programs that offer cost-share assistance for prairie and grassland restoration. There are also a couple of programs that offer rental payments in addition to cost-share payments. Most notably is the newly approved Gulf Coast Prairies SAFE Project. SAFE, State Acres for Wildlife Enhancement, is part of the USDA Conservation Reserve Program (CRP). The Gulf Coast Prairie SAFE Project will target 3,500 acres in portions of southwest Louisiana for restoration of prairie vegetation and associated wetlands. In addition, a similar project targeting 28,000 acres is under consideration.

While it would be ideal to restore the natural plant diversity of the Cajun Prairie, for now, restoration efforts in Louisiana will have to take a pragmatic approach. Locally adapted native prairie seed sources are not yet available. Therefore, these early prairie restoration efforts in Louisiana will utilize only the few species of plants that are commercially available, thus more closely resembling a grassland planting rather than true prairie restoration. As seeds of locally adapted native prairie species become available, these plantings can begin to resemble a natural community and a true prairie restoration. However, even rudimentary restoration work will benefit a wide array of wildlife dependent on grassland habitat. Species such as mottled ducks, bobwhite quail, Henslow's sparrows and Le Conte's sparrows will benefit. Perhaps someday even whooping cranes and prairie chickens will again call Louisiana home.

Photo by Larry Allain USGS National Wetlands Resource Center

Kansas blazing star *(Liatris pycnostachya)* on prairie remnant.

For more information on Louisiana's coastal prairie visit the following web sites:

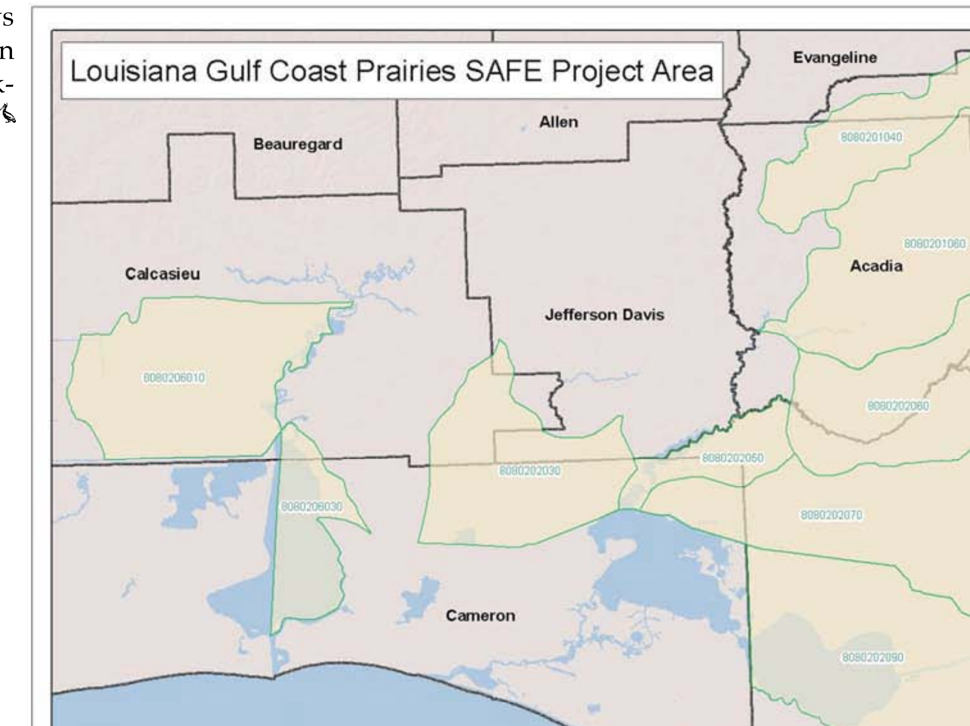
nwrc.usgs.gov/prairie/
acadianaarcd.com
cajunprairie.org

The LDWF Private Lands Program biologists in the Lake Charles (337-751-2575) or Opelousas (337-948-0255) offices are also able to provide information and assistance to land managers interested in prairie restoration or native grassland establishment.

Fred Kimmel is upland game program manager with LDWF. He is a frequent contributor with ***Louisiana Conservationist.***

Gulf Coast Prairies SAFE

The Gulf Coast Prairies SAFE is a conservation reserve program aimed at restoring a minimum of 3,500 acres of native grasslands and shallow water habitats in southwest Louisiana. This project is limited to the selected watersheds depicted on the map below.



To be eligible, land within the selected watersheds must meet the basic program requirements, including that it must have been planted in an agricultural commodity in four of the six years between 1996 and 2001. SAFE participants will be encouraged to establish a mix of native grasses and legumes. In addition, shallow water areas may be created on portions of the land.

SAFE participants will receive the following payments:

- **$100 per acre sign-up incentive**
- **Up to 90 percent of the cost of installing the conservation practices**
- **Up to 15 years of annual land rental payments**
- **Up to 50 percent of the cost of mid-contract management practices**

The Gulf Coast Prairie SAFE is a continuous sign-up program so landowners can apply at anytime rather than waiting for an announced CRP sign-up period. For more information contact your local USDA Service Center. LA Department of Wildlife and Fisheries private lands biologists in Lake Charles (337-751-2575) or Opelousas (337-948-0255) can also provide information and assistance.

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Prairie Cajuns and the Cajun Prairie: A History

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Prior to the late 19th century, nearly one million contiguous ha of coastal tallgrass prairie existed in the southwestern corner of Louisiana. For the most part, the density and height of the associated vegetation precluded both the exploration and settlement of this vast habitat. French Acadians (locally known as "Cajuns") were exiled from Nova Scotia in the mid-eighteenth century. A large number of them began arriving in southern Louisiana by 1765, joining pockets of settlers (mostly soldiers and colonial administrators) left over from previous expeditions and colonization efforts by the French government. Together, these Francophone settlers ventured into the prairie region, setting up a subsistence-type lifestyle which involved hunting, fishing, and trapping, along with limited cropping and livestock operations. For the succeeding 100 years (ca. 1775–1875) the Cajuns lived in near total isolation, thus developing a strong sub-culture featuring unique cuisine, entertainment, and folkways. Upon the completion of a railway traversing the entire prairie district in the late 19th century, a flood of farmers and ranchers immigrated from the mid-western U.S. and neighboring Texas. They supplanted the sustainable agricultural lifestyles of the Cajuns with the beginnings of high-yield agricultural technologies, which the Cajuns gladly accepted. As a result, quasi-pristine prairie habitat fell to overgrazing and the plow at ever-increasing rates. By 1920, the vast majority of the "Cajun Prairie" had disappeared. Today, less than 40 ha of prairie remains, mostly (ironically) confined along remaining railroad rights-of-ways. Fortunately, a recent revival of interest in "Prairie Cajun" folkways has resulted in a heightened awareness of the prairie ecosystem and an interest in restoring it.

INDEX DESCRIPTORS: tallgrass prairie, Cajuns, Acadians, Louisiana, folkways, agriculture.

The general purpose of this article is to introduce the reader to the prairies of southwestern Louisiana. These prairies resemble those of the Midwest in flora and fauna historically, but there are significant differences. One of the major differences is the process by which the prairie was settled while another difference is the people who settled this prairie. The history of the prairie is knitted to the history of the people and vice versa. Weaving this story is a tremendous challenge because the story is an oral history, with much of it told in several languages. The local people of this prairie region avoided education and, thus, left little as written record. Therefore, the following portrays our best knowledge of the people and the prairie.

THE ECOLOGICAL CONTEXT

Once encompassing a triangular-shaped area of nearly 1 million contiguous ha within the southwestern corner of Louisiana, a coastal tallgrass prairie ecosystem existed in pristine condition for at least 12,000 yrs. Curiously, this system, which possessed a floristic community remarkably similar to that of tallgrass prairies within the midwestern U.S., arose from geo-climatic events quite different from that of the better known midwestern prairies. In contrast to the deep layers of loessial soils blown into the midwestern U.S. systems ca. 12,000 yrs ago, coastal tallgrass prairie soils were mostly marine-derived with only shallow layers of loess soil. The prairie soils are tight, calcareous clays laid down in sedimentary layers as a result of coastal flooding due to the dramatic rises in sea level. These rises characterized the interglacial periods of each of the last several Pleistocene "Ice Age" events which occurred in the northern hemisphere.

The highly plastic, shrink-swell, nature of clay soils is much exaggerated along the Louisiana coastal zone, where alternating wet and dry spells combine to produce prairie soil conditions which alternate between waterlogged and often anoxic when wet and rock-hard when dry. This situation, combined with frequent lightning-generated fires, served to preclude the establishment of woody vegetation on the prairie proper. On the other hand, herbaceous plant species were able to establish and thrive upon the relatively thin, organically-derived layer of topsoil which gradually formed above the Pleistocene/post-Pleistocene clays.

For the most part, the Louisiana coastal tallgrass prairie region is a rather featureless plain, ranging from ca. 1.5 m in elevation nearest to the Gulf Coast to ca.16 m at its northern reaches. However, the region is characterized by two rather subtle physiographic features: 1) occasional shallow water-filled depressions, referred to as *marais,* "little marsh," or *platins,* nearly circular ponds, by the Cajuns, and 2) occasional series of low, circular mounds, ranging 2–20 m in diameter and a few centimeters to over 1.5 m in height. In some areas, as much as 25% of the landscape may be covered by these hillocks (Smeins et al. 1992), which are most often referred to as "pimple or mima mounds." There is ongoing conjecture as to the origin of both of these features. Thus far, the most plausible explanation may center around a "differential erosion" concept whereby the lands containing these features were subjected to wind and wave action during historic coastal environments (Smeins et al. 1992).

Another set of associated physiographic features which allowed early coastal tallgrass prairie travelers to more easily navigate and

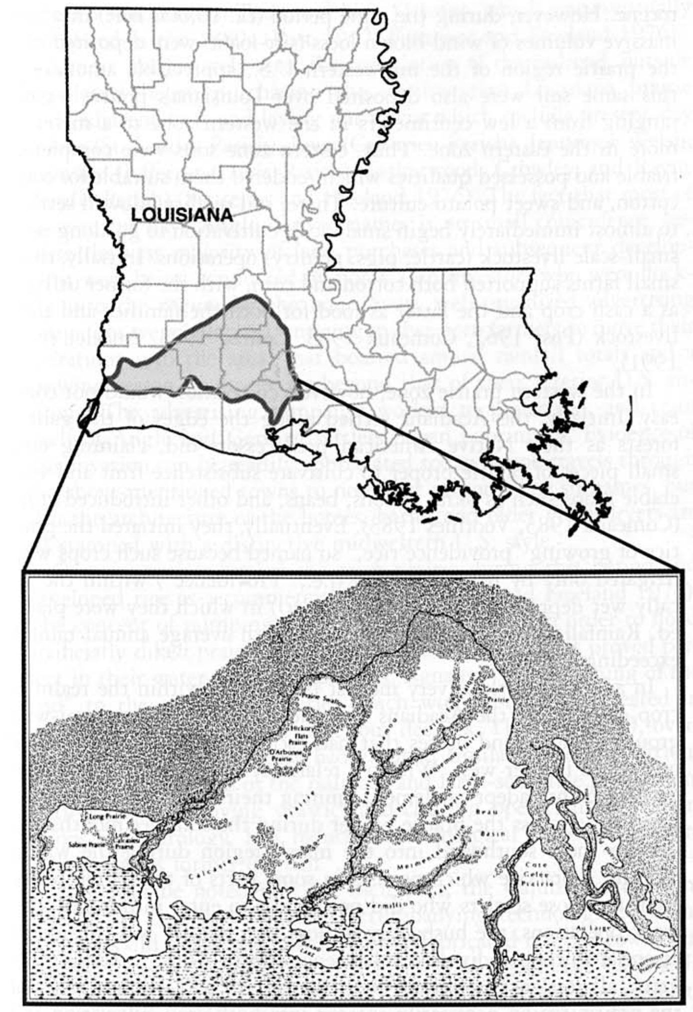

Fig. 1. The historical range of the Cajun Prairie extends across parts of eight parishes in southwestern Louisiana. The prairie is subdivided by a number of streams, most of which are tributaries of the Mermentau River system (the large central drainage in the map). To the east, the prairie is drained by the Vermilion River and the Bayou Teche, while the western prairie is drained by the Calcasieu River. These streams and their tributaries are lined by fairly extensive gallery forests. Lafayette is the largest city at the eastern edge of the prairie, while Lake Charles is the largest city at the western edge of the prairie. Much of the area east of the Mermentau River is "cotton and corn" country, while the area west is "rice and cattle" country. The earliest settlements of the Cajuns were approximately 20 km north (Opelousas frontier) and 10 km south (Attakapas frontier) of the current city of Lafayette. The maps are adapted from Newton's (1972) atlas.

orient themselves within the region is the presence of several bayous, sluggish streams, which dissect it in north-south fashion at various intervals. Riparian hardwood, gallery forests developed along the better-drained natural levees of these streams. Ranging in width from 10–1000 m, these strip-like, gallery forests were inhabited and traveled through by Native American and early Francophone settlers alike. Also, these streams with their associated woodlands served to separate the vast grassland into sub-sections replete with various wooded landmarks which could be utilized for more efficient orienteering (Fig. 1).

A final physiographic consideration which contributed greatly to the eventual cultural disposition of southwestern Louisiana's prairie region involves its degree of physical isolation resulting from the ecology/physiography of the lands which surrounded the region. To the north, the prairie system was bounded by a substantial pine/hardwood "flatwoods" system possessing sandy soils, that were too nutritionally poor and/or wet to clear for crops. Together with eastern Texas, much of that area was considered the Big Thicket (Ajilvsgi 1979). To the east lay the vast Atchafalaya Basin, one of North America's largest river swamps, and the entire southern edge of the prairies was bounded by an equally impenetrable mosaic of fresh-water, brackish, and salt marshes.

The prairie region was isolated from the East by the immense Atchafalaya Basin, but the Attakapas people, a primitive and nomadic Native American group, occupied it. Few non-native people settled or even surveyed the region prior to the mid to late 18th century (Kniffen 1965). Finally, during the 19th century, land surveyors C. C. Robin (1807) and Samuel Lockett (1969) visited small portions of the region in 1803 and ca. 1850, respectively, and provided generalized written accounts of it, containing very little information regarding flora and fauna. Before it was obliterated, the prairie region came quite close to receiving a proper botanical survey in 1870 by Louisiana State University botanist, A. Featherman (1871). Alas, Professor Featherman had arrived at the prairie region during the summer season, and due to the lack of blooming specimens, felt that his collecting time would be better served elsewhere. In light of this total lack of historical botanical documentation, it is fortunate that Allen and Vidrine "stumbled" onto the last few existing strips of remnant southwestern Louisiana prairie in 1986, eventually documenting many plants and animals associated with the ecosystem (Allen and Vidrine 1989 and 1990).

Historical documentation of southwestern Louisiana prairie fauna prior to the turn of the 20th century is similarly lacking. Fortunately, Louisiana State University zoologist George Lowery, Jr. amassed as much pre-twentieth century bird and mammal data as he could, including it in volumes which he later authored. Of the historical bird life on the prairie, most noteworthy from Lowery (1974a) were several references characterizing the Whooping Crane (*Grus americana*) and Attwater's Prairie Chicken (*Tympanuchus cupido attwateri*), both presently hovering on the brink of extinction, as "common" and "abundant," respectively, in the region. Similarly, Lowery (1974b) recounted the details surrounding the discovery of both the red wolf (*Canis rufus*) and the Louisiana prairie vole (*Microtus ochrogaster ludovicianus*), both thought to be presently extinct, within the prairie region of southwestern Louisiana. Like that of the region's plant life, it is generally believed that historical bird, amphibian, reptile and mammal life in this region was extremely diverse (Lowery 1974a and b, Dundee and Rossman 1989, Johnson 1999). The diversity and abundance of contemporary mammal life were substantially high. During the winter months in particular, notably large numbers of raptors, waterfowl, shorebirds, sparrows, blackbirds, and other birds still migrate into the prairie region, now almost totally supplanted with rice, sugar cane, cattle, and crayfish farms (Vidrine et al. 1995, Huner 2000).

THE CULTURAL CONTEXT

As was emphasized in the previous section, the only human inhabitants of the coastal tallgrass prairie region prior to the mid 18th century were small bands of Attakapas Indians, who seasonally encamped along the gallery forests associated with the various bayous that dissected the region. But by the latter half of the 18th century, this pattern would change. French immigrants who had settled in Nova Scotia, Canada, in an area they called *Acadie,* were exiled by the British colonial government, ostensibly on the basis of religious differences, in 1755. Some of these exiles went back to France, but most of them spent the next decade wandering the Atlantic coast in search of colonies that might take them in. While some were eventually accepted into various New England colonies, most were not. Eventually, the "Acadians" got word of French colonies that existed along the north-central coast of the Gulf of Mexico and began making their way to this region. Between 1764 and 1788, an estimated 2635 Acadians arrived in the Louisiana colony followed in 1809 by a still-unknown number. These were quickly relocated west of the Mississippi River along the eastern edge of the prairie region (Brasseaux 1987 and 1991). During this period, French and/or Spanish settlement in that region was scanty and limited to clusters around two military installations: the *Poste des Attakapas* in present-day St. Martin Parish and the *Poste des Opelousas* in present-day St. Landry Parish. Upon arriving at these areas, the Acadian exiles, who already possessed a long tradition of subsistence farming, livestocking, hunting, fishing, trapping, and gathering, wasted no time in removing themselves from these established settlements. Some moved east into the great Atchafalaya Swamp, and others moved west into the prairie. Prior to this time period, some non-Acadian French settlers, mostly retired soldiers from previous expeditionary and occupation forces, along with a few Spanish settlers were established along the edges of the prairie. The prairie area remained under Spanish governance through the end of the 18th century; however, first the French gained control and then sold the area to the Americans at the beginning of the 19th century. Against the background of governmental change, the settlers were already employed in small-scale farming and ranching activities along the northern and eastern boundaries of the prairie region (Comeaux 1983).

The migration of these French settlers was heralded in the epic poem *Evangeline* by Longfellow (1847). Other non-Cajun myths and stories developed on the prairie and its associated environs. Two of the most famous characters were Jean Lafitte, the pirate, and Jim Bowie, knifefighter and speculator; interestingly these two were contemporaries in both business and adventures in the surviving stories (Ramsay 1996, Thorp 1991). However, it is the Prairie Cajuns that have received the greatest attention. The Jean Lafitte National Historic Parks of Louisiana commissioned a detailed study of the Cajuns and produced a five-volume project report (in Ancelet et al. 1991). The park system houses it in the Prairie Cajun visitor center in Eunice, Louisiana.

Over time, the Cajuns gradually became entrenched within the prairie proper, doubtlessly finding the long growing season (compared with that of France and Canada), plentiful game, and seemingly infinite range of livestock forage well-suited for their subsistence lifestyles. But living there was by no means easy, due primarily to the great difficulty experienced in carving out a homestead and/or traveling for even short distances amidst exceedingly thick and tall prairie vegetation (Fontenot and Freeland 1976). Lifelong Evangeline Parish (north-central boundary of the prairie) resident Burkeman Veillon (born: 1921) once recounted to one of the authors stories from his grandfather (ca. 1870–1890) of men traveling on horseback through the "Mamou Prairie" where the only things visible of them were their hats!

Living there in near-total physical and cultural isolation from the rest of colonial America, a strong, resilient, and ultimately fascinating culture would develop over the next 100 yrs.

Agriculturally, the prairie could be divided into two cultural zones, the "corn and cotton" zone in the east and a larger "rice and cattle" zone in the west (Comeaux 1983). The reasoning for such a division lies in the soils and the lay of the land. As previously mentioned, the bulk of southwestern Louisiana prairie soils are dense calcareous clays derived from repeated flooding/sediment laying via the adjacent Gulf of Mexico during interglacial periods of the Pleistocene. However, during the same period (ca. 10,000 B.P.) in which massive volumes of wind-blown loess (silt-loam) were deposited over the prairie region of the midwestern U.S., appreciable amounts of this same soil were also deposited over Louisiana's prairie region, ranging from a few centimeters in the western zone to a meter or more in the eastern zone. Thus, eastern zone soils were completely friable and possessed qualities which rendered them suitable for corn, cotton, and sweet potato culture. There, soil quality allowed settlers to almost immediately begin small-scale cultivation to go along with small-scale livestock (cattle, pigs, poultry) operations. Initially, these small farms supported both cotton and corn, with the former utilized as a cash crop and the latter as food for both the families and their livestock (Post 1962, Comeaux 1983, Conrad 1983, Ancelet et al. 1991).

In the western prairie zone, however, cultivation would not come easy. Initially, the Acadians settled along the edges of the gallery forests as their Native American predecessors did, claiming only small pieces of prairie proper to cultivate subsistence fruit and vegetable crops such as okra, melons, beans, and other introduced crops (Comeaux 1983, Voorhies 1983). Eventually, they initiated the practice of growing "providence rice," so named because such crops were irrigated only by natural rainfall (i.e., "Providence") within the locally wet depressions (*marais* and *platins*)) in which they were planted. Rainfall is generous in the region, with average annual rainfall exceeding 1.25 m.

In addition to these very modest beginnings within the realm of crop cultivation, the Acadians also encountered remnant semi-wild groups of cattle and horses that had escaped from Spanish colonial operations further west. Within a relatively short time the Acadians developed into adept cattlemen, running their herds "free range" (*au large*) style across the prairie proper during the summer months and driving them southward into the marsh region during the winter months, a practice which persists in some parts of the region today. Even for those settlers who did not choose to enter into larger livestock operations, the husbandry of hogs and poultry was considered essential to their individual subsistence efforts. Thus, to varying degrees, all settlers throughout both the eastern and western zones of the prairie region necessarily entered into both crop cultivation and livestock operations in a dual system that is still employed by the majority of contemporary prairie region inhabitants.

The Cajun culture remains complex with distinctive folkways (e.g., cuisine, language, medicine, music, and religious traditions). These are discussed in several sources (Lynch 1942, Newton 1972, Dormon 1983, Savoy 1984, Holmes 1990, Ancelet et al. 1991, Fontenot 1992, Reese 1992, Vidrine et al. 1995).

THE DEMISE

By 1850, New Orleans was already a 130-year-old city, and its ever-increasing population was already outstripping the steady supply of agricultural products which flowed into it from surrounding rural areas. The supply of beef in particular was most problematic because lands suitable for cattle ranching were in short supply to the north and east. At that time, any goods shipped into New Orleans from the west faced a treacherous boat journey across a 60–70 km maze of shallow lakes, swamps, rivers, and bayous within the Mississippi River floodplain and the great Atchafalaya Swamp to its immediate west (Davis 1968). Barging live cattle across this massive swamp complex with its ever-fluctuating water levels was out of the question; and because a boat trip across that forested wetland system could take 3–6 weeks (depending on water levels), shipping processed meat was logistically impossible as well. Thus, the only viable option which remained was the construction of a railway system between southeastern Texas and New Orleans, which was eventually completed in the 1880s (Post 1962, Fontenot and Freeland 1976).

Almost immediately after the completion of the railroad, outside speculators began purchasing the southwestern Louisiana prairie lands adjacent to it and laying out towns which include present-day Eunice (St. Landry Parish), Iowa (Calcasieu Parish), Jennings, Welsh, Roanoke (Jefferson Davis Parish), Estherwood, Crowley, and Rayne (Acadia Parish) (Fontenot and Freeland 1976). The fact that most of these towns have Anglo-derived names is no small coincidence, because the vast majority of land purchases and subsequent development were being conducted by non-Cajun investors who were flocking into the region by the hour. Soon, well-organized advertising campaigns were launched, enticing midwestern farmers to move their operations into the area, that boasted annual rainfall totals and a growing season that were far beyond that of their interior U.S. environs. The advertising campaign worked to perfection, and train loads of Anglo and German settlers began pouring in. Evidence of this invasion can be readily appreciated today as one travels through the above-mentioned towns to note that not only the surnames, but also the architecture of the homes, barns, and older grain dryers are all stamped with a distinctive midwestern U.S. style.

German settlers settled the open prairie during this period and developed rice as a commercial crop (Fontenot and Freeland 1976). The concept of pumping water out of local bayous in order to flood artificially diked prairie lands, whose dense clay subsoils proved perfect in their water-holding capacities, signaled "the beginning of the end" to the ecological prairie, which would be hastily cleared in wholesale fashion over the next four decades. Thus, by 1920, overgrazing (the cattle industry had attained similarly epic proportions upon the completion of the railroad) and large-scale rice production, with its accompanying drastic land-clearing operations and alterations in hydrology, had reduced the ecological prairie to a mere fraction of its former domain.

It should be noted that for their part, the Cajuns heartily embraced the Germans and their accompanying technologies, for the Germans did not linger within the pre-fabricated railroad towns but instead dived right into the prairie proper alongside the Cajuns. In fact, within the space of only one or two generations, the majority of German settlers had become virtually indistinguishable from their Cajun brethren. Like the Spanish prairie settlers before them, the Germans were overpoweringly and rapidly absorbed into the Cajun lifestyle in an ongoing cultural phenomenon which remains in force today. It is obvious that southwestern Louisiana prairie dwellers of Spanish, German, African, and even Native American extractions all contributed shares of folkways that entered the mix of what is known today as "prairie Cajun culture." However, it is equally apparent that the overwhelming majority of descendants of these various ethnic contributors have taken on the foods, customs, religious customs, music, and language of the Cajuns. In part, the underpinnings of this phenomenon can be explained by the simple fact that Cajun women substantially outnumbered the women who would arrive later with the non-Cajun settler groups, and, as a result, a greater number of non-Cajun men would necessarily marry into Cajun families. As is usually the case with most ethnically mixed marriages, the children are more apt to take on the customs, beliefs, etc. of the mother (Ancelet et al. 1991, Brasseaux 1991, Brasseaux et al. 1994).

In efforts to mainstream Cajun children into American culture, the Cajun French language was forbidden to be spoken on school property by the mid-1920s. Further mainstreaming events would occur in relatively rapid succession with the advent of the automobile, World War II (where the majority of young Cajun men would discover and absorb American culture firsthand), the television, and other technologies. Therefore, by 1950 the prairie Cajun culture would exist as a mere shadow of its former self, and the Cajun Prairie would be reduced to fragments so small as to be completely forgotten by its inhabitants.

Fortunately, this period of cultural demise would end almost as suddenly as it began, with the establishment of the Council for the Development of French in Louisiana (CODOFIL) in 1960. Initially comprised of a small group of Cajun musicians, educators, and politicians, membership and interest in this organization mushroomed over the next 20 yrs. As a result, Cajun heritage programs, conferences, and facilities began to spring up throughout the region, and the Cajun French language found its way back into the school system.

By 1984 interest in both the cultural and ecological aspects of the Cajun Prairie ignited within the staff of the Lafayette Natural History Museum in Lafayette, Louisiana and culminated in the opening of a Cajun Prairie exhibit at that facility in the fall of 1986. In that same year, Louisiana State University at Eunice biologists would rediscover remnant strips of Cajun Prairie along the right-of-ways of the same railroads which had initiated its demise some 100 yrs earlier.

The latest chapter in the story of the Prairie Cajuns and the Cajun Prairie involves the initiation of several ecological restoration projects (Allen and Vidrine 1989 and 1990, Fontenot 1992, Allain and Johnson 1997, Allain et al. 1999). Sadly, because no adequate pre-settlement vegetational records exist for the region, the present restoration efforts represent collections of those residual plant species that have persisted within the small remnant strips. By the same token, it has already become evident that these residual plant species are creating a vegetational matrix which appears to exclude the majority of invasive exotic plant species present within the region and attracts and supports a surprisingly high diversity of native animals, both vertebrate and invertebrate. Workers are thus hopeful that over time, the entire community of organisms that once constituted the historical coastal tallgrass prairie may recreate a habitat that closely approximates that of the original (Vidrine et al. 1995, Vidrine and Borsari 1998). Hopefully, this will inspire its human inhabitants to more ethically understand the complete circle of life where the land itself comes to be viewed as the real community to which the people belong (Leopold, 1949 and 1999, Jackson 1999).

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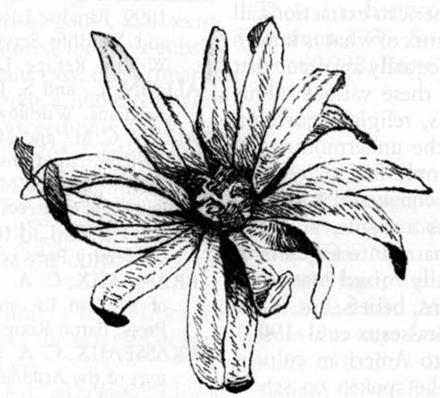

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The Cajun Prairie Restoration Project

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The Cajun Prairie is that part of the coastal tallgrass prairie found in southwestern Louisiana. With less than 40 ha remaining of the original 1,000,000 ha, it is possibly the most imperiled ecosystem in North America. A restoration project was initiated to see if prairie restoration techniques used elsewhere could be successfully employed in southwestern Louisiana. In 1988, restoration of 4 ha began in the city of Eunice. Seeds were hand-collected from local railroad prairie remnants. Seeds were broadcast following site preparation. Additional plants were propagated in containers from roots, stems, and seeds and then transplanted. Sods were removed from remnants to protect plants and to inoculate the site with the soil biota of native prairie. Prescribed winter burns of the site were conducted annually. In a 1995 census, more than 250 species of prairie plants were established. In a 2000 census, aggressive, early succession plants (native and exotic) had disappeared. In 2000, diameters of clumps of colonial prairie plant species were measured; average annual increase ranged from 8.3 cm to 91.3 cm. This experimental restoration project demonstrates that restoration of Cajun prairie is feasible. The project is an important repository for locally adapted prairie ecotypes and a model for other restoration efforts being attempted.

INDEX DESCRIPTORS: Cajun Prairie, tallgrass prairie, prairie restoration, Louisiana.

The western Gulf of Mexico coastal plain is known for its diverse habitats and wildflowers (Brown 1972, Ajilvsgi 1979, and Tveten and Tveten 1993). The region is characterized by marshes, prairies, savannas, bottomland hardwood, and upland pine forests. A major feature is the coastal tallgrass prairie (Allain et al. 1999, Smeins et al. 1992). The Cajun Prairie is part of the coastal tallgrass prairie found in southwestern Louisiana (Allen and Vidrine 1989, Allain and Johnson 1997, Allain et al. 1999 Allain and Castille 2000). Cajun Prairie annual rainfall frequently exceeds 1.25 m. Short winters and long summers expand current concepts of North American prairie. Several plant species occur in this prairie that do not occur in prairies elsewhere. Less than 40 ha of the 1,000,000 ha of pre-settlement prairie in southwestern Louisiana remain, making Cajun Prairie one of the most imperiled ecosystems in North America (Allain and Johnson 1997). The remaining prairie exists primarily as remnants along railroad rights-of-way, each sustaining its own assortment of native plants and animals and each surviving a variety of assaults. In a period of only five yrs, from 1995 to 2000, remnant area has been halved. Despite the scarcity of this ecosystem, our surveys of these remnants uncovered more than 600 species of plants and hundreds of insect species (Allen and Vidrine 1990, Vidrine and Allen 1993, Allain and Castille 2000). A restoration project was initiated to see if prairie restoration techniques used elsewhere could be successfully employed in southwestern Louisiana.

METHODS

In 1988, the city of Eunice, Louisiana leased a 4 hectare lot from Union Pacific Railroad for the purpose of reconstructing prairie in the city limits of Eunice (The Cajun Prairie Restoration Project). Also, the Cajun Prairie Habitat Preservation Society was created to preserve and restore this ecosystem. A number of local agencies cooperated in this effort (Allen and Vidrine 1989, Vidrine et al. 1995). In September, 1988, the site was mowed and herbicided with glyphosphate. After plant senescence, a prescribed burn was conducted to remove biomass.

In the fall of 1988, seeds were collected from local prairie remnants along railroad rights-of-way. Most of the seeds were collected by students from local schools and clubs. The seeds were stored dry at 4°C until the day of planting but received no other treatment. Since most of the seeds were collected during the autumn, the majority of the seeds were from summer and autumn bloomers. Sod was rescued from remnants in danger of destruction by hand digging. Plants were propagated in containers from cuttings and seeds.

On 9 December 1988, the seeds were distributed by hand by the individual who had collected them producing a heterogeneous distribution. The area was then harrowed in order to work the seeds into the soil. The following two winters, hand-collected seed was sown into bare areas. At the same times, plants grown in containers and sods from remnants were transplanted into sites that were selected based upon soil moisture patterns. The sods added additional species as well as inoculated the soil at the site with the soil biota of the native prairie.

Burns were conducted annually beginning in 1989. Minimal weeding was done. Removal of Chinese tallow trees (*Sapium sabifera*) is proving to be the greatest obstacle, requiring a tremendous amount of time. Tallow trees initially invade wet areas where there is often little fuel. They also invade disturbed areas in prairie. At only three to five yrs of age they suppress fuel and are no longer controlled by fire (Grace 1998). If the trees are left to grow, they are

Table 1. Plant species suitable for use in planting matrix for prairie restoration in Louisiana. In some cases, several species in a genus are listed as a single entry and separated by a front-slash. An asterisk indicates aggressive colonizers.

Grasses:
Andropogon gerardii
Panicum virgatum
Paspalum plicatulum
*Schizachyrium scoparium**
Sorghastrum nutans
Tripsacum dactyloides
Forbs:
Arnoglossum ovatum
*Aster concolor/hemisphericus/patens**
*Baptisia alba/bracteata/nutalliana/sphaerocarpa**
*Bidens aristosa**
*Chamaecrista fasciculate**
Coreopsis lanceolata/pubescens/tripteris
*Eryngium yuccifolium**
*Euthamia leptocephla/tenuifolium**
*Gaura lindheimeri**
*Helianthus angustifolius/mollis**
*Lespedeza capitata/virginica**
Liatris acedota/squarosa
*Liatris pycnostachya/spicata**
*Monarda fistulosa/lindheimeri/punctata**
Pityopsis graminifolia
*Pycnanthemum tenuifolium**
*Rudbeckia hirta**
Silphium gracile/lacinatum
Solidago nitida/odora/rugosa
*Tephrosia onobrychoides**

very difficult to eradicate. Birds eat their seeds and disperse them in their droppings, providing ample opportunity for this invasive weed to get established (Grace 1998).

The project was evaluated by conducting a census in 1995 and again in 2000. Relative abundance of plant species was determined from observation and analysis of photographs. Also, in 2000, diameters of clumps of colonial prairie plant species were measured along their greatest axes. Average annual increase in clump diameter was determined for six species (four grasses and two forbs).

RESULTS

The 1995 census estimated that half of the site was dominated by native prairie plants (Vidrine et al. 1995). More than 250 plant species of the nearly 600 known from nearby remnants were established. Remaining portions of the site, most at lower elevations, succumbed to exotic vegetation, primarily the Chinese tallow tree. Exotic species that became established at higher elevations were eventually excluded from the site. General evaluations in 1995 and 2000 demonstrated that succession was occurring. A number of aggressive, early succession natives were either no longer evident or greatly reduced. Some of these included: *Agalinis* spp., *Ambrosia* spp., *Aster praealtus, Bidens aristosa, Croton capitatus, Chamescrista fasciculata, Erigeron philadelphicus, Eupatorium* spp., *Euthamia* spp., *Helianthus angustifolius, Ipomoea* spp., *Passiflora incarnata, Ranunculus* spp., *Senecio glabellus,* and *Solidago canadensis* (Vidrine et al. 1995 and 2000, Allen 2000). Exotics that were excluded from well-drained sites include *Verbena brasiliensis* and *Paspalum urvillei* (Vidrine et al. 1995 and 2000, Allen 2000).

Several new species have appeared and flowered in the last five yrs including *Asclepias longifolia, Asclepias obovata, Ctenium aromaticum,* and *Pteroglossaspis ecristata.* Due to the isolation of the site, these conservative species are thought to have been present either in the original seed mix or in the sod. However, germination and/or flowering was delayed.

Borsari and Vidrine (1997) examined the clump-size increase in six major species of plants in the site. These clumps were again evaluated in 2000, and the resulting data are summarized in Table 2. Ten growing seasons have been completed since the original sods were placed at the site. No fertilizer, watering, or other intervention other than fire have affected the plants to our knowledge. The results clearly depict that the sod-forming plants that appear as clumps can be readily examined and measured. The larger clumps have disintegrated in their centers, and numerous other native plants are now growing in and among the separate sprouts. Of the measured species, the fastest growing grass was *Tripsacum dactyloides* (eastern gama grass) with an average annual increase of 15.6 cm. The fastest growing forb was *Pycnanthemum muticum* (mountain mint) with an average annual increase of 91.3 cm. The slowest growing grasses were *Andropogon gerardii* (big bluestem) and *Sorghastrum nutans* (Indiangrass) with average annual increases of 8.3 and 8.4 cm, respectively. All six species appeared to increase in diameter continuously; thus, measurements were confined to plants with this life history strategy. In contrast many other species, e.g., *Coreopsis lanceolata* (lanceleaf tickseed), *Schizachyrium scoparium* (little bluestem), and *Schizachyrium tenerum* (slender bluestem), formed distinctive clumps of a limited size. Recruitment by seed may be more important for these species. The two life history strategies are obviously important in the overall restoration process as evidenced by events in plant succession at the site.

DISCUSSION

Successful establishment of a diverse perennial prairie community on the well-drained portion of this site clearly demonstrated that

Table 2. Clump-size estimates for six major matrix plants at the Cajun Prairie Restoration Project in Eunice, Louisiana. The diameters for the initial sod plugs were estimated in 1989 as they were planted. In 2000, the mean and standard deviation of the clumps for each species, the range of diameters measured, and the average increase in diameter per year of growth for each species are provided. The number is the number of clumps measured; all other measurements are in centimeters.

Species	Number	1989	2000	2000	Average
Andropogon gerardii	34	20	103 ± 29	58–194	8.3
Sorghastrum nutans	9	20	104 ± 37	53–180	8.4
Panicum virgatum	26	20	145 ± 33	67–200	12.5
Tripsacum dactyloides	15	20	176 ± 32	120–240	15.6
Pycnanthemum muticum	7	20	933 ± 269	660–1400	91.3
Helianthus mollis	24	20	332 ± 88	190–520	31.1

restoration of Cajun Prairie is feasible. However, it appeared that determining site suitability and matching species to site conditions are critical parts of restoration planning (Allain and Castille 2000). Most exotic and early succession plant species have been displaced as succession occurs in the restoration (Allen 2000, Vidrine et al. 2000). After six yrs, insect diversity in the restoration site resembled that of remnant prairies (Allen and Vidrine 1990, Vidrine and Borsari 1999). This indicated that, to some extent, ecosystem complexity was recovering.

The process of planting prairies involves both the selection of plants and the proper placement of plants in the site. An initial planting of seeds of native species that rapidly colonize cultivated restoration sites is referred to as a restoration matrix (Betz 1986). These early succession species facilitate future colonization of the site by conservative prairie plant species typical of later successional seres (McClain 1997). Table 1 provides a list of Cajun Prairie matrix species for future prairie restorations in southwestern Louisiana. These native plant species were very successful during the first 10 yrs of restoration in Eunice. Some of these species have already disappeared from the restoration project in Eunice. An alternate model for restoration involves simultaneously sowing seeds of both early succession and conservative, late succession species (Schramm 1990). This latter method hypothesizes that the more conservative species will germinate by successfully competing with the early successional species after the site has matured. Further, this latter hypothesis contends that conservative species cannot be successfully introduced into a perennial matrix that excludes newcomers.

Either of the two methods or a combination of these strategies is recommended for future research avenues in the search for better methods of restoring prairies in Louisiana.

The Cajun Prairie Restoration Project provides a model for other restoration efforts in southwestern Louisiana. One of the greatest drawbacks for further projects is the availability of local seeds and propagules of native plants. Because there are no remnant prairies in Louisiana being preserved, the importance of restorations as reservoirs of locally adapted ecotypes is immeasurable. Remnants are rarely burned, facilitating the rapid spread of Chinese tallow, a great cause for alarm (Grace 1998).

The Cajun Prairie Restoration Project provides a habitat for the development of a diverse and dynamic biological community. The project has provided opportunities for varied kinds of research. Borsari and Shirley (1993) examined the soil profiles after only three yrs into the restoration process of development and clearly demonstrated an accumulation of organic matter in the restoration site. This evidence indicates the impact that the prairie plants have upon soils in maintaining and generating soil fertility nutrients. Vidrine and Borsari (1998 and1999) developed philosophical models for agriculture and for integrated pest management using Cajun Prairie vis-à-vis the Cajun Prairie Restoration Project for small farms and landscapes. The development of diverse insect and arachnid communities is obvious in the restoration site (Allain and Johnson unpubl. data, Vidrine and Allen 1993).

The paradigm of restoring habitat was developed by Aldo Leopold (Leopold 1949, 1999), and we continue this paradigm. However, there is a great need for more and larger projects, from gardens to farms to landscape scale restorations (Vidrine and Borsari 1998 and 1999, Jackson 1999, Vidrine et al. 1999a, b, and c, Semar and Vidrine 2000). This experimental project demonstrates that restoration of Cajun prairie is feasible. The project is an important repository for locally adapted prairie ecotypes and a model for other restoration efforts being attempted. Additional studies are critical if restoration and maintenance of this valuable community are to be succesful.

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Vascular Flora of the Cajun Prairie of Southwestern Louisiana

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Cajun Prairie is a Coastal Prairie developed in southwestern Louisiana between the Atchafalaya and Sabine rivers where most of the European settlers were Cajuns (French Acadians). This prairie occurs in an area with 125 cm (50 in) of annual rainfall; possible explanations for its development in this region include a hard claypan below the surface and frequent fires. Most of the original 1,000,000 ha of prairie have been destroyed with only a few remnant railroad strips (200 ha) remaining; this flora is based on the species observed in the remnant strips in Acadia, Allen, and Jefferson Davis parishes over a twelve year period (1987–1999). The vascular flora includes 512 taxa in 92 families and 277 genera. The family with the most taxa is the Asteraceae (80), followed by the Poaceae (78), Cyperaceae (50), Fabaceae (35), Lamiaceae (19), Scrophulariaceae (18), and Onagraceae (14). Some common Asteraceae taxa include *Arnoglossum plantagineum, Rudbeckia hirta, R. grandiflora, Silphium gracile, S. laciniatum, Solidago odora*, and several species of *Liatris* and *Symphotrychum*. Some common and conspicuous grass (Poaceae) species include *Andropogon gerardii, Panicum virgatum, Schizachyrium scoparium, Sorghastrum nutans*, and *Tripsacum dactyloides*. Other notable species include several species of *Baptisia, Dalea candida, Eryngium yuccifolium, Euphorbia corollata, Hedyotis nigricans*, and *Tephrosia onobrychoides*.

INDEX DESCRIPTORS: Louisiana flora, cajun prairie, Asteraceae, Poaceae, Cyperaceae.

Many authors map the southeastern extent of the true prairie in the United States in east Texas (Weaver 1954, Risser et al. 1981, Sims 1988, Kucera 1991). However, there is an area of remnant coastal tallgrass prairie in southwestern Louisiana between the Atchafalaya and Sabine rivers that has been called Attakapas Country, the Great Southwestern Prairie, or more recently, Cajun Prairie (Allen and Vidrine 1989). This grassland originally stretched across parts of Acadia, Allen, Calcasieu, Cameron, Evangeline, Iberia, Jefferson Davis, Lafayette, St. Landry, St. Martin, and Vermilion parishes. From 1869 to 1872, the prairie occupied an area of 1,000,000 ha (Post 1969).

Several interrelated factors help explain the presence of prairie in an area which receives an average of 125 cm of rainfall per year (National Oceanic and Atmospheric Administration 1987). The terrain is flat, and there is a densely-packed, hard clay pan located 20 to 40 cm below the surface (Clark et al. 1962, USDA 1970, Kilpatrick et al. 1980). Tree roots usually penetrate much deeper than roots of grasses and other herbaceous plants, but tree roots do not penetrate the clay pan (Brown 1972). Fires caused by lightning and later set by Indians and by European settlers also helped to retard the growth of trees (Allen and Vidrine 1989).

Today, most of the original prairie has been destroyed and replaced by cultivated crops, in particular rice. However, a few remnant prairies currently persist along railroad rights-of-way. Most of these remnants were never tilled or have not been tilled since the railroad acquired the land approximately 150 yrs ago. The remnants are all very narrow, mostly less than 30 m wide and no more than 800 m long. The estimated total area of intact Cajun Prairie today is 200 ha (Allen and Vidrine 1989). This ecosystem is ranked G2 (imperiled globally because of rarity or because of some factor(s) making it vulnerable to extirpation) by The Nature Conservancy (Grossman et al. 1994), and in Louisiana it is ranked S1 (critically imperiled in state because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the state) by The Natural Heritage Program (Smith 1995).

Two early visitors to Cajun Prairie, C. C. Robin in 1803 to 1805 (Robin 1807) and Samuel Lockett in 1868 to 1872 (Post 1969), listed several species observed in this grassland during their travels. Brown (1972) briefly described Cajun Prairie and provided a partial list of the flora there. The objective of this study was to thoroughly document the vascular flora of the remnant Cajun Prairie strips.

STUDY AREA

Ten remnant strips were selected for this study based primarily on size and lack of disturbance. Each of the ten remnants was approximately 1,500 m long along railroad rights-of-way and consisted of two to four unbroken stretches. In the western and especially northwestern strips, there were small patches of pine savannah vegetation within the strips. Most of the remnant strips included small patches of disturbed vegetation within their boundaries. Five of the remnants were in Acadia Parish, three of which were along U.S. 90 between Estherwood and Mermentau, one along LA 91 south of Morse, and one west of LA 13 south of Eunice (Fig. 1). Four remnants were in Jefferson Davis Parish with three along U.S. 165 between Iowa and Kinder and one along U.S. 90 east of Elton. One remnant was in Allen Parish along U.S. 165 south of Kinder. The soils in these ten remnants were Crowley or Midland silt loam both with a clay hardpan (Clark et al. 1962, USDA 1970, Kilpatrick et al. 1980).

METHODS

The ten Cajun Prairie remnants were surveyed every two weeks from February to November, 1987, and the presence of all vascular plants was recorded. These ten remnants plus three other smaller remnant strips have been searched for taxa sporadically throughout

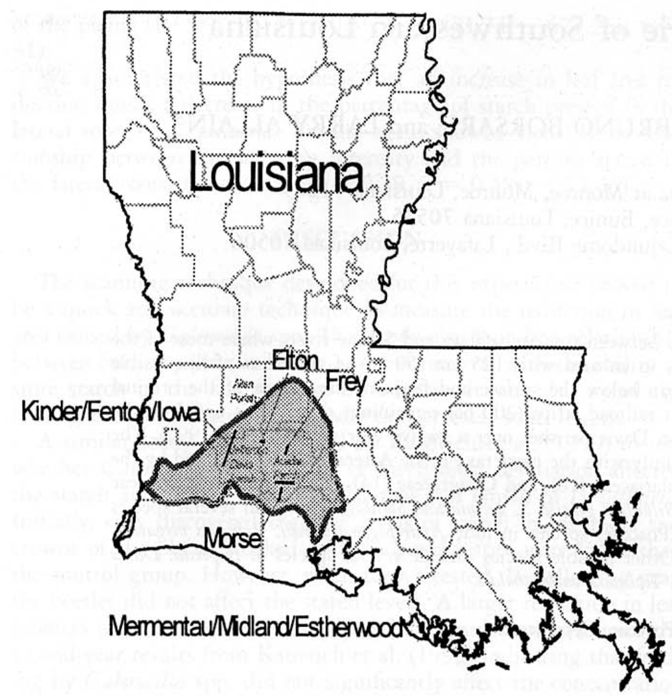

Fig. 1. Map of Louisiana with Cajun Prairie (shaded area) and ten remnant strips (dark lines).

the year from 1988 to present. Taxa were identified in the field by the senior author or keyed in the lab using the regional or state floras of Radford et al. (1968), Correll and Johnston (1970), or Allen (1992). For the less common taxa, herbarium specimens were collected and were deposited in the Herbarium of The University of Louisiana at Monroe (NLU). Notes were taken on abundance of each taxon; C (common) for those taxa that were observed in large numbers in almost all remnants, U (uncommon) for those taxa observed in small numbers in most remnants, and R (rare) for those taxa observed in small numbers in only one or two remnants (Appendix 1). The habitat within the remnant was also denoted; P (prairie), S (pine savannah), and D (disturbed areas). The atlases of Thomas and Allen (1993, 1996, 1998) were consulted to determine the native or introduced status of all taxa. Scientific names follow those in the Plants Database (USDA, NRCS 1999). To determine percent similarity, the list of Cajun Prairie plants was compared to similar lists from the Konza Prairie Research Natural Area in Kansas (Freeman and Hulbert 1985) and four Iowa prairies (Sorensen 1962, Crum 1972, Glenn-Lewin 1976, Wetzel et al. 1999).

RESULTS

A total of 512 taxa representing 92 families and 277 genera were identified from the ten remnant strips and/or other remnants (Appendix 1). The Asteraceae was the family with the most taxa 80 (15.62%) followed by Poaceae 78 (15.23%); Cyperaceae 50 (9.77%); Fabaceae 35 (6.84%); Lamiaceae 19 (3.71%); Scrophulariaceae 18 (3.51%); and Onagraceae 14 (2.73%). The most diverse genera were *Cyperus* and *Rhynchospora*, each with 12 taxa, and *Polygala* with nine. There were six genera with seven taxa each: *Asclepias, Carex, Dichanthelium, Eupatorium, Juncus*, and *Paspalum*. Most (482) of the 512 taxa were native (94.14%) with only 30 (5.86%) introduced taxa. Thirty-three (6.44%) taxa were noted in pine savannah vegetation and not a part of the prairie vegetation. A total of 235 taxa (45.90%) were identified from disturbed areas in the strips, especially along the edges. The remaining taxa (244 taxa, 47.66%) constituted the Cajun Prairie Flora. Three hundred and thirty-nine (66.21%) taxa were rated uncommon in abundance and distribution while 44 (8.59%) were rare and 129 (25.19%) were common.

Common Asteraceae taxa occurring in these strips included *Arnoglossum plantagineum, Rudbeckia hirta, R. grandiflora, Silphium gracile, S. laciniatum, Solidago odora*, and several species of *Liatris* and *Symphotrychum*. Some common and obvious grass (Poaceae) species included *Andropogon gerardii, Panicum virgatum, Schizachyrium scoparium, Sorghastrum nutans*, and *Tripsacum dactyloides*. Other notable species included several species of *Baptisia, Dalea candida, Eryngium yuccifolium, Euphorbia corollata, Hedyotis nigricans*, and *Tephrosia onobrychoides*.

DISCUSSION

The Cajun Prairie Flora is based on the few remaining remnant strips and not the large contiguous vegetation that once covered the area. Our flora could be missing taxa that did not survive in the remnant strips but likewise could have additional taxa that prefer the edge and may not have been present in the original Cajun Prairie landscape.

The Louisiana Flora as reported by Thomas and Allen (1993, 1996, 1998) included 3249 taxa; 512 taxa (15.79%) were identified from the Cajun Prairie remnant strips. The 512 taxa (15.79%) is notable given the small total area of the remnant strips.

The comparison of this flora to other floras is difficult because most prairie studies do not include a comprehensive list of taxa (Anderson and Adams 1981, Smeins and Diamond 1983, Diamond and Smeins 1984, 1985, Kebart and Anderson 1987). The Konza Prairie Research Area in Kansas (Freeman and Hulbert 1985) included 441 species with 103 (20.12%) of those also found in the Cajun Prairie remnants. Of the 512 Cajun Prairie taxa, 62 (12.11%) were also listed for one or more Iowa prairies (Sorensen 1962, Crum 1972, Glenn-Lewin 1976, Wetzel et al 1999). Thus, the Cajun Prairie Flora is best described as a coastal plain flora overlaid with a major Midwestern prairie component.

The Cajun Prairie Habitat Preservation Society, U.S. Fish and Wildlife Service, USGS, and USDA/NRCS are pursuing preservation and restoration projects to protect this rapidly disappearing ecosystem. The oldest (1988) and best developed is in Eunice, Louisiana (Allen and Vidrine 1989).

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APPENDIX 1. List of taxa by major plant group and then by family from Cajun Prairie of southwestern Louisiana.

Key

* before name = introduced taxon
The first letter in parentheses after the name is the abundance rating where R = rare, U = uncommon, and C = common
The second letter in parentheses after the name is the habitat in the remnants where P = prairie, S = pine savannah, and D = disturbed area
The third superscripted letter, if present, in parentheses after the name indicates a report from Midwestern prairies where [I] = Iowa and [K] = Konza

PTERIOPHYTES

ASPLENIACEAE
Asplenium platyneuron (L.) B.S.P. (U,S)
DENNSTAEDTIACEAE
Pteridium aquilinum (L.) Kuhn (U,S)
LYGODIACEAE
**Lygodium japonicum* (Thunb. ex Murr.) Sw. (U,D)

GYMNOSPERMS

PINACEAE
Pinus palustris P. Mill. (R,S)
Pinus taeda L. (U,D)
TAXODIACEAE
Taxodium distichum (L.) L.C. Rich. (R,S)

MONCOTYLEDONS

AGAVACEAE
Manfreda virginica (L.) Salisb. ex Rose (C,P[K])
COMMELINACEAE
Commelina erecta L. (U,D)
Tradescantia hirsutiflora Bush (C,D)
Tradescantia virginiana L. (C,D[I])
CYPERACEAE
Bulbostylis capillaris (L.) Kunth ex C.B. Clarke (U,D)
Carex alata Torr. (U,D)
Carex albolutescens Schwein. (U,D)
Carex cherokeensis Schwein. (U,D)
Carex complanata Torr. & Hook. (U,D)
Carex frankii Kunth (U,D)
Carex microdonta Torr. & Hook. (U,P)
Carex vulpinoidea Michx. (C,D[I])
Cladium mariscus (L.) Pohl ssp. *jamaicense* (Crantz) Kükenth. (R,P)
Cyperus acuminatus Torr. & Hook. ex Torr. (C,D[I])
Cyperus croceus Vahl (U,D)
Cyperus echinatus (L.) Wood (R,D)
Cyperus erythrorhizos Muhl. (U,D)
Cyperus haspan L. (U,D)
**Cyperus iria* L. (U,D)
Cyperus oxylepis Nees ex Steud. (U,D)
Cyperus pseudovegetus Steud. (C,D)
Cyperus retrorsus Chapman (C,D)
**Cyperus rotundus* L. (U,D)
Cyperus strigosus L. (U,D[I])
Cyperus virens Michx. (C,D)
Eleocharis microcarpa Torr. (U,D)
Eleocharis montana (Kunth) Roemer & J.A. Schultes (C,D)
Eleocharis obtusa (Willd.) J.A. Schultes (C,D)
Eleocharis quadrangulata (Michx.) Roemer & J.A. Schultes (U,D)
Eleocharis tuberculosa (Michx.) Roemer & J.A. Schultes (U,S)
Fimbristylis autumnalis (L.) Roemer & J.A. Schultes (U,D)
Fimbristylis miliacea (L.) Vahl (U,D)
Fimbristylis puberula (Michx.) Vahl (U,P[K])
Fuirena pumila (Torr.) Spreng. (R,S)
Isolepis carinata Hook. & Arn. ex Torr. (U,D)
Kyllinga brevifolia Rottb. (U,D)
Kyllinga odorata Vahl (U,D)
Rhynchospora caduca Ell. (C,P)
Rhynchospora cephalantha Gray (C,P)
Rhynchospora chalarocephala Fern. & Gale (U,S)
Rhynchospora colorata (L.) H. Pfeiffer (R,P)
Rhynchospora corniculata (Lam.) Gray (C,D)
Rhynchospora elliottii A. Dietr. (C,P)
Rhynchospora globularis (Chapman) Small (C,P)
Rhynchospora glomerata (L.) Vahl (C,P)
Rhynchospora harveyi W. Boott (U,P)
Rhynchospora microcarpa Baldw. ex Gray (C,P)
Rhynchospora pusilla Chapman ex M.A. Curtis (U,P)
Rhynchospora rariflora (Michx.) Ell. (U,S)

Scleria ciliata Michx. (C,P)
Scleria pauciflora Muhl. ex Willd. (C,P)
Scleria reticularis Michx. (R,S)
Scleria verticillata Muhl. ex Willd. (R,S)
IRIDACEAE
Herbertia lahue (Molina) Goldblatt (R,P)
Iris virginica L. (U,P[I])
Sisyrinchium angustifolium P. Mill. (C,P)
Sisyrinchium atlanticum Bickn. (U,P)
Sisyrinchium exile Bickn. (C,D)
Sisyrinchium langloisii Greene (C,P)
JUNCACEAE
Juncus brachycarpus Engelm. (C,D)
Juncus effusus L. (C,D)
Juncus marginatus Rostk. (C,P)
Juncus nodatus Coville (C,D)
Juncus polycephalus Michx. (C,D)
Juncus tenuis Willd. (C,D[I])
Juncus validus Coville (C,D)
LILIACEAE
Aletris aurea Walt. (R,S)
Aletris farinosa L. (R,S)
Allium canadense L. var. canadense (C,D[I K])
Allium canadense L. var. *mobilense* (Regel) Ownbey (U,P)
Hymenocallis liriosme (Raf.) Shinners (U,P)
Hypoxis hirsuta (L.) Coville (C,P[I K])
Nothoscordum bivalve (L.) Britt. (C,P[K])
ORCHIDACEAE
Calopogon oklahomensis D.H. Goldman (R,P)
Platanthera nivea (Nutt.) Luer (R, S)
Pteroglossaspis ecristata (Fern.) Rolfe (R,P)
Spiranthes vernalis Engelm. & Gary (C,P[K])
POACEAE
Agrostis hyemalis (Walt.) B.S.P. (C,P[I K])
Alopecurus carolinianus Walt. (U,D)
Andropogon gerardii Vitman (C,P[I K])
Andropogon glomeratus (Walt.) B.S.P. (C,P)
Andropogon gyrans Ashe var. *gyrans* (U,P)
Andropogon ternarius Michx. (U,P)
Andropogon virginicus L. (C,P[K])
Anthaenantia rufa (Nutt.) J.A. Schultes (U,P)
Aristida longispica Poir. var. *longispica* (U.D[K])
Aristida oligantha Michx. (U,D)
Aristida purpurascens Poir. var. *purpurascens* (C,P[K])
Axonopus fissifolius (Raddi) Kuhlm. (U,D)
Bothriochloa exaristata (Nash) Henr. (R,P)
**Bothriochloa ischaemum* (L.) Keng (U,D)
Bothriochloa longipaniculata (Gould) Allred & Gould (U,D)
Briza minor L. (U,D)
Bromus catharticus Vahl (U,D)
**Chloris canterai* Arech. (U,D)
Coelorachis cylindrica (Michx.) Nash (U,P)
Coelorachis rugosa (Nutt.) Nash (U,S)
Ctenium aromaticum (Walt.) Wood (U,S)
Cynodon dactylon (L.) Pers. (U,D)
Dichanthelium aciculare (Desv. ex Poir.) Gould & C.A. Clark (C,P)
Dichanthelium acuminatum (Sw.) Gould & C.A. Clark (C,P[I K])
Dichanthelium dichotomum (L.) Gould var. *dichotomum* (U,P[K])
Dichanthelium oligosanthes (J.A. Schultes) Gould var. *scribnerianum* (Nash) Gould (C,P[I K])
Dichanthelium ovale (Ell.) Gould & C.A. Clark (U,P[K])
Dichanthelium scoparium (Lam.) Gould (C,P[K])
Dichanthelium sphaerocarpon (Ell.) Gould var. *sphaerocarpon* (C,P[K])
Digitaria ciliaris (Retz.) Koel. (C,D)
Digitaria cognata (J.A. Schultes) Pilger (U,P[K])
Digitaria filiformis (L.) Koel. (U,P[K])
Digitaria ischaemum (Schreb.) Schreb. ex Muhl. (C,D[I])
Digitaria violascens Link (U,D)
Echinochloa crus-galli (L.) Beauv. (U,D[I])
Eragrostis bahiensis (Schrad. ex J.A. Schultes) J.A. Schultes (U,D)
Eragrostis elliottii S. Wats. (U,P)
Eragrostis hirsuta (Michx.) Nees (C,P)
Eragrostis lugens Nees (C,P)
Eragrostis refracta (Muhl.) Scribn. (C,P)
Eragrostis spectabilis (Pursh) Steud. (C,P[I K])
Gymnopogon brevifolius Trin. (U,P)
Leersia hexandra Sw. (U,D)
Limnodea arkansana (Nutt.) L.H. Dewey (U,D)
Lolium perenne L. (U,D)
Muhlenbergia capillaris (Lam.) Trin. (C,P)
Panicum anceps Michx. (C,P)
Panicum brachyanthum Steud. (U,P)
Panicum hemitomon J.A. Schultes (U,P)
Panicum rigidulum Bosc ex Nees var. *rigidulum* (U,D)
Panicum virgatum L. (C,P[I K])
**Paspalum dilatatum* Poir. (U,D)
Paspalum floridanum Michx. (C,P)
Paspalum laeve Michx. (U,P)
Paspalum plicatulum Michx. (U,P)
Paspalum praecox Walt. (R,P)
Paspalum setaceum Michx. (C,P[I K])
**Paspalum urvillei* Steud. (U,D)
Phalaris angusta Nees ex Trin. (U,D)
Phalaris caroliniana Walt. (U,D)
Schizachyrium scoparium (Michx.) Nash (C,P[I K])
Schizachyrium tenerum Nees (C,P)
Setaria parviflora (Poir.) Kerguélen (U,D)
Setaria pumila (Poir.) Roemer & J.A. Schultes (U,D[I])
Sorghastrum nutans (L.) Nash (C,P[I K])
**Sorghum halepense* (L.) Pers. (U,D)
Spartina spartinae (Trin.) Merr. ex A.S. Hitchc. (U,P)
Sphenopholis obtusata (Michx.) Scribn. (C,P[I K])
Sporobolus compositus (Poir.) Merr. (U,P[K])
**Sporobolus indicus* (L.) R. Br. (U,D)
Sporobolus junceus (Beauv.) Kunth (U,P)
Sporobolus silveanus Swallen (R,P)
Steinchisma hians (Ell.) Nash (C,D)
Tridens ambiguus (Ell.) J.A. Schultes (U,P)
Tridnes strictus (Nutt.) Nash (C,P)
Tripsacum dactyloides (L.) L. (U,P[K])
Urochloa platyphylla (Munro ex Wright) R. Webster (U,D)
Vulpia octoflora (Walt.) Rydb. (U,D)
PONTEDERIACEAE
Pontederia cordata L. (U,P[K])
SMILACACEAE
Smilax rotundifolia L. (U,D)
TYPHACEAE
Typha latifolia L. (U,D[I])
XYRIDACEAE
Xyris difformis Chapman var. diformis (U,S)
Xyris laxifolia Mart. (U,S)
Xyris torta Sm. (U,S)

DICOTYLEDONS

ACANTHACEAE
Hygrophila lacustris (Schlecht. & Cham.) Nees (U,P)
Justicia ovata (Walt.) Lindau (U,P)
Ruellia humilis Nutt. (C,P[I K])
AMARANTHACEAE
**Alternanthera philoxeroides* (Mart.) Griseb. (U,D)
ANACARDIACEAE
Rhus copallinum L. (U,D)
Toxicodendron radicans (L.) Kuntze (U,D[I])
APIACEAE
Centella erecta (L. f.) Fern. (U,P)
Chaerophyllum tainturieri Hook. (U,D)
Cicuta maculata L (U,P[I])
Cynosciadium digitatum DC. (U,P)
Eryngium integrifolium Walt. (U,S)
Eryngium yuccifolium Walt. (U,S)
Polytaenia nuttallii DC. (U,P)
Ptilimnium capillaceum (Michx.) Raf. (C,D)
Ptilimnium costatum (Ell.) Raf. (U,S)

Spermolepis echinata (Nutt. ex DC.) Heller (U,D)
APOCYNACEAE
Amsonia tabernaemontana Walt. (U,P[K])
AQUIFOLIACEAE
Ilex decidua Walt. (U,D)
Ilex vomitoria Ait. (U,D)
ASCLEPIADACEAE
Asclepias lanceolata Walt. (U,P)
Asclepias longifolia3 Michx. (U,P)
Asclepias obovata Ell. (C,P)
Asclepias tuberosa L. (U,P[I K])
Asclepias verticillata L. (U,P[I K])
Asclepias viridiflora Raf. (U,P[I K])
Asclepias viridis Walt. (C,P[K])
Cynanchum laeve (Michx.) Pers. (U,D)
Matelea gonocarpos (Walt.) Shinners (U,D)
ASTERACEAE
Ambrosia artemisiifolia L. (U,D[I])
Ambrosia bidentata Michx. (U,D)
Ambrosia psilostachya DC. (U,D[I])
Ambrosia trifida L. (U,D[I])
Arnoglossum plantagineum Raf. (U,P[I K])
Baccharis halimifolia L. (U,D)
Bidens aristosa (Michx.) Britt. (U,P[K])
Bigelowia virgata (Michx.) DC. (R,P)
Boltonia asteroides (L.) L'Hér. (C,P[K])
Boltonia diffusa Ell. (C,P)
Chromolaena ivifolia (L.) King. & H.E. Robins. (U,P)
Chryopsis mariana (L.) Ell. (U,P)
Cirsium horridulum Michx. (U,D)
Conyza canadensis (L.) Cronq. (U,D)
Coreopsis gladiata Walt. (R,S)
Coreopsis lanceolata L. (C,P[K])
Coreopsis pubescens Ell. (C,P)
Coreopsis tinctoria Nutt. (C,D)
Coreopsis tripteris L. (U,P[K])
Echinacea pallida (Nutt.) Nutt. (U,P[I])
Erechtites hieraciifolia (L.) Raf. ex DC. (U,D[I])
Erigeron annuus (L.) Pers. (C,P[I K])
Erigeron philadelphicus L. (U,D)
Erigeron strigosus Muhl. ex Willd. (C,P[I K])
Eupatorium capillifolium (Lam.) Small (U,D)
Eupatorium hyssopifolium L. (C,P[K])
Eupatorium leucolepis (DC.) Torr. & Gray (U,S)
Eupatorium perfoliatum L. (U,P[I K])
Eupatorium rotundifolium L. (C,P)
Eupatorium semiserratum DC. (U,P)
Eupatorium serotinum Michx. (U,D)
Eurybia hemispherica (Alexander) Nesom (U,P)
Euthamia leptocephala (Torr. & Gray) Greene (C,P)
Euthamia tenuifolia (Pursh) Nutt. (U,P)
Gaillardia aestivalis (Walt.) H. Rock (U,P)
Gamochaeta purpurea (L.) Cabrera (U,D)
**Helenium amarum* (Raf.) H. Rock (U,D)
Helenium drummondii H. Rock (R,P)
Helenium flexuosum Raf. (C,P[K])
Helianthus angustifolius L. (C,P)
Helianthus mollis Lam. (C,P[K])
Iva annua L. (U,D)
Krigia caespitosa (Raf.) Chambers (U,D)
Krigia dandelion (L.) Nutt. (U,P[K])
Krigia virginica (L.) Willd. (U,D[I])
Lactuca canadensis L. (U,D[I])
Lactuca floridana (L.) Gaertn. (U,D[I])
Liatris acidota Engelm. & Gray (C,P)
Liatris elegans (Walt.) Michx. (U,P)
Liatris pycnostachya Michx. (C,P[I K])
Liatris spicata (L.) Willd. (C,P)
Liatris squarrosa (L.) Michx. (U,P[K])
Mikania scandens (L.) Willd. (U,D)
Oligoneuron nitidum (Torr. & Gray) Small (C,P)
Packera glabella (Poir) C. Jeffrey (U,D)
Packera tomentosa (Michx.) C. Jeffery (R,S)
Pityopsis graminifolia (Michx.) Nutt. (C,P)
Pluchea camphorata (L.) DC. (U,D)
Pluchea foetida (L.) DC. (U,D)
Pluchea rosea Godfrey (U,D)
Pseudognaphalium obtusifolium (L.) Hilliard & Burtt (U,P[K])
Pterocaulon virgatum (L.) DC (R,P)
Pyrrhopappus carolinianus (Walt.) DC. (C,P[K])
Rudbeckia grandiflora (D. Don) J.F. Gmel. ex DC. (C,P)
Rudbeckia hirta L. (C,P[I K])
Rudbeckia texana (Perdue) P. Cox & Urbatsch (U,P)
Silphium gracile Gray (C,P)
Silphium laciniatum L. (U, P[I K])
Solidago canadensis L. (C,D[I K])
Solidago odora Ait. (C,P)
Solidago rugosa P. Mill. (U,P)
Solidago sempervirens L. var. *mexicana* (L.) Fern. (U,P)
Sonchus asper (L.) Hill (U,D)
Sonchus oleraceus L. (U,D)
Symphyotrichum dumosum (L.) Nesom (C,P[K])
Symphyotrichum lateriflorum (L.) A.& D. Löve (C,P[K])
Symphyotrichum oolentangiense (Riddell) Nesom (U,P[I K])
Symphyotrichum patens (Ait.) Nesom (C,P[K])
Symphyotrichum pratense (Raf.) Nesom (U,P)
Vernonia gigantea (Walt.) Trel. (U,P)
Vernonia texana (Gray) Small (U,P)
BIGNONIACEAE
Campsis radicans (L.) Seem. ex Bureau (U,D)
BORAGINACEAE
Myosotis verna Nutt. (U,D)
BRASSICACEAE
Cardamine hirsuta L. (U,D)
Cardamine parviflora L. var. *arenicola* (Britt.) O.E. Schulz (U,D)
Lepidium virginicum L. (U,D[I])
BUDDLEJACEAE
Polypremum procumbens L. (C,D)
CALLITRICHACEAE
Callitriche heterophylla Pursh (U,D)
CAMPANULACEAE
Lobelia appendiculata A. DC. (C,P)
Lobelia puberula Michx. (C,P)
Triodanis perfoliata (L.) Nieuwl. (U,D[I])
CAPRIFOLIACEAE
**Lonicera japonica* Thunb. (U,D)
Sambucus nigra L. ssp. *canadensis* (L.) R. Bolli (U,D[I])
CARYOPHYLLACEAE
Cerastium glomeratum Thuill. (U,D)
Silene antirrhina L. (U,D)
CISTACEAE
Lechea mucronata Raf. (U,P[K])
Lechea tenuifolia Michx. (U,P[K])
CLUSIACEAE
Hypericum crux-andreae (L.) Crantz (U,P)
Hypericum drummondii (Grev. & Hook.) Torr. & Gray (U,D)
Hypericum gentianoides (L.) B.S.P. (U,D)
Hypericum gymnanthum Engelm. & Gray (U,D)
Hypericum hypericoides (L.) Crantz ssp. *hypericoides* (U,P)
Hypericum nudiflorum Michx. ex Willd. (U,P)
CONVOLVULACEAE
Dichondra carolinensis Michx. (U,D)
Ipomoea lacunosa L. (U,D)
Ipomoea sagittata Poir. (U,P)
Stylisma aquatica (Walt.) Raf. (R,P)
CORNACEAE
Cornus drummondii C.A. Mey. (U,D[I])
CUCURBITACEAE
**Cucumis melo* L. (U,D)
Melothria pendula L. (U,D)
CUSCUTACEAE
Cuscuta indecora Choisy (U,P)

DROSERACEAE
Drosera brevifolia Pursh (U,S)
EBENACEAE
Diospyros virginiana L. (U,D)
ERICACEAE
Vaccinium arboreum Marsh. (U,D)
EUPHORBIACEAE
Acalypha gracilens Gray (C,P[K])
Caperonia palustris (L.) St.-Hil. (U,D)
Chamaesyce humistrata (Engelm.) Small (U,D)
Chamaesyce maculata (L.) Small (U,D[I])
**Chamaesyce nutans* (Lag.) Small (U,D[I])
Croton capitatus Michx. (C,D)
Croton glandulosus L. (U,D)
Croton willdenowii G.L. Webster (U,P[K])
Euphorbia corollata L. (C,P[I K])
Euphorbia spathulata Lam. (U,D)
Tragia betonicifolia Nutt. (U,P)
**Triadica sebifera* (L.) Small (U,D)
FABACEAE
**Aeschynomene indica* L. (U,D)
Baptisia alba (L.) Vent. (U,P[I K])
Baptisia bracteata Muhl. ex Ell. var. *laevicaulis* (Gray ex Canby) Isely (U,P)
Baptisia bracteata Muhl. ex Ell. var. *leucophaea* (Nutt.) Kartesz & Gandhi (U,P[I K])
Baptisia nuttalliana Small (R,S)
Baptisia sphaerocarpa Nutt. (U,P)
Centrosema virginianum (L.) Benth. (U,P)
Chamaecrista fasciculata (Michx.) Greene (C,P[I K])
Crotalaria sagittalis L. (U,P[K])
Dalea candida Michx. ex Willd. (U,P[I K])
Desmodium ciliare (Muhl. ex Willd.) DC. (U,P)
Desmodium paniculatum (L.) DC. (U,P[K])
Desmodium sessilifolium (Torr.) Torr. & Gray (U,P[K])
Galactia volubilis (L.) Britt. (U,P)
**Glottidium vesicarium* (Jacq.) Harper (U,D)
**Kummerowia striata* (Thunb.) Schindl. (U,D)
Lespedeza capitata (Michx. (U,P[I K])
Lepsedeza repens (L.) W. Bart. (U,P[K])
Lespedeza virginica (L.) Britt. (U,P[K])
**Medicago lupulina* L. (U,D[I])
**Medicago polymorpha* L. (U,D)
**Melilotus indicus* (L.) All. (U,D)
Mimosa microphylla Dry. (C,P)
Neptunia lutea (Leavenworth) Benth. (U,P)
Neptunia pubescens Benth. (U,P)
Orbexilum pedunculatum (P. Mill.) Rydb. var *psoralioides* (Walt.) Isley (U,P)
Orbexilum simplex (Nutt. ex Torr. & Gray) Rydb. (U,P)
Rhynchosia minima (L.) DC. (R,D)
Strophostyles umbellata (Muhl. ex Willd.) Britt. (C,P)
Stylosanthes biflora (L.) B.S.P. (C,P)
Tephrosia onobrychoides Nutt. (C,P)
Trifolium bejariense Moric. (U,D)
**Trifolium dubium* Sibthorp (U,D)
**Trifolium resupinatum* L. (U,D)
Vicia ludoviciana Nutt. (U,D)
FAGACEAE
Castanea pumila (L.) P. Mill. var. *pumila* (U,P)
Quercus falcata Michx. (U,D)
Quercus incana Bartr. (U,D)
Quercus marilandica Muenchh. (U,D)
Quercus nigra L. (U,D)
Quercus stellata Wangenh. (U,D)
Quercus virginiana P. Mill. (U,D)
GENTIANACEAE
**Centaurium pulchellum* (Sw.) Druce (U,D)
Sabatia brachiata Ell. (U,S)
Sabatia campestris Nutt. (U,P[K])
Sabatia gentianoides Ell. (U,S)
Sabatia stellaris Pursh (U,P)
GERANIACEAE
Geranium carolinianum L. (U,D[I])
HALORAGACEAE
Proserpinaca palustris L. (U,P[K])
HAMAMELIDACEAE
Liquidambar styraciflua L. (U,D)
HYDROPHYLLACEAE
Hydrolea ovata Nutt. ex Choisy (C,P)
JUGLANDACEAE
Carya illinoinensis (Wangenh.) K. Koch (U,D)
LAMIACEAE
Hyptis alata (Raf.) Shinners (U,P)
Lamium amplexicaule L. (U,D)
Lycopus americanus Muhl. ex W. Bart. (R,P[I K])
Monarda fistulosa L. (C,P[I K])
Monarda lindheimeri Engelm. & Gray ex Gray (U,P)
Monarda punctata L. (U,P[K])
Physostegia intermedia (Nutt.) Engelm. & Gray (U,P)
Physostegia virginiana (L.) Benth. ssp. *praemorsa* (Shinners) Cantino (U,P[K])
**Prunella vulgaris* L. (C,D)
Pycnanthemum albescens Torr. & Gray (U,P)
Pycnanthemum muticum (Michx.) Pers. (U,P)
Pycnanthemum tenuifolium Schrad. (C,P[K])
Salvia azurea Michx. ex Lam. (C,P[K])
Salvia lyrata L. (C,D)
Scutellaria integrifolia L. (C,P)
Scutellaria parvula Michx. (U,P[K])
Stachys crenata Raf. (U,D)
**Stachys floridana* Shuttlw. ex Benth (R,D).
Teucrium canadense L. (C,P)
LAURACEAE
Sassafras albidum (Nutt.) Nees (U,D)
LENTIBULARIACEAE
Pinguicula pumila Michx. (R,S)
Utricularia subulata L. (R,S)
LINACEAE
Linum medium (Planch.) Britt. var. *texanum* (Planch.) Fern. (C,P[K])
Linum sulcatum Riddell (R,P[K])
LOGANIACEAE
Mitreola petiolata (J.F. Gmel.) Torr. & Gray (U,P)
Mitreola sessilifolia (J.F. Gmel.) G. Don (U,P)
LYTHRACEAE
Cuphea glutinosa Cham. & Schlecht. (R,P)
Lythrum alatum Pursh var. *lanceolatum* (Ell.) Torr & Gray ex Rothrock (C,P)
MALVACEAE
Callirhoe papaver (Cav.) Gray (U,P)
Hibiscus moscheutos L. ssp. *lasiocarpos* (Cav.) O.J. Blanchard (U,P)
Modiola caroliniana (L.) G. Don (U,D)
Sida rhombifolia L. (U,D)
MELASTOMATACEAE
Rhexia mariana L. (C,P)
MELIACEAE
**Melia azedarach* L. (U,D)
MOLLUGINACEAE
**Mollugo verticillata* L. (U,D)
MYRICACEAE
**Morella cerifera* (L.) Small (U,P)
NYSSACEAE
Nyssa sylvatica Marsh (U,D)
OLEACEAE
**Ligustrum sinense* Lour. (U,D)
ONAGRACEAE
Gaura lindheimeri Engelm. & Gray (C,P)
Gaura longiflora Spach (C,P[K])
Ludwigia decurrens Walt. (U,D)
Ludwigia glandulosa Walt. (U,D)
Ludwigia hirtella Raf. (U,P)
Ludwigia leptocarpa (Nutt.) Hara (U,D)
Ludwigia linearis Walt. (C,P)
Ludwigia palustris (L.) Ell. (U,D)
Oenothera biennis L. (U,P[K])
Oenothera laciniata Hill (U,D)

Oenothera linifolia Nutt. (U,D)
Oenothera pilosella Raf. ssp. *sessilis* (Pennell) Straley (R,P)
Oenothera spachiana Torr. & Gray (R,P)
Oenothera speciosa Nutt (U,D)

OXALIDACEAE
Oxalis stricta L. (U,D)
Oxalis violacea L. (U,P^K)

PASSIFLORACEAE
Passiflora incarnata L. (C,P)

PHYTOLACCACEAE
Phytolacca americana L. (U,D)

PLANTAGINACEAE
Plantago aristata Michx. (U,D)
Plantago heterophylla Nutt. (U,D)
Plantago virginica L. (C,D)

POLEMONIACEAE
Phlox pilosa L. (C,P^K)

POLYGALACEAE
Polygala cruciata L. (R,S)
Polygala incarnata L. (U,P^K)
Polygala leptocaulis Torr. & Gray (U,P)
Polygala mariana P. Mill. (C,P)
Polygala nana (Michx.) DC. (R,S)
Polygala ramosa Ell. (R,S)
Polygala sanguinea L. (U,P^K)
Polygala verticillata L. (U,P^K)

POLYGONACEAE
Polygonum hydropiperoides Michx. (C,D)
Rumex verticillatus L. (U,D)

PORTULACACEAE
Claytonia virginica L. (R,P^K)

PRIMULACEAE
Anagallis arvensis L. (U,D)
Anagallis minima (L.) Krause (U,D)

RANUNCULACEAE
Anemone caroliniana Walt. (R,P^K)
Ranunculus fascicularis Muhl. ex Bigelow (U,P^K)
Ranunculus laxicaulis (Torr. & Gray) Darby (U,D)
Rananculus muricatus L. (U,D)
Ranunculus pusillus Poir. (U,D)

RHAMNACEAE
Berchemia scandens (U,D)
Ceanothus americanus L. (U,P^K)

ROSACEAE
Crataegus crus-galli L. (U,D)
Geum canadense Jacq. (U,D)
Prunus serotina Ehrh. (U,D)
Rubus argutus Link (U,P)
Rubus trivialis Michx. (U,P)

RUBIACEAE
Cephalanthus occidentalis L. (U,D)
Diodia teres Walt. (U,D)
Diodia virginiana L. (U,D)
Galium aparine L. (U,D)
Galium tinctorium L. (U,D)
Galium virgatum Nutt. (R,P)
Hedyotis nigricans (Lam.) Fosberg (C,P^K)
Houstonia micrantha (Shinners) Terrell (U,D)
Oldenlandia boscii (DC.) Chapman (U,D)

RUTACEAE
Zanthoxylum clava-herculis L. (U,D)

SALICACEAE
Salix nigra Marsh. (U,D)

SAPINDACEAE
Cardiospermum halicacabum L. (U,D)

SAXIFRAGACEAE
Lepuropetalon spathulatum Ell. (U,D)

SCROPHULARIACEAE
Agalinis fasciculata (Ell.) Raf. (C,D)
Agalinis heterophylla (Nutt.) Small ex Britt. (U,D)
Agalinis oligophylla Pennell (U,P)
Agalinis skinneriana (Wood) Britt. (U,P^K)
Agalinis viridis (Small) Pennell (U,P)
Bacopa rotundifolia (Michx.) Wettst. (U,D)
Buchnera americana L. (C,P)
Gratiola neglecta Torr. (U,P^K)
Gratiola virginiana L. (U,D)
Lindernia dubia (L.) Pennell var. dubia (U,D)
Mecardonia acuminata (Walt.) Small (C,P)
Nuttallanthus canadensis (L.) D.A. Sutton (U,D)
Nuttallanthus texanus (Scheele) D.A. Sutton (U,D)
Pedicularis canadensis L (R,P^K)
Penstemon digitalis Nutt. ex Sims (U,P^K)
Penstemon laxiflorus Pennell (U,P)
Veronica arvensis L. (U,D)
Veronica peregrina L. (U,D)

SOLANACEAE
Physalis angulata L. (U,D)
Physalis heterophylla Nees (U,P^K)
Solanum americanum P. Mill. (U,D)
Solanum carolinense L. (U,D)
Solanum dimidiatum Raf. (R,D)
Solanum elaeagnifolium Cav. (U,D)

STERCULIACEAE
**Melochia corchorifolia* L. (U,D)

STYRACACEAE
Styrax americanus Lam. (U,P)

ULMACEAE
Celtis laevigata Willd. (U,D)
Ulmus americana L. (U,D)

URTICACEAE
Boehmeria cylindrica (L.) Sw. (U,S)

VALERIANACEAE
Valerianella radiata (L.) Dufr. (C,D)

VERBENACEAE
Glandularia pulchella (Sweet) Troncoso (U,D)
Phyla nodiflora (L.) Greene (U,D)
Verbena bonariensis L. (R,D)
Verbena brasiliensis Vell. (C,D)
Verbena halei Small (C,D)
Verbena litoralis Kunth (U,D)

VIOLACEAE
Viola lanceolata L. (R,P^K)
Viola sagittata Ait (R,P^K)

VITACEAE
Ampelopsis arborea (L.) Koehne (U,D)
Parthenocissus quinquefolia (L.) Planch. (U,D)
Vitis cinerea (Engelm.) Millard (U,D)