Functional Assessment of Three Wetlands Constructed by the West Virginia Division of Highways

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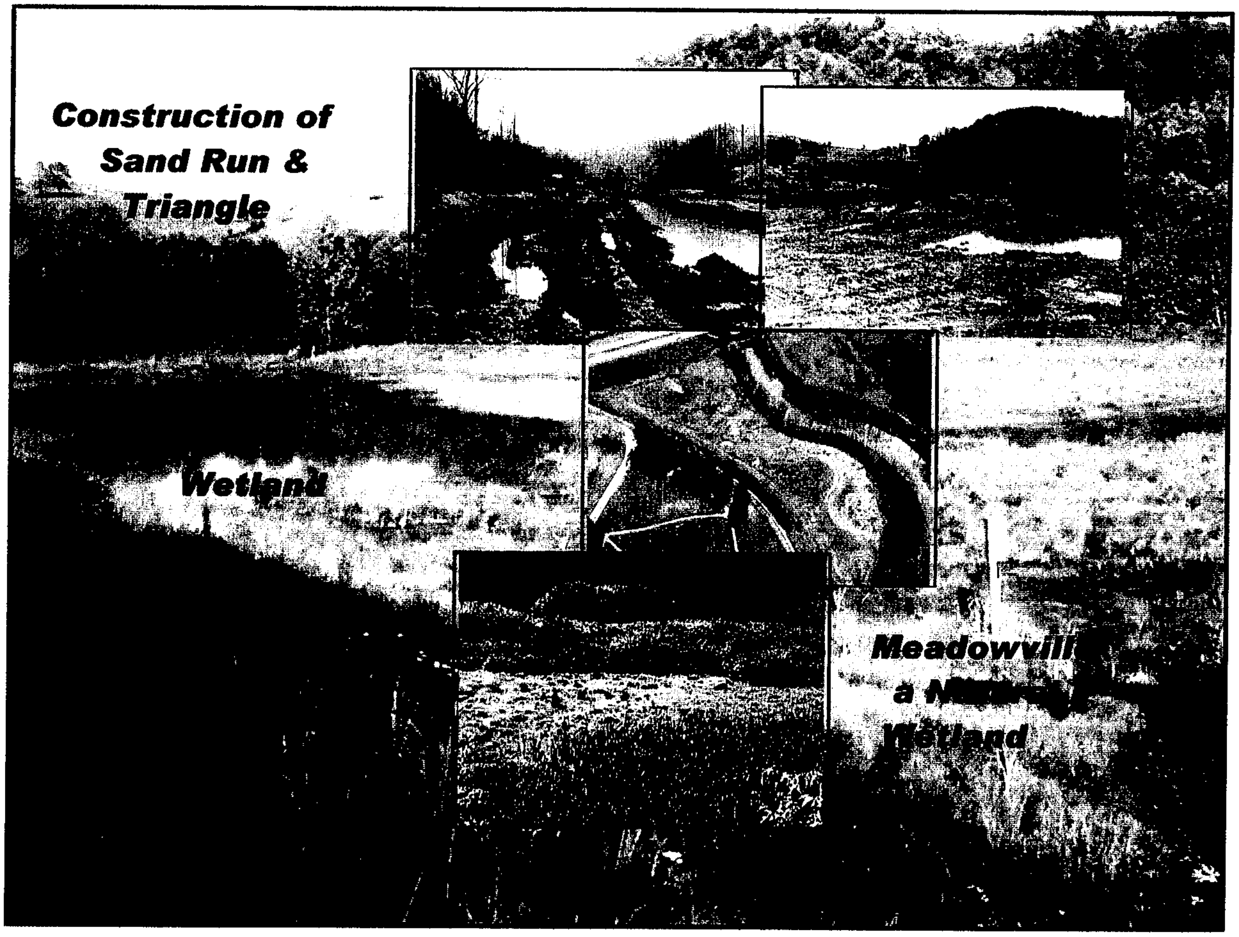

Triangle Wetland

Final Report

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EXECUTIVE SUMMARY

As a result of Section 404 of the Clean Water Act, there is not only a professional interest but a legal mandate to protect wetland resources in the United States. Jurisdictional wetlands can no longer be destroyed or degraded without review by a regulatory agency. The construction or restoration of wetlands as mitigation for unavoidable impacts to existing wetlands is a common agency action. In West Virginia, dozens of wetlands have been constructed. Some have been mitigated for extractive mineral operations and highway construction; others have been created as treatment facilities for land fill leachate and domestic sewage plant discharge. The use of constructed wetlands for mitigation is commonly associated with highway construction projects. The West Virginia Division of Highways (DOH) has constructed or restored more than 12 wetlands as mitigation for unavoidable environmental impacts.

Because wetland construction is a relatively new technology, few wetland designs have been thoroughly evaluated. In the central Appalachian Mountain region, there have been no published evaluations of the ecological functioning of constructed wetlands. In 1996, Fortney and Edinger completed a preliminary functional assessment of one DOH-constructed wetland. Following this work, the DOH authorized an additional functional assessment study that would include more wetlands areas and study parameters. This report includes the findings of the second study, which included three constructed wetlands (Triangle, Sand Run, and Sugar Creek) and three reference wetlands (Meadowville, Preston, and Seefus). All six wetlands were within the same watershed and ecoregion. At the time of the field investigations, the constructed wetlands ranged in age from one to four years old.

The purpose of this study was to evaluate the natural functions that have developed in the three DOH-constructed wetlands. Specifically, we carried out a multidisciplinary study to identify and evaluate factors that could be quantitatively measured as indicators of natural functions. Among the functions that could be studied are:

1) soil nutrient concentrations (including evidence of nutrient transformations and cycling)
2) wildlife usage (direct observation of functional level--breeding, feeding, resting, etc.)
3) storage of floodwater
4) relative diversity of certain groups of organisms (vascular plants and birds)
5) evidence of food chains (plant and animal diversities and presence of several feeding levels in animal groups)
6) productivity (evidence of biomass production).

In this study we focused on soil nutrients, wildlife usage, diversity of vascular plants and major wildlife groups, and productivity as indicators. To provide a comparison to baseline values for these parameters, we selected three natural wetlands to serve as reference areas. Each reference area had similar vegetation and hydrology. Before and after data were collected and analyzed, a literature search of works was conducted for studies on similar aspects of mitigation wetlands to allow comparison of our results with other published work.

Standard methods for field investigations were employed for each study discipline. Vascular plants were sampled in 20 m x 50 m quadrats. Analysis of quadrat data included species diversity, standing crop, plant indicators, and ordinations. The same quadrats were used for soil samples. During one growing season, soils were sampled at depths of 0-10 cm and 10-20 cm. Samples were analyzed for extractable bases, texture, pH, and color. Observations of hydroperiod conditions included subjective recordings of the water table relative to the ground surface and observation wells placed in two constructed and one reference wetland.

Amphibians and reptiles were surveyed by calls, captured with dip nets and funnel traps, and identified through visual sightings, including larval forms. Relative abundance of small mammals was determined by using snap traps and Sherman live traps. Transects were established through each wetland. The relative abundance of large mammals was determined by recording the numbers of direct sightings, tracks, and fecal droppings along two, 100-meter transects in each area. Sightings and vocalizations of birds were recorded along standard transects for each wetland. Birds encountered just upland of the wetland perimeter were recorded in field notes, but not included in the data set of birds within the wetland.

The species richness and diversity of vascular plants was surprising high for vascular plants, particularly for Triangle and Sugar Creek wetlands. Although both areas had a relatively high number of nonnative species, each supported a rich diversity of herbaceous species. This was unexpected for Sugar Creek since it was only one year old at the time of most of the data collection efforts. However, both it and Triangle were subject to overbank flooding by adjacent waterways, which probably resulted in transport and import of new plant propagules. Further, for each site, there were portions of pre-existing wetlands incorporated into the new construction area that could also have served as sources for propagules.

The natural wetlands had the highest standing crop and highest percentage of facultative and wetter plant species. Comparing the species composition of the constructed and reference wetlands, we determined that there was a trend toward more natural assemblies of plant species as the constructed wetlands developed through invasion by new wetland species and apparent succession. The presence of nonnative and invasive plants was highest in habitats where the water table dropped below the surface for most of the growing season. The high proportion of native hydrophytes occurred in the wettest habitats.

Wetland soils were found to be developing at all constructed sites. However, organic carbon was lower in constructed wetlands than reference wetlands. This may account for the poor reproduction and survivorship of woody species planted following construction. To improve woody plant success, we suggest that the organic carbon content of topsoil applications be at least 15% carbon by weight.

Amphibians, because of external fertilization, depend upon appropriate aquatic habitats during spawning, egg and larval stages, and therefore are one measure of wetland functioning as habitat. Standard sampling revealed general numbers of spring peepers, green frogs, and bullfrogs were similar in mitigation and reference wetlands. Mitigation wetlands had somewhat higher numbers of American toads and gray treefrogs, while reference wetlands had higher numbers of red-spotted newts. Wood frogs were present in one reference and two mitigation wetlands. For the remaining rarer species, no clear pattern of predominance in one type of wetland or another was apparent. Given that some amphibians "home" (return to breed in the same wetland where they emerged as young adults), the mitigated wetlands, in spite of their age of one to four years, are attracting a diverse amphibian population. The numbers of reptiles encountered, including aquatic snapping turtles, were insufficient to make a comparison between the two types of wetlands.

Based on wildlife trapping and sign data, constructed wetlands did not differ appreciably from reference wetlands in the species of mammals present. However, a few short-tailed shrews were only found in reference wetlands, while a couple of meadow-jumping mice were found in mitigation sites. While small mammal population densities were generally similar between mitigation and reference wetlands, white-footed mice were 10 times more abundant in reference wetlands. This may reflect this species' preference for wooded or brushy habitat, which was more prevalent in reference woodlands.

Except for Triangle, mitigated and reference wetlands had similar year-long wetland bird species diversity. Triangle, a mitigation site built on the site of an old wetland, had 14 wetland bird species, exceeding the diversity of the next closest wetland by 40%. The average high densities of wetland birds breeding in mitigated and reference wetlands was similar, about 25 per 9.5 acres. The Preston wetland had the highest density of 38, while Triangle was second highest with 29. Higher populations of Canada geese and Yellow warblers explained this difference.

Data from the censuses indicates the different habitat characteristics of each of the six wetlands. A beaver pond reference wetland (Seefus) included many dead snags, which were important nesting sites for several primary and secondary cavity-nesting species, such as woodpeckers, swallows, and bluebirds. A habitat-diverse mitigation wetland (Triangle) was particularly well frequented by wetland birds during spring and fall migrations.

While the vertebrate census data summarized in this report indicate near parity between mitigation and reference wetlands, they do indicate some differences. Smaller numbers of red-spotted newts in mitigated wetlands may reflect less wooded habitat directly surrounding mitigation wetlands. A ten-fold lower number of white-footed mice in mitigation wetlands probably represents less coverage by wetland shrubs and trees. Smaller areas of seasonally exposed mudflat, found in some mitigation and reference wetlands, probably contributed to lower usage of these wetlands by migratory and breeding shorebirds.

These considerations can be addressed in plans for future mitigation wetlands. For example, wetlands can be constructed near forest edges. Mitigated wetlands sited near rivers and with channels connected to rivers could capitalize on the wetland plant seeds that would naturally stock the wetland. And, wetlands with a hydrologic plan similar to that of the Triangle site would create seasonal mudflats needed by certain wetland birds.

For planning purposes, we also suggest that most future mitigation sites should be located on bottomlands or floodplains. Occasional overbank flooding enhances species recruitment and soil nutrients. In fact, with onsite and nearby seed sources, it may be possible to limit the amount of special post construction planting to enhance species diversity. This should also increase the rate at which natural functions of constructed wetlands become more like natural wetlands. However, because of swift currents during flood conditions, dikes and dams that control the flow of surface water should be built to withstand high energy currents. This would help prevent structural failure and subsequent lowering of the water table.

Wetland mitigation plans should consider which type of reference wetland will be emulated: stream headwater beaverpond, floodplain marsh, floodplain swamp, etc. To increase the success of each constructed wetland, close study of the characteristics of reference wetlands in the region of proposed wetland construction should be performed to help direct the design of the mitigation site.

Finally, the results of this study indicate that DOH's efforts to construct mitigation wetlands appear to be successful. Although constructed sites do not totally emulate natural wetlands, they are developing functional levels (or evidence of functions) that show that with time they should develop into fully functional wetlands. This is indicated by the established wetland hydrological regimes, soil characteristics, wildlife usage, and composition of plant communities.

CHAPTER 1

INTRODUCTION

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CHAPTER 1

INTRODUCTION

1.1 Mitigation Wetland

In the United States (US), constructing new wetlands or restoring degraded wetlands has become acceptable means of compensating for unavoidable impacts to wetlands. These widely accepted methods are used by federal, state, and local regulatory and resource management agencies. Thousands of acres of wetlands have been constructed during the past two decades, mostly through activities associated with Section 404 of the federal Clean Water Act. Constructed wetlands are generally referred to as *mitigation wetlands* and are intended to replace the land function of the wetland lost through human activity (Mitsch and Gosselink 2000). Some wetland construction activities are restoration projects, i.e., the rehabilitation of wetlands that have been degraded in some manner. Others are creation projects in which wetlands are constructed where they did not previously exist. Many of these projects are connected with mitigation requirements associated with highway construction projects.

Wetland agreements to execute mitigation activities result in establishing a ratio of wetland area disturbed to wetland area to be restored or created. Agencies involved in the Section 404 permit process in West Virginia have agreed to guidelines for determining the amount of area involved in a mitigation effort. Ratios generally range from 1:1 for reestablishing a palustrine emergent type to 3:1 for mitigating a palustrine forested area. West Virginia mitigation guidelines presently used by the West Virginia Divisions of Environmental Protection (DEP) and Natural Resources (DNR) fall within these limits. The specific habitat types and replacement ratios required by DNR and DEP (Interagency guidelines 1994) are:

Palustrine Forested	3 to 1
Scrub-Shrub	3 to 1
Open Water	1 to 1
Emergent	1 to 1

These guidelines are modeled after those jointly adopted by the U. S. Fish and Wildlife Service and Environmental Protection Agency.

Efforts to monitor the success rate of constructed wetlands have been limited (Atkinson et al. 1993, Reinartz and Warne 1993, Wilson and Mitsch 1996), with minimal available documentation and corresponding quantitative descriptions. This is especially true for inland freshwater wetlands in the central Appalachian Mountain region, where there are few short-term and fewer still long-term studies. None are known for West Virginia prior to this study. Recently, however, Mitsch *et al.* 1998, reported on a whole-ecosystem level experiment in self-design of wetlands that was conducted in a structured research setting at the Ohio State University Olentangy River Wetland Research Park. This is an important effort in understanding the process of wetland development in a human-manipulated system, which will ostensibly have application in field settings. But there are still significant information gaps in our understanding of the success of real mitigation wetland creation projects. With tens of millions of dollars being spent annually in the mid-Appalachian region alone, it is important to assess the *mitigation wetland* in terms of the success in: (1) compensating for lost land values elsewhere and (2) applying various construction standards and methods . Such studies are especially germane for state highway agencies, since activities associated with highway construction commonly result in the construction of mitigation wetlands.

For the West Virginia Division of Highways (DOH), designing and building mitigation wetlands have become routine activities associated with highway construction. Recent projects include sites for Appalachian Corridors H and L. For Corridor H alone, five major wetland mitigation sites have been constructed (Fig. 1.1). They are the Triangle and Sand Run wetlands near Buckhannon, the first wetlands constructed by DOH. These were followed by Sugar Creek near Belington, Leading Creek near Elkins, and Walnut Bottom near Moorefield (Fig. 1.1). Other wetlands constructed or planned by DOH include Cheat Lake, Meadow River, Enoch Branch, and Tug Fork.

1.2 Wetland Values Versus Function

There is much discussion in the scientific literature about wetland values versus wetland functions and the difference between the two (Brinson 1993, Atkinson 1993, Lee et al. 1994, Murphy et al. 1994, Verhoeven *et al.* 1994, Young 1994). Evaluating the success of mitigation wetlands means developing a quantitative evaluation scheme that assesses either a wetland's values or the ecological functions and processes performed by wetlands in scientific terms. Value implies an anthropocentric importance. Specifically, the value society gives a natural resource is often the result of a subjective interpretation. A general consensus that seems to have developed among wetland scientists during the past 10 years (and expressed in the wetland literature) is assessing functions in scientific terms avoids the subjective interpretation of what is valuable in human terms (Lee *et al.* 1994, Mitsch and Gosselink 2000). However, wetland functions and processes are usually correlated with societal values.

Several natural wetland features or processes can be quantified and used to assess functional levels, or at least provide evidence of the relative level at which functions and processes are occurring. Among these are:

1) soil nutrient concentrations (evidence of nutrient transformations and cycling)

2) wildlife usage (direct observation of functional level--breeding, feeding, resting, etc.)
3) storage of floodwater
4) relative diversity of certain groups of organisms (vascular plants and insects)
5) evidence of food chains (plant and animal diversities and presence of several feeding levels in animal groups)
6) productivity (evidence of biomass productivity).

Some of these functions can be directly measured or calculated, e.g., species diversity of certain biotic groups (vascular plants and birds), productivity, and water storage capacity. For productivity, there have been several studies in natural wetlands that document productivity levels. A Minnesota study reported a sedge-dominated wetland was more productive than an old-field (Bernard 1974). The high productivity for this wetland was attributed to the influx of nutrients through run-off and silting from upland areas. A study of a Canadian wetland by Auclair *et al.* (1976), showed standing crop coincided positively and significantly with several environmental factors, such as soil organic matter, nitrogen, sodium, calcium, and magnesium. Another study on primary production processes stated that a true measure of productivity was dependent on hydrology, soil chemistry, community type, stand history, species life history, and extrinsic biological factors (de la Cruz 1978). Szumigalski and Bayley (1996) discovered that not all nutrient rich wetlands have high standing crops. Other studies on productivity analyzed hydrology (Gosselink and Turner 1978, Hultgren 1989, Whigham and Simpson 1992) and suggested more attention needs to be given to flooding frequency, duration, regularity, and depth of inundation in analyzing productivity.

It is not always possible or practical to directly measure other functional levels (Lee *et al.* 1994). Therefore, measuring the effects or evidence of some functions becomes the most employable option in assessing functions and processes of wetlands.

Construction projects that result in unavoidable loss of wetland area and/or loss of wetland function should offer compensatory mitigation in the form of wetland restoration, enhancement, or creation. Measurements of wetland functions are the biological basis for judging the quality of restoration efforts and for assessing their effectiveness in offsetting unavoidable impacts. Four general categories have been used for functional assessment of wetlands: (1) hydrological, (2) biogeochemical, (3) plant community maintenance, and (4) animal community maintenance (Brinson et al. 1994). Associated functions involve maintaining site water balance, facilitating energy flow, supporting nutrient cycling, and maintaining species diversity (Brinson and Rheinhardt 1996).

Biological diversity, specifically vascular plants and animal biodiversity, has been extensively used as an indicator for the degree of functioning in a mitigation wetland. Generally, the higher the biodiversity, if the diversity is contributed to by wetland adapted organisms, the greater the probability that the mitigation wetland is functioning similarly to a natural wetland. Since the early 1970's, more and more biologists have come to realize that a variety of wildlife species in an area can be an indicator of a healthy community (Anderson 1985), although, as we will discuss later, this is not always the case. Biodiversity typically refers to the diversity of life in all its forms, including, subspecies, species, populations, communities, and ecosystems. In its simplest form, biodiversity reflects the number of different species present in a community (such as a wetland). In a more complex concept, it reflects the number of species and the relative abundance of each species within the wetland under consideration.

Establishing high biodiversity levels is considered a basic goal of most wetland management efforts, whether done to provide a variety of plants and animals for the general public to observe or to obtain ecosystem stability. All life forms have some value, economic or ecological, realized or potential, and by managing for diversity we manage for all life forms (Hunter 1990). Though an exotic species in an ecosystem may add to diversity, it may also detract from the quality of that environment.

Particularly for animals, it is often quite difficult (and costly) to document the abundance of all species within all taxonomic groups that typically inhabit a wetland. Thus, indicator species or indicator species-groups have been used to monitor and evaluate the biodiversity and the related functioning of wetlands. The typical definition of an indicator species is a species whose presence is used as a barometer of the health of a community (Robinson and Bolen 1989). The concept of indicator species must be used cautiously. No one species can be an indicator of the whole system. Species or species-groups with narrow environmental tolerances, and hence those most susceptible to ecological disturbance, are the best indicators of wetland functioning (Graul and Miller 1984). The maintenance of the indicator species (or indicator species-groups) at desired levels means that the wetland is functioning similarly to healthy, natural wetlands (Graul *et. al.* 1976).

Amphibians and birds are the best indicators of wetland functioning because of their habitat requirements and positions within the trophic levels, and their relative ease of sampling. Amphibians, especially frogs and toads, are good indicators because many of them require high-quality, standing water to complete the aquatic phase of their life cycle. Some species of birds are good indicators because, as a group, they exhibit a wide range of food habits (seeds, fruit, insects, amphibians, small mammals, etc.) and a wide range of habitat requirements (grassland, shrub, forest, shallow water, deep water, etc.). Ducks, geese, shore birds, herons, and some passerines are so reliant on wetland habitats they cannot survive or reproduce without them.

Amphibians are often excellent indicators of ecosystem quality and wetland functioning because they possess the following characteristics: (1) physiological traits such as permeable skin, gills, and eggs that are susceptible to alterations in the environment, (2) ecological traits such as biphasic life cycle with aquatic and terrestrial stages (larvae/tadpoles and adults), which exposes them to perturbations in both environments, (3) dependency on ectothermy for temperature control, which makes them vulnerable to environmental fluctuations, (4) behavioral traits such as hibernation and/or estivation in soils that may expose them to toxic conditions, and (5) their vital role as both predator and prey in both aquatic and terrestrial food webs (Dunson et al., 1992 and Heyer *et al.*, 1984).

Amphibians are an important upper-level consumer in the wetland community because of their utilization of invertebrate prey that are too small for most birds and mammals (Pough 1983). Amphibians are a key component of a wetland food chain as the main predator of invertebrates and as important prey for mammals and birds (Pough et al. 1987). Salamanders in a northeastern forest have been shown to be 60% efficient at converting ingested energy into new tissue (Burton and Likens 1975a); 20% of the energy available to birds and mammals passes through salamanders. Burton and Likens (1975b) also demonstrated that the biomass of salamanders in an eastern forest is double that of birds and is equivalent to that of small mammals.

Amphibians are the first animals to emerge in the spring, and as a result provide food for predators during early spring when other food sources are scarce. Amphibians are predators (as adults) and primary consumers (as tadpoles) in both forest and pond ecosystems (Dunson, 1982). The abundance and diversity of predatory salamander larvae are important criteria in determining types and amounts of zooplankton and insects (Dodson 1970, Dodson and Dodson 1971), while abundance and diversity of tadpoles are important in determining types and amounts of phytoplankton, magnitude of nutrient cycling, and levels of primary production (Seale 1980).

The abundance/diversity of amphibians in the mitigation wetlands created along West Virginia highways is an excellent indicator of overall wetland habitat quality and functioning. Functioning wetlands will provide breeding, egg-laying, and feeding habitats for the larvae (tadpoles) and adults of numerous amphibian species. For wetlands to support diverse amphibian populations, the water quality within the wetlands must be adequate to support invertebrate populations and to provide suitable conditions for the development of eggs into tadpoles and the development of tadpoles into adults.

Several studies dealing with the ecology and natural history of aquatic salamanders, frogs, and toads in temporary and permanent pools have been conducted in North America. Studies in West Virginia prior to 1980 were quite limited, but in recent years there has been an increased interest in amphibians because of potential population declines. Pauley and Kochenderfer (1994) conducted studies in constructed temporary pools in the Fernow Experimental Forest in Tucker County, WV. Twenty-two pools were constructed in skid roads in the fall of 1993 and each was monitored for two years. In 1993, seven species of amphibians were found in the pools and four of the seven species used the pools as successful breeding sites. In 1994, nine amphibian species and one reptile species were observed using the pools and six of the species used the pools for breeding sites.

Pauley and Barron (1995) compared species in newly mitigated pools with those in old permanent pools in the Green Bottom Wildlife Management Area in Cabell County. The mitigated pools were created in 1992 and this study was conducted in 1993 and 1994. The same species that were known to breed in the original pools successfully reproduced in the created pools. In addition, two species not found in the old pools, *Bufo americanus* and *Hyla chrysoscelis*, were found breeding in the new pools. All environmental factors except water pH were the same in the created and original pools. The difference in pH was not considered a problem since all values were close to 7.0.

Vascular plant species diversity is also frequently used as an indicator of functional levels. However, plant diversity levels must be referenced to the stage of succession of wetlands. Early stages of plant succession in wetlands are typically dominated by few herbaceous species, such as broadleaf cattail or rice cutgrass in temperate freshwater wetlands in the eastern U.S. The result is low species diversities, even though the wetlands have other functional attributes, e.g., high productivity, nutrient transformations, and storage of floodwater.

1.3 West Virginia Division of Highways Wetland Mitigation Projects

In 1992, DOH completed construction on two mitigation wetlands in the Buckhannon, WV area. These sites were part of a program to mitigate unavoidable impacts to wetlands during construction of Appalachian Corridor H between Buckhannon and Elkins. The two sites, referred to here as the Triangle and Sand Run wetlands, were constructed as replacement areas, in part, for palustrine forested, scrub-shrub, open water, and emergent habitats negatively impacted by construction of the corridor (Interagency Field Review 1990). In accordance with the 1990 agreement, the average habitat in-kind replacement acreage ratio for this segment of Corridor H was 1:1 to 2:1. The most recently agreed to average ratio for determining replacement ratios for the constructed mitigation wetland for Corridor H is 2.3:1. This figure was used as the ratio for the Sugar Creek wetland, the most recently DOH-constructed wetland (Per Com, Carte 1998).

The Triangle wetland is a 4.0 ha area (with 0.3 ha of wetland pre-existing on site prior to construction); Sand Run is a 3.5 ha area, with about a 0.4 ha wetland area preexisting on site. Additionally, the Triangle site historically was a wetland but was used as a waste site for earth excavated as part of a flood control project for the city of Buckhannon. Both sites were planned to include a combination of palustrine forested, scrub-shrub, emergent, and open water habitats.

During the 1993 and 1994 growing seasons, the principal investigator conducted two preliminary visits to the Triangle wetland, during which he made the following observations (Fortney and Edinger 1996):

1) The diversity of vascular plants appeared to markedly increase between 1993 and 1994.
2) The abundance of invasive and nonnative species appeared to decrease during this time period.
3) The herbaceous vascular flora of the wetland by 1994 (two years after construction) resembled natural emergent wetlands in this region in terms of the species diversity and abundance.

These observations led to the development of a preliminary functional assessment study of the Triangle wetland (Fortney and Edinger 1996). The Triangle site was selected for the location of a pilot study because it was the larger of the two constructed wetlands and appeared to support more diverse hydrophytic vegetation. Two naturally occurring wetlands in this region of the state with similar vegetation and hydrology were selected to serve as references for conditions at Triangle. The main goals of the preliminary study were: (1) to assess (quantify) levels of natural functions or evidence of functions that had developed in the Triangle wetland since its construction in 1992 and (2) to assess design standards and construction methods for the Triangle site. The principal outcomes were to provide evidence (direct or indirect) of the levels of ecological functions that have developed at the Triangle wetland.

CHAPTER 2

PURPOSE AND SCOPE

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CHAPTER 2

PURPOSE AND SCOPE

2.1 Preliminary Study

The initial study was initially proposed to be a two-phased investigation. Phase I, or the preliminary phase, was designed to quickly collect and assess readily available evidence of functional levels by comparing various physical and ecological features of the Triangle wetland to those of two nearby naturally occurring wetlands (reference wetlands) with similar hydrology and vegetative cover. The second level of investigation, Phase II, would follow the initial study. Phase I was completed in the spring of 1996 and Phase II was initiated later that year. Phase II was designed to assess additional study functions, cover a longer study period, and include additional constructed and reference wetlands.

2.2 Pedagogy and Goals for Phase II

While the results of Phase I indicated that the Triangle wetland was successfully progressing toward a functional wetland, the findings were considered tentative. They would need to be verified with replicate sampling during a full growing season. Further, the lack of quantitative data on the startup conditions at the Triangle site (i.e., baseline conditions) limited the scope of the conclusions that could be ascertained from the Phase I study. In this study, the comparison of the conditions at Triangle to reference areas was, therefore, only for existing conditions at Triangle, not for the difference between startup conditions at Triangle in 1992 and those occurring at the time of the Phase I study. Other limiting factors included a lack of data on spring migratory and breeding bird usage, reptile and amphibian populations, soil morphogenesis and biomass productivity. It should be noted that these limitations were givens for the Phase I study.

The Phase II study had three objectives:

1) To establish baseline conditions for the Sugar Creek Wetland, the most recently constructed wetland.

2) To document evidence of the levels of ecological functions at Triangle, Sand Run, and Sugar Creek wetland sites, and compare their physical environments and biota to naturally occurring wetland areas.

3) To use the data obtained through the study of these wetlands to: a) evaluate methods and construction standards used by the West Virginia

Division of Highways to construct mitigation wetlands and b) comply with regulatory requirements to monitor mitigation wetlands.

Documenting baseline conditions for the Sugar Creek wetland was critical. Construction of Sugar Creek was completed during the summer of 1995, which provided an opportunity to study the wetland within about first year of its construction. Since construction methods used and habitat types developed for this site were similar to those at Triangle, Sugar Creek could provide a reference for the four-years of development of the Triangle and Sand Run wetlands,

To address objective three, there are several functional aspects of wetlands that could be studied, as described by Mitsch and Gosselink (2000), Lee et al. (1994) and others. For this study we selected the following parameters as measurable variables that could be quantified:

1) Species diversity
2) Species richness
3) Wildlife usage
4) Soil nutrient levels, pH, organic content, structure, texture, color, and soil genesis
5) Site productivity (plant biomass standing crop as g/m^2)
6) Wetland Plant Indicator Status (IS) and Weighted Average (WA)

It is important, because of the comparative nature of this investigation, for the groups of biota selected for study to have an extensive background data set available on their distribution and species biology. For this reason the following groups of plants and animals were selected for study:

1) Vascular plants
2) Birds--spring and summer populations
3) Reptiles and amphibians
4) Large mammals
5) Small mammals

These groups of biota are generally well studied within WV and the central Appalachian Mountain region. Therefore, an extensive set of baseline data on the habitat requirements, life histories, and distributions are known for these groups, which can be applied to the reference and constructed wetlands in this study.

CHAPTER 3

SITE DESCRIPTIONS

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SITE DESCRIPTIONS

3.1 Background Information

An essential aspect of the study was to select natural wetlands to serve as reference sites for the three DOH-constructed wetlands, Triangle, Sand Run, and Sugar Creek. The prerequisites of the reference sites were: 1) they occur in the same ecological region, 2) they have similar vegetative cover, and 3) they have similar hydrological regimes. Two reference wetlands were used in the preliminary study-- the Pleasant Creek Wildlife Management Area wetland near Phillippi, WV, and the Meadowville wetland near Belington, WV. For Phase II, we selected two additional constructed wetlands as reference sites, dropping the Pleasants Creek wetland used in Phase I because it is strongly influenced by periodic flooding by Tygart Lake, causing it to have a unique hydrology.

All study sites, constructed and reference, are within the Tygart River drainage basin (Fig. 3.1). They also occur within the Appalachian Plateaus Physiographic Province (Fenneman 1938). Typical for the Plateau is a land form of low hills, narrow valleys, level to nearly level bedrock of sandstones and shales, and a dendritic drainage pattern.

The three reference study sites all occurred as parts of larger wetland complexes that ranged in size from 4.5 ha to 15.9 ha. Only portions of the reference sites resembling conditions at the constructed wetlands were selected for study. The sections selected for study were established to fall within the general size range of the constructed wetland areas–3 to 6 ha. The general characteristics for all sites are summarized in Table 3.1.

3.2 Triangle Wetland

This site is on the floodplain of the Buckhannon River at an elevation of approximately 427 m, less than 1000 m downstream of the Buckhannon city limits (Fig. 3.2). As its name implies, the Triangle wetland is three-sided, a NE side delineated by an embankment of an access road, a SE side (along the Buckhannon River) delineated by a berm formed by the excavation of the wetland itself, and a NW side delineated by an embankment for Corridor H. On the NE side behind the access road and within the main drainage basin for the site is a railroad grade, cemetery, and State Route 13.

The site was historically a wetland, but in the 1960's it was used as a waste area by the U. S. Army Corps of Engineers (COE) for earth excavated during the construction of a cutoff river channel for the Buckhannon River within the city limits of Buckhannon. Adjacent vegetative cover is forb/graminoid-dominated meadow on one side, scrub-shrub thicket between the wetland and railroad, and mid-aged riparian forest principally dominated by silver maple (*Acer saccharinum*) and box elder (*Acer negundo*). The water source for the wetland is a combination of surface runoff, spring/seeps, and occasional overbank flow from the Buckhannon River.

The Triangle wetland was created by excavating portions of the fill placed on site by the Corps, leaving a berm between the excavated area and the Buckhannon River, and by compacting a clay liner to impede subsurface drainage. The liner was covered with soil (with an estimated organic matter content of 5%). An area in the SE section of the wetland does not have a continuous liner because the subsurface hydraulic conditions limited the use of heavy equipment in this area during construction (Carte pers. comm. 1996). Following excavation and site preparation, the area was seeded with red top (*Agrostis alba*), switch grass (*Panicum virgatum*) and millet (*Echinochloa crusgalli*) to produce a cover crop. This cover crop was planted to add a quick source of soil organic matter and to control erosion. Following a planting scheme developed by the DOH, several wetland vascular plant species were planted to add diversity to the site and to facilitate the development of different wetland vegetation types, including palustrine emergent, scrub-shrub, and forest types (Table 3.2). This planting scheme included original and follow-up replanting over a two-year period. The present vegetative cover on the site is predominantly sedge, rush, and/or grass-dominated marshes, wet meadows, and bottomland overflow sites.

The wetland featured two separate sections, an upper area on the north side with a high elevation of approximately 429 m and a lower area on the south end with an elevation of approximately 428 m (Fig. 3.3). In each of these areas there are three basic habitat types/vegetation types, all of which are in palustrine emergent categories. Marsh (emergent persistent and some non-persistent) habitats are generally contiguous with the open water areas; wet meadows (emergent persistent) are scattered throughout the project; and bottomland overflow habitats, which occur chiefly on the margins of the wetland, are relatively small, better-drained islands within the wetland in both sections. Most of the open water habitat is located in the southern section, with open water in the north section restricted to relatively small, scattered depressions.

During construction, the surface of the substrate, in most locations, was intentionally left with rough, irregularly spaced depressions, ranging from mere small depressions to broad, deep equipment tracks over 0.3 m deep. This uneven surface, a planned feature of the site, resulted in a site with widely varying hydrologic regimes. Permanently flooded areas have small, elevated areas where the water table drops below the surface during the growing season; conversely, better drained areas have depressions where water stands for extended periods of time.

Drainage within the site flows generally from north to south. The point of egress is through the berm on the SE end, where water discharges directly into the Buckhannon River. Since its construction in 1992, the area has been fully inundated once by overbank flow from the Buckhannon River (February 1994) and partially flooded on at least two occasions, inundating only the lower section.

3.3 Sand Run

The Sand Run wetland is located between Sand Run and an embankment on the north side of U. S. Route 33. The wetland, which is separated by an access road from Sand Run, is 8.0 km from the confluence with the Buckhannon River (Fig. 3.4). This wetland was constructed in 1992, about the same time as the Triangle wetland. Its elevation is approximately 472 m. Like other DOH-constructed wetlands, the site was created by excavating a concave area, on which a clay liner was constructed. A mineral soil layer was added. The soil hydrologic regimes range from standing water throughout the year to intermittently flooded. The water sources for the wetland are surface runoff and springs. During significant rain events, it may receive overbank flow from Sand Run. Past rain events have resulted in the deposition of sediments in the upper end of the wetland.

The site design resulted in a progressively deeper water level going from the upper section to the point of egress at the downstream end. The same basic habitats created for Triangle were also created here (Fig. 3.5). Unlike Triangle, the Sand Run wetland does not have a persistent water source during the summer months. As a result, typically, during spring and early summer, about three quarters of the site will have standing water. By August, only the downstream section usually has standing water–about one-sixth to one-fourth of the site. As a result, the hydrological regime over much of the site varies significantly during the growing season.

A small section of the Sand Run site was a wetland prior to construction. The area, which has a mixture of shrubs and trees, is on the U. S. Route 33 side. With an expanded wetland habitat, the area has been affected by the increased water level, as several of the trees in the original wetland area have died. Further, during the last year or so, beavers have added slightly to the water level, by blocking the outflow and adding to the downstream dam wall.

Like the Triangle site, following excavation and site preparation, the site was seeded with red top, switch grass, and millet to produce a cover crop to control erosion and as an added source of soil organic matter. Following a planting scheme developed by the DOH (Table 3.2), several wetland vascular plant species were planted to add diversity to the site and to facilitate the development of different wetland vegetation types, including palustrine emergent, scrub-shrub, and forest types. Also like Triangle, the original and follow-up replantings were completed over a two-year period. The present vegetative cover on the site is predominantly composed by sedges, rushes, and/or grasses, occurring in graminoid-forb-dominated wet meadows and bottomland overflow habitats.

3.4 Sugar Creek

Construction on the Sugar Creek wetland was completed in mid-summer 1995. At 8 ha, it is the largest studied DOH mitigation wetland (Figs. 3.6 and 3.7). The area, with an average elevation of approximately 478 m, has two sections, an upstream and a downstream section, separated by the site access road.

The upstream section, which has a more or less linear design and is bisected by Sugar Creek, is a combination of small excavated depressions with open water fringed with emergent herbaceous vegetation or depressions with saturated soils and emergent vegetation. The largest wetland unit in this section is at the extreme upstream portion. An area of about 0.5 ha, it is a combination of open water and emergent herbaceous cover. Throughout the upstream section are patches of scrub-shrub and young forested stands. Species common in these include: laurel oak (*Quercus laurifolia*), crab apple *(Pyrus coronaria)*, hazelnut (*Corylus americana*), and hawthorn (*Crataegus* spp). Strong evidence of past farming activities remain in this section, as evidenced by widespread early successional woody cover and old fence lines.

The downstream section is the largest contiguous area. This section, which is about 6 ha, is a mosaic of wetland and aquatic habitats, ranging from scattered, unvegetated ponds to temporarily flooded areas. Like Triangle and Sand Run wetlands, this area has a mineral soil over a compacted clay liner. Hydrology is controlled by a series of dikes and levees, designed to control surface flows and retain water. This section is delineated by Sugar Creek on the south side, a natural shrub-dominated wetland on the west, and upland meadows on the north and east sides.

Both the upstream and downstream sections are designed to receive overbank flow during significant rain events. Also in both are relatively small preexisting wetlands retained within the new wetland complex.

At the time of the inventory of the vegetation of this site, supplemental planting of wetland species had not occurred.

3.5 Preston

This wetland area occurs along Sandy Creek at an elevation of 405 m (Fig.3.8). It is delineated on the north by U.S. Route 50, by Sandy Creek on the south side, an active hay meadow on the east side, and a pasture on the west. The wetland is dominated by emergent herbaceous vegetative cover, with shrub and immature forest cover along Sandy Creek and along an unnamed tributary bisecting the area (Fig 3.9). The forested cover is restricted to a floodplain levee immediately adjacent to Sandy Creek.

The hydrological regime ranges from intermittently flooded on the levee, to permanently flooded areas influenced by water impounded behind beaver dams. The herbaceous dominated habitats inventoried had saturated to semipermanently flooded regimes. Within the wetland and adjacent to the highway is a portion of an old channel of Sandy Creek which was isolated when the existing channel was constructed. It could not be confirmed, but we suspect that the original stream channel was relocated when U.S. Route 50 was upgraded. The overall hydrology for the wetland appears to be controlled principally by the Sandy Creek levee system and by beaver activity.

Soils on the site are Atkins or Philo Series (Patton *et al.* 1959). Atkins, a poorly drained mineral alluvial soil, occurs where hydrological regimes are the wettest, with Philo occurring on the levee system along Sandy Creek.

3.6 Meadowville Wetland

This site is part of a bottomland wetland complex along Glady Fork, a tributary of Sugar Creek (Fig. 3.10). The site, which is bisected by Glady Fork, is bordered on the east side by State Route 92, on the north by a deciduous scrub-shrub thicket and agricultural meadow, on the west by a young hardwood forest, and on the south by an abandoned agricultural meadow. The elevation is approximately 570 m.

Past land use throughout the site appears to have been agricultural meadowland. This is evident by the presence of a partially erect fence on the south end of the area and along State Route 92. Presently, there are no active agricultural activities within the study area. Based on discussions with local residents, this area has progressively become wetter during the past 20 to 30 years.

Water sources for the site are direct surface runoff, spring flow, and bank overflow from Glady Fork and an unnamed intermittent stream flowing onto the site from the east through a culvert under Route 92. The hydrologic regimes range from semi-permanently flooded to saturated, with the driest area in the southern end. Along Glady Fork is a narrow riparian forest cover composed of sycamore (*Platanus occidentalis*) and silver maple.

The Meadowville wetland has a diverse vegetative cover (Fig. 3.11). This area is a combination of scrub-shrub and emergent types. The largest coverage is by graminoid and forb emergent (persistent) types, which include nearly monotypic stands of Caricies (*Carex* spp.), rice cutgrass (*Leersia oryzoides*), and cattail (*Typha latifolia*). Scrub-shrub cover is also well-developed, with mixed stands of spirea (*Spiraea alba*), swamp rose (*Rosa palustris*), brookside alder (*Alnus serrulata*), and silky cornel (*Cornus amomum*) occurring throughout the site.

3.7 Seefus

This site, which occurs in the headwater section of Laurel Fork, has an elevation of 600 m (Fig 3.12). The source of water appears to perennial springs and surface runoff during rain events. The prominent features of this site are the continuous surrounding forest community dominated by mixed hardwood trees and the series of beaver impoundments that effectively control the site hydrology. The site is situated near the upper end of a catchment with moderately steep slopes. Instead of having a "v-shaped" valley, which is typical of this section of the Appalachian Physiographic Providence, the area appears to have an elevated valley floor, built up by alluvium deposited behind the series of beaver dams.

In fact, the entire wetland area appears to have been created and maintained through beaver activities (Fig 3.13). The site is a mosaic of open beaver ponds separated by emergent herbaceous dominated meadows, with numerous tree snags. Although beaver activity is currently limited, dams persist, creating several ponds. The presence of beaver dams is, doubtless, the reason the hydrological regime throughout the site ranges from permanently flooded to saturated, with saturation persisting throughout the growing season. Beaver activity on the site is apparently a recent event, as evidenced by the numerous tree snags and the absence of evidence of beaver activity for this site on the Barbour County soil survey maps (Beverage et al. 1968). Some fresh beaver sign was noted during the 1996 survey, but none was noticed in 1997 and 1998.

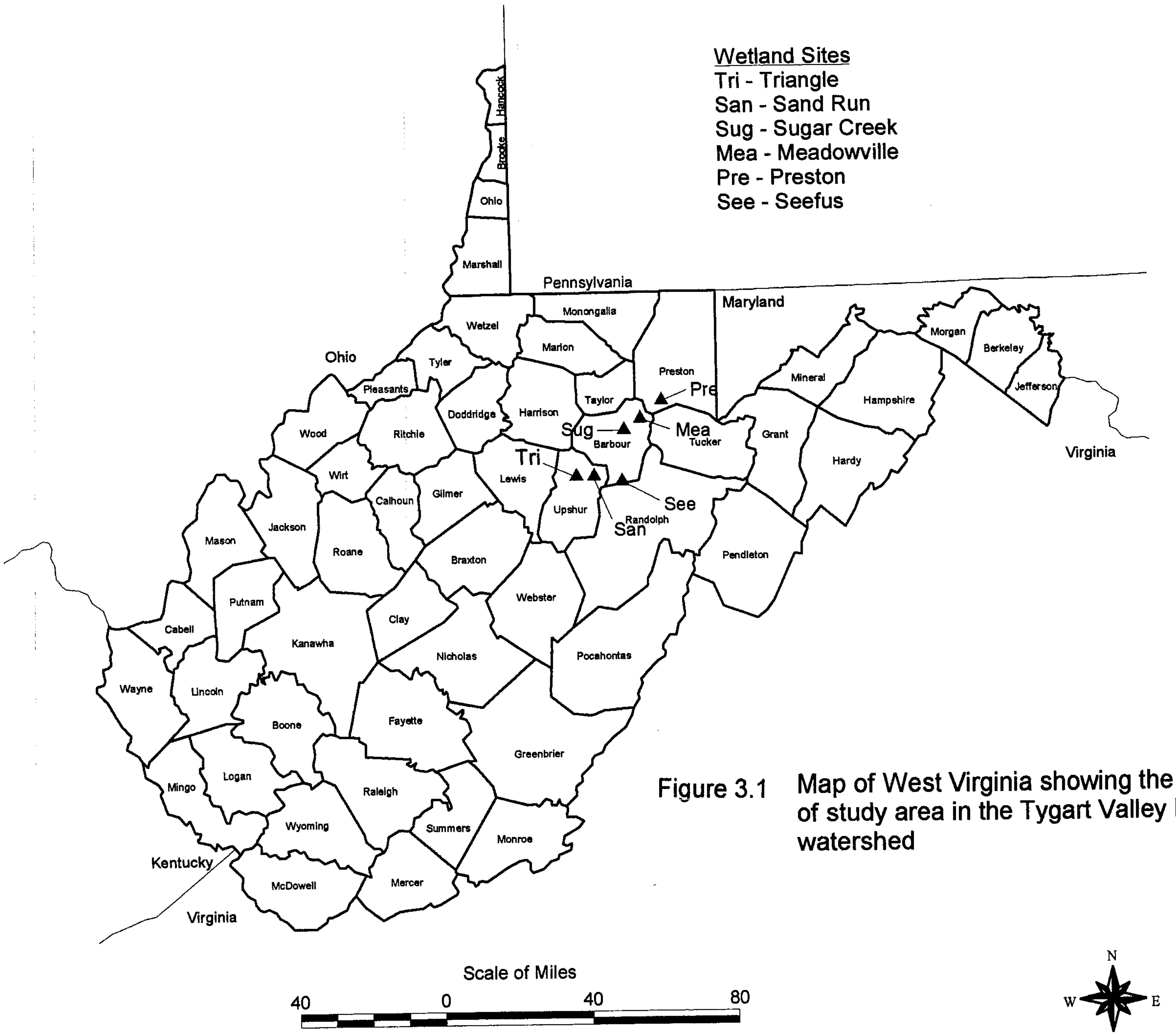


Figure 3.1 Map of West Virginia showing the location of study area in the Tygart Valley River watershed

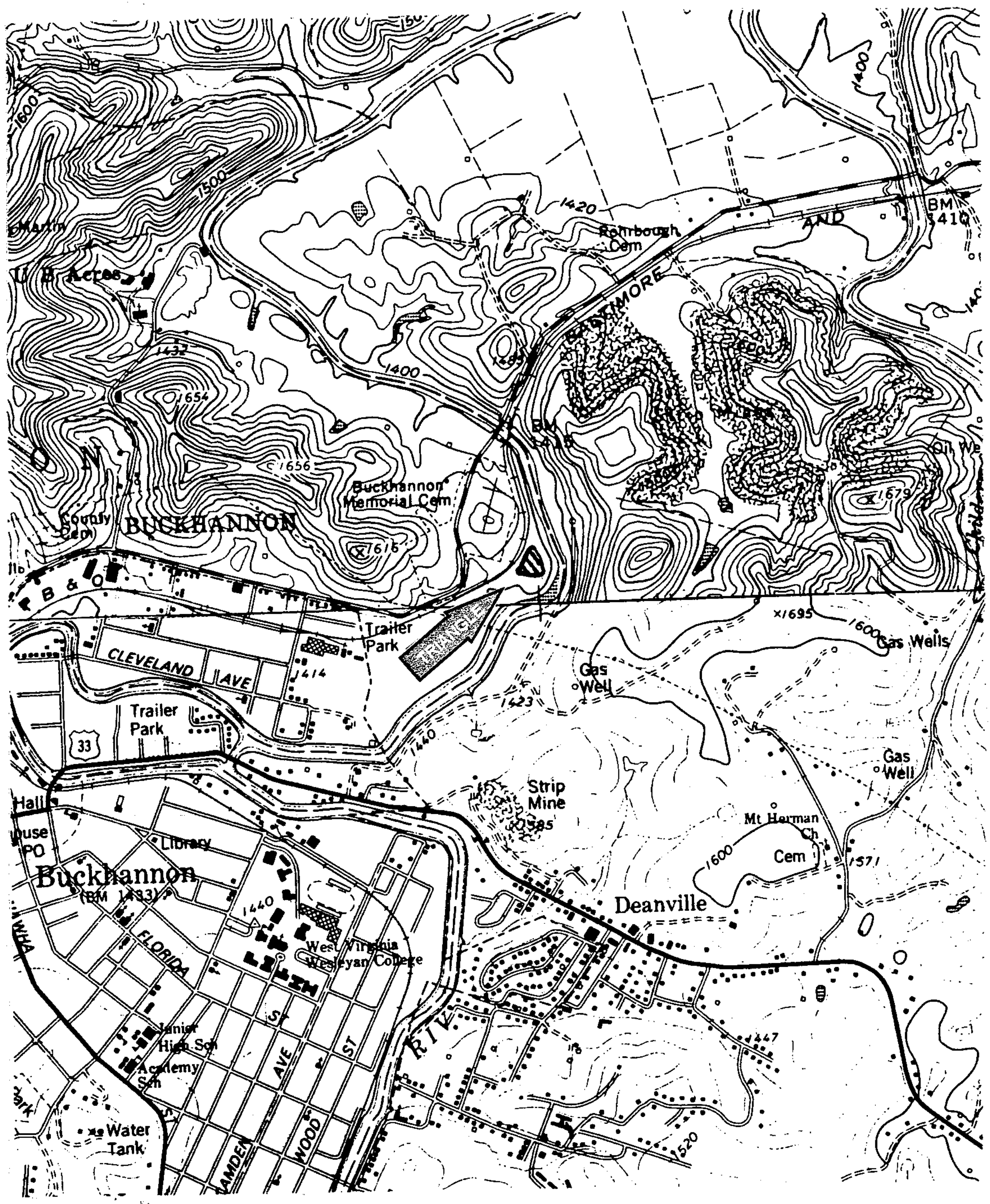


Figure 3.2. Sections of the Buckhannon and Century USGS 7.5 quadrangle maps showing the location of the Triangle wetland.

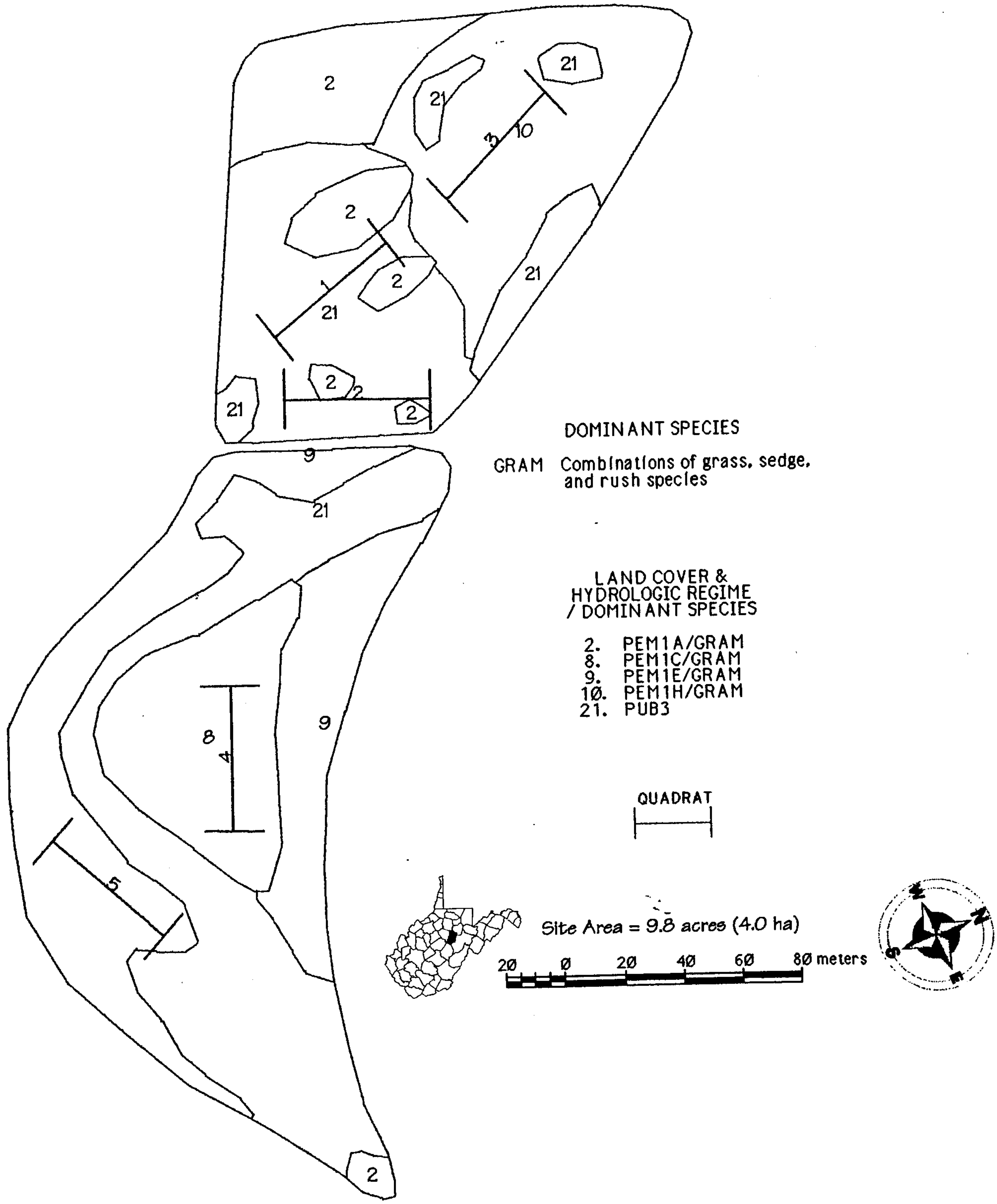


Figure 3.3 Site map for the Triangle wetland study area showing wetland types, vascular plant species and groups of plant species, hydrologic regimes, and sample quadrat locations.

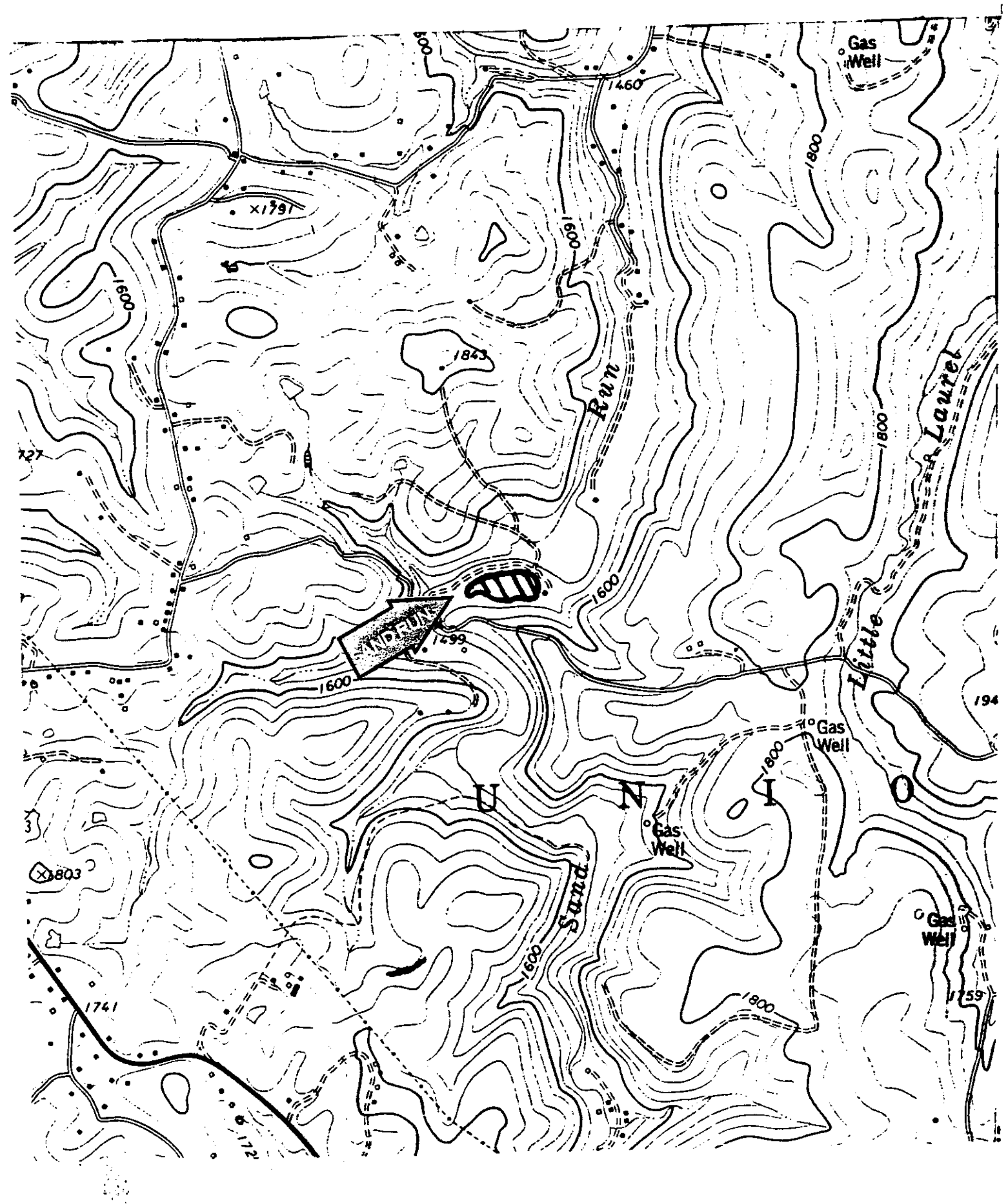
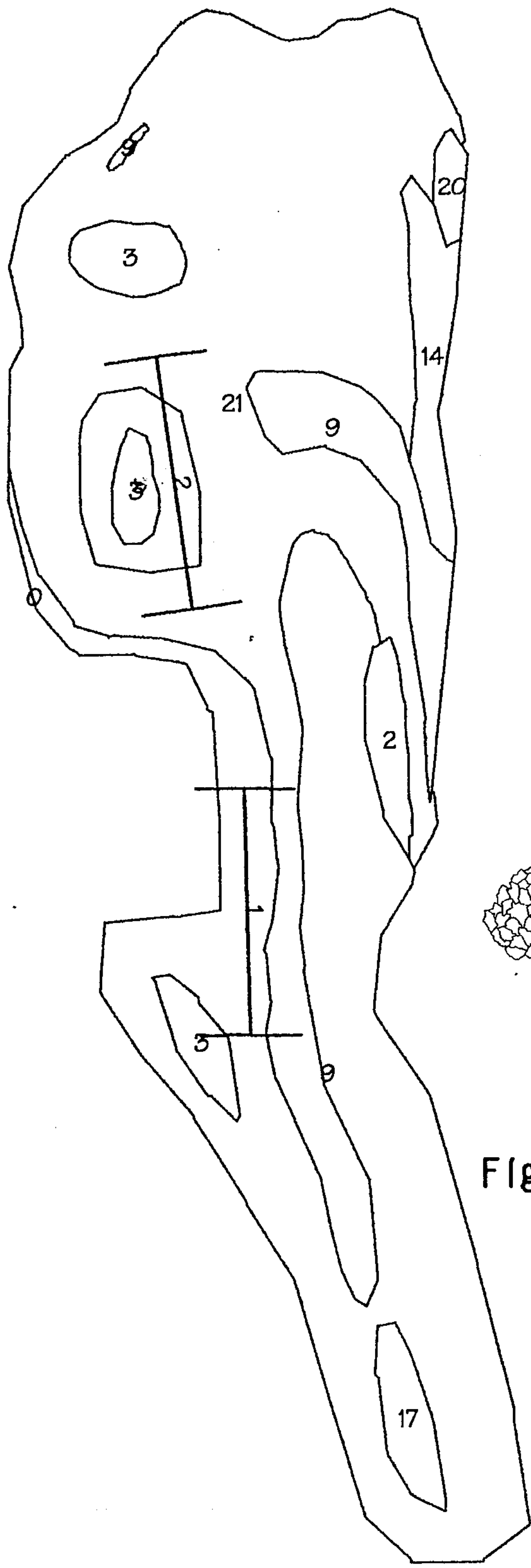


Figure 3.4. Section of the Buckhannon USGS 7.5 quadrangle map showing the location of the Sand Run wetland.



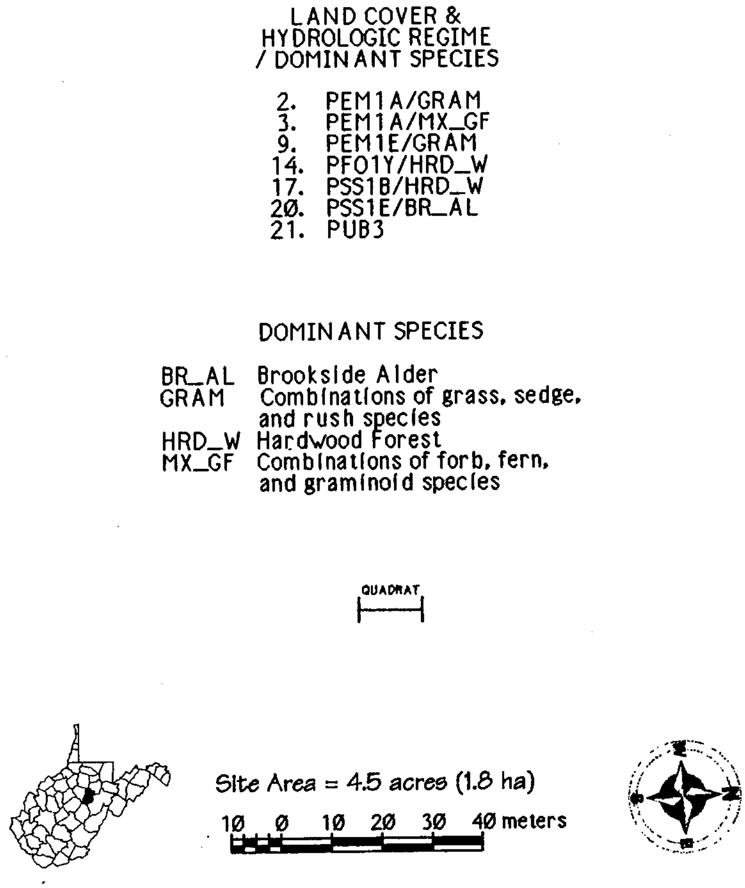


Figure 3.5 Site map for the Sand Run wetland study area showing wetland types, vascular plant species or groups of species, hydrologic regime, and sample quadrat locations.

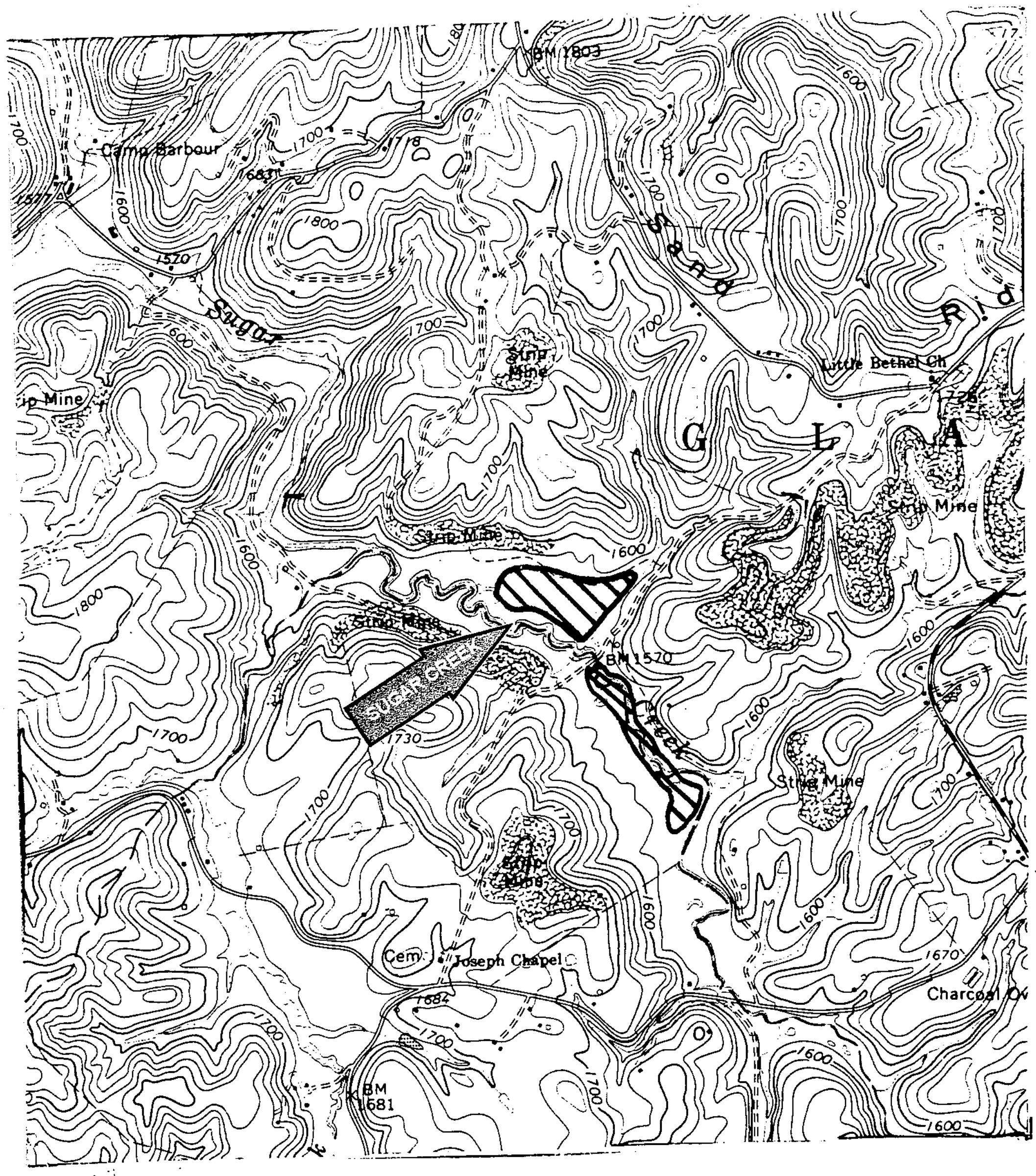


Figure 3.6 Section of the Belington USGS 7.5 quadrangle map showing the location of the Sugar Creek wetland.

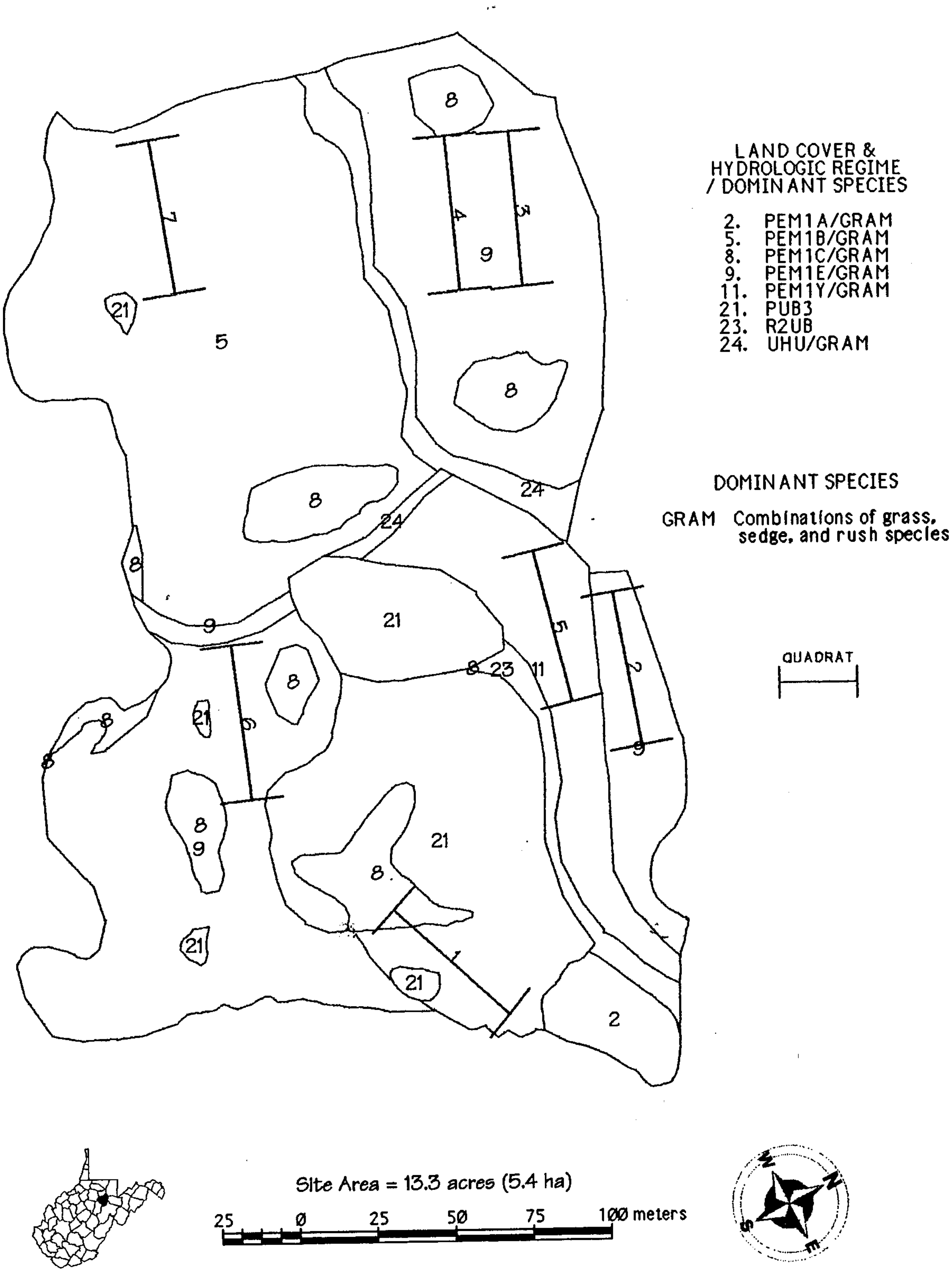


Figure 3.7 Site map for the Sugar Creek wetland study area showing wetland types, vascular plants and groups of vascular plants, hydrologic regimes, and sample quadrat locations.

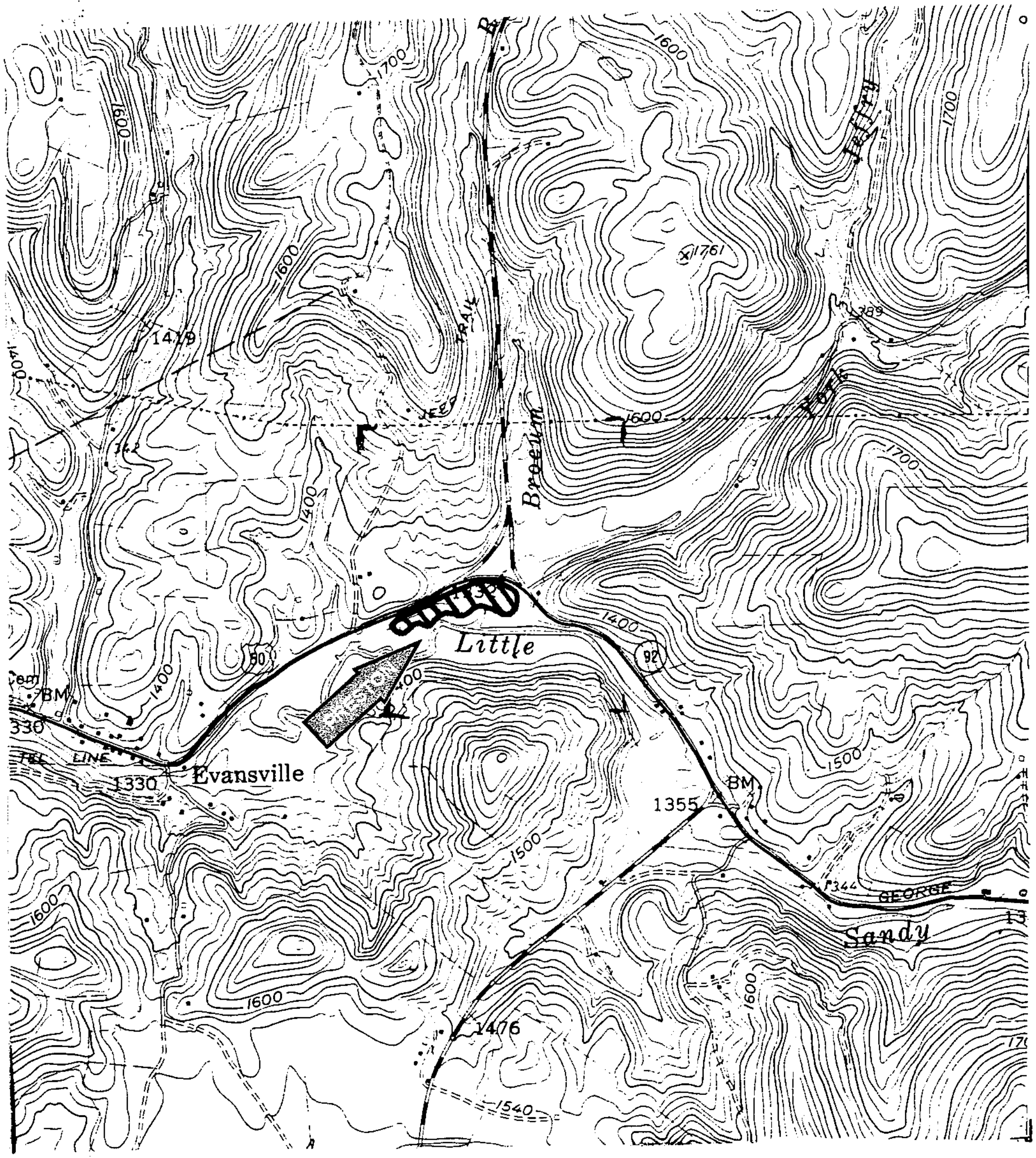


Figure 3.8. Section of the Fellowsville USGS 7.5 quadrangle map showing the location of the Preston wetland.

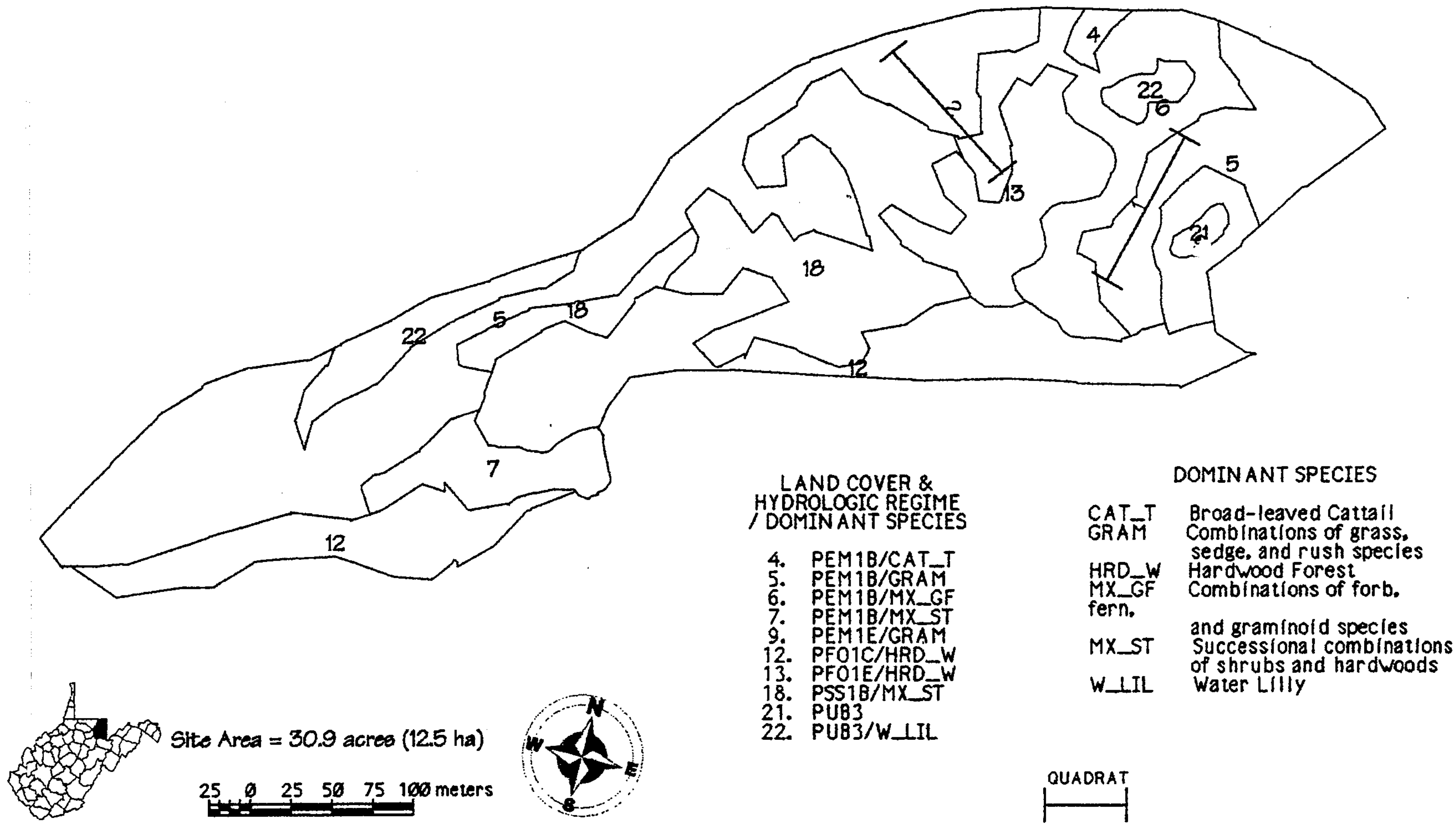


Figure 3.9 Site map for the Preston wetland study area showing wetland types, vascular plant species and groups of species, hydrologic regimes, and sample quadrat locations.

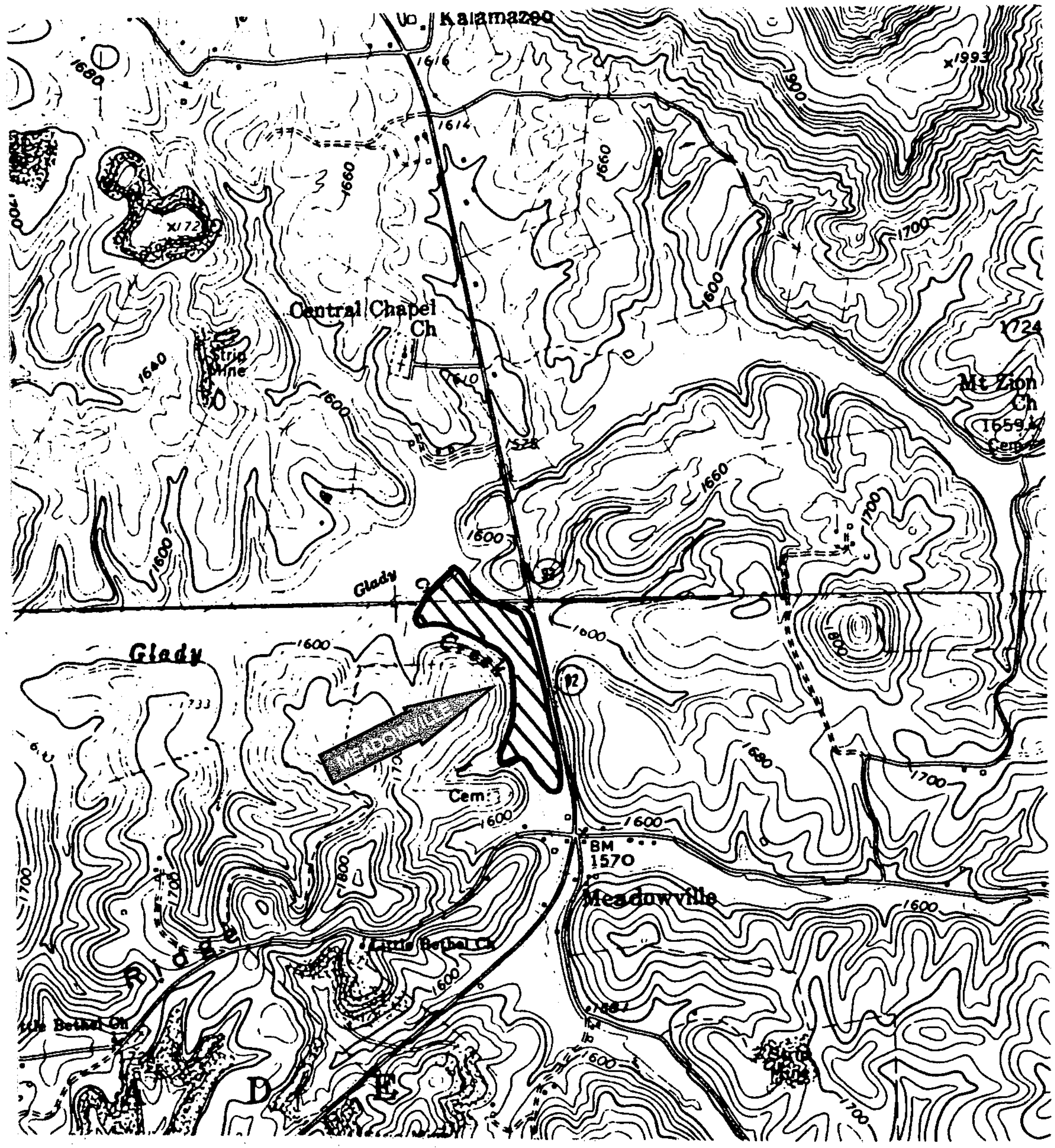


Figure 3.10. Section of the Bellington and Nestorville USGS 7.5 quadrangle maps showing the location of the Meadowville wetland.

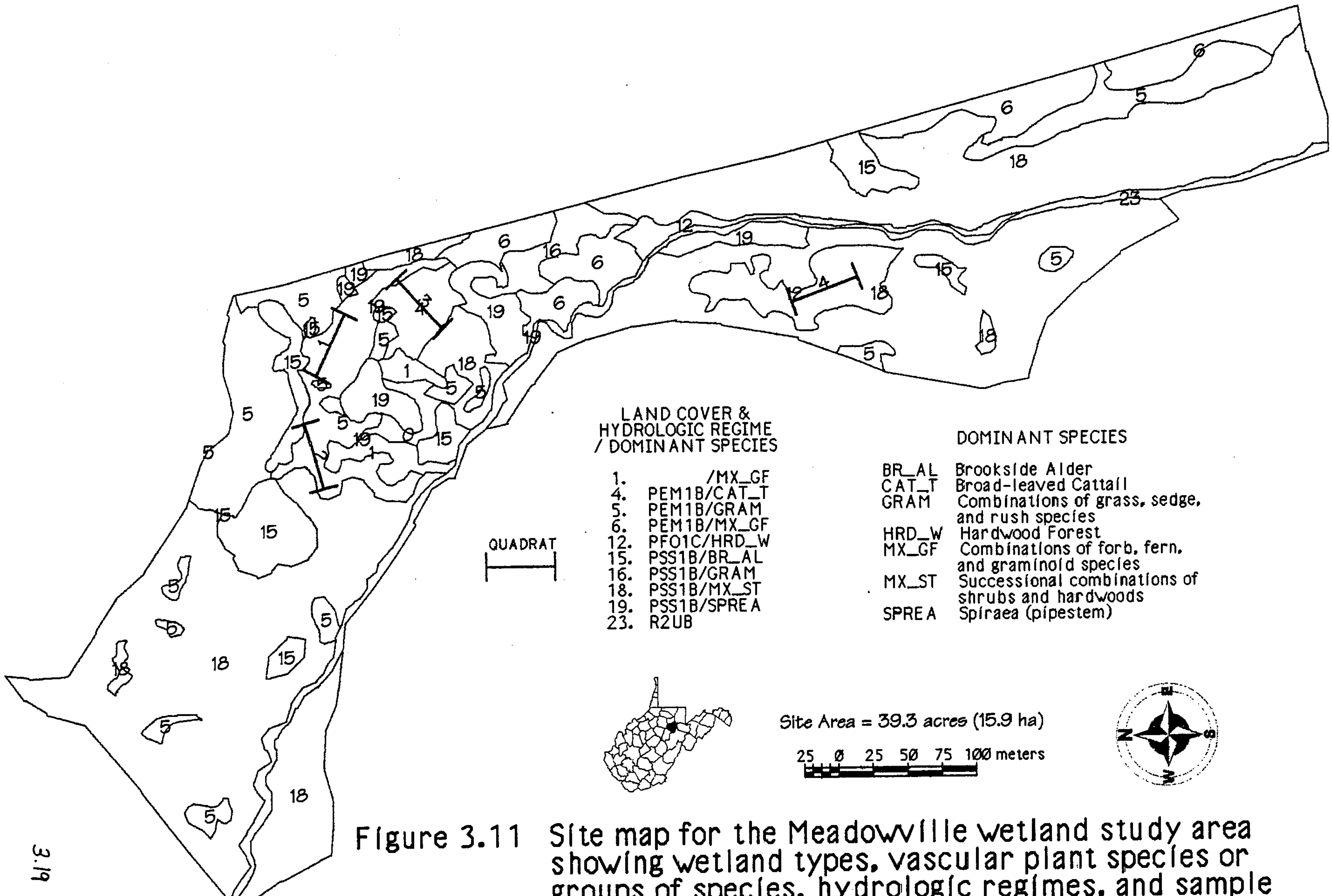


Figure 3.11 Site map for the Meadowville wetland study area showing wetland types, vascular plant species or groups of species, hydrologic regimes, and sample quadrat locations.

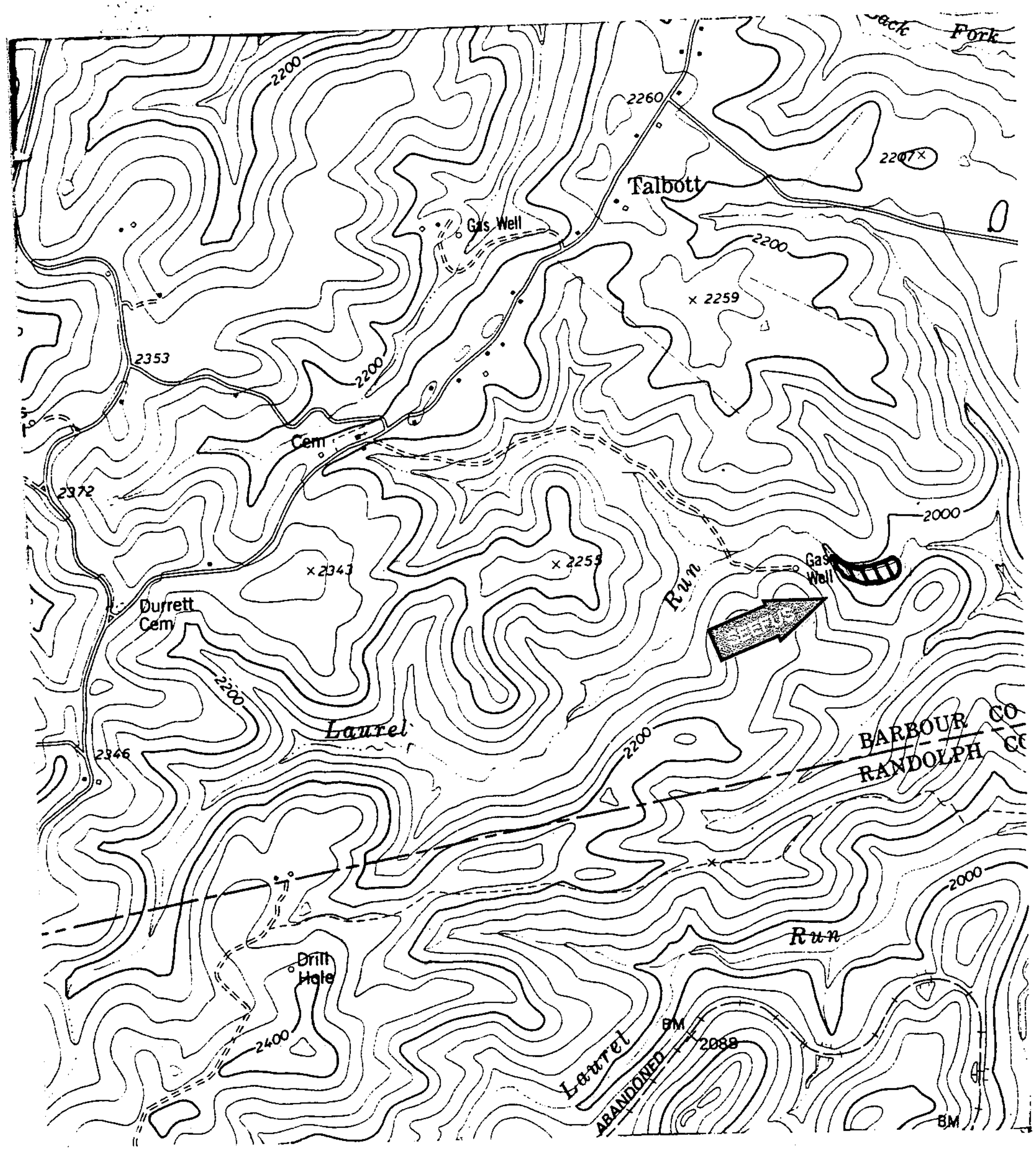


Figure 3.12. Section of the Junior USGS 7.5 quadrangle map showing the location of the Seefus wetland.

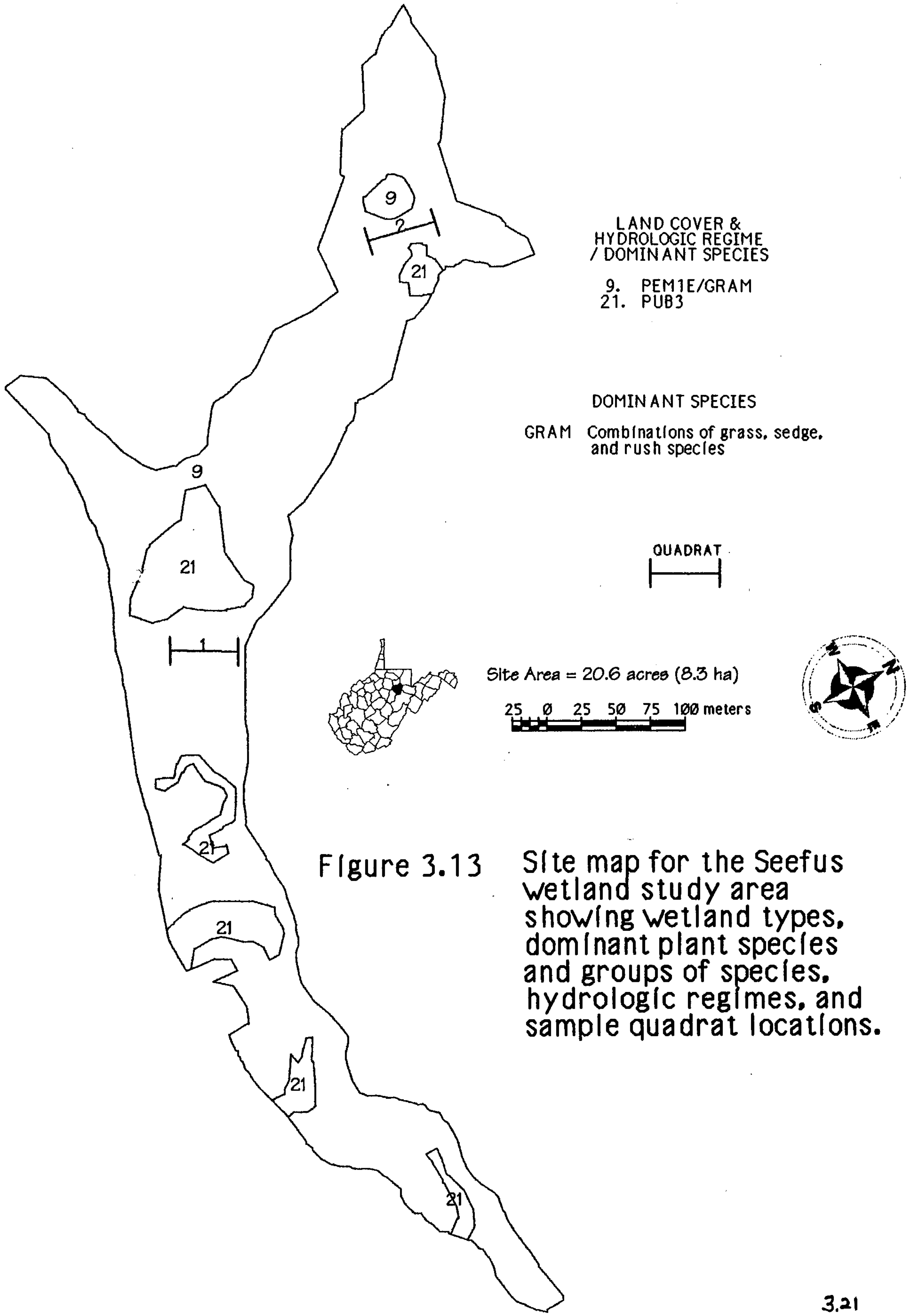


Figure 3.13 Site map for the Seefus wetland study area showing wetland types, dominant plant species and groups of species, hydrologic regimes, and sample quadrat locations.

Table 3.1. General site characteristics of three constructed and three reference wetlands.

Site	Origin	Elevation (m)	Area (ha)	Drainage Basin	FWS Wetland Classification[1]	Soil Classification[2]
Triangle (Tri)	Constructed	427	4.0	Tygart River	Palustrine Emergent Persistent	Fill (mineral/clay)
Sand Run (San)	Constructed	472	3.5	Tygart River	Palustrine Emergent Persistent	Fill (mineral/clay)
Sugar Creek (Sug)	Constructed	478	8.0	Tygart River	Palustrine Emergent Persistent	Fill (mineral/clay)
Meadowville (Mea)	Reference	470	15.9	Tygart River	Palustrine Emergent Persistent	Atkins silt loam
Preston (Pre)	Reference	405	12.5	Tygart River	Palustrine Emergent Persistent	Atkins/Philo silt loam
Seefus (See)	Reference	600	8.3	Tygart River	Palustrine Emergent Persistent	Recent sediment (beaver)

[1] Cowardin *et al.* 1978
[2] NRCS soil surveys for Upshur, Barbour, and Preston Counties

Table 3.2. Species planted, planting schedule, locations, and numbers of species planted by the West Virginia Division of Highways in Triangle and Sand Run wetlands.

Growth Habit	Species	Species Planted and Planting Schedule			Planting Location	Planted as
		Number Planted		Time		
		Triangle	Sand Run			
Woody	Cephalanthus occidentalis (Buttonbush)	2,275	200	Fall 1992 Spring 1993 Fall 1993	Planted along channel edges	Seedlings--clumps of 5
	Sambucus canadensis (Black elderberry)	1300	300	Spring 1993 Fall 1993	In various habitats and edges of future overflow forest areas	6-inch seedlings
	Aronia arbutifolia (Red chokeberry	270		Spring 1993	On site for future overflow forest area	12-inch seedlings
	Acer saccharinum (Silver maple)	225	40	Fall 1992 Spring 1993	Toe of road embankment and on future overflow forest area	12-inch seedlings
	Amelanchier laevis (Serviceberry)	204	---	Fall 1993	On terrace between wetland and Buckhannon River	12-18-inch seedlings
	Quercus bicolor (Swamp white oak)	235	---	Spring 1993	On terrace between wetland and Buckhannon River	4-6-inch seedlings
	Spiraea alba (Pipestem)	100	---	Fall 1993	Around emergent areas and on future overflow forest area	12-inch seedlings
	Ilex verticillata (Winterberry)	30	---	Fall 1993	Around open water and on site of future overflow forest area	18-24-inch seedlings
Herba-ceous	Sagittaria latifolia (Duck potato)	1300	100	Fall 1992 Spring 1993 Fall 1993	Along channel edges	Dormant tubers/plugs
	Scirpus americanus (Common threesquare)	3,000	---	Spring 1993	All emergent areas	Dormant rootstocks
	Carex lurida (Sedge)	350	---	Fall 1993	In clumps in emergent areas	Plugs
	Scirpus atrovirens (Woolgrass)	1250	500	Fall 1992 Fall 1993	In clumps in emergent areas	Plugs
	Onoclea sensibilis (Sensitive fern)	350	---	Fall 1993	Variously spaced in emergent areas	Rootstock
Seed	Panicum virgatum (Switchgrass)	15 lbs/acre	15 lbs/acre	Fall 1992 Spring 1993	Sown over entire area	Seed
	Agrostis alba (Redtop)	10 lbs/acre	10 lbs/acre	Fall 1992 Spring 1993	Sown over entire area	Seed
	Echinochloa crusgalli (Wild millet)	10 lbs/acre	10 lbs/acre	Fall 1992 Spring 1993	Sown over entire area	Seed

CHAPTER 4

PLANT COMMUNITIES, FLORISTICS, AND PRODUCTIVITY

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CHAPTER 4. PLANT COMMUNITIES, FLORISTICS, AND PRODUCTIVITY

4.1 Methods--Vascular Plant Communities

The number of sample quadrats established at each of the study sites varied from two to six. The number used was based on the size and variability of the sites. For each site, at least one quadrat was established in each major herbaceous-dominated plant community type, with Sugar Creek having the largest number of quadrats because it was the largest area. In addition, because we were establishing baseline conditions for Sugar Creek in its first full year of development, we wanted to develop a large data set. The number of quadrats for each site, cover class for each site, and other present cover classes are shown in Table 4.1.

The methods for quantitatively sampling the vegetation were based on Gauch (1982) in which permanent 20 by 50 m (0.1 ha) quadrats were established within distinct plant community types. The center point for each plot was established by a researcher standing near the center of a plant community and tossing a metal stake without looking exactly where it was being tossed.

Within each quadrat, the composition and structure of the vegetation were determined using standard sampling methods as described by Stephenson and Adams (1986). Because herbaceous vegetation dominated each sample site, trees, shrubs, and saplings were not quantitatively sampled. Estimates of percent cover of herbaceous plants were recorded from ten 1.0 m by 1.0 m plots placed at 5.0 m intervals along a center line running with the long axis of the quadrat. All cover values were estimated using a cover class rating scale described by Daubenmire (1968) (Table 4.2). Species observed within each plot but not sampled were recorded; a list of species for each site was also compiled. Field data were used to calculate relative cover and relative frequency for herbaceous plants. Species importance value indices for herbaceous plants were determined as one-half the sum of relative cover and relative frequency. A list of species encountered but not sampled in each wetland area was made. For each quadrat, Shannon's Index (Shannon and Weaver 1963) was used to calculate a value of species diversity for the herbaceous stratum at each locality, using importance values indices as input data (see methods for insects below for additional detail on Shannon's Index). Also calculated were weighted averages (WA) for the vegetation in each quadrat based on work by Whittaker (1951 and 1978) and Curtis and McIntosh (1951); percent of species by wetland indicator (IS) status (Table 4.2) (National List 1996); percent of total species present that were nonnative or native and introduced[1]; two species richness values (one for native, nonhuman introduced species and one that included native and non-native species); and Sorensen Index for community similarity (Smith 1996). Strausbaugh and Core (1970, 1971, 1974, 1977) was used as the authority for taxonomic nomenclature.

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[1]For the Triangle Sand Run sites, species planted by DOH that were likely to have been introduced by natural vector, e.g., water and waterfowl were treated as naturally occurring species; these species include *Carex lurida* and *Agrostis alba*.

Weighted averages have been used by Carter et al. (1988), Wentworth et al. (1988), Scott et al. (1989), and Atkinson et al. (1993) as a tool for designating areas as wetland or upland. They are based on the following formula:

$$WA = (y_1u_1 + y_2u_2 + ... + y_mu_m)/100$$

where $y_1, y_2, ..., y_m$ are the relative cover estimates for each species in a plot, and $u_1, u_2, ..., u_m$ are the indicator values (Table 4.2) of each species (Atkinson et al. 1993). A value of less than 3.0 on a scale of 1.0 to 5.0 indicates wetland vegetation. Generally, a plant community with any value between 2.5 and 3.0 is considered to have a marginal wetland vegetation cover and should be evaluated more closely.

4.2 Methods--Vegetation Standing Crop (Productivity)

The above-ground biomass (g/m^2) was sampled within the same permanent 20 m by 50 m (0.1 ha) quadrats used for sampling vascular plants. However, in each quadrat, new sampling subplots were established two meters to the left or right of four randomly selected from the ten 1 x 1 m vegetation plots that had been established as part of the vascular plant study. Samples were taken in a single harvest during peak growing season between early and mid August of 1996 with methods used by Brewer and McCan (1982) and de la Cruz (1978). The aboveground vegetation in the four half meter square circular plots was clipped at ground level using methods described by Chapman (1976) and Smith (1996). The subplots were offset because harvesting was completed using a destructive-type method. For all six wetlands, a total of 84 subplots in 21 quadrats were sampled. Circular plots were selected to help reduce edge error (Brewer and McCann 1982). Before clipping a plot, the vascular plant species were identified and assigned cover values using the cover class rating scale based on Daubenmire (1968) (Table 4.2). Using the cover values, dominant vascular plant species for plots were determined by calculating an importance value (IV) for each species (IV=relative cover + relative frequency/2). The IV was used to correlate dominant plant species with productivity for whole sites and individual quadrats.

To determine aboveground biomass, the clippings from each sample plot were placed in paper bags and labeled. Each sample was dried in a conventional dry kiln at a temperature of 66^0C. This basic method of estimating standing crop biomass follows de la Cruz (1978) and Westlake (1963). Drying continued until a constant weight was reached or the mass of the plot sampled decreased less than two percent of the previous weighing. The mass of each plot was divided by the sample area to yield productivity in units of g/m^2.

Differences in mean standing crop between wetlands were calculated using a t-test to a 95% confidence interval (t-test, $p<05$). These data were pooled for the statistical analysis. Using the same methodology, the transect differences were also calculated.

Each quadrat was assigned a hydrologic regime modifier as described by Cowardin et al. (1979). The hydrologic regime was determined through repeated observation of each area's predominant ground and surface water levels. The modifiers were given values ranging from 1 (wettest) to 5 (driest) (Table 4.2). Values for modifiers were calculated for each wetland site and individual quadrats.

Researchers from the Division of Plant and Soil Sciences, West Virginia University collected soil data for each site. (See Chapter 5, Soils and Hydrology for more information.) These data were used to correlate standing crop values with soil physical parameters.

A linear regression model was used to calculate the correlation coefficient of several environmental variables. Correlations between standing crop, importance value, hydrologic regime, pH, percent carbon, calcium, magnesium, potassium, sodium, hydrogen, nitrogen, sulfur, and phosphorus were examined. Also, a correlation between importance value and productivity was tested with those transects where these species were sampled. A value of +1.000 represents a direct relationship while a value of -1.000 would show an indirect relationship. Coefficients near 0 mean no relationship. The significance of the correlation was verified using a one-tailed t-test (Kent and Coker 1994).

4.3 Methods--Wetland Plant Community Comparisons

We calculated an index of species diversity for each quadrat using the Shannon Index (Shannon and Weiner 1963). Species importance values were the input data for this statistic. The Shannon Index assumes that individuals are randomly sampled from an "infinitely large" population, and that all the species from a community are included in the sample. Because the index combines species richness and species evenness, it is generally preferred among ecologists (Kent and Coker 1993).

The Sørensen Coefficient was calculated as a measure of species similarity between the six study wetlands. For this statistic, an overall site species list was compiled from the quadrat data. The value of the index ranges from 1.00, indicating uniformity, to 0.00, when no species are common to both sites. This index relies on presence/absence data, permitting us to include those species that were seen in the study site, but not in the sampling unit. This was particularly important for the constructed wetlands, which had a substantial number of these plants. Because the Sorensen Coefficient gives greater weight to those species that are in common to each site pair, it is generally preferred over other similarity indices (Kent and Coker 1992).

We also performed detrended correspondance analysis (DECORANA) of the species and environmental data using PC-ORD software (McCune and Mefford 1997). For this analysis, pH was transformed to the concentration of hydronium (H_3O^+) ions. Because we were primarily interested in how these communities responded to environmental gradients rather than the response of individual species, the main focus of the ordination will be on quadrats. DECORANA is an indirect method of ordination. It yields a graphic array of quadrats based on their vegetative composition. This method is suitable for a study with a relatively small number of sampling units. Here, we had three objectives: 1) to arrange the 21 quadrats in a two dimensional graph such that points close together correspond to quadrats with similar species composition, and conversely, points that are far apart correspond to sites that are dissimilar; 2) to detect correlations between the arrangement of quadrats with underlying environmental variables; high correlations may suggest, but do not necessarily mean a causal relationship exists; and 3) to infer relationships between the arrangement of points and several derived statistics such as weighted average, species diversity, species richness, and productivity. For these correlations, the aim is to better describe the distribution of quadrats, and no causality is implied. All correlations were expressed as Pearson product moment coefficients of correlation, and their statistical significance was verified using a one-tailed t-test.

4.4 Results

4.4.1 Plant Communities and Floristics

For vegetation descriptions, the importance values for all species sampled at each site are presented in Tables 4.3 (Triangle), 4.4 (Sand Run), 4.5 (Sugar Creek), 4.6 (Preston), 4.7 (Meadowville) and 4.8 (Seefus). Species observed but not sampled in each of the wetlands are presented in Table 4.9 for constructed wetland sites and Table 4.10 for reference wetlands. Summaries for species richness, diversity indices (H'), evenness, number of nonnative plants, and mean weighted average (WA) are presented in Tables 4.11 (constructed wetlands) and 4.12 (reference wetlands). Tables 4.13 (constructed) and 4.14 (reference) present the percentages by plant indicator status (IS) for sample quadrats and the site average.

Triangle Wetland

All dominant vascular plant species in the five quadrats sampled were persistent emergent herbaceous species. Quadrat 1, which was positioned in a wet meadow habitat with a saturated hydrologic regime, was dominated by red top (IV=13.6) and common rush (*Juncus effusus*) (IV=22.5), with various forbs and graminoids intermixed. There were two dominants in Quadrat 2, red top (IV=18.4) and rice cutgrass *(Leersia oryzoides)* (IV=26.7). The hydrologic regime was also saturated. Quadrat 3, located in a marsh type habitat (hydrologic regime semipermanently flooded), was dominated by cattail (*Typha latifolia*) (IV=19.9) and rice cutgrass (IV=18.7). Quadrat 4, which was located in the driest of any habitat sampled (designed to be a bottomland overflow area with temporarily flooded regime), did not any have clear dominant species; purple-leaved willow-herb (*Epilobium coloratum*) and red top had the highest importance values (IV = 9.3 and 10.0, respectively). For Quadrat 5, rice cutgrass was the clear dominant, with an IV = 45.8. This quadrat was flooded most of the growing season during the first year of this study, but during 1997, saturated soils developed by early July.

The species richness (all species) for the five quadrats ranged from 9 in Quadrat 5 to 32 in Quadrat 4, with a total richness for the whole study area of 116. During the preliminary study (Fortney and Edinger 1996) 112 species were reported for the site. For the whole site, 85.5% of the vascular flora was composed of native species. Quadrats 3 and 9, which were the wettest quadrats, had the lowest number of introductions and nonnative species and the lowest richness value of 17; Quadrat 4 (the driest) had the highest number of introductions. The species diversities by habitat ranged from a low of 1.03 for Quadrat 3 (wettest site) to a high of 1.34 for Quadrat 4, the driest.

The wetland IS value for the vegetation of the Triangle wetland as a whole was 3.1% OBLU, 12.4% FACU, 7.3% FAC, 53.9% FACW, and 23.1% OBLW. The percentages for the individual quadrats were varied. The highest percentage of FACW and OBLW occurred in Quadrat 3, a cattail-dominated marsh that also had the wettest hydrological regime. The lowest percentage in these categories occurred in Quadrat 4, the driest of the sample sites. As expected, the reverse correlation was found for FACU and FAC species in these quadrats.

The mean weighted average (WA) for all quadrats ranged from 0.73 for Quadrat 5, the area dominated by rice cutgrass, to 0.1.95 for Quadrat 4, the driest site and the site with the highest number of FACU and OBLU species. The combined WA for Triangle was 1.10. Any value below 2.50 is a score indicating a predominance of wetland plant species. This value is more heavily weighted to the wetland end of the 1-5 scale, and is ostensibly lower than the 2.53 site score reported by Fortney and Edinger (1996). This decrease may be due to changes made to the IS values of plant species in the most recent publication of *National List of Plant Taxa that Occur in Wetlands* (U.S. Fish and Wildlife Service, 1996), and in part by the increase in the number of OBL species since the initial study by Fortney and Edinger.

Sand Run Wetland

All dominant vascular plant species in the two quadrats sampled were persistent emergent herbaceous species. Quadrat 1, which was positioned in a wet meadow habitat with a saturated hydrologic regime, was dominated by rice cutgrass (IV=33.3) and common rush (IV=17.8), intermixed with various forbs and graminoids. Three herbs shared dominance in Quadrat 2, common rush (IV=22.6), seedbox (*Ludwigia alternifolia*) (IV=20.1), and marsh purslane (*Ludwigia palustris*) (IV=18.5). The hydrologic regime of Quadrat 2 was also semipermanently flooded. This quadrat tended to be flooded most of the growing season, but in Quadrat 1, saturated soils generally developed during the latter part of the growing season. The hydrology of the upper end of the latter quadrat was also influenced by sediments that had been deposited in the wetland from overflow events of Sand Run.

The species richness values (all species) for the two quadrats were 18 and 16, respectively, with a total site richness of 56 species. Excluding nonnative and introduced native species, site richness decreased 6 species to 50. Like Triangle, the presence of high numbers of nonnative species artificially inflates species richness.

The overall species richness and diversity of Sand Run were somewhat lower than those of Triangle. This is related to the fact that a larger portion of the Sand Run site has a larger area with permanent or semipermanent hydrological regimes. Also, Sand Run does not appear to have the overall spatial complexity of habitats. Conversely, Sand Run has a lower percentage of nonnative species, which also may be related to the wetter hydrological regimes of Sand Run, e.g., areas with permanent and semipermanently hydrological regimes. Such habitats are, doubtless more hospitable to many invasive, nonnative plant species.

The wetland IS value for the vegetation of the Sand Run wetland as a whole was 0.0% OBLU, 2.2% FACU, 0.0% FAC, 40.4% FACW, and 57.3% OBLW. Obviously, the highest percentage occurred in FACW and OBLW categories. This is consistent with the persistence of high water levels during the growing season, and is reflected in the low number of nonnative plants.

The mean weighted average (WA) for the site as a whole was 0.74, which clearly indicates a predominance of hydrophytes. The WA site score is also consistent with the types and extent of hydrologic regimes present.

Sugar Creek Wetland

All dominant vascular plant species in the six quadrats sampled were persistent emergent herbaceous species. Quadrat 1, which was positioned in a wet meadow habitat with a saturated hydrologic regime, was dominated by millet (IV=21.9) and deertongue grass (*Panicum clandestinum*) (IV=19.2), with various forbs and graminoids intermixed. Dominants were less obvious in Quadrat 2, with red top (IV=15.6), reed canary grass (*Phalaris arundinacea*) (IV=14.1), millet (IV=10.9), and deertongue grass (IV=10.4) being the most prominent species. At the time of the field survey, a levee in the lower section of the wetland had been breached by floodwater the previous winter, which caused one wetland cell to be partially drained. Quadrats 1 and 2 were located in this cell, and as a result, the hydrologic regime for both quadrats was drier than anticipated, with water tables well below the surface during much of the growing season. The breach has since been repaired and the intended saturated hydrologic regime was reestablished. This change in hydrology should have a marked influence on the vegetation development pattern for these sites.

The vegetation in Quadrats 3, 4, 5, and 6 were similar to Quadrat 2 in that reed canary grass was the dominant or codominant species, with importance values ranging from 21.3 to 46.4. For Quadrats 4, 5, and 6, millet shared dominance with various forbs and graminoids intermixed. For these quadrats, the hydrologic regime is saturated.

The species richness (all species) for the six quadrats ranged from 16 in Quadrat 4 to 25 in Quadrat 1, with a site richness value of 114. For the whole site, excluding nonnative and introduced species, the richness value was 97, and 85.1% of the flora was composed of native species. There are at least two contributing factors to the relatively high species diversity for Sugar Creek at this early stage of development. First, the site was completely inundated by overbank flow from Sugar Creek in January 1997, about eight months after construction of the site was completed. There was also evidence that the site was partially flooded a second time later that year. These two events doubtless introduced new species to the site. Second, there were small wetland areas existing on the site prior to construction that were largely left intact. These sites were probably sources for propagules. At the time of the fieldwork, no plantings had been made except for millet, switchgrass, and red top as cover crops.

The average percentages for IS values for the vegetation of the Sugar Creek wetland as a whole were 6.7% OBLU, 28.4% FACU, 11.7% FAC, 40.6% FACW, and 12.5% OBLW. The percentages for the individual quadrats varied, with FACW and FACU being, overall, the highest percentages. The high values for OBLU and relatively low values for FAC and OBLW are probably related to the newness of the site and the prevalence of habitats with saturated hydrologic regimes.

The average WA for this site was 2.02. While considerably higher than that of Triangle and Sand Run, the site's overall vegetation scores were well within the wetland vegetation range. Only Quadrats 5 and 6, with WA's of 2.51 and 2.60, respectively, had marginal scores. Both quadrats had high importance values for millet, a FACU species.

Preston Wetland

All dominant vascular plant species in the two quadrats sampled were persistent emergent herbaceous species. At the time of the site investigation, the hydrological regime of Quadrat 1 was controlled by a nearby beaver impoundment, making the site permanently inundated, a condition that persisted through 1997. Dominants at this site were rice cutgrass (IV=74.7) and woolgrass (*Scirpus atrocinctus*) (IV=14.1), with overall, a limited association of forbs and graminoids. The clear dominant in Quadrat 2 was rice cutgrass (IV=75.2), with no other species with an IV greater than 9.5. The prevalence of rice cutgrass probably reflects relatively recent disturbances or fluctuating water tables providing opportunities for rice cutgrass to colonize bare soil areas.

The species richness (all species) for the two quadrats was 5 and 7 and for the whole site were 34. These were relatively low values compared to the levels of species richness for other wetlands. The two factors important in understanding these low numbers are the influence of beaver as flooding agents, creating young, disturbed habitats, and the fact that the water tables throughout the site appeared to be high throughout the growing season, which may also be related to beaver activity. The persistently high water tables is further indicated by having only plants present with OBLW (87.7%) and FACW (12.2%) IS values. There were also no nonnative plants found within the wetland, and the average WA for the site was well within the wetland value at 0.86. Overall, this site resembles Quadrat 5 at Triangle and 1 and 2 at Sand Run.

Meadowville Wetland

This site was used as a reference wetland for the preliminary assessment study by Fortney and Edinger (1996). The important vascular plant species in the four quadrats sampled were all emergent, persistent graminoid and forb species. The most diverse quadrat was Quadrat 4, with 14 species. It also contained the only nonnative species. Dominant species were *Carex stricta* (IV = 21.2), virgin's bower (*Clematis virginiana)* (IV = 18.5), and tear thumb (*Polygonum sagittatum*) (IV = 18.5). This was also the driest site sampled, with a hydrological regime of saturated to temporarily flooded. The hydrologic regime resembled Quadrat 4 at Triangle. For Quadrat 1, which had a richness value of 8 and diversity index of 1.91, the most dominant species were rice cutgrass (IV = 24.3) and manna grass *(Glyceria striata*) (IV=20.7), followed by *Carex stricta* (IV = 20.7), monkey flower (*Mimulus ringens*) (15.5), and bedstraw (*Galium tinctorium*) (12.3). All species sampled were native. For Quadrat 2, the richness value was 13 and the diversity index was 2.03. The dominant species was blue joint grass (*Calamagrostic canadensis*) (IV=36), with the sedge *Carex stricta* an important but secondary species at IV=14.9. In Quadrat 3, cattail (IV = 72.0) was clearly dominant. This was the wettest of the four sample quadrats, and also had the lowest diversity index (0.89) and richness value (4 species). For the whole study area, the species richness was 118.

Quadrat 2 had the highest percentage of FACW and OBLW species. Quadrat 4 had the lowest percentage of FACW and OBLW. The average IS values for the four sample quadrats were OBLU 4.0%, FACU 11.0%, FAC 16.0%, FACW 31.3%, and OBLW 37.7%, with WA values ranging from 0.58 to 1.91 and a site average of 0.95. These values clearly represent a prominence of hydrophytes.

Seefus Wetland

The Seefus site was selected because it represented a site with recent disturbances (beaver activity) and with consistently high hydrologic regimes throughout the growing season (persistently semipermanently flooded to saturated). The uniformity in hydrology is directly related to the strong influence of present and past beaver activity on the site, which helped to maintain relatively stable water levels. These conditions are similar to the wettest wetland habitats created in the constructed wetlands.

The dominant species in Quadrat 1 were rice cutgrass (IV = 31.7) and American burreed (*Sparganium americanum*) (IV = 19.4). In Quadrat 2, rice cutgrass (IV = 39.0) and American burreed (IV = 37.7) were also the dominant species. No FACU and OBLU species were collected within the sample quadrats. For the site as a whole, FACW and OBLW species were the most important, with a combined IV of 88%. The WA for the site was consistent with the indices at 0.85, the lowest average WA value of any site.

4.4.2 Species Diversity and Richness

The species diversity and species richness of a wetland can be an important indicator of the relative level of several ecosystem functions, although high species diversity values may not always mean high functional levels (Mitsch and Gosselink 2000). The highest diversity levels occurred in the better-drained sample quadrats at the Triangle site, which were Quadrats 2 and 4. These were also the sites with the highest number of nonnative plant species. The sites with the lowest species diversity and richness were the sites with the wettest hydrological regime and the lowest number of nonnative species, a result not unexpected. Based on these findings, the number of non-native species was highest in the best-drained sites. By mid growing season, the water table at these areas was well below the surface. This created, basically, upland conditions similar to such disturbed sites as roadsides and old fields. The occurrence of unsaturated conditions appears to be important to the establishment of relatively large numbers of nonnative species. Whether these invasive species persist as the site develops can only be determined in later follow-up investigations. The presence of a relatively large number of nonnative species at the Triangle site could, in part, explain the low community coefficients between quadrats at this site and those at the Meadowville study area.

Like baseline soil conditions, it is important to establish baseline conditions for newly created or restored wetlands so that changes in such parameters as loss or gain of invasive species and increase or decrease of overall species diversity can be measured.

It is widely supported in the wetland literature (Gosselink and Mitsch 2000) that generally habitats with fluctuating water tables tend to have the highest species diversity. This appears to be applicable to the sites investigated here, i.e., the wetter the site the lower the diversity of species. Also, habitat disturbance, in general, leads to invasion of nonnative species (Smith 1996).

However, the high species richness at Triangle, at least in part, is an indicator of the diversity of habitats and the extent to which ecological edges were designed into the site. The uneven land surface, the amount of edges created between open water and emergent habitats, and the fluctuating water tables all contribute to the high diversity and richness values. The number of plant species planted to augment the diversity was also contributing factor. However, there are several planted species, including rice cutgrass, arrowleaf, and black elderberry, that would have probably been established naturally and colonized the area. Further, only a few planted species appear to have had any reproductive success. The most successful one appears to be the American bullrush (*Scirpus americanus*), which has become extensively established in 3-4 locations in the lower section of Triangle. Most planted species have not spread or colonized any site within the area, including the areas at which they were planted.

An additional factor contributing to the relatively high diversity of the Triangle site, and in part to the surprisingly high diversity for the young Sugar Creek site, is over-bank flow from the adjacent streams. Rivers and streams can be a major off-site source for propagules of plant species, i.e., a vector for seed dissemination from upstream sources. As a general observation for the Triangle site, there appeared to be an increase in the occurrence of wetland species following the flood event in 1994. Designing created or restored wetlands to be periodically flooded by nearby streams or rivers can be important in having a high instance of naturally established plant species.

There are some studies that suggest that rapidly establishing high plant species diversity is important in controlling such aggressive species as cattail. Reinartz and Warne (1993), working in small created wetlands in Wisconsin, found those seeded with native wetland species had much higher diversity and richness of native wetland species than unseeded wetlands after two years. Further, cattail cover after two years was lower in seeded sites. Their conclusion was that early introduction of a diversity of wetland plants may enhance the long-term diversity of vegetation in created wetlands and may limit colonization of cattail, preventing this species from developing near monoculture stands. However, during the past two years, the area dominated by broadleaf cattail in the Triangle wetland has increased significantly in both the upper and lower cells. This has occurred even though two plantings of hydrophytic species were made the first year following construction, along with naturally established hydrophytes. Therefore, augmenting species diversity with special plantings may not necessarily result in limiting encroachment from such aggressive species as cattail.

4.4.3 Productivity

Comparing standing crops for all wetlands, the reference sites had higher average values than the three constructed wetlands (Table 4.15). Preston had the highest standing crop (828.8 g/m^2), followed by Meadowville (816.2 g/m^2). The Seefus site, which was heavily impacted by beaver impoundment, had the lowest value of any reference site (596.9 g/m^2). This low standing crop was probably due to prolonged innundation and low water circulation, both limiting oxygen needed for plant growth (Pagtrick and Mikkelsen 1971, Armstrong 1975, Harms 1973). The three constructed sites had comparable standing crops (573.3 g/m^2, 524.8 g/m^2, 532.0 g/m^2) and hydrologic regimes, but differed greatly in vegetative cover. Reed canary grass was dominant in Sugar Creek, while virtually nonexistent in Triangle and Sand Run.

Comparing individual quadrats between and within constructed and reference sites (Table 4.15 and 4.16) showed that the highest standing crop values occurred where one species tended to dominate. The highest value occurred at Meadowville 3, which had a virtual monoculture of cattail, with a standing crop of 1047.8 g/m^2 (Table 4.16). The second highest value occurred at Preston 2, a site dominated by rice cutgrass. Sugar Creek 2 and 6 had the lowest standing crop value (390.0 g/m^2) and 428.7 g/m^2, respectively) of all 21 quadrats surveyed. Contributing to these low values were the occurrence of several large bare spots. Dominants here were millet and reed canary grass (Table 4.15). Sugar Creek 3 (836.3 g/m^2) and Sugar Creek 4 (721.6 g/m^2) were two quadrats that were obviously more productive than the others at this site. Reed canary grass was a dominant species in both quadrats.

The constructed and reference wetlands covered a range of four hydrologic regimes. The mitigated sites were generally drier, with three of 13 quadrats temporarily flooded, compared to only one of eight for the reference sites. No correlation could be found between productivity and hydrologic regime, using an averaged transect or wetland value, likely due to deep, permanent flooding of two transects. Studies on swamp tupelo and water tupelo have shown that height growth and relative growth rate are significantly lower in deep flooded regimes than surface flooded regimes (Harms 1973). When the permanently flooded water regime was eliminated from the calculation, a perfect correlation (r=1.00) occurred between averaged wetland productivity and water regimes of temporarily flooded, saturated, and semi-permanently flooded. Because of the low number of samples, this correlation was not statistically significant, although it does strengthen the theory that wetter transects have higher productivity, up to a certain point.

We averaged soil parameters for each transect and found significant correlations between percent carbon, hydrogen, nitrogen, sulfur, and aboveground biomass. Percent carbon was two to five times greater in the reference wetlands (Table 4.17), ranging from 4.58% at Preston and 10.8% at Seefus, to 1.88% and 2.71% at Sand Run and Sugar Creek, respectively. We found a significant correlation between carbon content and nitrogen (r = 0.96), sulfur (0.96), and hydrogen (0.83). Jackson (1958) and Stanford and Lancaster (1962) found nitrogen and sulfur are functions of soil organic content (Table 4.18). Boyd and Hess (1970), however, suggest that some nutrients are found in abundance due to mineralization of organic matter by microorganisms, and that this contributes to higher standing crop values. A study by Auclair et al. (1976) supports this by showing significant correlations between productivity and edaphic factors such as nitrogen, carbon content, potassium, sodium, and calcium.

Examination of soil nutrient levels by quadrat yielded three significant correlations (Table 4.18), but none when compared at the site level (Table 4.20). Hydrogen ion concentrations and productivity were positively correlated (r = 0.64). Hydrogen concentrations in reference wetlands ranged from 38.91 cmol(+)/kg in Meadowville 3 to 15.10 cmol(+)/kg for Preston 2, notably higher than 2.36 cmol(+)/kg for Triangle 2 (Table 4.20). When comparing productivity and other soil nutrients, we also found significant correlations for nitrogen (r= 0.67) and sulfur (r= 0.67). Auclair (1976) found a similar relationship in a study of nitrogen and productivity. Table 4.20 also shows that the variation in nitrogen content between reference and constructed wetlands was quite large, from a high of 0.866 ppm at Meadowville 3, to 0.01 ppm at Triangle 2 and Triangle 4. In many ecosystems, productivity is limited by the availability of mineralized nitrogen (Chambers 1996), and the relatively low productivity of the constructed sites, particularly Sugar Creek, may be due to the depauperate reserves of organic carbon and nitrogen of this recently constructed site. No significant correlations were found between productivity and other soil nutrients, including calcium, magnesium, potassium and phosphorus.

4.4.4 Floristics and Productivity

Using the data collected for the standing crop vegetative cover values for the 0.5 m^2 sample sites only, constructed sites had greater species richness, which is consistent with the other cover data derived from the ten 1 m^2 plots for each quadrat. Also, there was a general pattern of high standing crop values and low species richness in both constructed and reference wetlands, particularly in the reference wetlands (Figure 4.16). Ten out of 21 transects had standing crops of approximately 600 g/m^2. Seven out of the ten transects were from reference sites and three were from mitigated sites.

In an attempt to determine if there was a relationship between productivity and dominant plant species, species were chosen by the highest importance values in the ten most productive transects. Three dominant plant species were found in the ten highest productive transects. They were cattail, rice cutgrass, and reed canary grass (Tables 4.15 and 4.16). Two species, cattail and rice cutgrass, correlated positively but not significantly, while the third, reed canary grass, did not correlate at all (Table 4.21).

Cattail was a dominant species in two of the ten highest transects. These were Quadrat 3 at Meadowville and Quadrat 3 at Triangle. A positive correlation ($r = 0.95$) was calculated between the importance value of cattail and productivity. A study by Pearsall and Gorham (1956) showed that the aboveground standing crop in cattail sites is larger than that of sedge wetlands.

Rice cutgrass was the dominant species in six of the ten most productive quadrats, and in near monotypic numbers in three quadrats–1 in Meadowville, 1 in Preston, and 2 in Preston. These quadrats had standing crop values of approximately 820 g/m^2. Generally, as the rice cutgrass importance value decreased so did productivity. This can be seen in quadrats 2 and 5 Triangle, 1 and 2 in Sand Run, 1 and 2 in Seefus, and 4 in Meadowville, where rice cutgrass was codominant with other species, such as marsh purslane, *Eleocharis* spp., common rush, *Scirpus* spp., burreed, *Carex stricta*, and tearthumb.

The third dominant species, reed canary grass, was found in two of the ten most productive sites. Sugar Creek 3 and 4 had the highest standing crops of the mitigated sites. Other transects with reed canary grass (Sugar Creek 2 and 6) also had high importance values but low productivity values.

4.4.5 Wetland Indicators and Weighted Averages

Weighted averages (WA) and percentage of wetland indicator species (IS) at each site were used as indicators for dominance of hydrophytic species (Tables 4.11, 4.12, 4.13, and 4.14; Figure 4.1). All sites had summed percentages of FAC, FACW, and OBLW exceeding 50%. The WA for each of the 21 sample quadrats was less than 3.0. Above 3.0 indicates that a site may not be a wetland using the 1987 Federal Wetland Delineation Manual. Wentworth et al. (1988) recommended further evaluation of any site that has a WA value between 2.50 and 3.0, considering such values as representing marginal scores.

The WA values for all sites and quadrats were below 2.50, except two quadrats at Sugar Creek, which fell between 2.50 and 3.00 (Table 4.12). The vegetation on these sites, according to this assessment, only marginally meets the minimum criteria of 3.00. However, the hydrology of these sites was also impacted by the breached levee, causing the water table to be lower than originally designed, which could have influenced species composition and abundance.

4.4.6 Nonnative Species

The paucity of nonnative plant species in the wettest habitats of each study area reflects the unsuitability of these extreme wet habitats to such plants. Also, as apparent in Figure 4.1, the reference sites had the lowest percentage of nonnative plant species. There was also a correlation with the occurrence of nonnative species and hydrologic regime, with high proportion of nonnative species found in the driest sites. This was most apparent for Triangle and Sugar Creek. This suggests that a basic ecological principle applies here: invasive, nonnative plants, which are often plants adapted to mesic and xeric habitats, are often most successful in disturbed habitats. These sites not only were constructed wetlands, but had habitats that tended to have water tables below the surface during the summer season. Quadrat 4 at Triangle supported the most nonnative plants of any sample site at any area, the driest of all quadrats sampled. (See Table 5.1 for monthly water depth levels.)

It could not be ascertained from this study if the number of nonnative species was decreasing, increasing, or static at Triangle, the oldest of the constructed wetlands. Continuing to monitor this site for the next few years will probably answer this question. Another question is: will other invasive species invade the dryer portions of the Triangle wetland. There is some evidence to suggest that the number had increased in the two years since the preliminary study by Fortney and Edinger (1996); however, an increase of two, from 24 to 26, is not necessarily a noteworthy change. Of concern, though, is the occurrence of an invasive exotic plant species, purple loosestrife (*Lythrum salicaria*). This introduced plant from Europe (Strausbaugh and Core 1974) is a noxious weed in wetlands of the Northeast and is present in large numbers in some wetlands in West Virginia, particularly along the Ohio River. This species is already present in small numbers in a few wetlands in the Buckhannon area, including the Triangle wetland. The DOH staff has used hand removal methods to reduce its population in Triangle. Consistently, though, the wettest wetlands, e.g., Preston and Seefus had few, if any, nonnative plants.

4.4.7 Vegetation Similarity, Ordination, and Analysis

Table 4.22 shows the Sørensen Coefficients for the 15 possible site-pairs. Generally, the constructed wetlands were most similar to each other (mean coefficient = 0.42), and generally, the reference sites were most similar to each other (0.31). Conversely, similarity was somewhat lower, although not significantly lower, when constructed and reference sites were compared to each other (0.28). The exception was Meadowville. Because this index uses presence/absence data and not abundance, we could include the large number of plants that were seen in the study site, but did not occur in the sample sites. Both Triangle and Sugar Creek had high numbers of these taxa, as did the Meadowville site. Mean similarities between these three sites were relatively high (0.41).

The results of DECORANA for the 21 quadrats are shown in Figure 4.2. Each point on the graph corresponds to a sample quadrat, and thus represents the best fit of all of its individual species ordination coordinates. Thus, points close together represent quadrats with similar species composition, while those further apart have fewer plants in common. From the ordination, three groupings of quadrats, and one outlier, are apparent. Group 1 contains all six Sugar Creek sites and Triangle 4. These are all constructed wetlands, dominated by mixtures of barnyard grass and redtop (seeded species), and reed canary grass. These quadrats are generally drier, with either temporarily flooded or saturated hydrologic regimes. Group 2 is a transitional cluster of quadrats. On one end are Triangle 1 and 2, dominated by redtop and common rush on saturated soils. At the other end of the cluster are wetter quadrats with semipermanently flooded hydrologic regimes: Seefus 1 and Preston 1-2. These latter quadrats had fewer species present, and higher levels of dominance by obligate wetland species such as rice cutgrass and American burreed. Between two clusters are the constructed sites Sand Run 1 and 2, and Triangle 5. These quadrats are linked to Triangle 1-2 by high values for common rush, and to the Seefus and Preston sites by rice cutgrass. Triangle 3 is best linked to Group 2 because of its codominant, rice cutgrass, although cattail is present in significant numbers. Meadowville 3, with a virtual monoculture of cattail, is unique, and best considered an outlier. Group 3 consists of Meadowville 2 and 4, and is something of an anomaly. Meadowville 2 was dominated by blue joint grass, while virgin's bower was co-dominant at Meadowville 4. Neither of these plants occurred in any other wetland. The sedge, *Carex stricta*, was common to both quadrats with relatively high IV's, and is likely responsible for the grouping of these two points.

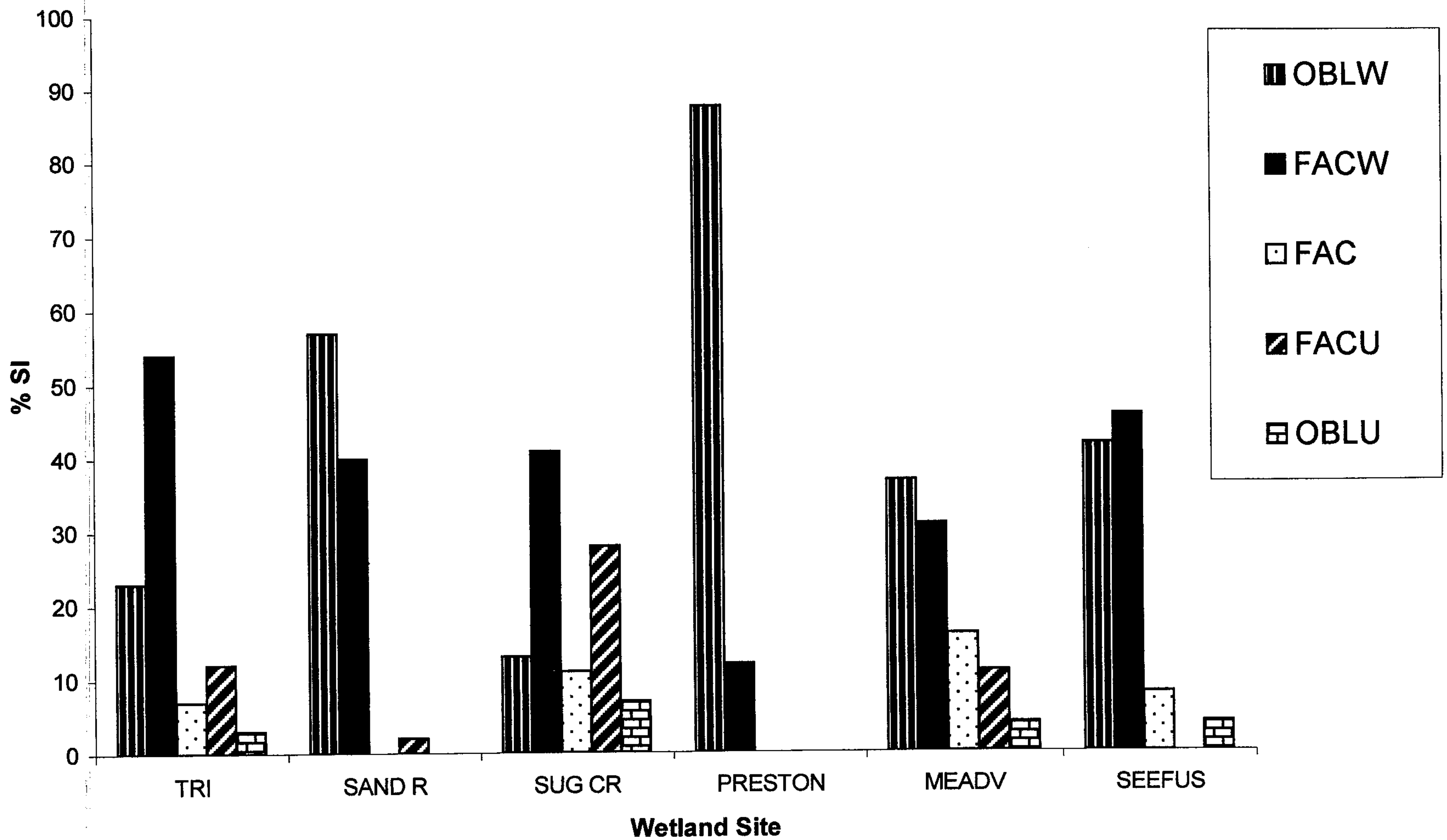
Only Axis 1 showed significant correlations with environmental variables (Table 4.23). Sulfur, carbon, nitrogen, and pH (expressed as H_3O^+ concentration) all showed strong correlation values (r) greater than |0.5| ($p \leq 0.05$, one-tailed test). These correlations generally correspond to the distribution of quadrats along Axis 1. Constructed wetlands, less acidic, and relatively lower in sulfur, nitrogen, and organic matter, occupied the middle and right side of the ordination. Reference sites, with higher levels of these soil nutrients and being more acidic, were found in the middle-left portion. The lower acidity of the constructed sites is consistent with a study cited by Mitsch and Gosselink (2000), which reported that for constructed wetlands, initial flooding often results in a convergence of soil pH toward neutrality. Acidic soils tend to become more alkaline, while alkaline soils become more acidic. The dichotomy of nutrient levels and wetland type (reference vs. constructed) in this study has several possible explanations. Because the reference sites tended to be wetter, higher nutrient levels there may be caused by more frequent innundation and accompanying nutrient pulses from feeder streams. Further information on the hydroperiods of these quadrats could confirm this. It may also be a consequence of ecosystem maturity. That is, the reference sites may have more functional communities of microbial organisms, active in the reduction of organic carbon, sulfur, iron and nitrates.

As discussed above, the ordination also suggests a wetness gradient along Axis 1. Drier, constructed sites tended to be on the right side of the graph, while a somewhat wetter mixture of constructed and reference sites occurred in the middle-left. Although hydrologic regime corresponds to degree of wetness, it is a non-linear, qualitative variable, and thus we could not calculate a correlation between it and the ordination axes. As an alternative measure of the degree of wetness, we used Weighted Average. This is a quantitative statistic based on a combination of wetland indicator status and abundance. A value of less than 3.0, based on a 1.0-5.0 scale, indicates wetland vegetation. Sites with scores between 2.5 and 3.0 are borderline wetlands. This statistic correlates very strongly with Axis 1 ($r=-0.720$, $p\leq0.025$), confirming the wetness gradient in the ordination. Mean weighted averages for the three ordination clusters and one outlier from right to left on the graph are 2.0, 0.74, 1.33, and 0.58, respectively.

A second gradient suggested by the ordination is time. The youngest and most recently constructed wetland (Sugar Creek) occurs on the extreme right side of the ordination, while the older constructed sites, Triangle and Sand Run, are positioned in the center. The reference wetlands occur from left-center to left, thus completing a temporal line that represents youngest to well established constructed wetands to natural sites. As the constructed wetlands mature (soils, vegetative cover, etc.), their position relative to the reference sites should converge, and the two should more closely resemble each other. This can be followed with periodic re-sampling of the wetlands.

Species richness, species diversity, and productivity also showed significant correlations with Axis 1, although not as strong as weighted average (Table 4.23). Species richness and diversity tended to be higher in the better drained constructed sites, although this may be due, in part, to the relatively higher numbers of nonnative plants and habitat diversity within the site. Conversely, productivity was greater in the wetter reference wetlands, although the degree of fluctuation of the water level appeared to be a modifying factor. Sand Run 2 was permanently flooded, making it one of the wettest quadrats; however, it also had a low productivity. The relationships between species diversity, species richness and ecosystem function have long been subjects of debate. In a study of Midwestern grasslands, Tilman and Downing (1994) found the more diverse plots retained the most nitrogen, accumulated the most biomass, and were quickest to recover from environmental perturbation. Mitsch and Gosselink (2000), however, report a study of freshwater marshes in eastern Canada, where species richness and productivity were inversely related. This corresponds more closely to productivity and diversity data from present study sites.

Figure 4.1. Chart showing the percentage of species for each wetland study site by wetland vascular plant species index (SI).



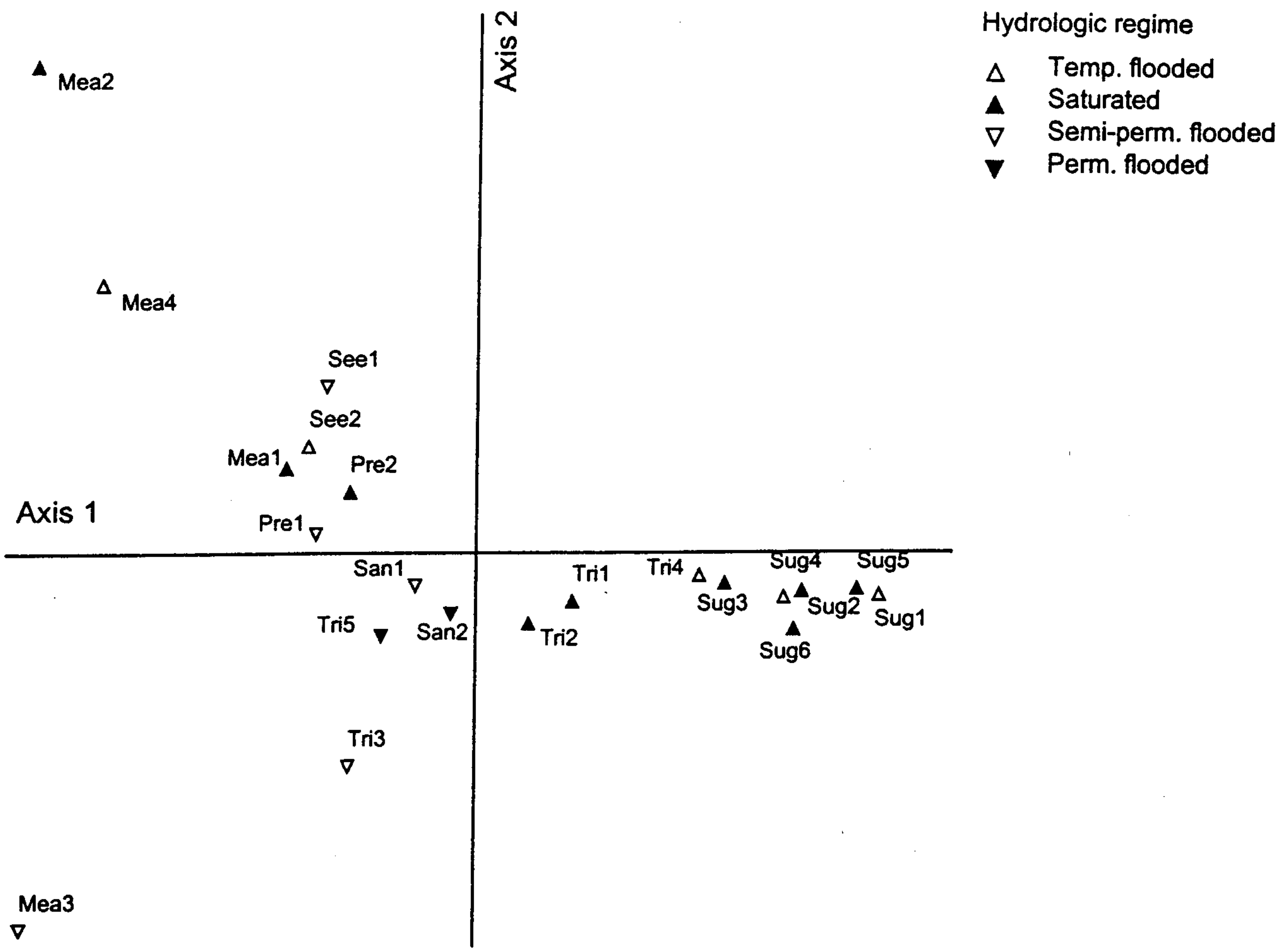


Figure 4.2. Ordination of the 21 quadrats sampled in the six wetland study areas using DECORANA.

Table 4.1. Number of quadrats sampled at each site, cover class at each site, and other cover classes present at each wetland study site.

Wetland Site	Number of Quadrats	Cover Classification	Other Cover Classes Present
Triangle	5	Herbaceous	Open Water
Sand Run	2	Herbaceous	Open Water; Scrub-Scrub
Sugar Creek	7	Herbaceous	Open Water: Scrub-Scrub
Preston	2	Herbaceous	Scrub-Scrub; Overflow Forest; Open Water
Meadowville	4	Herbaceous	Scrub-Scrub; Overflow Forest
Seefus	2	Herbaceous	Open Water

Table 4.2. Cover classes based on Daubenmire (1968) used to quantify the percent ground cover for vascular plant species sampled in 1 m^2 and 0.5 m^2.

Cover Class	Percent Cover Ranges
1	0 - 05
2	5 - 25
3	25 - 50
4	50 - 75
5	75 - 95
6	95 - 100

Table 4.2a. Wetland Indicator Status (IS) and probability ranges (Reed 1988) for plant species occurring in wetlands of the United States, and an indicator index value assignment for each status.

Indicator Status		Wetland Frequency	Indicator Index
Obligate Wetland	(OBLW)	>99%	1
Facultative Wetland	(FACW)	67-99%	2
Facultative	(FAC)	34-66%	3
Facultative Upland	(FACU)	1-33%	4
Obligate Upland	(OBLU)	<1%	5

Table 4.3. Importance values (IV = rel den + rel % grd cover/2), wetland indicator status (IS), and origin status (native or introduced) for herbaceous species sampled in the Triangle wetland. Asterisks (**) indicate planted by DOH. Data collected in 1996.

Species	DOH Intro (**)	IS	(N) Native (I) Intro	IV by Quadrat 1	2	3	4	5
Agrostis alba	**	2-	N	13.8	18.4	2.6	10.0	
Achillea millefolium		4	I				0.6	
Alisma subcordatum		1	N	1.0				1.3
Ambrosia artemisiifolia		4	N				3.9	
Asclepias syriaca		4-	N				0.6	
Bidens frondosa		2	N		0.9	9.9		
Carex lurida	**	1	N				0.6	
Carex projecta		2	N		0.9			
Carex scoparia		2	N	2.1				
Carex tribuloides		2+	N	2.1				
Carex vulpinoidea		1	N				2.8	
Chelone glabra		1	N		0.9	1.3	0.6	
Cirsium muticum		1	N				3.0	
Collinsia verna		3-	N		1.8			
Convolvulus sepium		3-	N	4.2			2.6	
Epilobium coloratum		2+	N	6.2	9.0		9.3	
Eleocharis obtusa		1	N	5.1	4.5	5.0		10.3
Erechtites hieracifolia		4	N	7.3	0.9	5.0	1.3	
Eupatorium perfoliatum		2	N				0.6	
Galium mollugo		4	I		1.8			1.3
Holcus lanatus		4	I	1.0				
Hypericum mutilum		2	N		0.9		3.2	
Impatiens capensis		2	N	4.1	1.8	1.3	2.2	
Juncus effusus		2+	N	22.5	3.6	3.8	2.2	
Juncus acuminatus		1	N		0.9	2.6		
Juncus tenuis		3-	N	2.1	1.8	1.3	2.6	
Leersia oryzoides		1	N	2.0	26.7	18.7		45.8
Lemna minor		1	N		0.9	8.8		7.7
Lolium perenne		4-	I	1.0	0.9			
Ludwigia palustris		1	N	6.1	7.2	7.4		19.0
Lycopus uniflorus		1	N	1.0	9.0		2.6	
Mentha arvensis		2	I				1.5	
Oxalis europaea		5	I	1.0			5.4	
Panicum clandestinum		3+	N				1.9	
Panicum virgatum		3	N	1.0	0.9		2.8	
Phalaris arundinacea		2	N				6.8	
Plantago lanceolata		5	I				0.6	
Polygonum coccineum		1	N				3.4	
Polygonum punctatum		1	N	7.9	0.9	2.5	0.6	
Potamogeton epihydrus		1	N			2.6		
Ranunculus repens		3	N		0.9			
Rubus sp.							0.6	
Rumex crispus		4	I	3.1		1.3		
Sagittaria latifolia	**	1	N		0.9			3.9
Setaria glauca		3	I				5.4	
Solanum carolinense		5	N	2.1			6.9	
Sparganium americanum		1	N			6.1		8.2
Typha latifolia		1	N		1.8	19.9		2.6
Unknown plant							0.6	
Verbesina alterniflora		3	N				1.3	
Vernonia altissima		3	N		1.8		6.9	
Vernonia noveboracensis		2+	N	3.1				
Vicia angustifolia		4-	I				6.4	

Table 4.4. Importance values (IV = rel den + rel % grd cover/2), wetland indicator status (IS), and origin status (native or introduced) for herbaceous species sampled in the Sand Run wetland. Asterisks (**) indicate planted by DOH. Data collected in 1996.

Species	DOH Intro (**)	IS	(N) Native (I) Intro	IV by Quadrat	
				1	2
Agrostis alba	**	2-	N	1.0	
Ajuga reptans		4	I		2.3
Asclepias incarnata		1	N		1.2
Bidens frondosa		2	N	6.1	5.8
Boehmeria cylindrica		2+	N	2.1	1.2
Carex scoparia		2	N	1.0	
Carex stipata		1	N	3.1	
Carex vulpinoidea		1	N	1.0	
Eleocharis obtusa		1	N	6.1	4.7
Galium tinctorium		1	N	8.2	10.9
Hypericum mutilum		2	N	1.0	
Juncus effusus		2+	N	17.8	22.6
Juncus acuminatus		1	N	7.1	5.8
Leersia oryzoides		1	N	33.3	
Ludwigia alternifolia		2+	N	1.0	20.1
Ludwigia palustris		1	N	6.1	18.5
Lysimachia nummularia		2-	I		1.2
Mimulus ringens		1	N		1.2
Penthorum sedoides		1	N	2.0	1.2
Polygonum sagittatum		1	N	1.0	
Potamogeton sp.		1			1.2
Rumex crispus		4	I		1.2
Scutellaria ovata		4	N	1.0	
Sparganium americanum		1	N		1.2
Typha latifolia		1	N	1.0	

Table 4.5. Importance values (IV = rel den + rel % grd cover/2), wetland indicator status (IS), and origin status (native or introduced) for herbaceous species sampled in the Sugar Creek wetland. Asterisks (**) indicate planted by DOH. Data collected in 1996.

Species	DOH Intro (**)	IS	(N) Native (I) Intro	IV by Quadrat 1	2	3	4	5	6
Acalypha rhomboidea		4-	N	4.8	3.1			4.8	
Agrostis alba	**	2-	N	11.3	15.6	6.9	5.1	4.5	14.3
Ambrosia artemisiifolia		4	N		1.6	0.9		9.8	
Amphicarpa bracteata		3	N			0.9	1.4		
Asclepias incarnata		1	N						1.3
Asclepias syriaca		5-	N	5.5					
Aster linariifolus		3	N		1.6				
Barbarea vulgaris		4	I	1.8	1.6	0.9	1.4		
Bidens frondosa		2	N						1.3
Cassia nictatans		4-	N					1.6	
Carex stricta		1	N		1.6				
Carex vulpinoidea		1	N			4.3	1.4		
Dactylis glomerata		4	I	0.9					
Echinochloa crusgalli	**	4	I	21.9	10.9		18.3	15.0	31.4
Eleocharis obtusa		1	N						1.3
Eleocharis tenuis		2+	N		7.8		3.7		1.3
Erigeron annuus		4	N		3.1				
Galium tinctorium		1	N	0.9	1.6	2.6	4.3	1.6	
Glechoma hederacea		4	I	2.7				3.1	
Hypericum mutilum		2	N	0.9	4.7		1.4	0.8	
Impatiens capensis		2	N	0.9					
Juncus effusus		2+	N	1.8		5.2	1.4		1.3
Juncus acuminatus		1	N			10.4			
Juncus tenuis		3-	N	1.8	1.6		5.1	3.9	2.2
Lolium perenne		4-	I	0.9					
Ludwigia alternifolia		2+	N			0.9			
Ludwigia palustris		1	N		3.1	7.6	4.3		9.1
Lycopus uniflorus		1	N	0.9		3.4	1.4	0.8	1.3
Mimulus ringens		1	N			3.4	1.4		
Oenothera fruticosa		3	N					0.8	
Oxalis europaea		5	I	5.6	4.7	2.6	1.4	10.7	1.3
Panicum clandestinum		3+	N	19.2	10.4	4.3	1.4	6.7	3.5
Phalaris arundinacea		2	N	2.7	14.1	34.0	46.4	23.5	21.3
Phleum pratense		4	I						1.3
Plantago lanceolata		5	I	2.7		0.9		2.3	
Polygonum coccineum		1	N					1.5	
Polygonum sagittatum		1	N			0.9			
Polygonum sp.					3.1	2.6			
Potentilla simplex		4-	N	0.9		1.7		1.6	1.3
Pteridium aquilinum		4	N	1.8					
Rubus sp.									1.3
Rumex crispus		4	I		1.6				1.3
Scirpus cyperinus		2+	N			0.9			
Scirpus polyphyllus		1	N		3.1				
Scutellaria lateriflora		2+	N		1.6	0.9		1.6	
Scutellaria ovata		4	N	1.8					
Sericocarpus linifolius			N			2.6			
Solanum carolinense		5	N		1.6				
Taraxacum officinale		4-	I	1.8					
Trifolium pratense		4-	I	2.7				2.4	1.3
Unknown plant				0.9					2.6
Verbena urticifolia		4	N		1.6				
Vernonia altissima		3	N			0.9		0.8	
Viola appalachiensis		4	N	2.7					
Viola papilionacea		3	N					2.4	

Table 4.6. Importance values (IV = rel den + rel % grd cover/2), wetland indicator status (IS), and origin status (native or introduced) for herbaceous species sampled in the Preston wetland. Data collected in 1996.

Species	IS	(N) Native (I) Intro	IV by Quadrat	
			1	2
Boehmeria cylindrica	2+	N	3.7	
Carex gynandra	1	N		2.9
Galium tinctorium	1	N		3.6
Impatiens capensis	2	N		2.9
Juncus effusus	2+	N	3.7	
Leersia oryzoides	1	N	74.7	75.2
Ludwigia palustris	1	N		9.5
Polygonum punctatum	1	N		2.9
Polygonum sagittatum	1	N		2.9
Scirpus atrocinctus	2+	N	14.1	
Sparganium americanum	1	N	3.7	

Table 4.7. Importance values (IV = rel den + rel % grd cover/2), wetland Index, and origin status (native or introduced) for herbaceous species sampled in the Meadowville wetland. Data collected in 1996.

Species	WI	(N) Native (I) Intro	IV by Quadrat			
			1	2	3	4
Apocynum cannabinum	4	N				3.1
Asclepias incarnata	1	N				0.8
Aster sp.						2.8
Boehmeria cylindrica	2+	N		1.3	12.6	2.8
Calamagrostis canadensis	2+	N		36.0		
Carex stipata	1	N		7.8		
Carex stricta	1	N	20.7	14.9	8.6	21.2
Carex tribuloides	2+	N		1.3		
Clematis virginiana	3	N				18.5
Cuscuta gronovii	3	N				0.8
Galium asprellem	1	N		7.7		5.3
Galium tinctorium	1	N	12.3	3.9		8.5
Glyceria canadensis	1	N	2.7	1.3		
Glyceria striata	1	N		1.3	6.9	
Hypericum perforatum	5	I				1.4
Impatiens capensis	2	N	12.0	7.6		8.3
Leersia oryzoides	1	N	24.3			
Ludwigia palustris	1	N	7.0			
Mimulus ringens	1	N	15.5	3.9		1.6
Polygonum coccineum	1	N				5.3
Polygonum punctatum	1	N		1.3		
Polygonum sagittatum	1	N	5.5	11.6		13.8
Typha latifolia	1	N			72.0	
Verbesina alterniflora	3	N				5.8

Table 4.8. Importance values (IV = rel den + rel % grd cover/2), wetland Index, and origin status (native or introduced) for herbaceous species sampled in the Seefus wetland. Data collected in 1996.

Species	IS	(N) Native (I) Intro	IV by Quadrat	
			1	2
Carex blanda	3	N	5.6	2.0
Carex gynandra	1	N	4.8	
Carex scoparia	2	N	5.6	
Galium tinctorium	1	N	9.8	2.0
Hypericum mutilum	2	N	5.3	
Impatiens capensis	2	N	7.8	7.0
Leersia oryzoides	1	N	31.7	39.0
Mimulus ringens	1	N	1.3	
Polygonum sagittatum	1	N	2.6	2.0
Scirpus atrocinctus	2+	N	2.6	4.1
Scutellaria lateriflora	2+	N	2.6	6.1
Sparganium americanum	1	N	19.4	37.7

Table 4.9. Species seen but not sampled in Triangle, Sand Run and Sugar Creek constructed wetlands.

Triangle Species	IS[1]	N or I[2]	Sand Run Species	IS[1]	N or I[2]	Sugar Creek Species	IS[1]	N or I[2]
Acer saccharinum	2	N	Acer saccharinum	2	N	Achillea millefolium	4	I
Achilea millefolium	4	I	Carex tribuloides	2+	N	Agrostis hyemalis	3	N
Amelanchier laevis		**	Carex intrumescens	2+	N	Allium canadense	4	N
Aronia arbutifolia	2	**	Carex baileyi	1	N	Alnus serrulata	1	N
Asclepias incarnata	1	N	Carex lupulina	1	N	Ambrosia artemisiifolia	4	N
Barbarea valgaris	4	I	Cephalanthus occidentalis	1	N	Anthoxanthum ordoratum	4	N
Cardamine arenicola	4	I	Cornus amomum	2	N	Apocynum cannabinum	4	N
Carex intrumescens	2+	N	Desmodium perplexum		N	Arctium minus	4-	N
Carex normalis	4	N	Eleocharis tenuis	2+	N	Brasenia schreberi	1	N
Carex squarrosa	2	N	Erigeron annuus	4	N	Carex vulpinoidea	1	N
Carex stipata	1	N	Eupatorium perfoliatum	2+	N	Carex caroliniana	4	N
Carex striata	1	N	Gentiana clausa	2	N	Carex tribuloides	2+	N
Cirsium arvense	4	I	Helenium flexulosum	3-	I	Carex scoparia	2	N
Cleome spinosa	4-	I	Hypericum punctatum	3-	N	Cornus amomum	2	N
Cyperus strigosus	2	N	Hystrix patula	5	N	Cyperus strigosus	2	N
Dactylis glomerata	4	I	Ilex verticillata	2+	N	Desmodium perplexum		N
Eleocharis tenuis	2+	N	Impatiens capensis	2	N	Dianthus armeria	5	I
Erigeron annuus	4	N	Lobelia cardinalis	2+	N	Eleocharis tenuis	2+	N
Eupatorium coelestinum	3	N	Ludwigia alternifolia	2+	N	Epilobium coloratum	2+	N
Eupatorium fistulosum	2	N	Lysimachia quadrifolia	4-	N	Erigeron canadensis	5	N
Galium asprellum	1	N	Lysimachia nummularia	2-	I	Eupatorium perfoliatum	2+	N
Galium obtusum	2+	N	Onoclea sensibilis	2	N	Eupatorium coelestinum	3	N
Galium tinctorium	1	N	Penstemon laevigatus	4	N	Euphorbia maculata	2	N
Glyceria canadensis	1	N	Phalaris arundinacea	2	N	Galium asprellum	1	N
Hypericum elipticum	1	N	Platanus occidentalis	2-	N	Gratiola neglecta	1	N
Glyceria striata	1	N	Polygonum aviculare	4	I	Gratiola virginicum	1	N
Helenium autumnale	2+	N	Rhus radicans	3	N	Helenium autumnale	2+	N
Ilex verticillata	2+	N	Salix nigra	2+	N	Heliopsis scabra		N
Lindernia dubia	1	N	Scirpus polyphyllus	1	N	Holcus lanatus	4	I
Lobelia cardinalis	2+	N	Scutellaria lateriflora	2+	N	Hypericum ellipticum	1	N
Lycopus americanus	1	N	Thelypteis asplenioides		N	Lolium prenne	4-	I
Lobelia inflata	4	N				Lysimachia quadrifolia	4-	N
Lysimachia nummularia	2-	I				Lysimachia nummularia	2-	N
Mimulus ringens	1	N				Lysimachia ciliata	2	N
Myosotis scorpioides	1	N				Oenothera perennis	3+	N
Onoclea sensibilis	2	N				Onoclea sensibilis	2	N
Nuphar advena	1	N				Panicum virgatum	3	N
Osmunda cinamomea	2	N				Penthorum sedoides	1	N
Ranunculus repens		N				Polygonum hydropiperoides	1	N
Penthorum sedoides	1	N				Polygonum hydropiper	1	N
Polygonum cespitosum	4	I				Potamogeton epihydrus	1	N
Potamogeton diversifolius	1	N				Potentilla simplex	4-	N
Potentilla norvegiea	4	I				Potentilla norvegica	4	N
Prunella vulgaris	4+	N				Rhus radicans	3	N
Rorippa islandica	1	N				Rorippa islandica	1	N
Rosa multiflora	4	I				Rosa palustris	1	N
Quercus bicolor	2+	**				Rudbeckia triloba	4	N
Sajureja vulgaris	5	I				Sambucus canadensis	2	N
Salix nigra	2+	N				Satureja vulgaris	5	N
Sambucus canadensis	2	N				Scipus rubrocosus	2+	N
Scirpus americanus	1	**				Scirpus validus	1	N
Scirpus atrovirens	1	N				Solidago sp.		
Scirpus validus	1	N				Sparganium americanum	1	N
Senecio aureus	2	N				Specularia perfoliata	3	N
Sonchus asper	3	I				Thallictrum polyganum	3+	N
Sisyrinchium angustifolium	2-	N				Thelypteris palustris	2+	N
Spirea alba	2+	**				Trifolium agrarium		I
Trifolium agrarium		I				Trifolium repens	4-	N
Valerianella locusta		I				Trifolium pratense	4-	I
Verbascum blattaria	5	I						
Verbascum thapsus		I						
Verbena hastata	2+	N						
Verbena utricifolia		N						

[1] Hydrologic Indicator Status
[2] Native (N); Introduced (I)
** Planted by DOH

Table 4.10. Species seen but not sampled in reference wetlands.

Preston	IS[1]	N or I[2]	Meadowville	IS	N or I[2]	Seefus	SI[1]	N or I[2]
Acer rubrum	2+	N	Acer saccharinum	2	N	Carex intrumescens	2+	N
Agrostis alba	2-	N	Agrimonia gryopsepala	4	N	Carex larida	1	N
Alnus serrulata	1	N	Alnus serrulata	1	N	Carex baileyi	1	N
Apocynum medium		N	Apios americana	2	N	Carex laevivaginata	1	N
Cardamine bulbosa	1	N	Carex squarrosa	2	N	Carex incomptera	2+	N
Carex lurida	1	N	Carex crinita	1	N	Dennstaedtia punctilobula	5	N
Carex tribuloides	2+	N	Carex scoparia	2	N	Eleocharis tenuis	2+	N
Carex laevivaginata	1	N	Carex molesta	4	N	Glyceria striata	1	N
Cephalanthus occidentalis	1	N	Carpinus carolinana	3	N	Impatience capensis	2	N
Clematis virginiana	3	N	Convolvulus sepium	3-	N	Juncus effusus	2+	N
Cornus amomum	2	N	Cornus amomum	2	N	Osmunda cinamomea	2	N
Pyrus coronaria		N	Cornus rugosa		N	Panicum clandestinum	3+	N
Cuscuta gronovii		N	Crataegus sp.		N			
Glyceria striata	1	N	Dianthus ameria	5	I			
Gratiola neglecta	1	N	Epilobium coloratum	2+	N			
Nuphar advena	1	N	Galium mollugo		I			
Onoclea sensibilis	2	N	Galium obtusum	2+	N			
Panicum clandestinum	3+	N	Holcus lanatus	4	I			
Prunus serotina	4	N	Hypericum elipticum	1	N			
Salix nigra	2+	N	Hypericum perforatum		I			
Sambucus canadensis	2	N	Juncus effusus	2+	N			
Symplocarpus feotidus	1	N	Juncus tenuis	3-	N			
Prunus serrotina	4	N	Juncus acuminatus	1	N			
			Lobelia cardinals	2+	N			
			Lobelia spicata	3-	N			
			Lugwigia alternafolia	2+	N			
			Lycopus americanus	1	N			
			Lycopus uniflorus	1	N			
			Mimulus ringens	1	N			
			Oxalis europaea	5	I			
			Oxypolis rigidor	1	N			
			Phalaris arundinacea	2	N			
			Phleum pratense	4	I			
			Platinus occidentalis	2-	N			
			Prunus serotina	4	N			
			Pyrus coronaria		N			
			Rosa palustris		N			
			Rubus sp.		N			
			Rudbeckia triloba	4	N			
			Rumex acetocella		I			
			Rumex crispus	4	I			
			Sagittaria latifolia	1	N			
			Salix nigra	2+	N			
			Setaria glauca	3	I			
			Sisyrinchium angustrifolium	2-	N			
			Solanum carolinense	5	N			
			Spiraea alba	2+	N			
			Solidago graminifolia	3	N			
			Sparganium americanum	1	N			
			Stenanthium gramineum	2	N			
			Thallictrum polygamum	3+	N			
			Viburnum recognitum	2-	N			
			Vernonia noveboracensis	2+	N			
			Verbesina alternifolia	3	N			

[1] Hydrologic Indicator Status

[2] Native (N); Introduced (I)

* Includes species seen but not sampled.

Table 4.11. Summary table for vegetation characteristics by quadrat for Triangle, Sand Run, and Sugar Creek constructed wetland sites; based on data collected during the 1996 and 1997 growing seasons.

PARAMETER	TRIANGLE						SAND RUN			SUGAR CREEK						
	QUADRAT					Whole Site*	QUADRAT		Whole Site*	4. QUADRAT						Whole Site*
	1	2	3	4	5		1	2		1	2	3	4	5	6	
Richness (Total species)	22	25	18	32	9	**116**	18	16	**56**	25	22	23	16	21	19	**114**
Richness (Number and % of native species)	18/ 81.8	23/ 92.0	17/ 94.4	26/ 81.3	9/ 100	**53/ 45.7**	15/ 100	13/ 81.2	**50/ 89.3**	16/ 64.0	18/ 81.8	20/ 87.0	13/ 81.3	18/ 85.7	14/ 73.7	**97/ 85.1**
Nonnative and planted species (Number and %)	2/ 9.1	2/ 8.0	1/ 5.6	6/ 18.7	0/ 0.0	**63/ 54.3**	0/ 00	3/ 18.8	**6/ 10.1**	9/ 36.0	4/ 18.2	3/ 13.0	3/ 18.7	3/ 14.3	5/ 26.3	**17/ 14.9**
Shannon Index (H')	2.66	2.49	2.47	3.14	1.64	**3.1**	2.22	2.19	**2.21**	2.63	2.40	2.50	1.90	2.54	2.12	**2.35**
Shannon Index (H') (Excluding nonnative and planted species)	2.51	2.41	2.43	2.92	1.64	---	2.22	2.05	---	2.20	2.18	2.38	1.63	2.19	2.00	---
Evenness (E)	0.86	0.77	0.87	0.90	0.75	**0.83**	0.77	0.79	**0.78**	0.82	0.78	0.79	0.69	0.83	0.73	**0.77**
Mean Weighted Average	1.22	1.00	0.59	1.95	0.73	**1.10**	0.46	1.02	**0.74**	2.09	1.74	1.42	1.73	2.51	2.60	**2.02**

Table 4.12. Summary table for vegetation characteristics by quadrat for Preston, Seefus, and Meadowville wetland reference sites; based on data collected in 1996 and 1997.

PARAMETER	MEADOWVILLE					PRESTON			SEEFUS		
	QUADRAT				Whole Site*	QUADRAT		Whole Site	QUADRAT		Whole Site
	1	2	3	4		1	2		1	2	
Richness (Total species)	8	13	4	14	**112**	5	7	**34**	12	8	**78**
Richness (native species) (Number and % of native species)	8/ 100	13/ 100	4/ 100	14/ 92.9	**88/ 78.6**	5/ 100	7/ 100	**34/ 100**	12/ 100	8/ 100	**78/ 100**
Nonnative and planted species (Number and %)	0/ 0%	0/ 0%	0/ 0%	1/ 7.1	**24/ 21.4**	0.0	0.0	**0.0**	0.0	0.0	**0/ 100%**
Shannon Index (H')	1.91	2.03	0.89	2.32	**7.15**	0.86	0.97	**0.92**	2.10	1.46	**1.78**
Shannon Index (H') (Excluding nonnative and planted species)	1.91	2.03	0.89	2.28	----	0.86	0.97	----	2.10	1.46	
Evenness (E)	0.92	0.79	0.64	0.86	**0.80**	0.53	0.50	**0.52**	0.84	0.70	**0.77**
Mean Weighted Average	0.58	0.75	0.57	1.91	**0.95**	0.83	0.89	**0.86**	0.98	0.71	**0.85**

* Includes species seen but not sampled for entire wetland area.

Table 4.13. Percentage of plant species by wetland Indicator Status (IS) for sample quadrats at the Triangle, Sand Run, and Meadowville wetland study sites; based on data collected in 1996 and 1997.

INDICATOR STATUS	TRIANGLE						SAND RUN			SUGAR CREEK						
	QUADRAT					Whole Site	QUADRAT		Whole Site	QUADRAT						Whole Site
	1	2	3	4	5		1	2		1	2	3	4	5	6	
Obligate Wetland (OBLW)	23.1	53.7	74.9	13.7	98.7	**53.0**	69.0	45.8	**57.3**	1.8	9.7	34.5	12.8	3.9	13.5	**12.5**
Facultative Wetland (FACW)	53.9	35.5	17.5	36.3	0.0	**28.6**	30.0	50.7	**40.4**	17.7	45.3	51.6	59.1	30.3	41.1	**40.6**
Facultative (FAC)	7.3	7.2	1.2	23.8	0.0	**8.8**	0.0	0.0	**0.0**	21.2	14.0	6.4	7.9	14.6	6.0	**11.7**
Facultative Upland (FACU)	12.4	3.6	6.2	12.9	0.0	**7.0**	1.0	3.5	**2.2**	45.2	24.3	3.7	19.7	38.2	38.0	**28.4**
Obligate Upland (OBLU)	3.1	0.0	0.0	13.1	1.3	**3.4**	0.0	0.0	**0.0**	14.0	6.5	3.7	1.4	13.0	1.3	**6.7**

Table 4.14. Percentage of plant species by wetland Indicator Status (IS) for sample quadrats at the Meadowville, Preston, and Seefus wetland study sites; based on data collected in 1996and 1997.

INDICATOR STATUS	MEADOWVILLE					PRESTON			SEEFUS		
	QUADRAT				Whole Site	QUADRAT		Whole Site	QUADRAT		Whole Site
	1	2	3	4		1	2		1	2	
Obligate Wetland (OBLW)	87.5	53.8	87.4	56.6	**71.9**	78.2	97.1	87.7	70.2	80.8	**75.2**
Facultative Wetland (FACW)	12.5	46.2	12.6	11.1	**20.6**	21.5	2.9	12.2	24.1	17.2	**20.6**
Facultative (FAC)	0.0	0.0	0.0	25.1	**6.3**	0.0	0.0	0.0	5.7	2.0	**3.8**
Facultative Upland (FACU)	0.0	0.0	0.0	3.1	**0.8**	0.0	0.0	0.0	0.0	0.0	**0.0**
Obligate Upland (OBLU)	0.0	0.0	0.0	1.4	**0.4**	0.0	0.0	0.0	0.0	0.0	**0.0**

Table 4.15. Dominant vascular plant species (Importance Value ≥10), species sampled, standing crop, and hydrologic regime by sample quadrat for three constructed wetland sites.

Site/Quadrat	Dominant Vascular Plants and Importance Values (IV = Rel Dom + Rel Freq/2)		Species Sampled	Net Standing Crop by Quadrat (g/m^2)	Hydrologic Regime[2]
	Juncus effusus	13.0			
	Veronica sp.	11.8			
	Impatiens capensis	10.7			
Triangle/1	Others combined	64.5	17	515.74	Saturated
	Leersia oryzoides	34.3			
	Glyceria canadensis	21.0			
	Agrostis alba	16.6			
Triangle/2	Other combined	28.1	10	497.60	Saturated
	Typha latifolia	54.9			
Triangle/3	Other combined	45.1	11	618.13	Semipermanently Flooded
	Epilobium coloratum	20.0			
	Oxalis europeae	15.4			
	Setaria viridis	13.9			
Triangle/4	Other combined	50.7	14	523.91	Temporarily Flooded
	Leersia oryzoides	44.5			
	Ludwigis palustris	28.1			
	Eleocharis obtusa	20.5			
Triangle/5	Other combined	6.90	4	468.39	Permanently Flooded
	Leersia oryzoides	32.5			
	Juncus effusus	21.9			
Sand Run/1	Other combined	45.5	10	465.97	Semipermanently Flooded
	Juncus effusus	17.8			
	Leersia oryzoides	17.8			
	Sparganium americanum	16.5			
	Ludwigia palustris	15.0			
	Scirpus sp.	15.0			
Sand Run/2	Other combined	17.9	7	598.11	Permanently Flooded
	Agrostis alba	17.2			
	Carex stricta	17.2			
	Eleocharis obtusa	17.2			
	Echinochloa frumentacea	13.3			
Sugar Cr./1	Other combined	35.1	9	526.81	Temporarily Flooded
	Phalaris arundinacea	44.1			
	Echinochloa frumentacea	20.1			
Sugar Cr./2	Other combined	35.8	8	428.74	Temporarily Flooded
	Phalaris arundinacea	33.9			
	Juncus effusus	19.3			
	Eleocharis obtusa	17.5			
Sugar Cr./3	Other combined	29.3	7	836.31	Saturated
	Phalaris arundinacea	31.6			
	Echinochloa frumentacea	17.6			
	Agrostis alba	12.4			
Sugar Cr./4	Other combined	38.4	9	721.55	Saturated
	Echinochloa frumentacea	60.0			
	Agrostis alba	26.6			
Sugar Cr./5	Other combined	13.4	4	536.38	Saturated
	Echinochloa frumentacea	34.3			
	Phalaris arundinacea	31.4			
	Agrostis alba	11.9			
Sugar Cr./6	Other combined	22.4	7	390.01	Saturated

Table 4.16. Dominant vascular plant species (Importance Value ≥10), species sampled, and standing crop by sample quadrat for three reference wetland sites.

Site/Quadrat	Dominant Vascular Plants with Importance Values (IV = Rel Dom + Rel Freq/2)		Total Species Sampled	Average Standing Crop by Quadrat (g/m^2)	Hydrologic Regime
	Leersia oryzoides	42.9			
	Carex stricta	14.7			
	Galium tinctorium.	14.1			
	Impatiens capensis	14.1			
Meadowville/1	Other	14.2	7	812.62	Saturated
	Calamagrostis canadensis	25.9			
	Carex stricta	23.8			
	Agrostis alba	15.9			
	Galium tinctorium.	11.2			
Meadowville/2	Other	23.2	8	709.68	Saturated
	Typha latifolia	60.7			
	Carex stricta	16.5			
	Galium tinctorium	10.6			
Meadowville/3	Other	12.0	5	1047.75	Semipermanently Flooded
	Carex stricta	26.9			
	Polygonum sp.	21.4			
	Impatiens capensis	13.3			
	Clementis viarginiana	12.1			
Meadowville/4	Other	26.3	9	694.96	Temporarily Flooded
	Leersia oryzoides	85.2			
Preston/1	*Sparganium americanum*	14.8	2	812.00	Semipermanently Flooded
	Leersia oryzoides	89.7			
Preston/2	*Ludwigia palustris*	10.3	2	845.52	Saturated
	Leersia oryzoides	29.4			
	Sparganium americanum	29.4			
	Carex stricta	16.4			
	Galium tinctorium	11.5			
Seefus/1	Other	13.3	6	629.72	Semipermanently Flooded
	Sparganium americanum	40.0			
	Leersia oryzoides	27.7			
Seefus/2	Other	32.3	7	564.06	Saturated

Table 4.17. Comparison of edaphic parameters for three constructed and three reference wetlands. (Carbon, nitrogen, and sulphur in percentages (%); phosphorus in parts per million (ppm); all others cmol(+)/kg)

Location	#Samples	Ca	Mg	K	Na	H	C	N	S	P
		cmol(+)/kg					%			ppm
Constructed										
Triangle	21	11.20	0.99	0.14	0.28	4.33	2.15	0.09	0.02	9.81
Sand Run	16	4.34	0.70	0.20	0.14	3.85	1.88	0.07	0.02	12.29
Sugar Creek	48	7.26	1.02	0.40	0.09	14.41	2.71	0.17	0.02	9.60
Reference										
Meadowville	32	7.34	2.05	0.39	0.17	24.85	6.82	0.47	0.10	10.17
Preston	16	7.30	0.78	0.19	0.22	18.19	4.58	0.20	0.06	0.54
Seefus	8	7.11	1.41	--	--	23.28	10.80	0.53	0.14	5.82

Unpublished data from Sencindiver, Division of Plant and Soil Sciences, West Virginia University.

Table 4.18. Correlation coefficients between transect productivity and 10 edaphic factors for the upper 10 cm for three constructed and three reference wetlands. (T-test significant values for 17, 18, and 19 are 2.57, 2.55, and 2.34, respectively.)

df	**18**	**18**	**18**	**18**	**17**	**17**	**18**	**18**	**18**	**18**
Factors	pH	%C	Ca	Mg	K	Na	P	N	S	Hydrologic Regime
Coefficients	-0.51	0.62	-0.07	0.36	-0.08	0.64	-0.37	.67	.67	0.08
t-test	-2.50	3.33	-0.32	1.65	-1.34	-0.36	-1.69	3.80	3.85	0.34

Table 4.19. Correlation coefficients between the average site production and 10 edaphic factors for the upper 10 cm for three constructed and three reference wetlands. (T-test significant values for 1, 2, 3, and 4 are 12.71, 4.30, 3.18, and 2.78, respectively.)

df	**4**	**4**	**4**	**3**	**3**	**4**	**4**	**4**	**4**	**2**	**1**
Factors	%C	Ca	Mg	K	Na	P	N	H	S	Hydrologic Regime[1]	Hydrologic Regime excluding Permanently Flooded[1]
Coefficients	0.37	-0.10	0.42	-0.25	-0.31	-0.59	0.44	0.70	0.43	0.06	1.00
t-test	0.79	-0.20	0.94	-0.52	0.65	-1.47	0.98	1.97	0.95	0.09	10.75

Table 4.20. Comparison of carbon, hydrogen, nitrogen, and sulfur for three constructed and three reference wetlands.[1]

Wetland Site	Avg. % Carbon	Avg. Hydrogen (cmol(+)/kg)	Avg. % Nitrogen	Avg. %Sulfur
Constructed Wetland				
Triangle/1	2.08	5.16	0.13	0.02
Triangle/2	1.87	2.36	0.08	0.01
Triangle/3	2.07	3.47	0.11	0.03
Triangle/4	2.69	4.66	0.11	0.01
Triangle/5	2.13	6.50	0.03	0.02
Sand Run/1	2.16	3.04	0.09	0.02
Sand Run/2	1.60	4.65	0.06	0.02
Sugar Creek/1	2.17	10.83	0.12	0.02
Sugar Creek/2	3.41	17.31	0.22	0.02
Sugar Creek/3	2.92	13.54	0.21	0.02
Sugar Creek/4	2.29	10.99	0.14	0.02
Sugar Creek/5	2.81	17.34	0.17	0.02
Sugar Creek/6	2.66	16.44	0.18	0.02
Reference Wetlands				
Meadowville/1	6.88	25.28	0.47	0.07
Meadowville/2	4.69	18.96	0.32	0.05
Meadowville/3	11.91	38.91	0.86	0.18
Meadowville/4	3.79	15.24	0.24	0.08
Preston/1	5.34	21.28	0.25	0.08
Preston/2	3.82	15.10	0.16	0.05
Seefus/1	10.80	23.28	0.53	0.14
Seefus/1	-2-	-2-	-2-	-2-

[1]Unpublished data from Sencindiver, Plant Sciences, West Virginia University.

[2]Data unavailable.

Table 4. 21. Correlation coefficients between the average site production and three plant species that occurred as dominants in three constructed and three reference wetlands. (T-test significant values for 2, 4, and 10 are 4.30, 2.78, and 2.23, respectively.)

df	**2**	**4**	**10**
Species	***Typha latifolia***	***Phalaris arundinacea***	***Leersia oryzoides***
Coefficients	0.95	0.09	0.56
t-test	4.30	0.18	2.15

Table 4.22. Sørensen Coefficient for three reference and three constructed wetlands.

Site	Meadowville	Sand Run	Preston	Seefus	Sugar Creek
Triangle	0.422	0.335	0.238	0.209	0.455
Meadowville	–	0.328	0.314	0.198	0.342
Sand Run		–	0.302	0.286	0.380
Preston			--	0.407	0.221
Seefus				–	0.147

Table 4.23. Pearson product moment correlations of environmental variables and calculated statistics with DECORANA ordination axes. ($p \leq 0.05$, one-tailed test)

Variable	**Axis 1**
Species Richness	0.66
Species Diversity	0.54
Weighted Average	0.72
Productivity	-0.55
H_3O^+ Concentration	-0.60
Organic Carbon	-0.54
Sulfur	-0.65
Nitrogen	-0.51

CHAPTER 5

SOILS AND HYDROLOGY

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CHAPTER 5

SOILS AND HYDROLOGY

5.1. Overall Study Strategies–Hydrology

Hydrology is an important factor influencing wetland development and maintenance. It influences soils, vegetation, and wildlife of wetlands (Mitsch and Gosselink 2000). Hydrology (more specifically referred to as the hydrological regime) was monitored by installing and regularly reading water wells in selected wetlands.

5.1.1. Hydrology Methods

As future reference wetlands for continued monitoring activities, the Triangle and Sugar Creek wetlands were selected as study sites for monitoring ground and surface water levels over extended periods. As a reference area, the Meadowville wetland was selected, because it has habitats that represent a broad diversity of natural physical conditions and biota; further, we know of no immediate threats to the site. Two water wells were installed in each of these wetlands, with one located near the lowest elevation within the wetland and near a quadrat sample site; the second well was placed at a higher elevation and near a sample quadrat.

Wells consisted of heavy gauge, 4 in PVC pipe placed in drilled holes to a minimum depth of 80 decimeters. A power auger and soil core extractor were used to form the holes. The pipes were equipped with tip points and were slotted (0.05 mm width). The holes were backfilled with washed river stone (1-2 cm in diameter) and silica sand. Bentenite was poured around the pipe at the surface of the ground to seal the hole. Pipes were capped and locked.

Observation of the wells began in November 1997. For the first four months, the water wells were read approximately every two weeks. In March, the frequency of well observations was changed to once per month. Monthly observations were continued through December 1998.

5.1.2. Results and Discussion

The data reported here represent about one year of observations. The water levels in the wells generally followed predictable pattern, with the highest levels occurring in late winter and early spring and the lowest in the fall (Table 5.1). We will

Table 5.1 Water levels in water wells at the Triangle, Sugar Creek, and Meadowville wetlands. Ground level = 0.

Date Observed	Water Level in Wells (cm)					
	Tri 1	Tri 2	Sugar Cr 1	Sugar Cr 2	Meadow-ville 1	Meadow-ville 2
11/12/97	+26	0	+3	+5	+2	-8
12/14/97	+34	+12	+4	+7	0	- 9
1/10/98	+35	+14	+10	+15	+12	-1.5
2/1/98	+31	+8	+8	+6	+7	-3
2/22/98	+31	0	+7	+10	+6	-6.5
3/15/98	+29	+5	+5	+8	+5	-7
4/8/98	+25	+2	+9	+7	+5	-7.5
5/1/98	+18	+1	+5	+3	+3	-8.0
6/1/98	+16	-3	-5	-1	-8	-13
7/31	+11	-1	-11	-15	-20	-24
8/25/98	+30	+6	-30	-13	-34	-36
10/24/98	+19	-1	-19	-11	-26	-29
11/25/98	+22	+3	-14	-7	-17	-21
12/12/98	+25	+5	-10	-1	-11	-14

5.2. Overall Study Strategies–Soils

Like hydrology, soils are an important component, depending in part on the hydrology and determining much of the biotic characteristics of wetlands. Soils were evaluated for each of the three constructed and reference wetlands, each receiving the same treatment. The only exception was soils in the Seefus Quadrat 2 were not evaluated because of high water levels during each attempt to collect soil samples.

5.2.1 Methods and Materials

Soils in all six wetlands were sampled at all established transects between May 31 and June 13, 1996. Samples collected at this time are called summer 1996 samples in this report. On October 14 and 15, 1996, two transects at the Triangle wetland (constructed) and two transects at the Meadowville wetland (natural) were resampled. On October 15, soil samples were collected from under two alder and two spiraea shrubs. These samples were not related to any transect. All October samples are called fall samples in this report. Soil samples were taken at points one, four, six, and nine on each flagged 10-point transect within a quadrat at a distance of one meter from the flag on the right side of the flag when facing toward point #10. They were collected with a Dutch auger at depths of 0-10 cm and 10-20 cm. Texture was determined by the feel method, and color was determined by Munsell soil color charts for each sample. All samples were placed in plastic bags and transported to the soil research laboratory in the Agricultural Sciences Building at West Virginia University where they were air-dried and prepared for analyses.

Soil pH, extractable bases, and extractable acidity were determined by methods published by the Soil Survey Staff (1996b). Soil pH was determined on a 1:1 soil to water suspension using a Fisher Scientific Accumet Digital pH meter with a combination electrode. Basic cations (Ca, Mg, K, Na) were extracted with 1*N* NH_4OAc buffered at pH 7.0 using a mechanical vacuum extractor. The extracts were analyzed on a Perkin-Elmer 5000 Atomic Absorption Spectrophotometer. For determination of extractable acidity, samples were leached with a $BaCl_2$-TEA solution buffered at pH 8.2. The extracts were back-titrated with HCl on a Radiometer VIT90 Video Titrator.

Extractable P was determined by the Mehlich-3 method (Mehlich 1984). Total carbon, sulfur and nitrogen were determined on a LECO CNS-2000 instrument.

5.3 Results and Discussion

Field descriptions of soils to a depth of 20 cm in all wetlands are presented in Tables 5.1-6. Soil texture varied. Silt loam or loam was the predominant texture in the surface layer (0-10 cm) of all wetlands. Silt loam, loam, and silty clay loam were the predominant textures in the subsurface layers (10-20 cm) in the natural wetlands (Meadowville, Preston, Seefus). Subsurface layers of the constructed wetlands included the textures already mentioned plus sandy loam, clay loam, sandy clay loam and clay.

Colors indicate that the natural wetland soils had depleted matrices within 20 cm of the surface at most sampling points. A depleted matrix has a color value of 4 or higher and a chroma of 2 or less. One field indicator of a hydric soil is a layer at least 15 cm thick with a depleted matrix within 25 cm of the soil surface (Mid-Atlantic Hydric

Soil Committee 1997). Although data to a depth of 25 cm are not presented in the table, these data were collected. All sampling points in the natural wetlands, except one point at Meadowville and one point at Seefus, were hydric based upon the depleted matrix criteria. Some of the sampling points in the constructed wetlands fit the hydric soil field indicators, but many did not. It is assumed that the constructed soils simply are too young to be hydric soils. If the constructed soils remain saturated with water, they should develop the properties of hydric soils.

Keys to Soil Taxonomy (Soil Survey Staff 1996a) defines organic soil material as having 12% or more organic C if the soil material has no clay. If clay is present, then the organic C requirement increases as the clay increases. None of the soils in this study had enough C in the top 20 cm to fit the organic soil material criteria (Tables 5.7-15). Therefore, all soils in this study would be classified as inorganic soils. However, the natural wetlands generally had more C than the constructed wetlands.

Field and laboratory observations indicate that most of the soils in the natural wetlands fit the description of Atkins (fine-loamy, mixed, acid, mesic Typic Fluvaquents). However, soils at some sampling points were not Atkins because the texture at depths below 20 cm were composed mostly of clay. Atkins does not have clay textures below 20 cm. Soils in the constructed wetlands were not given a series name because of the variability of materials that is expected in constructed soils.

The laboratory data presented for both the natural and constructed wetlands (Tables 7-12) are comparable to data presented for similarly poorly drained soils in Pennsylvania (Cunningham *et al.* 1971). The constructed wetlands had higher pH values, lower extractable acidity, and higher P values than the natural wetlands. Nitrogen values were higher in the natural wetlands than in the constructed wetlands, generally following the C values.

Data for samples collected in the fall from the Meadowville wetland (Table 13) and the Triangle wetland (Table 14) were similar to the summer data (Table 7 for Meadowville and Table 11 for Triangle) from both wetlands, except for P. The fall samples had less P than the summer samples. Although plant consumption of P may explain part of the reason for the difference, none of the other nutrients used by plants showed any difference. Therefore, additional sampling will be required to ascertain a reason for this discrepancy.

Table 5.15 presents data from soils collected from beneath two clumps of alder and spirea in the Meadowville wetland. There appears to be very little difference in the soils in which these plants grow.

These soil data represent baseline values for Triangle, Sand Run, and Sugar Creek wetlands. To detail soil morphogenisis for such constructed substrates, the methods used in this first study should be repeated every two to three years so a continuum of the physical changes can be documented.

Table 5.2. Field descriptions of soils in the Meadowville wetland - summer 1996

Transect	Depth (cm)	Texture[1]	Matrix Color	Redox Concentrations (Abundance[2] and color)	Water Table (cm above or below soil surface)
1	0 - 10	SIL	10YR 4/2 or 4/3	None	3 to 5 cm above
	10 - 20	SIL, L, CL, SCL	10YR or 7.5YR 4/3, 4/1, 5/1	C to M 5YR 4/6 or 7.5YR 4/6 or 5/8	----
2	0 -10	SIL, L, SICL	10YR 4/2 or 4/3 7.5YR 5/2	C 7.5 YR 5/8 or 5YR 5/6	1 to 9 cm below
	10 - 20	L, CL, SICL	10YR 5/1 or 7.5YR 5/2	C to M 5YR & 7.5YR 5/8, 5YR 4/6	----
3	0 - 10	organic	10YR 3/2, 3/3, 4/2, 4/3	None	6 to 12 cm above
	10 - 20	SIL, SICL	10YR 4/1, 5/1, 5/2	F to M 7.5YR 4/6,6/8 5YR 4/6	----
4	0 - 10	SIL	2.5Y or 5Y 4/2 or 4/3	F to M 5YR 3/3, 4/6 7.5 YR 5/6, 5/8	10 to 30 cm below
	10 - 20	SIL	2.5Y 4/2, 4/3, 5/2 10YR 4/2	C to M 7.5YR 5/8 5YR 4/6 10YR 5/8	----

[1] L = loam, SIL = silt loam, CL = clay loam, SCL = sandy clay loam, SICL = silty clay loam
[2] F = few (0-2%), C = common (2-20%), M = many (>20%)

Table 5.3. Description of soils in the Preston wetland - summer 1996

Transect	Depth (cm)	Texture[1]	Matrix Color	Redox Concentrations (Abundance[2] and Color)	Water Table (cm above or below the soil surface)
1	0 - 10	SIL, L (0-5 cm = organic)	2.5Y 4/2, 4/3 10YR 4/1,5/2	C 5YR & 7.5YR 4/6	2 to 23 cm above
	10 - 20	SIL, L	2.5Y 4/2, 4/3 10YR 4/1, 5/2	C to M 5YR & 7.5YR 4/6	—
2	0 - 10	SIL, SICL (0-5 cm = organic)	5Y 5/2	M 5YR 5/6	1 to 10 cm above
	10 - 20	SIL, SICL	5Y 5/2	M 5YR 5/6	—

[1] L = loam, SIL = silt loam, SICL = silty clay loam
[2] C = common (2-20%), M = many (>20%)

Table 5.4. Description of soils in the Seefus wetland - summer 1996

Transect	Depth (cm)	Texture[1]	Matrix Color	Redox Concentrations (Abundance and Color)	Water Table (cm above or below soil surface)
1	0 -10	L, SIL (0-5 cm = organic)	5Y 4/2 2.5Y 3/3, 4/2	None	14 cm below to 8 cm above
	10 - 20	L, SIL, SICL, SCL	5Y 4/2 2.5Y 4/2, 6/4	None	—

[1] L = loam, SIL = silt loam, SICL = silty clay loam, SCL = sandy clay loam

Table 5.5. Description of soils in the Sand Run wetland - summer 1996

Transect	Depth (cm)	Texture[1]	Matrix Color	Redox Concentrations (Abundance[2] and Color)	Water Table (cm above or below soil surface)
1	0 - 10	L, SIL, SL, SCL	5Y 3/2, 4/2, 5/3,4/3	None	8 to 30 cm above
	10 - 20	L, SL, CL, C	5Y 4/2,4/3	C 10YR 6/8, 5YR 4/6 7.5YR 5/8	----
2	0 - 10	L, SL, SIL	5Y 3/2, 4/2 2.5Y 4/2	None	8 to 49 cm above
	10 - 20	L, SL, SCL, C	2.5Y & 5Y 4/2	C 5YR & 7.5YR 4/6 5YR 3/4	----

[1] L = loam, SIL = silt loam, SL = sandy loam, CL = clay loam, SCL = sandy clay loam, C = clay
[2] C = common (2-20%)

Table 5.6. Description of soils in the Triangle wetland - summer 1996.

Transect	Depth (cm)	Texture[1]	Matrix Color	Redox Concentrations (Abundance[2] and Contrast)	Water Table (cm above or below the soil surface)
1	0 - 10	SIL, L	10YR 3/2, 4/2, 4/3	F - M 10YR 5/6, 5/8	8 cm below to 10 cm above
	10 - 20	CL, SICL, C	10YR 4/2, 4/3 2.5YR 4/3, 2.5Y 4/2	C 10YR 5/6, 6/6 5YR 5/3, 5/4 5Y & 2.5Y 5/4	----
2	0 - 10	L, CL, SCL	2.5Y 4/2, 4/2, 5/2	C 5YR 4/4, 4/6 10YR 5/6, 5/8	0 to 19 cm above
	10 - 20	C, SCL	Mixed, 5YR 4/6 2.5YR 3/3, 3/4 2.5Y 5/4, 5/2, 4/4 10YR 5/6, 5/8	See matrix color	----
3	0 - 10	FSL, L, SIL	2.5Y & 5Y 3/2 10YR 4/3, 4/4	None	0 to 13 cm above
	10 - 20	FSL, L, SIL	2.5Y 3/2, 4/2 10YR 4/4	C 5YR 4/4, 4/6, 10YR 5/8 2.5Y 4/4, 5/4	----
4	0 - 10	L, SL	2.5Y 3/3, 4/3, 5/2	F 10YR 6/8	0 to 20 cm below
	10 - 20	L, C	2.5Y 3/3 5Y 4/3	C - M 2.5Y 6/6, 2.5YR 4/6 5YR 4/6, 5/8	----
5	0 - 10	L, SL, SCL, C	5YR 4/3 2.5Y 3/2, 3/3, 4/2, 5/1	F - C 7.5YR 4/6, 10YR 5/8 5Y 5/4, 6/6, 2.5Y 6/4	8 cm below to 10 cm above
	10 - 20	C, SCL	2.5Y 4/2, 5/1, 5/3 10YR 4/2, 5/1	F- C 5YR & 7.5YR 4/6	----

[1] L = loam, SL = sandy loam, SIL = silt loam, FSL = fine sandy loam, CL = clay loam, SCL = sandy clay loam, SICL = silty clay loam, C=clay
[2] F = few (0-2%), C = common (2-20%), M = many (>20%)

Table 5.7. Description of soils in the Sugar Creek wetland - summer 1996

Transect	Depth (cm)	Texture[1]	Matrix Color	Redox Concentrations (Abundance[2] and Color)	Water Table (cm above or below the soil surface)
1	0 - 10	SIL, SICL	2.5Y 4/2, 5/2	C 10YR & 7.5YR 5/8, 6/8	1 to 8 cm below
	10 - 20	SIL, SICL, C	2.5Y 4/2,5/2	C 10YR & 7.5YR 5/8, 6/8	----
2	0 - 10	SIL	10YR 3/2, 4/2	C 7.5YR 4/6, 5/6	43 to 100 cm below
	10 - 20	SIL	10YR 3/2, 4/2	C 7.5YR 4/6, 5/6	----
3	0 - 10	SIL	2.5Y 3/2	C 7.5YR 4/4, 5/6 2.5Y 5/4, 6/6	0 to 6 cm above
	10 - 20	L, SCL, SIC	2.5Y 3/2 10YR 5/6	F - C 7.5YR 4/4, 5/6, 5/8 5YR 5/8	----
4	0 - 10	SIL	5Y 4/2 2.5Y 3/2	F - C 7.5YR 4/4, 5/8 10YR 5/6	1 cm below to 6 cm above
	10 - 20	SIL, SICL, SIC	2.5Y 3/2, 6/4 10YR 5/8	C - M 7.5YR 4/4, 5/8 2.5Y 6/6, 10YR 5/6	----
5	0 - 10	SIL, SIC, C	10YR 3/2, 3/3 2.5Y 7/2	F - C 10YR 4/6, 5/6, 6/6	7 cm below to 5 cm above
	10 - 20	SIL, SICL, SIC, C	10YR 3/2, 3/3, 6/6 2.5Y 7/2	F - C 10YR 4/6, 5/6	----
6	0 - 10	SIL	10YR 3/2, 4/2 2.5Y 3/2, 4/2	C 7.5YR 5/4, 5/6 10YR 5/6	7 cm below to 10 cm above
	10 - 20	L, SIL, SICL, SCL	10YR 4/2, 6/8 N 6/0 2.5Y 3/2, 6/6	C 7.5YR 5/4, 5/8, 6/8 2.5Y 6/6	----

[1] L = loam, SIL = silt loam, SCL = sandy clay loam, SICL = silty clay loam, SIC = silty clay, C = clay
[2] F = few (0-2%), C = common (2-20%), M = many (>20%)

Table 5.8. Soil chemical data for the Meadowville wetland - summer 1996

			pH		Ca		Mg		K		Na	
					cmol(+)/kg							
Transect	Depth (cm)	N	Mean	STDEV[1]	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV
1	0-10	4	5.11	*	9.32	2.54	2.44	0.79	0.45	0.12	0.21	0.12
	10-20	4	4.87	*	6.21	1.64	1.86	0.47	0.36	0.05	0.09	0.05
2	0-10	4	5.02	*	6.28	0.32	1.86	0.19	0.40	0.04	0.09	0.04
	10-20	4	5.05	*	3.86	0.85	1.20	0.28	0.24	0.06	0.05	0.06
3	0-10	4	4.72	*	6.16	1.93	1.60	0.44	0.39	0.03	0.26	0.03
	10-20	4	4.83	*	2.53	0.60	0.73	0.18	0.18	0.07	0.11	0.07
4	0-10	4	5.39	*	7.62	0.52	2.05	0.10	0.34	0.04	0.12	0.04
	10-20	4	5.14	*	4.06	0.52	1.28	0.12	0.23	0.06	0.10	0.06
1-4	0-10	16	5.00	*	7.34	1.96	2.05	0.52	0.39	0.07	0.17	0.11
	10-20	16	4.96	*	4.17	1.63	1.28	0.49	0.25	0.09	0.09	0.04

			Acidity cmol(+)/kg		C		S		N		P ppm	
					%							
Transect	Depth (cm)	N	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV
1	0-10	4	26.27	6.84	6.88	2.59	0.07	0.02	0.47	0.19	6.11	1.75
	10-20	4	20.08	2.96	5.23	1.58	0.07	0.03	0.36	0.11	15.46	5.47
2	0-10	4	18.96	2.03	4.69	0.60	0.05	0.00	0.32	0.04	13.82	6.36
	10-20	4	12.35	0.73	1.76	0.17	0.02	0.00	0.08	0.02	7.68	2.54
3	0-10	4	38.91	9.00	11.91	3.94	0.18	0.04	0.85	0.26	5.01	0.60
	10-20	4	18.27	3.29	3.94	1.61	0.06	0.03	0.28	0.11	6.81	2.43
4	0-10	4	15.23	1.95	3.79	0.59	0.08	0.09	0.24	0.03	15.76	2.91
	10-20	4	13.80	1.56	2.45	0.69	0.03	0.01	0.19	0.06	16.88	6.14
1-4	0-10	16	24.85	3.89	6.82	3.89	0.10	0.07	0.47	0.28	10.17	5.82
	10-20	16	16.12	1.74	3.35	1.74	0.04	0.03	0.22	0.13	11.71	6.13

1. STDEV = Standard Deviation. Standard deviation not calculated for pH.

Table 5.9. Soil chemical data for the Preston wetland - summer 1996.

			pH		Ca		Mg		K		Na	
					cmol(+)/kg							
Transect	Depth (cm)	N	Mean	STDEV[1]	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV
1	0-10	4	5.11	*	6.44	0.68	0.70	0.10	0.18	0.06	0.13	0.05
	10-20	4	5.15	*	5.37	0.55	0.70	0.10	0.06	0.05	0.13	0.05
2	0-10	4	5.38	*	8.15	0.96	0.85	0.10	0.22	0.06	0.33	0.12
	10-20	4	5.39	*	6.74	1.77	0.85	0.25	0.13	0.07	0.27	0.09
1-2	0-10	8	5.22	*	7.30	1.20	0.77	0.12	0.20	0.06	0.23	0.14
	10-20	8	5.25	*	6.05	1.42	0.77	0.19	0.10	0.07	0.20	0.10

			Acidity		C		S		N		P	
			cmol(+)/kg		%						ppm	
Transect	Depth (cm)	N	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV
1	0-10	4	21.28	2.31	5.33	0.72	0.08	0.02	0.25	0.04	0.19	0.07
	10-20	4	17.21	3.27	3.39	0.95	0.04	0.02	0.12	0.06	0.48	0.51
2	0-10	4	15.10	1.44	3.81	0.24	0.05	0.01	0.15	0.01	0.90	0.70
	10-20	4	12.84	0.93	2.42	0.22	0.02	0.00	0.07	0.02	0.94	0.15
1-2	0-10	8	18.19	3.75	4.57	0.95	0.06	0.02	0.20	0.06	0.54	0.60
	10-20	8	15.03	3.22	2.90	0.82	0.03	0.02	0.10	0.05	0.71	0.43

1. STDEV = Standard Deviation. Standard deviation not calculated for pH.

Table 5.10. Soil chemical data for the Seefus wetland - summer 1996.

			pH		Ca		Mg		K[2]		Na[2]	
					cmol(+)/kg							
Transect	Depth (cm)	N	Mean	STDEV[1]	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV
1	0-10	4	4.99	*	7.11	4.43	1.41	0.85	-	-	-	-
	10-20	4	5.04	*	3.48	2.38	0.63	0.40	-	-	-	-

			Acidity		C		S		N		P	
			cmol(+)/kg		%						ppm	
Transect	Depth (cm)	N	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV
1	0-10	4	23.28	5.74	10.80	6.46	0.14	0.09	0.52	0.27	5.33	0.98
	10-20	4	12.40	4.96	3.75	1.82	0.05	0.03	0.17	0.13	7.55	2.67

1. STDEV = Standard Deviation. Standard deviation not calculated for pH.
2. Data Unavailable.

Table 5.11. Soil Chemical data for the Sand Run wetland - summer 1996.

			pH		Ca		Mg		K		Na	
					cmol(+)/kg							
Transect	Depth (cm)	N	Mean	STDEV[1]	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV
1	0-10	4	5.87	*	4.61	2.49	4.61	2.49	0.20	0.03	0.15	0.02
	10-20	4	5.47	*	3.01	1.15	3.01	1.15	0.19	0.05	0.13	0.05
2	0-10	4	6.01	*	4.08	1.21	4.08	1.21	0.20	0.03	0.13	0.03
	10-20	4	5.15	*	3.14	0.60	3.14	0.60	0.17	0.03	0.10	0.03
1-2	0-10	8	5.94	*	4.34	1.84	4.34	1.84	0.20	0.03	0.14	0.03
	10-20	8	5.28	*	3.07	0.85	3.07	0.85	0.18	0.04	0.12	0.04

			Acidity cmol(+)/kg		C		S		N		P ppm	
					%							
Transect	Depth (cm)	N	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV
1	0-10	4	3.04	1.94	2.16	1.22	0.02	0.01	0.09	0.04	11.16	4.02
	10-20	4	2.73	1.18	1.11	0.14	0.01	0.00	0.03	0.01	14.32	7.05
2	0-10	4	4.65	0.96	1.59	0.58	0.02	0.01	0.06	0.03	13.41	6.06
	10-20	4	5.71	2.12	1.14	0.39	0.01	0.00	0.03	0.02	15.49	3.89
1-2	0-10	8	3.85	0.94	1.88	3.89	0.02	0.01	0.07	0.04	12.29	4.91
	10-20	8	4.22	0.27	1.13	0.27	0.01	0.00	0.03	0.01	14.90	5.31

1. STDEV = Standard Deviation. Standard deviation not calculated for pH.

Table 5.12. Soil chemical data for the Triangle wetland - summer 1996.

			pH		Ca		Mg		K		Na	
					cmol(+)/kg							
Transect	Depth (cm)	N	Mean	STDEV[1]	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV
1	0-10	4	6.92	*	14.43	5.66	0.99	0.23	0.20	0.13	0.48	0.20
	10-20	4	7.06	*	12.20	3.32	0.86	0.22	0.25	0.07	0.48	0.15
2	0-10	5	7.39	*	9.53	3.88	1.06	0.42	0.19	0.07	0.16	0.14
	10-20	5	7.79	*	17.08	4.23	0.93	0.32	0.23	0.08	0.31	0.25
3	0-10	4	7.05	*	14.31	6.68	1.22	0.25	0.09	0.07	0.71	0.47
	10-20	4	6.91	*	16.04	9.26	1.22	0.48	0.12	0.05	0.44	0.19
4	0-10	4	6.59	*	10.14	2.44	0.93	0.15	0.12	0.05	0.06	0.03
	10-20	4	7.03	*	18.31	14.34	1.04	0.32	0.10	0.09	0.07	0.04
5	0-10	4	6.17	*	7.56	0.95	0.71	0.10	0.10	0.05	0.03	0.01
	10-20	4	6.48	*	14.80	13.73	0.95	0.52	0.11	0.16	0.07	0.04
1-5	0-10	21	6.62	*	11.20	4.72	0.98	0.29	0.14	0.08	0.29	0.34
	10-20	21	6.88	*	15.69	9.28	1.00	0.36	0.16	0.11	0.27	0.23

			Acidity		C		S		N		P	
			cmol(+)/kg		%						ppm	
Transect	Depth (cm)	N	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV
1	0-10	4	5.16	1.17	2.08	0.59	0.02	0.00	0.12	0.03	7.58	2.88
	10-20	4	4.85	0.99	1.77	0.67	0.02	0.00	0.11	0.05	7.00	1.35
2	0-10	5	2.36	1.17	1.87	0.99	0.01	0.01	0.08	0.05	18.83	15.70
	10-20	5	1.53	0.35	0.99	0.20	0.01	0.00	0.04	0.01	8.96	4.91
3	0-10	4	3.47	0.89	2.07	0.48	0.02	0.01	0.11	0.04	6.80	4.15
	10-20	4	3.95	1.17	2.09	0.59	0.02	0.01	0.11	0.03	7.86	3.48
4	0-10	4	4.66	2.18	2.69	0.72	0.01	0.01	0.11	0.03	8.08	2.81
	10-20	4	3.26	2.26	1.79	0.81	0.01	0.01	0.06	0.05	7.61	4.27
5	0-10	4	6.50	1.01	2.12	0.53	0.02	0.00	0.03	0.02	7.77	2.30
	10-20	4	5.09	2.09	1.82	0.69	0.01	0.00	0.05	0.02	8.42	7.64
1-5	0-10	21	4.43	1.92	2.17	0.70	0.02	0.01	0.09	0.04	9.81	8.91
	10-20	21	3.73	1.92	1.69	0.68	0.01	0.01	0.07	0.04	7.97	4.35

1. STDEV = Standard Deviation. Standard deviation not calculated for pH.

Table 5.13. Soil chemical data for the Sugar Creek wetland - summer 1996.

			pH		Ca		Mg		K		Na	
					cmol(+)/kg							
Transect	Depth (cm)	N	Mean	STDEV[1]	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV
1	0-10	4	5.62	*	5.55	0.73	0.92	0.18	0.41	0.15	0.02	0.01
	10-20	4	5.60	*	5.43	0.86	0.82	0.18	0.33	0.03	0.03	0.02
2	0-10	4	5.45	*	8.20	0.74	1.59	0.29	0.56	0.08	0.04	0.00
	10-20	4	5.46	*	7.58	0.49	1.20	0.18	0.45	0.08	0.04	0.01
3	0-10	4	5.93	*	8.91	1.06	1.07	0.18	0.29	0.03	0.03	0.01
	10-20	4	5.57	*	7.13	3.57	0.92	0.37	0.21	0.08	0.02	0.03
4	0-10	4	5.81	*	8.48	2.93	0.88	0.21	0.26	0.10	0.04	0.02
	10-20	4	5.68	*	6.86	3.11	0.76	0.28	0.25	0.12	0.05	0.03
5	0-10	4	5.45	*	6.06	0.94	0.72	0.21	0.48	0.30	0.12	0.05
	10-20	4	5.45	*	6.32	1.62	0.72	0.15	0.39	0.13	0.10	0.07
6	0-10	4	5.60	*	6.37	1.88	0.94	0.24	0.43	0.12	0.16	0.09
	10-20	4	5.35	*	4.68	2.15	0.68	0.17	0.22	0.12	0.13	0.11
1-6	0-10	24	5.61	*	7.26	1.94	1.02	0.34	0.40	0.17	0.09	0.13
	10-20	24	5.51	*	6.33	2.25	0.85	0.27	0.31	0.13	0.06	0.07

			Acidity cmol(+)/kg		C		S		N		P ppm	
					%							
Transect	Depth (cm)	N	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV
1	0-10	4	10.83	0.62	2.17	0.58	0.02	0.01	0.12	0.04	6.15	1.29
	10-20	4	10.93	0.61	2.11	0.38	0.02	0.00	0.12	0.03	7.37	2.39
2	0-10	4	17.31	1.13	3.40	0.55	0.02	0.00	0.22	0.03	20.32	6.77
	10-20	4	17.81	0.62	3.30	0.07	0.02	0.00	0.22	0.01	13.15	2.06
3	0-10	4	13.54	1.58	2.92	0.09	0.02	0.00	0.21	0.04	6.48	0.78
	10-20	4	12.31	2.51	2.12	1.30	0.02	0.01	0.13	0.11	5.04	3.13
4	0-10	4	10.99	1.58	2.29	1.03	0.02	0.01	0.13	0.08	6.11	3.60
	10-20	4	10.99	1.95	1.63	0.87	0.01	0.00	0.09	0.06	3.76	1.88
5	0-10	4	17.34	5.24	2.81	1.43	0.02	0.01	0.17	0.11	13.20	8.04
	10-20	4	17.46	4.29	2.33	0.80	0.02	0.01	0.14	0.07	7.92	4.20
6	0-10	4	16.44	1.55	2.66	0.54	0.02	0.01	0.18	0.04	5.33	1.23
	10-20	4	15.39	5.93	2.08	1.31	0.02	0.01	0.13	0.10	4.11	1.52
1-6	0-10	24	14.41	3.58	2.71	0.84	0.02	0.01	0.17	0.07	9.60	6.92
	10-20	24	14.15	4.13	2.26	0.96	0.02	0.01	0.14	0.08	6.89	4.04

1. STDEV = Standard Deviation. Standard deviation not calculated for pH.

Table 5.14. Soil chemical data for the Meadowville wetland - fall 1996

			pH		Ca		Mg		K		Na	
					cmol(+)/kg							
Transect	Depth (cm)	N	Mean	STDEV[1]	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV
1	0-10	4	4.98	*	7.82	0.52	1.60	0.23	0.49	0.08	0.21	0.04
	10-20	4	5.14	*	5.23	0.72	1.06	0.25	0.26	0.05	0.17	0.05
2	0-10	4	5.07	*	7.11	1.64	1.57	0.38	0.42	0.08	0.16	0.04
	10-20	4	5.16	*	4.71	1.40	1.22	0.36	0.23	0.05	0.11	0.05
1-2	0-10	8	5.03	*	7.46	1.19	1.58	0.29	0.45	0.08	0.18	0.05
	10-20	8	5.15	*	4.97	1.07	1.14	0.30	0.25	0.05	0.14	0.05

			Acidity cmol(+)/kg		C		S		N		P ppm	
					%							
Transect	Depth (cm)	N	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV
1	0-10	4	23.93	5.73	5.79	1.42	0.09	0.04	0.31	0.10	0.75	0.34
	10-20	4	16.88	1.44	3.96	0.89	0.05	0.02	0.18	0.06	2.46	0.94
2	0-10	4	21.29	1.57	5.03	0.08	0.06	0.01	0.28	0.02	1.23	0.71
	10-20	4	12.94	1.30	1.99	0.40	0.02	0.00	0.08	0.03	1.09	0.76
1-2	0-10	8	22.61	4.14	5.41	1.02	0.07	0.03	0.29	0.07	0.99	0.58
	10-20	8	14.91	2.46	2.97	1.23	0.03	0.02	0.13	0.07	1.77	1.08

1. STDEV = Standard Deviation. Standard deviation not calculated for pH.

Table 5.15. Soil chemical data for the Triangle wetland - fall 1996.

			pH		Ca		Mg		K		Na	
					-----cmol(+)/kg-----							
Transect	Depth (cm)	N	Mean	STDEV[1]	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV
1	0-10	4	6.55	*	11.80	0.70	0.86	0.12	0.19	0.11	0.35	0.10
	10-20	4	7.13	*	14.21	4.76	0.79	0.15	0.09	0.04	0.26	0.14
2	0-10	4	7.28	*	19.17	6.84	1.17	0.53	0.14	0.06	0.26	0.11
	10-20	4	7.65	*	27.06	9.74	1.12	0.58	0.17	0.06	0.20	0.09
1-2	0-10	8	6.78	*	15.48	5.98	1.02	0.39	0.16	0.09	0.31	0.11
	10-20	8	7.32	*	20.63	9.88	0.95	0.43	0.13	0.06	0.23	0.11

			Acidity cmol(+)/kg		C		S		N		P ppm	
					-----%-----							
Transect	Depth (cm)	N	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV
1	0-10	4	6.53	0.37	2.78	0.45	0.02	0.01	0.13	0.03	1.37	0.20
	10-20	4	3.87	0.65	1.42	0.56	0.01	0.01	0.07	0.03	0.98	0.39
2	0-10	4	3.51	1.05	1.77	0.66	0.02	0.00	0.06	0.03	2.61	1.06
	10-20	4	1.94	0.70	0.90	0.16	0.01	0.00	0.03	0.01	1.42	0.37
1-2	0-10	8	5.02	1.77	2.28	0.75	0.02	0.01	0.10	0.04	1.99	0.97
	10-20	8	2.90	1.21	1.16	0.47	0.01	0.01	0.05	0.03	1.20	0.42

1. STDEV = Standard Deviation. Standard deviation not calculated for pH.

Table 5.16. Chemical analyses of soils under alder and spirea at the Meadowville wetland - fall 1996.

			pH		Ca^2		Mg^2		K^2		Na^2	
					---------------------------------		cmol(+)/kg				----------------------------------	
Species	Depth (cm)	N	Mean	STDEV[1]	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV
Alder	0-10	2	5.33	*	7.61	-	2.12	-	0.30	-	0.10	-
	10-20	2	5.44	*	6.39	2.88	1.60	0.88	0.21	0.12	0.10	0.00
Spirea	0-10	2	5.06	*	6.69	2.14	1.71	0.54	0.38	0.13	0.15	0.07
	10-20	2	5.10	*	2.90	0.42	0.75	0.27	0.09	0.04	0.07	0.04
Combined	0-10	4	5.17	*	7.00	1.60	1.85	0.45	0.35	0.10	0.13	0.06
	10-20	4	5.24	*	4.64	0.89	0.82	0.23	0.10	0.03	0.08	0.03

			Acidity[3] cmol(+)/kg		C		S		N		P ppm	
					----------------------------		%-		----------------------------			
Species	Depth (cm)	N	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV
Alder	0-10	2	18.97	2.36	5.50	1.02	0.04	0.01	0.43	0.10	0.81	0.52
	10-20	2	16.16	-	3.75	0.88	0.04	0.00	0.27	0.08	1.79	1.79
Spirea	0-10	2	20.23	0.02	5.87	0.97	0.07	0.02	0.39	0.04	2.35	0.74
	10-20	2	12.14	0.35	1.92	0.36	0.02	0.00	0.13	0.03	0.89	0.62
Combined	0-10	4	19.60	1.55	5.68	0.84	0.06	0.02	0.41	0.07	1.58	1.03
	10-20	4	13.48	2.33	2.83	1.20	0.03	0.01	0.20	0.10	1.34	1.21

1. STDEV = Standard Deviation. Standard deviation not calculated for pH.
2. N = 1 for Alder 0-10 cm.
3. N = 1 for Alder 10-20 cm.

CHAPTER 6

AMPHIBIANS AND REPTILES

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CHAPTER 6

AMPHIBIANS AND REPTILES

6.1 Overall Study Strategy

The purpose of this portion of the study was to determine qualitatively what species of amphibians and reptiles are long term or ephemeral residents of constructed wetlands selected for study. Population sizes are estimated based on inference and by extension of captures.

6.2 Methods

The six wetlands were surveyed during April-June 1996 and June 1997 to determine the relative abundance of amphibian and reptile species. Adult anurans (frogs and toads) were identified by calls, and adult salamanders and all amphibian larvae were captured with dip nets and funnel traps. Reptiles were identified by visual sightings. Amphibian adults and larvae were either identified on site or returned to the laboratory and examined with a dissecting microscope.

For call counts, each wetland was visited at least twice for 5 minute periods. All calls were identified and the number of individuals per species was counted. Ten sweeps in two 5-meter areas were made in each pond on one visit per wetland. Two to four funnel traps were placed in each pond within each wetland for at least one week from 22 May to 3 June, 1996. Survey techniques mostly follows Heyer, et al. (1994). Scientific and common names for reptilian and amphibian species cited in this study are shown in Table 6.1.

6.3 Results

The results of surveys at each of the 6 wetlands are presented in Tables 6.2 through 6.7, with dates visited, species observed, number of individuals/species, age class, and method of collection. A summary for all sites combined is presented in Table 6.8.

6.4 Discussion

The mitigation wetlands support populations of amphibians and reptiles that are similar to those supported by reference wetlands. Eleven species of amphibians/reptiles were recorded for mitigation wetlands compared to 12 in reference wetlands. More in-depth surveys would almost definitely document that mitigation wetlands support all of the amphibian/reptile species that occur in reference wetlands.

Following is a description of the current status of amphibians and reptiles in each wetland.

6.4.1 Triangle Wetland

This wetland supports large populations of *Bufo a. americanus, Pseudacris c. crucifer, Hyla chrysoscelis,* and *Rana clamitans melanota* (Table 6.2). While we did not hear adult *R. catesbeiana* calling or find larvae, this species is probably here. Early spring surveys will probably detect populations of *R. sylvatica* and possibly *R. palustris. Ambystoma maculatum* and *Notophthalmus v. viridescens* should also be present. *Chelydra s. serpentina* and *Nerodia s. sipedon* are probably present.

6.4.2 Sand Run

Sand Run wetland is possibly the most interesting wetland because of the difference in water depths. The western end is shallow and the eastern end deep, providing habitat for several amphibian and reptile species. In addition to those species listed in Table 6.3, *Rana sylvatica* and *R. palustris* are probably also present. *Pseudacris brachyphona* probably breeds in the shallow end and/or in mud puddles in the road. This wetland should also support *Ambystoma maculatum, Chelydra s. serpentina, Chrysemys picta marginata* and *Nerodia s. sipedon.*[1]

6.4.3 Sugar Creek Wetland

This wetland had the greatest number of amphibians of any wetland surveyed (Table 6.4), supporting large numbers of *Bufo a. americanus, Pseudacris c. crucifer, Hyla chrysoscelis, and Rana clamitans melanota*. In addition to these species and others listed in the results, *Ambystoma maculatum* and *A. jeffersonianum* probably occur in this wetland. One *Chelydra serpentina* was observed crossing the road at the creek. One of funnel trap was crushed in a fashion that was obviously from the mouth of a snapping turtle. *Nerodia s. sipedon* should also occur in this wetland complex.

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[1]One of our funnel traps was crushed in a fashion that was probably from the mouth of a snapping turtle attempting to get to tadpoles in the trap.

6.4.4 Preston Wetland

This wetland is the most disturbed of all wetlands surveyed due to the proximity of U.S. Route 50. In addition to the species observed (Table 6.5), we would expect to find *Ambystoma maculatum* and *Nerodia s. sipedon* at this wetland.

6.4.5 Meadowville Wetland

Due to sporadic water levels, mainly floods, we were unable to study this wetland with the detail extended to the other wetlands. In addition to the species detected by auditory censusing (Table 6.6), the following amphibian and reptile species are probably present in this wetland: *Rana sylvatica, R. palustris, Notophthalmus v. viridescens, Ambystoma maculatum, A. jeffersonianum, Chelydra s. serpentina,* and *Nerodia s. sipedon.*

6.4.6 Seefus Wetland

This wetland contains habitats different from those of the other wetlands. This wetland is more of a swamp with the large trees (although most are dead) than are the other wetlands. The lack of species diversity found at this wetlands was surprising (Table 6.7). In addition to the species observed, *Bufo a. americanus, Hyla chrysoscelis, Rana sylvatica* and *R. palustris* should also be present. *Ambystoma maculatum, Chelydra s. serpentina, Chrysemys picta marginata* and *Nerodia s. sipedon* could also occur in this pond.

Table 6.1. Scientific and common names of amphibians and reptiles found at wetland sites.

Scientific Name	Common Name
Pseudacris c. crucifer	Spring peeper
Pseudacris brachyphona	Mountain chorus frog
Bufo a. americanus	American toad
Hyla chrysoscelis	Gray treefrog
Rana clamitans melanota	Green frog
Rana sylvatica	Wood frog
Rana palustris	Pickerel frog
Rana catesbeiana	Bullfrog
Notophthalmus v. viridescens	Red-spotted newt
Hemidactylium scutatum	Four-toed salamander
Ambystoma maculatum	Spotted salamander
Elaphe obsoleta	Rat snake
Chelydra s. serpentina	Snapping turtle
Thamnophis sirtalis	Eastern garter snake

Table 6.2. Results of amphibian and reptile surveys for Triangle wetland.

DATE	SPECIES	NUMBER	SIZE	METHOD
4/19/96	*Pseudacris c. crucifer*	>50	Adults	Calling
	Bufo a. americanus	=10	Adults	Calling
5/13/96	No specimens observed*			Dip Net
5/22/96	*Pseudacris c. crucifer*	<10	Adults	Calling
	Hyla chrysoscelis	>10	Adults	Calling
	Rana clamitans melanota	<10	Adults	Calling
5/29/96	*Pseudacris c. crucifer*	=05	Adults	Calling
	Rana clamitans melanota	=10	Adults	Calling
6/06/96	*Rana palustris*	01	Larva	Trap
6/29/96	*Pseudacris c. crucifer*	=15	Adults	Calling
	Hyla chrysoscelis	=30	Adults	Calling
4/13/97	*Pseudacris c. crucifer*	05	Adults	Calling

= Indicates approximate numbers
* No species were captured by dip net sweeps.

Table 6.3. Results of amphibian and reptile surveys for Sand Run wetland.

DATE	SPECIES	NUMBER	SIZE	METHOD
4/19/96	*Pseudacris c. crucifer*	>50	Adults	Calling
	Bufo a. americanus	=10	Adults	Calling
5/13/96	*Pseudacris c. crucifer*	01	Larva	Dip Net
	Pseudacris brachyphona	03	Larvae	Dip Net
	Rana clamitans melanota	02	Larvae	Dip Net
5/29/96	*Pseudacris c. crucifer*	=50	Adults	Calling
	Rana clamitans melanota	=10	Adults	Calling
6/06/96	*Hyla chrysoscelis*	01	Adults	Calling
	Rana clamitans melanota	03	Adults	Calling
	Notophthalmus v. viridescens	03	Adults	Trap
6/29/96	*Hyla chrysoscelis*	=30	Adults	Calling
	Rana clamitans melanota	=20	Adults	Calling
	Rana catesbeiana	03	Adults	Calling
4/13/97	*Pseudacris c. crucifer*	05	Adults	Calling

NOTE: a small vernal pool at end of wetland near Rt. 33 bridge had >30 *Rana sylvatica* egg masses. None appeared to be viable. Water in pool was yellow suggesting iron deposits and low Ph.

Table 6.4. Results of amphibian and reptile surveys for Sugar Creek wetland.

DATE	SPECIES	NUMBER	SIZE	METHOD
4/19/96	*Pseudacris c. crucifer*	>50	Adults	Calling
	Bufo a. americanus	>50	Adults	Calling
5/16/96	*Pseudacris c. crucifer*	>50	Adults	Calling
	Hyla chrysoscelis	>50	Adults	Calling
	Bufo a. americanus	=10	Adults	Calling
5/28/96	*Pseudacris c. crucifer*	33	Larvae	Dip Net
	Hyla chrysoscelis	02	Adults	Calling
	Rana clamitans melanota	01	Adult	Calling
	Rana clamitans melanota	02	Larvae	Dip Net
	Rana sylvatica	105	Larvae	Dip Net
5/29/96	*Pseudacris c. crucifer*	>50	Adults	Calling
	Hyla chrysoscelis	03	Adults	Calling
	Bufo a. americanus	02	Adults	Calling
6/03/96	*Pseudacris c. crucifer*	=100	Larvae	Trap
	Rana clamitans melanota	10	Adult	Calling
	Rana clamitans melanota	25	Larvae	Trap
	Hyla chrysoscelis	20	Larvae	Dip Net
	Pseudacris c. crucifer	02	Froglets	Trap
	Notophthalmus v. viridescens	03	Adult	Trap
6/29/96	*Hyla chrysoscelis*	=05	Adults	Calling
	Rana clamitans melanota	=50	Adults	Calling
4/13/97	No individuals observed			

Table 6.5. Results of amphibian and reptile surveys for the Preston wetland.

DATE	SPECIES	NUMBER	SIZE	METHOD
4/19/96	*Pseudacris c. crucifer*	>50	Adults	Calling
	Bufo a. americanus	=10	Adults	Calling
	Rana palustris	=05	Adults	Calling
	Rana sylvatica	>100	Larvae	Sight
	Notophthalmus v. viridescens	11	Adults	Sight
	Chelydra s. serpentina	02	Adults	Visual
	Thamnophis sirtalis	01	Adult	Sight
5/16/96	*Pseudacris c. crucifer*	>50	Adults	Calling
	Hyla chrysoscelis	03	Adults	Calling
	Rana clamitans melanota	02	Adults	Calling
	Rana palustris	01	Adult	Calling
5/28/96	*Rana sylvatica*	15	Larvae	Dip Net
	Hyla chrysoscelis	18	Larvae	Dip Net
5/29/96	*Rana clamitans melanota*	03	Adults	Calling
6/03/96	*Rana sylvatica*	105	Larvae	Trap
	Rana palustris	01	Larvae	Trap
	Hyla chrysoscelis	05	Larvae	Trap
	Notophthalmus v. viridescens	01	Adult	Trap
6/29/96	*Hyla chrysoscelis*	10	Adults	Calling
	Rana clamitans melanota	01	Adults	Calling
	Rana catesbeiana	01	Adults	Calling
4/13/97	*Pseudacris c. crucifer*	05	Adults	Calling

= indicates approximate numbers

Table 6.6. Results of amphibian and reptile surveys for Meadowville wetland.

DATE	SPECIES	NUMBER	SIZE	METHOD
4/18/96	*Ambystoma maculatum*	12	Eggs	Sight
4/19/96	*Pseudacris c. crucifer*	>50	Adults	Calling
	Bufo a. americanus	>10	Adults	Calling
	Notophthalmus v. viridescens	06	Adults	Sight
5/16/96	*Pseudacris c. crucifer*	>50	Adults	Calling
	Hyla chrysoscelis	02	Adults	Calling
	Rana clamitans melanota	01	Adults	Calling
5/29/96	*Pseudacris c. crucifer*	>50	Adults	Calling
	Rana clamitans melanota	>50	Adults	Calling
	Hyla chrysoscelis	01	Adults	Calling
4/13/97	*Ambystoma maculatum*	03	Eggs**	Sight
	Pseudacris c. crucifer	05	Adults	Calling

* Numbers given for eggs refer to number of egg masses, not number of eggs. Number of eggs per mass was approximately 50.

Table 6.7. Results of amphibian and reptile surveys for Seefus wetland.

DATE	SPECIES	NUMBER	SIZE	METHOD
4/18/96	*Chelydra s. serpentina*	1	Adult	Sight
5/22/96	*Pseudacris c. crucifer*	>50	Adults	Calling
	Rana clamitans melanota	01	Adult	Calling
	Notophthalmus v. viridescens	01	Adult	Dip Net
5/29/96	*Pseudacris c. crucifer*	>50	Adults	Calling
	Rana clamitans melanota	01	Adult	Calling
6/06/96	*Rana clamitans melanota*	01	Subadult	Trap
	Rana clamitans melanota	02	Adult	Calling
	Notophthalmus v. viridescens	03	Adults	Trap
	Elaphe o. obsoleta	01	Adult	Hand
6/29/96	*Pseudacris c. crucifer*	03	Adults	Calling
	Rana clamitans melanota	=15	Adults	Calling
	Rana catesbeiana	02	Adults	Calling

Table 6.8. Relative abundance of amphibians and reptiles at various wetlands, based on total number of calls, sightings of adult and larvae, and/or egg masses recorded, April 1996-June 1997.

Species	Number Recorded					
	Mitigation Wetland			Reference Wetland		
	Triangle	Sand Run	Sugar Creek	Beaver	Preston	Meadow-ville
Pseudacris c. crucifer	84	106	285	103	105	155
Pseudacris brachyphona	0	3	0	0	0	0
Bufo a. americanus	10	10	62	0	10	13
Hyla chrysoscelis	40	31	80	0	36	3
Rana clamitans melanota	20	15	87	20	6	51
Rana sylvatica	0	30	105	0	220	0
Rana palustris	1	0	0	0	7	0
Rana catesbeiana	0	3	3	2	1	0
Notophthalmus v. viridescens	0	3	0	4	12	6
Hemidactylium scutatum	0	3	0	1	0	0
Ambystoma maculatum	0	0	0	0	0	2
Elaphe obsoleta	0	0	0	1	0	0
Chelydra s. serpentina	0	0	1	1	2	0
Thamnophis sirtalis	0	0	0	0	1	0
Total number of species	5	9	7	7	10	6
Total number of individuals	155	204	623	132	400	230

CHAPTER 7

MAMMALS

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CHAPTER 7. MAMMALS

7.1 Overall Study Strategies

The study strategy for the mammals was to ascertain their relative abundance not their absolute abundance. The results, because of equal treatment of all sites, are comparable from site to site.

7.2 Methods

Relative abundance of small mammals was determined at the six wetlands by sampling with Museum Special snap traps and Sherman live traps (3.5" X 3.5" X 9"). Small mammals trapped included shrews (Insectivora) and rodents (Rodentia). Transects were established through each wetland, with a total of 20 trap stations in each wetland. Trap stations were established 10 m apart, and were usually within 5 m of standing water. Each trap station contained two snap traps and one live trap. Traps were baited with a peanut butter-rolled oats mixture and trapping was conducted on 4 consecutive nights, 20-23 July.

Relative abundance of large mammals was determined by recording the numbers of direct sightings, tracks, and fecal droppings. Two, 100-meter transects were established in each wetland. These transects were walked during May and October 1996 and May 1997 and all sightings, tracks, and fecal droppings of mammals observed were recorded. It was originally planned to conduct these surveys during June and July, but dense vegetation greatly reduced visibility and made surveys impossible during summer months.

7.3 Results

A total of 160 small mammals was captured during the 4 nights of trapping (Table 7.1). The most abundant small mammal captured was the white-footed mouse (*Peromyscus leucopus*) (114 captures), followed by the meadow vole (*Microtus pennsylvanicus*) (40 captures), the short-tailed shrew (*Blarina brevicauda*) (4 captures), and the meadow jumping mouse (*Zapus hudsonius*) (2 captures). Also captured in small mammal traps were 8 crayfish and 1 green frog (*Rana clamitans*).

Mitigation wetlands had fewer small mammals than did reference wetlands: a total of 120 small mammals was captured in reference wetlands compared to only 40 in mitigation wetlands (Table 7.1). This large difference is due primarily to the relative abundance of white-footed mice (106 captures in reference wetlands and 8 in mitigation wetlands). The meadow vole was equally abundant in each type: 20 captures in mitigation wetlands and 20 in reference wetlands. While the meadow vole prefers habitats dominated by herbaceous vegetation, the white-footed mouse prefers habitats dominated by woody vegetation. Mitigation wetlands contained significantly less woody vegetation than did reference wetlands.

Sightings and sign were recorded for six different mammals: muskrat (*Ondatra zibethica*), beaver (*Castor canadensis*), raccoon (*Procyon lotor*), mink (*Mustela vison*), red fox (*Vulpes fulva*) and white-tailed deer (*Odocoileus virginianus)* (Table 7.2). A total of 231 different mammal sightings/sign was recorded: 109 muskrat, 70 deer, 28 raccoon, 18 beaver, 4 mink, and 2 red fox. Relative abundance was about equal between mitigation wetlands (122 sightings/sign) and reference wetlands (109 sightings/sign). When only wetland species (muskrat, raccoon, and beaver) were considered, mitigation wetlands had 89 sightings/sign compared to 66 in reference wetlands

7.4 Discussion

The higher abundance of white-footed mice in reference wetlands is explained by habitat preference of this species. While the meadow vole prefers habitats dominated by herbaceous vegetation, the white-footed mouse prefers habitats dominated by woody vegetation. Mitigation wetlands contained significantly less woody vegetation than did reference wetlands.

Trapping and direct observation of sign indicate that mitigation wetlands support the same species of mammals as do the reference wetlands. The only mammal species recorded for reference wetlands that was not recorded for mitigation wetlands was the short-tailed shrew. Only four short-tailed shrews were trapped during this survey. It should be noted that shrews are difficult to trap in both live traps and snap traps because of their small size and their reluctance to enter traps.

Muskrats have invaded, and are fairly abundant, in all three mitigation wetlands. The abundant herbaceous vegetation and the pools of water provided excellent muskrat habitat in the mitigation wetlands.

Table 7.1. Relative abundance of mammals at mitigation and reference wetlands, based on total number of captures, July 20-23, 1996.

	Mitigation Wetland			Reference Wetland			
Species	**Sugar Creek**	**Sand Run**	**Triangle**	**Preston**	**Meadow-ville**	**Seefus**	**TOTAL**
White-footed Mouse	22	6	0	35	24	46	114
Meadow vole	8	0	12	6	2	12	40
Short-tailed Shrew	0	0	0	0	4	0	4
Meadow jumping mouse	2	0	0	0	0	0	2
TOTAL	32	6	12	42	30	58	160

Table 7.2. Relative abundance of mammals at mitigation and reference wetlands, based on animal sightings and signs, May and October 1996, and May 1997.

	Mitigation Wetland			Reference Wetland			
Species	**Sugar Creek**	**Sand Run**	**Triangle**	**Preston**	**Meadow-ville**	**Seefus**	**TOTAL**
Muskrat	31	20	26	9	2	21	109
Racoon	5	2	2	6	3	10	28
Beaver	0	3	0	3	0	12	18
Mink	1	0	1	1	0	1	4
Red Fox	1	0	0	0	1	0	2
W.T. Deer	22	5	3	12	12	16	70
TOTAL	60	30	32	31	18	60	231

CHAPTER 8

BIRDS

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CHAPTER 8

BIRDS

8.1 Overall Study Strategies

Since wetland birds require vegetative cover, nest sites, and food sources appropriate for their specialized lifestyle, they will be of most interest for this study. By censussing all six wetlands for the presence of birds during several seasons, it will be possible to determine the functioning of the wetlands as avian habitat. The censussing method will allow determination of bird diversity, abundance, and method of habitat usage at each wetland.

8.2 Methods

8.2.1 General Method of Censussing and Identification

All detectable birds (sight and vocalizations) were sampled at all six wetland sites using the same methods during each visit. When a wetland was visited, the same traversing transects were walked. These paths were directly through the wetlands, along beaver dams, and along its borders. Certain pools and channels of wetland could not be traversed because of water above waist level, but could be clearly seen from other areas of the wetland. Each visit to the wetland lasted 45 minutes. No "pishing" or play-back of tape recorded songs was conducted. Censuses were not conducted during high winds or during precipitation, which would result in artificially low number of detections. Birds encountered just upland of the wetland perimeter were noted on field sketches, but not included in the data set of birds within the wetland.

Identification and species designations follow the American Ornithologists' Union (1983) checklist, as modified recently (American Ornithologists' Union 1997). With each identification, a seasonal status or habitat usage designation was often added. If the bird was giving territorial song, engaging in aggressive chases, or accompanying young, the species was deemed a summer breeding resident.

8.2.2 Timing of Censuses

Censuses were begun in May of 1996 and ended in early February of 1998. A total of 7 sets of censuses were conducted throughout the year to determine seasonal patterns in wetland use by birds (e.g., migration, wintering ground, and breeding). Spring and summer censuses were conducted from one half hour before sunrise to 4 hours after sunrise to avoid periods of low activity during warm times of the day, and therefore preventing biasing towards undercounting. Four censuses were conducted in late May and June, the breeding season, because of the importance of repeatable data for this most important of seasons for birds. Fall and winter censussing should not be performed before dawn because cold weather inhibits activity and biases towards undercounting. Fall and winter censussing began at 0815 and concluded by 1130. Because of the distances involved between the wetlands, only three wetlands could be censussed each morning. The other three wetlands would be censussed within two to four days to allow the data to be comparable.

8.2.3 Spot Map/Point Count Censussing

A spot map/point count method adapted from those used by the North American Breeding Bird Survey (Peterjohn 1994) was used. This method differs from the one used in our preliminary report (Fortney and Edinger 1996), to reflect the larger number of sites and site visits, the expanded seasonal coverage, and the greater amount of time available to census. During the wetland visit, while the observer was walking slowly through the wetland, birds were detected by song, call notes, and visually with the aid of 9x35 or 10x50 binoculars. For birds beyond the wetland border, distance beyond the border was estimated as less than 50 m, between 50 m to 100 m, between 100 m to 200 m, and beyond 200 m distance categories. Only birds detected within the wetland boundaries are included in the tables.

8.2.4 Calculation of Bird Species Density and Diversity

The area of wetland censussed for this study was, in three cases, about 9.5 acres. Given this consideration toward size of wetland area censussed, the count of birds given in Tables 8.3a and 8.3b can also be read as the population density of the species per 9.5 acres for these three wetlands. Given that some census visits do not detect all the birds present, because of their silence or hiding behavior -- particularly during the egg and nestling phases -- it is best to adopt the maximum number of birds of that species observed for the particular season as the best estimate of breeding numbers. While diversity indices have to be interpreted carefully when being used to evaluate conservation value of natural areas (Goetmark *et al.* 1986), they provide a comparative measure of the attractiveness of the sites for birds. It is important to keep separate total bird species diversity and wetland bird species diversity, and concentrate also on wetland species diversity during the breeding season and year-round.

8.3 Results

The results of the census visits are included in Table 8.3a and Table 8.3b. Since there is a very large amount of information in this table, it is necessary to breakdown this table into smaller tables to answer more specific questions about each wetlands' bird life with regard to species diversity, species abundance, and seasonal patterns of use.

The average year-long bird species diversity found in mitigation wetlands was slightly higher than that found in reference or natural wetlands (48 versus 42 species, or 12.5% higher). There was some variability (maximum of 20%) among the six wetlands in year-round bird species diversity.

It was different for year-long wetland bird species diversity; reference wetlands averaged higher than mitigation wetlands (10 versus 8.3, or 20% higher, Table 8.3c). In addition, there was considerable variability between the six wetlands, with the most wetland bird species-rich wetland (Triangle, a mitigated location) hosting 100% more wetland birds than the least wetland bird species-rich wetland (Sugar Creek, a mitigated site, and Seefus, a natural wetland, Table 8.3c).

Another way of evaluating avian wetland functioning is by comparing the densities of wetland species of birds in mitigated versus natural wetlands at different times of the year. Table 8.3d summarizes this comparison. One overall measure of a wetland's capacity to support breeding wetland birds, or its productivity, is the total of all breeding wetland birds censussed. The final column of this table shows the top of all wetlands in terms of wetland species diversity, Triangle, is only about average when compared to the three natural wetlands (29 versus an average of 26). The top wetland in terms of productivity is Preston, a reference wetland, with 48 breeding individuals. Variability was fairly large in this measure, varying from the high just mentioned to a low of 20, found at Sugar Creek. Average productivity for mitigated wetlands was 23 and 29 for reference wetlands, a difference of 25%. However, averages alone do not fully explain the differences found between individual mitigated and reference wetlands in regards to wetland bird habitat.

8.4 Discussion

8.4.1 Potential Limitations of the Study

Unlike the preliminary study (Fortney and Edinger 1996), this study fully censussed all six wetlands repeatedly during the breeding season. The American bittern, sora, swamp sparrow, and American woodcock are breeding wetland birds that were not encountered, but might have occurred, given the accounts of the distribution of West Virginia birds in Hall (1983) and Buckelew and Hall (1994). It is unlikely the middle two species occurred in the six wetlands, since the coverage was thorough, although it is possible the bittern and woodcock were missed since censussing did not occur at twilight or evening, when these two crepuscular species are often active.

Since repeated censussing was not performed within the spring migration, fall migration, or winter resident seasons, inferences from the data collected should be considered preliminary.

8.4.2 Birds as Wetland Indicators

Some bird species, such as those italicized in Table 8.3a and 8.3b, and listed in Table 8.3d, clearly depend upon wetlands, since they are rarely observed elsewhere. Other birds, such as red-shouldered hawks (Bosakkowski *et al.*, 1992), northern warriers, swallows, swifts, and several species of woodpeckers use and benefit from wetlands, but do not seem to be found exclusively in wetlands; however, for these species, wetlands are included within their home range. These might be called wetland facilitated species. Many other bird species have individuals who will feed and breed within wetlands, or within other habitats that satisfy their habitat needs.

8.4.3 Triangle Wetland

This mitigated wetland constructed on the site of a natural wetland proved to be very attractive to wetland birds, attracting more wetland bird species, year-round, than any other mitigated or reference wetland. Particularly surprising, given the proximity of Route 33, was the attractiveness of Triangle for migrant wetland birds. It had the only records for greater yellowlegs, marsh wren, and blue-winged teal, the highest population of green herons, and healthy populations of red-winged blackbirds, wood ducks, and common yellowthroats. Because of a poorly developed shrub layer within the wetland itself, willow flycatchers and yellow warblers, two wetland birds that prefer shrubby habitats, were relatively rare. Its productivity of wetland birds was above average when compared to all six wetlands (29 versus 25), and was the highest of all mitigated wetlands.

8.4.4 Sand Run Wetland

This wetland/pond attracted a different set of birds because of its permanently flooded western end and shallow wetland on the eastern, upstream end. Its deep western pool had healthy numbers of black ducks, wood ducks, and mallards, although only mallards seemed to breed successfully here. Its overall wetland bird species diversity was 10, average for the mitigated wetlands and slightly above the average for the reference wetlands (8.3 wetland species). Since shrubs are limited to primarily the fringes of this wetland, yellow warblers were not very abundant. The extremely steep slope up to Route 33 prevents establishment of wetland border on the elongated south side of the wetland. Wetland bird productivity was slightly low at 23 (compared to average of 25 for all six wetlands). As in the case of Triangle wetland, only partly developed shrub layer, but more importantly the lack of gradually sloping wetland borders, probably kept this value relatively low. The broad expanse of water with emergent insects attracted five species of swallows and swifts. While not wetland birds, this guild of bird is benefited by open areas with numerous flying insects.

8.4.5 Sugar Creek Wetland

While potentially benefitted by a remote location not served by a paved road, this youngest of the mitigated wetlands had the lowest year-long diversity of wetland birds, at 7, and relatively low populations of the wetland birds which were present, such as yellow warbler. Breaches in two dams lowered the water level during much of the study, although recent repairs have brought it back to original levels. Of the three mitigated wetlands, the shrub layer is least developed in Sugar Creek, explaining the lack of willow flycatchers and rarity of gray catbirds. The low productivity of wetland birds could also be the result of lack of water retention and shrub development during the study period. Even so, it was best of all the wetlands for attracting swallows and swifts, yet this property is more characteristic of grasslands than wetlands (while swallows and swifts may feed in wetlands, they are not obligatory wetland species).

8.4.6 Preston Wetland

This roadside natural wetland had two or three very high water levels during the study period, thanks to floods and a family of beavers. Unlike the three mitigated wetlands, its shrub layer is well developed. Its year-round wetland species diversity was the highest of the reference wetlands (only exceeded by Triangle, and matched by Sugar Creek). Its wetland bird productivity was the highest of all six wetlands; at 38 it was 31% higher than the next highest wetland, Triangle. These high scores may be attributed to the large amount of wetland surrounding the study wetland, relatively flat terrain, and well-developed shrub and tree layers. Unlike the results found in the mammal and amphibian surveys,the proximity of Route 50 did not appear to diminish wetland bird diversity, at least not to the point it scored much below the other five wetlands.

8.4.7 Meadowville Wetland

This wetland had the lowest overall species diversity and a wetland species diversity of 8, which was average for reference wetlands and slightly below average for mitigated wetlands. Its wetland bird productivity was also low, at 20 individuals. While the shrub layer is well developed at Meadowville, it has the smallest proportion of area as open water. When open water does occur, it is quite shallow. Both factors contributed to its singular lack of ducks and geese. A shortage of open mudflat edges probably helps explain the lack of shorebirds observed at Meadowville.

8.4.8 Seefus Wetland

This natural wetland had some characteristics not matched by any of the other natural or constructed wetlands. Its overall bird species diversity was about average for the two classes of wetlands, at 45, but its wetland species diversity was quite low at 7. Headwater, beaver pond wetlands are characterized by steep valley sides in West Virginia. Because of the lack of extended marsh-like border that can support emergent and "wet-feet" shrubs such as alder and willow, this type of wetland attracts few or no wetland birds such as yellow warbler, willow flycatcher, alder flycatcher, red-winged blackbird, and green heron, which use these habitats.

On the other hand, it had the greatest proportion of standing water and the highest number of standing dead snags. Its value as woodpecker habitat can only be called remarkable. All six species of woodpecker were present during the breeding season. One of these, the red-headed woodpecker, is associated with bottomlands and oak savannas, and was not encountered at any other wetland.

8.4.9 Other Comparisons of Bird Diversity in Constructed and Natural Wetlands

Delphey and Dinsmore (1993) found restored prairie potholes had significantly lower diversity of wetland birds other than waterfowl, such as common yellowthroat, red-winged blackbird, marsh wren, and swamp sparrow. They attributed this deficiency to incomplete development of typical vegetation structure for wetlands. Waterfowl were apparently less sensitive to typical vegetation development since duck pair counts and species richness did not differ significantly between restored and natural potholes.

A comparison of younger and older restored wetlands in Iowa point up the importance of wetland vegetation and size characteristics (VanRees-Siewert and Dinsmore 1996). The mean number of breeding birds was significantly greater in older restored wetlands than younger restored wetlands (7.2 species in 4-year-old wetlands versus 4.3 species in 1-year-old wetlands). Total and breeding bird species richness increased with percent cover of emergent vegetation. Waterfowl species richness and breeding waterfowl species richness were influenced more by wetland area than vegetation characteristics.

Havens, Varnell and Bradshaw (1995) found constructed tidal marshes had fewer bird nesting sites than natural reference marshes; this may have been related to the significantly lower vegetation density and zooplankton abundance in the constructed marshes.

All of these studies emphasize the importance of development of appropriate wetland vegetation and invertebrate populations before wetland vertebrate densities can be expected to reach those of natural wetlands.

Table 8.3a . Results of bird censuses of three mitigation (constructed or modified) wetlands. (Birds in italics require wetlands).

Species	Triangle							Sand Run							Sugar Creek						
Census Dates	5.03	5.31	6.08	6.15	6.25	10.18	1.31	5.03	5.31	6.08	6.15	6.25	10.18	1.31	5.03	5.31	6.08	6.15	6.25	10.18	1.31
	5.06	6.02	6.08	6.16	6.26	10.19	2.01	5.06	6.02	6.08	6.16	6.26	10.19	2.01	5.06	6.02	6.08	6.16	6.26	10.19	2.01
Bittern, American								1													
Blackbird, Red-winged	12	7	8	8	4			5	5	6	6	3			16	4	3	5	4		
Bluebird, Eastern										2										2	
Bunting, Indigo												1						1	2		
Cardinal, Northern	1																				
Catbird, Gray	1			1		1			2	2	1	2				1					
Chat, Yellow-breasted	1										1				1	2	1		1		
Chickadee, Black-capped																					
Chickadee, Carolina						1		2									2		2		
Coot, American																					
Cowbird, Brown-headed			1																		
Crow, American				1		1	2	2	2						1		2		1	9	
Cuckoo, Black-billed				1																	
Dove, Mourning				2																	
Duck, Black								4					2								
Duck, Wood	2	3	9	6	7	4	2			1		7			12	3	2			1	
Flicker, Northern		1						1									1				
Flycatcher, Acadian										1		1									
Flycatcher, Alder																					
Flycatcher, Great-crested											1										
Flycatcher, Least											1								1		
Flycatcher, Willow	1	1	1	1																	
Gnatcatcher, Blue-gray								1							1						
Goldfinch, American	1	4	1	2	2			1	2	1	2	2	10		2						
Goose, Canada								2													
Grackle, Common										3					1						
Grebe, Pied-billed													2								
Grosbeak, Blue																					
Grosbeak, Rose-breasted								1													
Harrier, Northern															1						
Hawk, Red-shouldered																					
Hawk, Red-tailed				1											2				1		
Heron, Great Blue			1									1									
Heron, Green	4		3					2		2	2	2				2		1			
Hummingbird, Ruby-thr.										1		1									
Jay, Blue																					
Junco, Dark-eyed													1								
Kestrel, American						2															
Killdeer				3											2	4	2				
Kingbird, Eastern				2				2		1	2	2									
Kingfisher, Belted						1		1						1							
Kinglet, Golden-crowned						1							1								
Kinglet, Ruby-crowned						1															
Mallard	1	2	1					4			4					3				2	
Mockingbird, Northern						1															
Nuthatch, White-breasted													1								1
Oriole, Baltimore	1		1					2		2						2	1				
Oriole, Orchard			1							1											
Pewee, Wood																					
Rail, Virginia																					
Robin, American	1	1				1															
Sandpiper, Spotted																		2			
Sparrow, Chipping				1																	
Sparrow, Field															1						1
Sparrow, Grasshopper																					
Sparrow, Henslow's						1															
Sparrow, Song	2	2		2	4	16	4	2	3	4	1	3	3		2	2	3	1	3	18	4

Table 8.3a. (Continued.) Results of bird censuses of three mitigation (constructed or modified) wetlands.

Species (continued)	**Triangle**							**Sand Run**							**Sugar Creek**						
Census Dates	5.03	5.31	6.08	6.15	6.25	10.18	1.31	5.03	5.31	6.08	6.15	6.25	10.18	1.31	5.03	5.31	6.08	6.15	6.25	10.18	1.31
	5.06	6.02	6.08	6.16	6.26	10.19	2.01	5.06	6.02	6.08	6.16	6.26	10.19	2.01	5.06	6.02	6.08	6.16	6.26	10.19	2.01
Sparrow, White-throated																					3
Starling, European		1	2					1					2								
Swallow, Bank											1				1						
Swallow, Barn								1				1			12			2			
Swallow, Rough-winged	2									2	2	1			8	2	3	1			
Swallow, Tree	4	1	2	2	2			1				2			9	1	2	2			
Swift, Chimney			3		2				2	3		4			2		4	1			
Tanager, Scarlet		1																			
Teal, Blue-winged	7																				
Titmouse, Tufted			1										1							4	
Towhee, Rufous-sided															2						
Thrasher, Brown	1			1																	
Vireo, Red-eyed									2		1	1				2	1		1		
Vireo, Solitary																					
Vireo, White-eyed								1							1			1	1		
Vireo, Yellow-throated										1											
Vulture, Turkey															1					4	
Warbler, Blackburnian																					
Warbler, Black-thr. green																					
Warbler, Blue-winged																					
Warbler, Cerulean																					
Warbler, Chestnut-sided								2													
Warbler, Golden-winged																					
Warbler, Hooded																					
Warbler, Magnolia																					
Warbler, Prairie												1							1		
Warbler, Worm-eating										1											
Warbler, Yellow	1	1						2	1	2	1	1				1	2				
Warbler, Yellow-throated			1	1						1	1										
Warbler, Yellow-rumped						2														4	
Waterthrush, Louisiana																					
Waterthrush, Northern	1																				
Waxwing, Cedar	1	1	2	2	5				7	10	5	4				3	2		2	2	
Woodpecker, Downy						1					1		2				1				
Woodpecker, Hairy																					
Woodpecker, Pileated																					
Woodpecker, Red-headed																					
Woodpecker, Red-bellied										1											1
Wren, Carolina														1							
Wren, House	1				1																
Wren, Marsh		1																			
Wren, Sedge	1															1	1				
Yellowlegs, Greater	2																				
Yellowlegs, Lesser	5							1													
Yellowthroat, Common	1	3	4	1	1			1			1					4	3	2	4		

Table 8.3b. Results of bird censuses of three reference (natural) wetlands.

Species	Preston							Meadowville							Seefus						
Census Dates	5.03	5.31	6.08	6.15	6.25	10.18	1.31	5.03	5.31	6.08	6.15	6.25	10.18	1.31	5.03	5.31	6.08	6.15	6.25	10.18	1.31
	5.06	6.02	6.08	6.16	6.26	10.19	2.01	5.06	6.02	6.08	6.16	6.26	10.19	2.01	5.06	6.02	6.08	6.16	6.26	10.19	2.01
Bittern, American																					
Blackbird, Red-winged	6	8	7	8	6			1	2	4	9	4				1	1				
Bluebird, Eastern													2	1	2	1	2		4	2	
Bunting, Indigo					2				1	1	1	1					1	1	2		
Cardinal, Northern						2	1		1		1	1	2	1							
Catbird, Gray	2	2	2	1	1			2	2	2	1	2	1								
Chat, Yellow-breasted												1									
Chickadee, Black-capped							1														
Chickadee, Carolina																2					
Coot, American	1																				
Cowbird, Brown-headed	1										1	1					1	1	1		
Crow, American						2		3				2									
Cuckoo, Black-billed	1	1	1								1					1		1			
Dove, Mourning																					
Duck, Black																			4		
Duck, Wood	2	1	1	2	10										15	6	13				
Flicker, Northern																1	1	3	2		
Flycatcher, Acadian																1					
Flycatcher, Alder																	1				
Flycatcher, Great-crested																					
Flycatcher, Least		1																			
Flycatcher, Willow		1	1	2	1				2	4	4	4									
Gnatcatcher, Blue-gray																					
Goldfinch, American				2		3	3	4												3	
Goose, Canada					4										2						
Grackle, Common		2	2	1	2				1	1	2										
Grebe, Pied-billed																					
Grosbeak, Blue	1																				
Grosbeak, Rose-breasted																			1		
Harrier, Northern																					
Hawk, Red-shouldered																		1			
Hawk, Red-tailed														1					1	2	
Heron, Great Blue																					
Heron, Green	2	1		2							1										
Hummingbird, Ruby-thr.										1		1						1	1		
Jay, Blue												1					1				
Junco, Dark-eyed																					
Kestrel, American																					
Killdeer															1						
Kingbird, Eastern	1		1	2	2											1					
Kingfisher, Belted																					
Kinglet, Golden-crowned																					
Kinglet, Ruby-crowned																					
Mallard							2														
Mockingbird, Northern						1															
Nuthatch, White-breasted																1			1	2	1
Oriole, Baltimore		1							1		1					1	1	2			
Oriole, Orchard	1				1																
Pewee, Wood		1														1		2	2		
Rail, Virginia																				1	
Robin, American		2	2	1					1		1	1				1					
Sandpiper, Spotted																					
Sparrow, Chipping																					
Sparrow, Field								1						5							
Sparrow, Grasshopper																					
Sparrow, Henslow's																					
Sparrow, Song	2	2	3	2	6	10	6		3		2	5	5	4		2	1	1	5	8	

Table 8.3b (continued). Results of bird censuses of three reference (natural) wetlands.

Species (continued)	**Preston**							**Meadowville**							**Seefus**						
Census Dates	5.03	5.31	6.08	6.15	6.25	10.18	1.31	5.03	5.31	6.08	6.15	6.25	10.18	1.31	5.03	5.31	6.08	6.15	6.25	10.18	1.31
	5.06	6.02	6.08	6.16	6.26	10.19	2.01	5.06	6.02	6.08	6.16	6.26	10.19	2.01	5.06	6.02	6.08	6.16	6.26	10.19	2.01
Sparrow, White-throated						3							5	5							
Starling, European		2	1	2		3															
Swallow, Bank																					
Swallow, Barn																					
Swallow, Rough-winged																	3				
Swallow, Tree												1				1	1	1	6		
Swift, Chimney	1											7									
Tanager, Scarlet								1			1						1		2		
Teal, Blue-winged																					
Titmouse, Tufted					2		2			2		2		1							
Towhee, Rufous-sided													2			1	1	1			
Thrasher, Brown					1				1	1											
Vireo, Red-eyed		1	1								4				1				2		
Vireo, Solitary																			1		
Vireo, White-eyed								1		1		5									
Vireo, Yellow-throated																					
Vulture, Turkey																			1		
Warbler, Blackburnian																					
Warbler, Black-thr. green																			1		
Warbler, Blue-winged		1	1	1																	
Warbler, Cerulean																1					
Warbler, Chestnut-sided																					
Warbler, Golden-winged								1	1	1											
Warbler, Hooded																			1		
Warbler, Magnolia																1					
Warbler, Prairie																					
Warbler, Worm-eating																					
Warbler, Yellow		4	4	1	2			1	1	2	3	2									
Warbler, Yellow-throated																	1				
Warbler, Yellow-rumped						17							4								
Waterthrush, Louisiana								1							2						
Waterthrush, Northern																1					
Waxwing, Cedar		2	4	3	3				1	2	4		5			2		2	20	2	
Woodpecker, Downy				1			1			1						3		1			
Woodpecker, Hairy																	1				
Woodpecker, Pileated																	1			2	1
Woodpecker, Red-headed															1						
Woodpecker, Red-bellied															2				1		
Wren, Carolina						2	1						1								
Wren, House	1		1																		
Wren, Marsh								1													
Wren, Sedge		1	1					2		1											
Yellowlegs, Greater																					
Yellowlegs, Lesser																					
Yellowthroat, Common	2	2	3	5	1			3	1	2	2	1									

Table 8.3c. Overall bird species diversity and wetland bird species diversity of mitigated and unmitigated wetlands, during different seasons.

Parameter	Triangle	Sand Run	Sugar Creek	Preston	Meadowville	Seefus
Bird species diversity:						
Breeding season	33	35	26	28	29	40
Spring migration	24	24	20	14	13	8
Fall migration	14	9	8	9	10	8
Winter resident	3	2	5	9	7	2
Overall	50	53	41	41	40	45
Wetland bird species diversity:						
Breeding season	9	8	7	7	5	5
Spring migration	12	7	2	5	6	3
Fall migration	1	2	2	0	0	0
Winter resident	0	0	0	0	0	0
Overall	14	10	7	10	8	7

Table 8.3d. Maximum density (per 9.5 acres) or highest count of species of wetland birds censussed during the breeding season in mitigated and unmitigated wetlands.

Species	Triangle	Sand Run	Sugar Creek	Route 50	Meadowville	Seefus
Blackbird, Red-winged	8	8	3	10	9	1
Duck, Black	0	0	0	0	0	4
Duck, Wood	9	9	2	13	0	13
Flycatcher, Alder	0	0	0	0	0	1
Flycatcher, Willow	1	0	0	3	4	0
Goose, Canada	0	0	0	5	0	0
Heron, Green	3	3	1	3	1	0
Mallard	2	5	2	3	0	0
Warbler, Yellow	1	3	1	5	3	0
Waterthrush, Northern	0	0	0	0	0	1
Wren, Marsh	1	0	0	0	0	0
Wren, Sedge	0	0	1	1	1	0
Yellowthroat	4	1	2	6	2	0
Wetland Species, Totaled	29	29	11	48	20	20

CHAPTER 9

GENERAL CONCLUSIONS AND RECOMMENDATIONS

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CHAPTER 9

GENERAL CONCLUSIONS AND RECOMMENDATIONS

9.1 Individual Nature of Each Wetland, Natural or Mitigated

Just as nature does not create wetlands following exactly the same recipe each time, this study provides evidence that every mitigation wetland constructed should not strive to establish a "laundry list" of location and engineered characteristics. Instead, consideration should be made to match the mitigation wetland to a type of natural wetland that is normally encountered in the region. The three reference wetlands considered in this study differed considerably in their topography, hydrology, proportion of open water, and history of formation. The Preston and Meadowville wetlands occupy flat floodplains and have considerable shrub development. The Seefus wetland, caused by a series of beaver dams on a headwater stream, occupies a steep valley and has little shrub development along its borders. It does have extensive tree snags that are important for cavity nesters and boring insect feeders, such as tree swallows, bluebirds, and various woodpeckers. It also has the most extensive pools of the natural wetlands. Beaver pond wetlands can be further divided into active and inactive types, with somewhat different characteristics (Grover and Baldassarre 1995).

The individual nature of each wetland, already demonstrated in the vegetation, amphibian, reptile and mammal data presented so far, also becomes apparent when comparing the birdlife found at each. Since the reference or natural wetlands varied considerably, there probably should not be a single goal or model for every mitigated wetland.

9.2 Creation of Impoundments and its Effects on Wetland Species

Engineers of mitigation wetlands have many choices when constructing impoundments. Everything from deep lakes to seasonally flooded shallow pools are possible. However, one risk is that seasonally flooded, nonpersistent and persistent emergent vegetation will convert to shallow, open-water areas (Weller et al. 1991). In the study just cited, while duck densities increased slightly, this was attributed to nest box programs and transplanting, and without these two activities, waterfowl densities may have declined because of a loss of wetland vegetation. Other wetland bird species did not increase.

9.3 Submergent Plants as Wildlife Food

For waterfowl, the establishment of submergent plants should be a goal for any mitigated wetland with pools deep enough to support them. They are important as food for mammals and birds, and for invertebrates that serve as food for mammals, birds, and amphibians. Mulyani and DuBowy (1993) found the species richness of submergent plants correlated positively with the number of species of several avian guilds (dabblers, wading birds, and plunge divers). Lillie et al. (1991) found annual fluctuations in mallard densities were not significantly correlated with macrophyte biomass or invertebrate density associated with these macrophytes. On the other hand, they found blue-winged teal densities were positively correlated with macrophyte density in heavily vegetated wetlands, but were positively correlated with invertebrate biomass in less heavily vegetated wetlands.

9.4 The Trade-off Between Wetland Vegetation and Open Water

While wetland vegetation may be necessary to establish wetland functioning, too much vegetation at the expense of open water or too much vegetation of the wrong type, such as cattails (*Typha* spp.) can also diminish wetland quality. Triangle wetland is experiencing an expansion of cattails that may threaten its other wetland characteristics. Linz et al. (1996) found that glyphosate-induced vegetation changes created more open water and increased the densities of diving ducks and dabbling ducks, as long as a mosaic of open water, live vegetation, and dead vegetation was maintained. We do not recommend glyphosate treatment for Triangle. However, the proportion of open water to emergent hydrophyte-dominated habitats evaluated in this study appears to be balanced, providing a diversity of hydrological regimes and vegetative cover.

9.5 Relative Size of Mitigated Wetlands

Five hectare wetlands or 50 ha wetlands? Relatively few studies have been conducted on the effects of constructed wetland size on wetland biota diversity. Some of those that have been done (e.g., Leschisin et al. 1992) suggest larger wetlands are better for waterfowl. This study found wetlands with larger surface areas and longer shoreline length had greater pair use for all but one duck species. A study of avian use of wetlands in reclaimed minelands found no significant relationship between bird species diversity and wetland size (Mulyani and DuBowy 1993). Since the predicted size of constructed wetlands is often under-estimated compared to the final wetland (McKinstry and Anderson 1994), this may proportionately reduce waterfowl usage. Similarly, for vascular plants, extensive ecotones appear to enhance diversity.

Relatively high habitat uniformity (at Sand Run vs. Triangle) results in lower species richness.

On the other hand, a moderate loss of some small wetlands can have an inordinately large effect on migration distances and extinction of local populations of some turtles, birds, and mammals that rely on wetlands (Gibbs 1993). Given the more rapid reproduction potential for salamanders or frogs, they do not appear to be at risk from the loss of some small wetlands. These data suggest providing several smaller, well functioning mitigated wetlands in an area where wetland loss has occurred (such as West Virginia), could reduce the risk of extirpation of local populations dependant upon wetlands.

9.6 Invasion of Woody Wetland Vegetation

If succession proceeds, woody vegetation will become established at the mitigation wetlands and will result in an increase of small mammals, reptiles, and birds. Woody vegetation, primarily wetland shrubs, provides food, cover, and perches that are not now present. With invasion of woody plants, the overall biodiversity of mitigation wetlands should become more comparable to that of the reference wetlands. Wetland birds likely to become established or more abundant, given their presence in reference wetlands, are yellow warbler, alder flycatcher, and willow flycatcher.

However, the critical question is how fast will invasion of woody plants occur. Typically in drained beaver ponds in Canaan Valley, WV, shrub invasion often occurs in 10 to 15 years (Fortney 1997). At this point, we cannot predict when significant invasion will occur in constructed wetlands. After five years, invasion of woody plants in both Triangle and Sand Run has been limited, even with efforts to facilitate this by planting woody plant materials. However, in the upper end of Sand Run, black willow and sycamore are well established. This area, though, has been modified by alluvial deposits of sand dropped by flood waters from Sand Run, changing the substrate and, doubtless, introducing these species.

Planting herbaceous, shrub and tree propagules in constructed wetlands is expensive. Given the current limited success plantings at Triangle and Sand Run, it may not be a cost-effective process. We suggest considering less costly methods of speeding new species into constructed wetlands. Harvesting local seed of wetland plants and broadcasting them into the mitigation wetlands in areas where the hydrological regime matches their optimum survivorship could be cost effective. Further, constructing wetlands so there is periodic overbank flow from nearby streams appears to be a logical means to enhance diversity. The data in this study supports this as a means of naturally enhancing species diversity, as noted for the Triangle and Sugar Creek wetlands. In any event, it is possible that invasion of wetland species will occur at constructed wetlands through natural ecological succession, if the hydrologic regime matches that of natural wetlands. If overbank flow occurs, dikes and dams should be engineered to withstand the swift currents of floodwaters. Large scale failure of dikes or dams, such as that which occurred at the Sugar Creek site, not only reduces wetland shrub establishment, but also results in lost pools and wetland mud margins that are important for yet other species of wetland animals and as sites for recruitment of emergent herbaceous plant species.

While some vegetation criteria may be imperative for establishing habitat for endangered or threatened species (Haltiner et al. 1997), no species of high importance would be impacted by a moderate delay in the establishment of woody vegetation at the three mitigation sites studied.

9.7 Invasion of Herbaceous Wetland Vegetation

Wetland grasses, rushes, sedges and forbs can increase habitat for wetland birds and mammals. Downy ducklings of mallards and teal preferred sedge stands when foraging, which were found to have more nektonic and emerging insects than the other shore types (Nummi and Poeysae 1995). If ponds of water are adjacent to where herbaceous wetland vegetation is desired, there is a good chance waterfowl will disperse seeds to these sites. Vivian-Smith and Stiles (1994) found that more than 75% of waterfowl in New Jersey salt marshes carried wetland plant seeds, primarily in the feathers but also on the feet. This principle of sticky seeds being transported by animals is known as epizoochory.

9.8 Location of Mitigation Wetlands: Isolation from Human Impacts Improves Some Wildlife and Aesthetic Values

The Sugar Creek mitigation wetland appears to support the greatest biodiversity of amphibians, reptiles, and mammals, but not birds. This may be partly due to the isolation, topographic position, and interspersion of standing water areas with wetland areas not having standing water, and its relative isolation. There are no major roads near the Sugar Creek site. In contrast, the Triangle and Sand Run sites are situated near heavily-traveled highways. Triangle and Sand Run wetlands are bordered on at least two sides by roads, and/or railroads, and/or steep wooded upland habitats. In contrast, Sugar Creek is situated near a rarely used dirt road. There are more nearby wetland habitats associated with Sugar Creek wetland than with the other two mitigation wetlands. This provides a source of wetland wildlife for natural "stocking" of the mitigation wetland. Even so, this did not contribute to the wetland bird species diversity found at Sugar Creek, which ranked low at only 50% to 70% of the other two mitigation wetlands (Table 8.3c).

Certain wetland species are relatively intolerant to human presence, such as mink, otter, some raptores (hawks and eagles), and some rails and herons. If a mitigation wetland is to achieve full functioning, its food web needs to be complete with top predators. Because of persecution from hunters or shyness, these carnivores are often absent from mitigation wetlands.

Wetlands have several values for humans, including aesthetic and recreational values. Although less accessible to interested humans than either the Triangle wetland or the Sand Run wetland, the Sugar Creek wetland provides isolation that adds to its aesthetic and recreational values. This isolation results in an increase of certain wary wildlife, which also increases the aesthetic and recreational values. In addition, traffic from busy highways, such as U.S. Route 33 adjacent to Triangle wetland, interferes with listening to and detecting species that communicate vocally, such as birds and amphibians.

9.9 Location of Mitigation Wetlands Near Streams, Rivers or Impoundments

All three mitigation wetlands are located near a stream. As noted earlier for plants, this is also quite important and apparently was a significant factor in the early establishment of amphibians and aquatic mammals, as adjacent streams, with their periodic wetlands, provide a corridor for wetland animals to reach the mitigation wetland. Adjacent riparian habitat is also important for wetland birds with home ranges larger than the wetland itself. On many occasions, wetland birds were observed moving between sites using wetlands and adjacent streams. Nearly all duck species, northern harrier, American coots, grebes, great blue and green herons, Canada geese, and belted kingfishers exhibited this behavior.

Nearby impoundments (lakes, ponds, reservoirs, large farm ponds) would also contribute to the attractiveness of a mitigated wetland from the perspective of waterfowl. This has been found in a Minnesota study that included several species of waterfowl also found in West Virginia (Leschisin *et al.* 1992). The relatively low populations of waterfowl at all six wetlands may reflect this preference for larger wetlands. Sugar Creek, because of its size, has the potential for providing excellent waterfowl habitat if dikes are stable and emergent and shrubby wetland vegetation can be established.

As noted above, streams can be important vectors for plant propagules. In fact, under the right conditions (a constructed wetland along a major river like the Buckhannon that floods every year or so) a newly constructed wetland may not need to receive special plantings of herbaceous and woody plant species, except for initial vegetative cover to control erosion. Having natural wetlands left within the boundaries or nearby, as is the case for Sugar Creek, also provides good sources for propagules.

9.10 Riparian Gallery Forests of Sycamore and Silver Maple

These habitats provide high perches and nesting cavities; the riparian shrubs and trees slow down floodwaters and push them perpendicular to the direction of stream flow, enhancing sediment deposition and growth of the floodplain and braided channels. This also enhances deposition of organic carbon, which contributes to typical wetland soil development. Constructed wetlands can be served well by locating them where mature or maturing riparian cover is present along nearby streams. Gallery forests exist at Triangle along the Buckhannon River. They can develop along Sugar Creek. For reference wetlands, they exist at Meadowville and Preston wetlands.

9.11 Wetland Acidity

Wetlands located near highway cuts through acid-producing strata have the potential danger of lowering the pH of the adjacent wetland. While some acidification is expected from organic humic acids that deposit in wetlands, excessive acidification can kill invertebrates and make amphibian eggs enviable. The discovery of an acid pool with inviable frog eggs in between Route 33 and Triangle wetland may be an isolated and local occurrence, but given the prevalence of acid-producing strata in West Virginia, it may be a larger problem. Acidification of wetlands in Sudbury, Ontario had profound effects on the functioning of many wetlands, having effects throughout the wetland food web. Molluscs and mayflies were strongly affected by acidification (Blancher and McNichol 1991). In turn, tree swallows that fed heavily on mayflies at unacidified wetlands, had smaller tree swallow egg clutch size, smaller egg clutch volume, and fewer fledglings per successful nest when breeding near acidified wetlands (Blancher and. McNichol 1988). Acidified water can increase the accumulation of toxic metals in aquatic plants and invertebrates found in constructed wetlands (Albers and Camardese 1993). Reduction of pH from 6.5 to 5 caused non-rooted floating plants to increase their levels of iron, magnesium, and manganese above maximum levels recommended for poultry feed. Zinc concentration increased in bur-reed in acidified wetlands. Mobilization of metals in response to acidification would depend upon their availability in the soil, surrounding rock, or any deposited wastes.

9.12 Substrate Features of Constructed Wetlands

Some of the sampling points in the constructed wetlands fit the hydric soil field indicators, but many did not. It is assumed that the constructed soils simply are too young to be hydric soils. If the constructed soils remain saturated with water, they should develop the properties of hydric soils, but this will require time. At this time, we do not have data to suggest a developmental pattern or time period.

Just as having a compacted clay liner is important in creating and maintaining desired hydrologic regimes, the soil placed over the clay liner has a corresponding importance. While there does not seem to be a convenient and economic source of topsoil high in organic matter ($\geq$ to 15%), it is important to the development of wetland vegetation cover to use a soil treatment high in organic matter. This will expedite recruitment of indigenous wetland herbaceous and woody species. Webster (1996) reported the use of organic sludge in wetlands constructed on the coastal plain of Virginia. However, the use may represent an environmental hazard, depending on the source (e.g., a sewage plant). We believe increasing the organic content of soil on constructed wetlands is an important consideration and one that should be studied further.

9.13 Wetland Design, Species Diversity, and Functions

The overall design of the Triangle and Sand Run wetlands appears to have been very effective in establishing wetland conditions. Such design features as creating extensive ecotone areas between open water and permanent emergent wetland types appears to have added to the physical and biological diversity of the site. Also, leaving a rough or undulating surface resulting in varying hydrologic regimes added diversity to the physical environment of the site, and consequently, the biological diversity. Some areas of the sites appear to be less poorly drained than others and subject to only occasional inundation. This is reflected in the weighted average for Quadrat 4 of Triangle, which was almost 2.0; however, according to Wentworth et al. (1988) scores of 2.5 and below clearly have hydrophytic plant cover. The invasion of relatively high numbers of nonnative species at Triangle is not a serious concern at this time, because while there were a relatively large number of such species, none had high importance values. The high WA values for two of the Sugar Creek quadrats are not of concern, considering the young age of the site.

The Triangle and Sand Run wetlands, based on the comparison to the reference wetlands, appear to be functional wetlands at this stage of their development. There is evidence of nutrient accumulations, wildlife usage, and high biological diversity of vascular plant species, particularly for Triangle. Its elevation appears to be too high to permit annual flooding from the Buckhannon River, which limits the connection with outside aquatic environments, thus limiting exportation of organic matter to aquatic systems, and value in flood abatement. Also, the limited flood frequency probably limits access to off-site seed sources, although the flood of 1994 apparently was an important event in introducing new seeds. Waterfowl species are also a vector for new introductions.

The design of the levee system in the Sugar Creek wetland is of some concern.

During the flood of January 1997, a portion of a major levee was breached, causing the water level behind it to fall. This, as noted above, produced a drier hydrologic regime than planned in this area of the wetland. This levee and others at Sugar Creek have also sustained damage from muskrat activities, mostly burrowing and excavation of the clay material composing the levees. Future wetland plans should include levee designs than can withstand the high energies often associated with flood waters and burrowing activities of muskrats. We suggest designing levees with a rock core and burying light gauge wire on the faces of levees to deter damages from burrowing.

Even with these few design shortcomings, Triangle and Sand Run wetlands meet most of the design principles cited by Mitsch (1992):

1. Designed to require minimum maintenance.
2. Designed to utilize natural energies, receiving flood waters (although not frequently).
3. Designed the system as an ecotone.
4. Designed to develop into a functional wetland over time.
5. Not over-engineered with rigid structures.
6. Success not based on the survival of plantings of herbaceous and shrub species.

Constructed wetlands do not become functional overnight, i.e., they do not develop a full array of all possible ecological functions within three or four years of their construction. In fact, it is plausible but not practical to develop high levels for most wetland functions over the short term. The Triangle wetland, based on our data, is basically a fully functioning marsh/wet meadow, with reasonably high diversity indices for most species groups studied. Further, there is heavy use of summer avian species that are not regarded as obligate or facultative to wetlands. Several upland bird species used the Triangle wetland as a feeding area, as did several avian species at the two reference sites.

Some wetland managers and regulators may argue that a constructed wetland is only fully functional if there is a well-developed woody strata. While the presence of a woody stratum adds vertical structure and may add biological diversity to a site, the fact that there is no evidence of shrub invasion at the Triangle site is of little consequence in terms of overall ecological functions. The shrub and tree plantings at the Triangle site do not show evidence of spreading, either sexually by seed production or asexually by rootstock development. Successful shrub and tree development may be dependent not only on an available seed source, but also on the development of amenable edaphic conditions, including functional microbial communities, soil nutrient levels, and organic content, as suggested by the soils investigation aspect of this study.

Therefore, from a soils developmental perspective, the functions associated with substrate conditions (e.g., nutrient storage and transformations) may not be functioning at a level comparable to natural wetlands. However, our assessment is that in this case, the functional level of a specific attribute in a constructed wetlands is not as important as looking at the overall functional environment for a site. In the case of Triangle and Sand Run, the two oldest constructed wetlands studied, soil conditions and standing crops did not match levels in natural wetlands, but otherwise, they had reasonable functional attributes, considering their age. A key point is as long as the integrity of the physical site features can be maintained, including levees and soil hydrological conditions, the relative level of functionality of constructed wetlands compared to natural wetlands should converge. The conditions that have developed at Triangle and Sand Run in six years, are encouraging. Both sites have functional levels generally comparable to the natural wetlands we studied.

In the case of some bird species, if it is determined the certain species are found at higher densities at the two reference wetlands, namely gray catbird, yellow-breasted chat, willow flycatcher, and song sparrow, and are important to provide habitat for, more woody shrubs could be encouraged. However, all of these species except the willow flycatcher are common and breed in habitats other than wetlands, and may not be an adequate reason to encourage more woody growth at Triangle.

A critical aspect of post-construction development of wetlands may be maturation of the substrate, as well as establishing appropriate and consistent hydrologic regimes. Indirect evidence of this is provided by the Des Plaines River wetland research project (Fennessy *et al.* 1994) and by Reinartz and Warne (1993) for vegetation development in created wetlands in southeastern Wisconsin. The presence of a relatively large number of nonnative plants in drier habitats is, doubtless, a site-related factor, i.e., young soils and recent site disturbances. Therefore, to aid in the rapid development of natural vegetation that is diverse and structured, construction design should include re-seeding/planting the area with a large number plant species and the placement of a substrate with high organic matter content. An alternative to a large number of plantings is to design wetlands so they flood occasionally from nearby streams. There is evidence from this study to suggest that past flood events at Triangle and Sugar Creek have augmented species recruitment for both sites.

CHAPTER 10

RECOMMENDATIONS FOR EXISTING AND FUTURE MITIGATION WETLANDS

1. Where practical, a portion of mitigation wetlands should be isolated from railroads and highways to improve wildlife safety and aesthetic considerations.

2. Wetlands should be situated near or adjacent to a stream or river, unless the wetland is being fashioned after a natural beaver pond wetland in a steep valley.

3. Where there is a choice, wetlands should be located near relatively flat bottomland and not surrounded by steep unnatural hillsides, to provide more extensive margin habitat between wetland and upland.

4. Wetlands should contain interspersed areas of standing water with water depth ranging from <0.5 meters to >3 meters, and the interface between open water habitat and wetland habitats should have highly irregular boundaries.

5. Wetlands should have an extensive dike/levee system to impound surface water and to provide temporary pools during spring months. These dikes/levees would provide nesting sites for birds such as waterfowl, travel corridors for mammals such as mink, and den sites for burrowing mammals such as muskrats. Dikes/levees also provide a substrate for the establishment of common wetland shrubs as alders, buttonbush, silky dogwood, and viburnums.

6. Dikes and levees should be designed to withstand high energy flows of flood water from nearby streams that is likely to inundate these structures, as it did at Sugar Creek in 1997. Constructing dikes and levees with rock cores is one way to strengthen these structures. An additional design consideration is to bury some type of wire, e.g, chicken wire, in the faces of levees and dykes to retard burrowing activities of muskrats.

7. The placement of overflow type habitats in constructed wetlands should be limited to small areas. They tend to be dry and subject to invasion by nonnative plant species.

8. Since there was a direct correlation between soil organic content and productivity, it is important to have an initial substrate high in organic content. This will enhance productivity and should help expedite the development of soil conditions that will support more complex vegetative cover.

9. If future constructed wetlands are designed and positioned so flooding from

nearby streams is occasional and other mature wetlands are nearby, it may not be necessary to have extensive and expensive plantings of hydrophytes to "jump start" the vegetative cover in all cases. Where possible, broadcasting locally harvested seeds of hydrophytes should increase recruitment.

10. Constructed wetlands should be viewed as being on a time line. Based on this study, there appears to be a linear progression in which constructed wetlands follow a natural successional process in species change. In fact, there appears to be a natural trend for a reduction in species diversity and an increase in the number of species in wetland index values as constructed wetlands mature and develop natural functions.

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15. Supplementary Notes

Constructing new wetlands has become an acceptable means of compensating for unavoidable impacts to wetlands. However, few studies have evaluated the levels of natural functions attained by constructed wetlands. This study analyzed three wetlands constructed by the West Virginia Division of Highways by comparing selected functional attributes of constructed and nearby natural wetlands that have similar vegetation and hydrology. The attributes measured included soil nutrients levels, wildlife usage, productivity, and vascular plant, bird, and small mammal diversities. Standard methods for field studies of soils, vegetation, and wildlife were used.

Constructed wetlands did not differ appreciably from reference wetlands in the species of mammals present. The species richness and diversity of vascular plants was surprising high for vascular plants. Generally, constructed and reference wetlands had similar wetland bird species diversity, including resident and migratory species. Constructed wetlands in early successional stages had lower bird diversity than a more mature constructed wetlands. For soils, natural wetlands generally had higher levels of organic carbon, while constructed wetlands had higher pH values, lower extractable acidity, and higher P values than the natural wetlands. The wetland index value increased as the constructed wetlands aged. Recommendations based on this study included: locating constructed wetlands near streams or rivers to permit overbank flooding as a source of plant propagules and nutrients and to provide an animal habitat continuum, building dike/levee systems to withstand flooding, having high initial soil organic carbon levels, and locating mitigation wetlands away from railroads and highways to improve wildlife safety and aesthetic considerations. Overall there was evidence that DOH's efforts to construct functional wetlands have been successful, as the natural functions of constructed wetlands approached those of natural wetlands.

17. Key Words	18. Distribution Statement
Wetlands, constructed, mitigation, wetland functions, wildlife, birds, small mammals, vegetation, soils, hydrology, flooding, species diversity, highways	

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