VASCULAR PLANT SPECIES NATIVE TO NORTHERN MISSISSIPPI FOR USE IN CONSTRUCTED WETLANDS FOR WASTEWATER TREATMENT

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INTRODUCTION

In the early 1990s, The Ecological Society of America proposed The Sustainable Biosphere Initiative (SBI) in response to calls from the scientific community and policy makers to set overarching priorities for ecological research. The response resulted in development of a framework for the acquisition, dissemination, and utilization of ecological knowledge (Lubchenco et al. 1991). The SBI focuses on the necessary role of ecological science in the wise management of resources for the maintenance of life support systems (Lubchenco et al. 1991). The SBI proposed three research priorities: global change, biological diversity, and sustainable ecological systems. After the successful launching of the broad SBI, the Freshwater Imperative (FWI) Research Agenda (Naiman et al. 1995) was envisioned as a more focused initiative concentrating on freshwater issues. The FWI agenda proposes establishment of long-term programs for freshwater research relating directly to improved watershed management and human sustainability.

BACKGROUND

Sustainability

Sustainable ecological systems are those systems that exist in a state of dynamic equilibrium. Maintenance of biodiversity and ecological integrity are two components of sustainability. Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland 1987). Focus on native plants implies that they are different from non-native ones, perhaps even superior to them. This many seem like an empty assumption, but some objectivity can be brought to the issue by an experiment that has been documented recently. In the late summer of 1997, the southeastern United States experienced a late summer drought, the second driest August in North Carolina since weather records have been kept, which separated the native species from many of the aliens (Duke Botanical Garden 1997). Flowering dogwood and red maple showed symptoms of water stress during the drought period, but they survived. On the other hand, many garden camellias and azaleas, both Asian in origin, died unless artificially watered. At least during human recorded history, native species experienced severe late summer drought and retained the genetic capability to survive drought and transmit that adaptation to their progeny. When assigned with the task of recommending plants for constructed wetlands, many scientists and engineers are still searching for one single plant that can out-perform all other species without considering that single species within the context of the landscape of which it is a part (Tilman and Pacala 1993). We suggest that native flora will supply the desired functions, perform well with minimum maintenance, and minimize the risk of introducing species with the potential to invade the lower watershed.

The diversity of wetland plant adaptations provides the wetland treatment system designer with numerous options. Some plant species produce large amounts of carbon that are able to support heterotrophic microbes important in nutrient transformations. Other plant species provide shading of the water surface, in turn, controlling algal growth and suspended solid levels in the discharge from the wetland treatment system. Many wetland species cannot withstand continuous inundation, preventing the use of certain wetland species for water quality treatment. Three issues are cited as being the reasons for vegetation failure in wastewater wetlands: loss of monoculture species due to unexpected contamination, insect or vertebrate infestation, and dramatic change in hydrology (Kadlec and Knight 1996). An understanding of the ecological properties of these wetland species is essential for successful wetland wastewater treatment system design (Kadlec and Knight 1996).

Wetlands

Wetlands are unique ecosystems for planned management designs because wetlands have multiple ecological functions. These functions include: serving as ecotones between aquatic and terrestrial systems, harboring biogeochemical agents, and acting as biological reservoirs (Mitsch 1996). As biological reservoirs, wetland environments lead to a wide diversity of plants, animals, and microbes. Because of the inherent biodiversity associated with wetlands, when disturbance occurs, biodiversity is often lost. Although there are many theories about alien plants, there is evidence to support the concept that disturbed ecosystems are most susceptible to biological invasions (Mitsch 1996). It is essential to investigate biological invasion by alien species, as well as to analyze the relationships between productivity and species richness as they may alter ecosystem properties

(De'Camps 1996). Wetland-based wastewater treatment systems can offer an effective means of integrating wastewater treatment and resource management at a cost below conventional wastewater treatment alternatives. Early ecosystem-level studies which addressed the ability of wetlands to enhance the water quality of domestic wastewater were conducted with cypress swamps in Florida (Boyt et al. 1977; Ewel and Odum 1984; Odum et al. 1977). Most activity involving the use of wetlands for wastewater treatment now centers on constructing new wetlands (Hammer 1989; Knight 1990) rather than using natural systems. Mitsch (1996) notes that because wetlands are among the most biologically active ecosystems on earth, we must continually compare constructed wetlands to natural ones to ensure ecological success. Most of the available data relate to nutrient uptake and to production and assimilation by specific plant species (Forseth 1997). Little is reported in the literature about the effectiveness of various components and long term plant productivity in constructed wetlands. The release of human waste creates a niche in which few plant species are adapted to survive.

The most obvious changes can be expected in the plant community. In previous studies, evidence has shown a resulting change in wetland plant community composition and a shift to more opportunistic species after the introduction of wastewater (USEPA 1993). While wetland plants are adapted to wide ranges in water levels and nutrients (Mitsch and Gosselink 1993), it is expected that some species will be less tolerant of wastewater than others. Whigham and Simpson (1977) found that after one growing season of wastewater application to a tidal marsh, *Impatiens capensis* was eliminated completely, while *Zizania aquatica* and *Acnida cannabina* were not affected. Ewel (1976) found an increase in small floating plants such as *Spirodela oligorhiza, Azolla caroliniana,* and *Lemna perpusilla* in cypress swamps receiving wastewater. In the same study, there was a decrease in diversity of *Erechtites hieracifolia, Lyonia lucida, Nymphaea odorata,* and *Utricularia* species. The microbial and plant species are typically the dominant structural and functional components in treatment wetlands. Macrophytic plants are essential in wetland treatment systems because they provide structure for the microbes that mediate most of the pollutant transformations that occur in wetlands (Kadlec and Knight 1996).

Reference Wetlands

Reference sites represent a standardized guideline for assessing the biotic community of wetlands (Brooks and Hughes 1988). Reference wetlands should be central to the development of standards against which impacts are evaluated. Attempts to generalize and predict the ecological consequences of present management activities are greatly aided by comparisons with undisturbed areas (Stone et al. 1978). To establish reference standards, conditions inherent to highly functioning sites must be identified for classes of wetlands that share similar geomorphic settings (Brinson and Rheinhardt 1996). The goal of incorporating reference sites in this project is to provide a means to compare impacted wetlands with relatively undisturbed, reference wetlands. For this study, hydrological (similar water levels as those expected in the wastewater wetlands), climatological (same temperature and rainfall), geological (same soil types), and the biological parameter (frost tolerance) were considered for the selection of the reference sites which serve to identify native herbaceous vegetation feasible for transplant into the wastewater wetlands, that were also aesthetically pleasing.

PROJECT OBJECTIVE

The University of Mississippi (Figure 1) has established The Center for Water and Wetland Resources (CWWR) to be located at The University of Mississippi Field Station (UMFS). Due to the hydrology and geology of the area, traditional wastewater treatment is not feasible to service CWWR. As a result, a constructed wetland system has been proposed for the wastewater treatment. The design of the six wetland cells is flexible in that the engineers are challenging researchers to suggest manipulations of the vegetation component. Dr. Bill Wolverton, the engineer designing the system, has traditionally worked on systems along the coast and uses tropical broad-leaf vegetation. When the immediately CWWR plans were first proposed, interest was directed towards trying native vegetation in this system. The use of native species supports the UMFS goal of maintaining biodiversity and the UMFS User Committee's desire not to encourage introducing exotic species which may become invasive. UMFS is at the headwaters of the Bay Springs Creek which flows into the Little Tallahatchie River. This project does not focus on the design issues of this system, but rather focuses on the vegetation composition. Current research agendas such as SBI (Lubchenco et al. 1991), FWI (Naiman et al. 1995), and the agenda set by the Organization of Biological Field Stations (Lohr et.al. 1995) have set priorities establishing long-term programs for freshwater research relating directly to improving watershed management and human sustainability. With the widespread misuse and alteration of watershed dynamics, watershed data acquisition is essential. This research project is connected to these agendas in that it examines the biodiversity of native vascular plant communities in northern Mississippi and reviews literature on the resilience of individuals to anthropogenic stress within constructed wetlands for wastewater treatment.

Hypothesis

This paper will examine one vegetation hypothesis: native herbaceous perennial vascular plants will comprise the greatest portion of the vascular plants found in wetland communities at UMFS. The hypothesis was developed to help provide a recommendation list of plants to be transplanted into the CWWR wastewater wetlands. The criteria established for the plants to be used in the wastewater wetlands include: native herbaceous perennial vegetation located at UMFS with the ability to retain nutrients in wastewater that are also aesthetically pleasing. These data from this hypothesis were used to make recommendations for vascular plant species to be transplanted into the CWWR wastewater wetlands. The planting scheme recommended meets the established criteria for this wastewater system and provides the potential for a diverse plant community.

SITE DESCRIPTION

This research project is being conducted and is specifically located at The University of Mississippi Field Station (UMFS) in the wastewater treatment facility (Figure 1), as well as in four reference sites (Figure 2). For a number of years, UMFS has been the site for the study of toxicology and human impacts on aquatic ecosystems (Knight 1996). UMFS is located in northern Mississippi approximately 18 kilometers northeast of the Oxford campus at the headwaters of the Little Tallahatchie River watershed. Currently, UMFS covers 246 hectares with over 200 experimental ponds and mesocosms, most of which are fed from gravitational flow of the numerous springs and seeps located at UMFS. The University of Mississippi has established the Center for Water and Wetland Resources (CWWR) to be based at UMFS. The completion of the wastewater treatment facility is anticipated by August of 1998. The reference sites for this project are also located at UMFS (Figure 2). Four reference sites were selected to serve as comparison of current plant community structure to the wastewater raceways. All the reference sites have similar hydrology to the expected hydrology of the wastewater raceways, similar open vegetative canopy cover, and species composition characteristic of the UMFS geographic region (Hunneycutt 1996).

METHODS

A vegetation survey was undertaken to provide a recommendation list of plants to be transplanted into the wastewater wetlands. Initially, a floristic study of UMFS was conducted, collecting in all areas: uplands, forested, open fields, and wetlands. Then four wetland areas were selected for concentrated examination; these will be referred to as reference sites (Figure 2). For this paper, the two floristic collections will be referred to as the UMFS collection, meaning the entire UMFS, and the second collection will be referred to as the reference site collection, being a subset of the UMFS collection. Species composition, species richness, average percent cover, and frequency were measured monthly in the reference sites with replicated quarter meter square quadrats (Holland and Burk 1990). Quadrat size selection was taken into account so that quadrat size would be small enough in relation to vegetation complexity for the entire quadrat to be viewed without shifting of the eyes to determine species percent cover and frequency (Daubenmire 1968). Species composition was determined by identifying all species within each quadrat (Radford et al. 1968). Species richness was calculated as the total number of species present within each reference site (Barbour et al. 1987). Species frequency was determined by calculating the fraction of all quadrats containing a given species (Barbour et al. 1987). Species percent cover was determined by the visual estimate of the percentage of the quadrat that was occupied by a given species (Barbour et al. 1987). Standard collecting procedures were followed. Confirmation of unknown species was made by Drs. M. B. Hunneycutt, or L. McCook. The numbered specimens are filed by family name in preparation for mounting and herbarium storage in the Department of Biology, University of Mississippi.

RESULTS

Floristic Sampling

Comparisons have been completed for numbers of native versus introduced species, woody versus herbaceous species, and annuals versus biennial versus perennial species (Davis 1998) for the entire study collection. In the native vs. introduced comparison, eighty-nine native species and eleven introduced species were collected at UMFS. Twenty-four native species and three introduced species were collected within the reference sites. In the woody vs. herbaceous comparison, 17 woody species were collected at UMFS. Twenty-six herbaceous species and three woody species were collected in the reference sites. For the perennial vs. biennial vs. annual species comparison, 79 perennial species, two biennial species, and 19 annual species were collected at UMFS, of which, 18 perennial species, no biennials species, and 10 annuals were collected in the reference sites. These data show that for the UMFS and the reference site collections, most species sampled were native herbaceous perennials.

Ecological Sampling

Species richness data support the mean species per quadrat data (Table 1). Species richness was greatest during June and July in reference sites number 62 and 99, and greatest in reference sites number 1 and 2 during August-February. For this study, the highest species richness occurred in August with 22 different species encountered in the reference sites (Table 1). Table 1 was prepared for species percent cover and species frequency to characterize the plant communities within each reference site (Holland and Burk 1984). The month of June 1998 had a low percent cover.

DISCUSSION

The North American Wetland Treatment System Database consists of 176 wetland treatment sites representing 203 separate wetland wastewater treatment systems (Kadlec and Knight 1996). This database reveals that diversity within constructed wetlands has not been a priority to date. As a result of this study, we suggest that diversity of wetland plant species should be a top priority for wetland treatment system design for three reasons. The first reason is the protection of watershed vegetation, since invasion of introduced species can influence the watershed vegetation composition. The invasions and subsequent spread of non-native species have classically been considered both causes and effects of habitat destruction (Holland and Burk 1990). The location of the UMFS wastewater treatment system at the headwaters of its watershed has the potential to influence watershed vegetation composition if exotic species are introduced and become invasive. The second reason diverse plant communities should be considered is as a possible solution to the problem of loss of monoculture species due to contamination, insect or vertebrate infestation, or dramatic changes in hydrology. The above problems are the main reasons constructed wetland vegetation has failed in constructed wetlands historically (Kadlec and Knight 1996). Finally, a decrease in plant diversity decreases the overall productivity of the community, and ecosystem sustainability is decreased (Lubchenco et al. 1991).

Based on the floristic data collected in this study, a diverse community of emergent wetland species are available at UMFS for transplant into the constructed wetlands. Cover data are particularly useful because they allow comparisons of the amount of surface occupied by different life forms (Daubenmire 1968). The relative importance of cover in assessing changes in vegetation depends, to a large extent, on the life forms of the plants involved (Holland and Burk 1990). For example, *Typha* spp. may occur with low cover but high aboveground biomass in a reference site and could possibly be interpreted as dominant based solely on aboveground biomass data. In contrast, high cover of *Galium* spp. with low aboveground biomass might be interpreted by aboveground biomass data only as being insignificant (Table 1). The month of June 1998 had a low percent cover possibly due to the inundation from excessive rainfall (Table 1). The months of August, September, and October had the highest percent cover. The increase in percent cover for the month of February is because *Juncus effusus* was beginning to reestablish after the winter months.

To make recommendations for vascular plant transplants, the original criteria for this study must be examined: we are looking for native, herbaceous, perennials that are aesthetically pleasing. Based on these criteria, we recommend the vascular plants to be transplanted in the constructed wetlands for CWWR at UMFS be selected from the species recommendation lists (Table 2). We suggest the plants should be transplanted over two growing seasons to allow for maximum transplant success. All the species suggested are native, herbaceous, perennials. The literature indicates all of these species have the ability to retain wastewater nutrients. These species also have extensive rhizomes which will be used for the nutrient retention as well as holding the substrate in place. The measure of aesthetics we used was to insure that some species would be blooming throughout the growing season. The first growing season (Table 2) we suggest cattails, sedges, and rushes be transplanted because they can more readily withstand direct sunlight. Also these species will be blooming in late summer through fall. We suggest the second recommendation list (Table 2) should be transplanted during the second growing season because they will have shading from the first growing season transplants, since these species can not withstand as much direct sunlight. The ferns will be aesthetically pleasing in spring, yellow-eye grass in late spring through early summer, arrowhead in early summer, knotweed in early through mid-summer, and iris in mid-summer. Figure 3 was constructed to demonstrate the suggested planting scheme. Figure 3 represents one of the four sections formed by the weir divisions in each raceway. We recommend this planting scheme be repeated in each of the sections of the two lower pairs of raceways. Design repetition results in a diverse plant community with varying shading. Aesthetically, this design would offer some species in bloom throughout the growing season. For nutrient retention, all of these species would be successful. The recommended plants for the first growing season: cattails, sedges, and rushes are the most opportunistic species and may need to be controlled. For the above reason, they are planted in the deeper center of the raceways where they could be flooded, if they become too competitive. All of these species have been sampled living together within the reference sites. We believe this list provides the potential for a diverse plant community that can withstand contamination, insect or vertebrate invasion, and changes in hydrology that could be expected to be experienced in the CWWR wastewater treatment system.

CONCLUSIONS

Observations of vascular plant community composition and the overall vascular plant productivity, measured by sampling biomass over time, have provided data for a recommendation list of a diverse plant community using a two year planting scheme. Species recommendations consist of ferns, sedges, grasses, rushes, and forbes that can survive in a system with fluctuating effluent concentrations, insect or vertebrate invasion, and changes in hydrology that could be experienced in the UMFS wastewater treatment system.

Other recommendations for the continuation of this project could include exploring the response of the recommended species to wastewater stress, comparing these data to the species in the established reference sites, continuing to monitor recommended species tolerance to temperature and rainfall fluctuations, documenting the development of the microbial community composition, making comparisons of the UMFS system with other similar systems already in operation, developing a functional diversity index for constructed wastewater treatment systems, and analyzing the wetland plant community structure after establishment, from a landscape perspective, with each species group within the community being examined for patch dynamics.

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Table 1. Vascular plant species richness and percent cover in reference sites at UMFS (June 1997 - February 1998).

Month	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Reference Site #1	5	2	13	7	5	2	2	2	2
Reference Site #2	7	6	5	6	7	3	2	2	2
Reference Site #62	5	7	2	6	3	1	0	1	1
Reference Site #99	8	7	9	6	6	0	0	0	2
Mean Species/Month	6	6	7	6	5	2	1	1	2
Total Species Richness	15	16	22	16	12	3	2	2	2
Total Percent Cover	53	37	90	87	75	9	5	16	40

Table 2. Recommendation of a two year planting scheme of vascular plant species to be transplanted into the CWWR constructed wetlands for wastewater treatment at UMFS.

First Year Recommendations		Second Year Recommendations	
Genus/Species	Common Name	Genus/Species	Common Name
Dulichium arundinaceum (L.) Britt.	Three-way Sedge	*Athyrium aspleniodes* Michx.	Southern Ladies Fern
Juncus validus Cov.	Rush	*Onoclea sensibilis* L.	Sensitive Fern
Juncus effusus L.	Soft Rush	*Osmunda cinnamonea* L.	Cinnamon Fern
Juncus diffusissimus Buckley	Rush	*Polygonum hydropiperoides* Michx.	Knotweed
Scirpus cyperinus (L.) Kunth	Bulrush	*Polystichum acrostichoides* Michx.	Christmas Fern
Typha angustifolia L.	Cattail	*Sagittaria latifolia* Willd.	Arrowhead

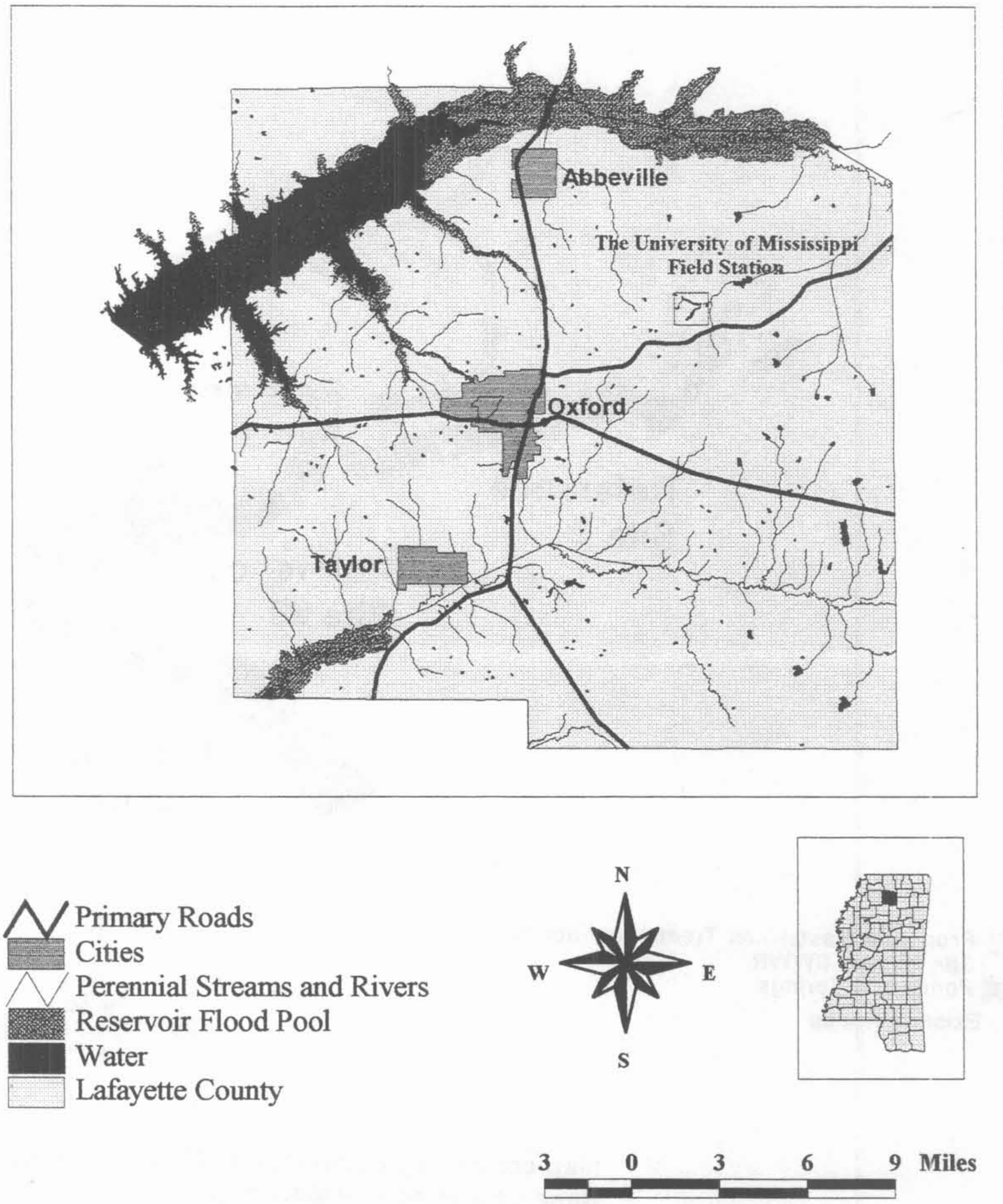

Figure 1. Location of The University of Mississippi Field Station, Center for Water and Wetland Resources Lafayette County, Mississippi.

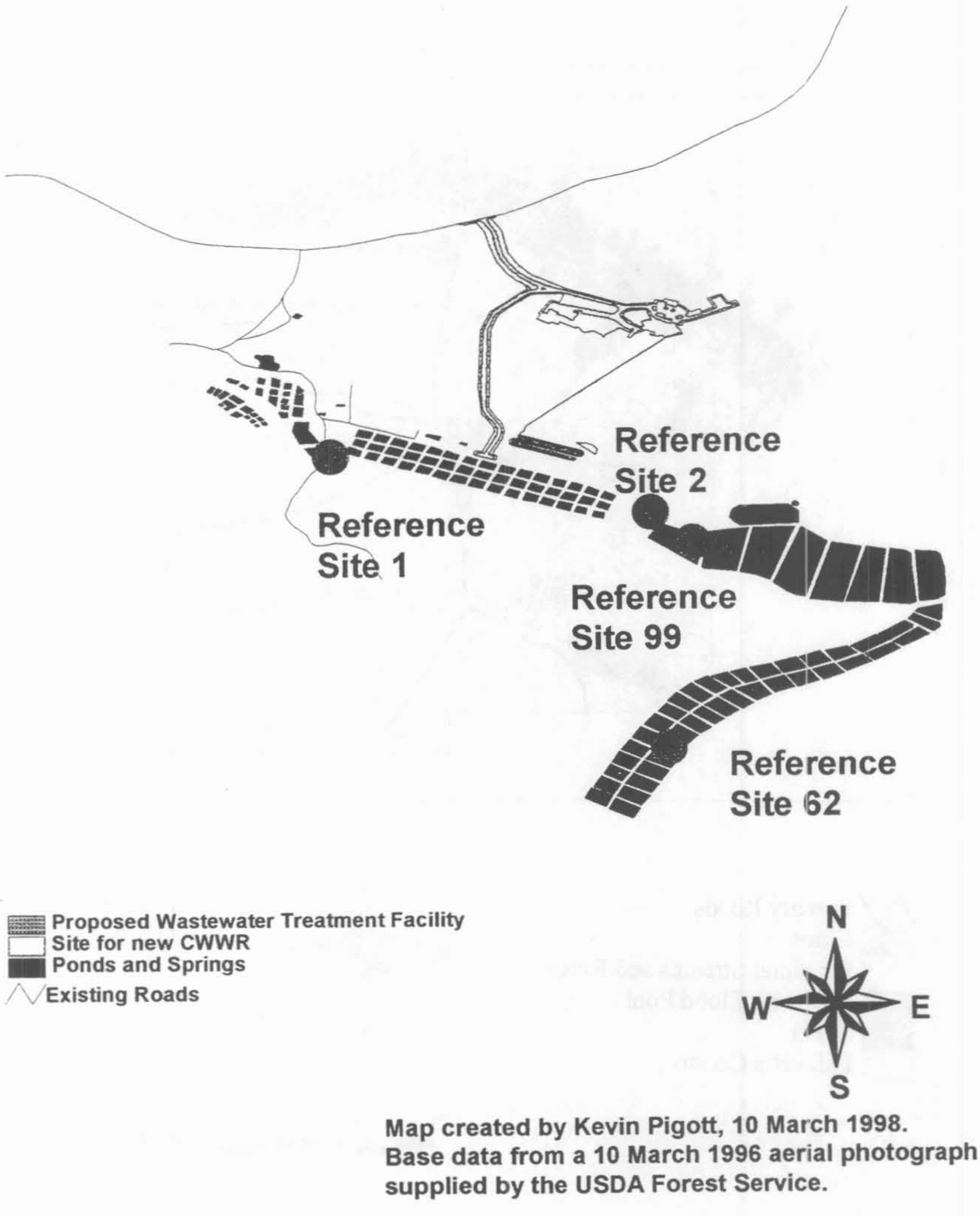

Figure 2. Location of reference sites at The University of Mississippi Field Station, 1996 - 1998.

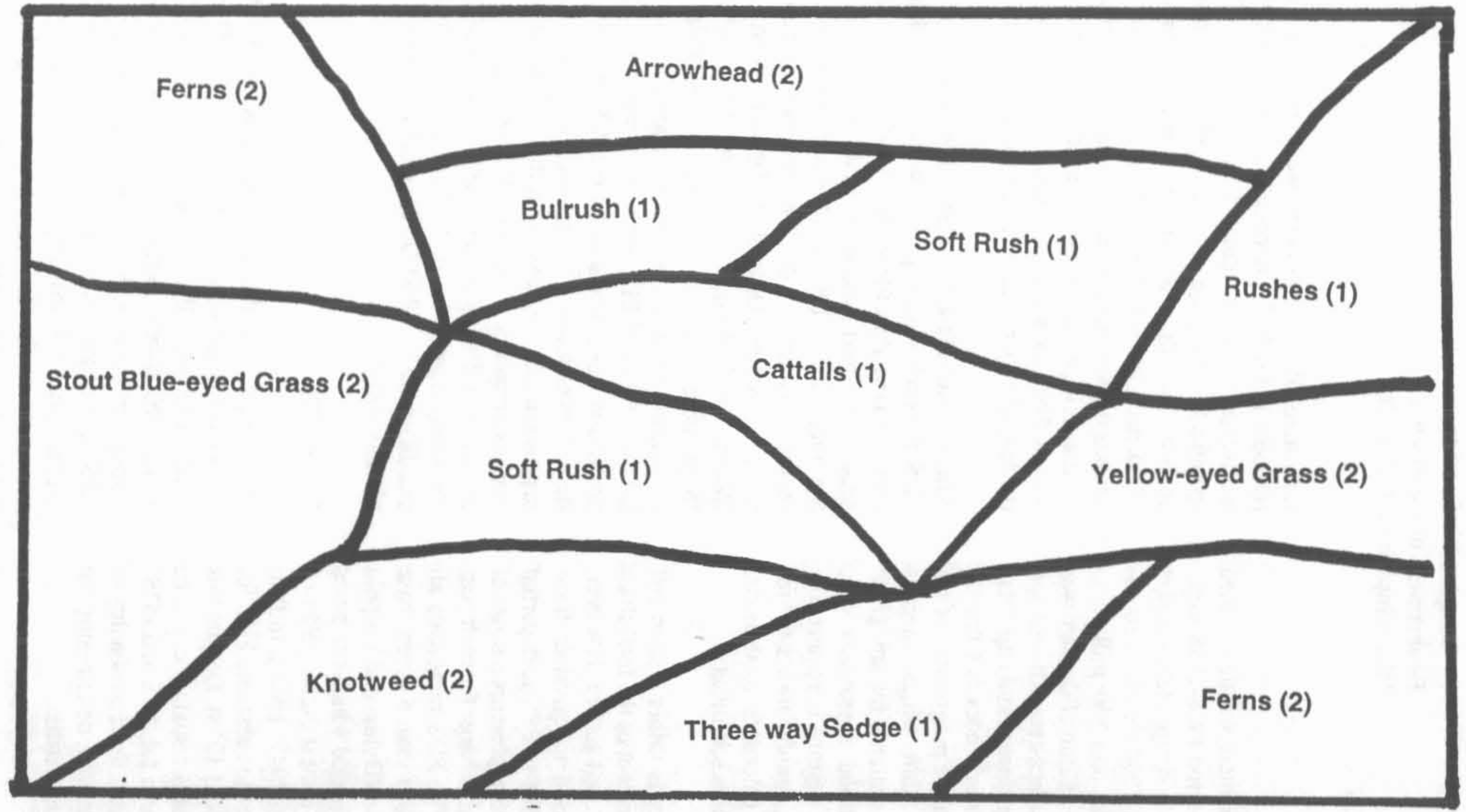

Figure 3. Two Year Planting Scheme for UMFS Wastewater Treatment Wetlands.
1=first year
2-second year