APPENDIX V. PALUSTRINE WETLANDS CONCEPTUAL MODEL

This model and text was developed by Dr. Darren Carlisle with the United States Geological Service for the Heartlands Inventory and Monitoring Network. Dusty Perkins adapted the model to fit the needs of the Southern Plains Network. A wetland model developed for the Great Lakes Network (also developed by Dr. Carlisle) was also used in the development of this model.

INTRODUCTION

The term "wetland" is a generic descriptor of a wide variety of places, including saltwater marsh, freshwater marsh, tidal marsh, wet meadow, wood swamp, bog, muskeg, mire, pothole, vernal pool, river bottom, mangrove forest, and floodplain swamp. The commonality among these environments is the presence of water sufficient to inundate the ground. The following U.S. Fish and Wildlife Service definition by Cowardin et al. (1979) is widely accepted

> *"Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water…wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes, (2) the substrate is predominantly undrained hydric soil, and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year."*

Wetlands naturally form in places where surface water periodically collects for some time or where groundwater discharge is sufficient to saturate soils. Such places include depressions surrounded by upland and with or without a drainage system; relatively flat, low-lying areas along major water bodies; shallow portions of large water bodies; sloped areas below sites of groundwater discharge; arctic and subarctic lowlands; and slopes below melting snow banks and glaciers.

Although wetlands often comprise a small portion of the world's land surface (4-6%, Mitsch and Gosselink 2000), they contribute greatly to local and regional biological diversity (National Research Council [NRC] 1995). Wetland-dependent fish, waterfowl, furbearers, and timber provide important and valuable harvests and recreational opportunities. Wetland ecosystems moderate floods, improve water quality, and have heritage and aesthetic values that are difficult to quantify. On a global scale, wetlands contribute to stable levels of available nitrogen, atmospheric sulfur, carbon dioxide, and methane. Wetland habitats are required for the survival of a disproportionately high percentage of threatened and endangered species. Despite comprising <10% of the landscape in North America, wetlands are important habitat for 68% of birds, 66% of mussels, and 75% of amphibians on the U.S. list of threatened and endangered species (Mitsch and Gosselink 2000).

Despite the obvious benefits of wetland environments, they have been extensively modified or destroyed by human development. In the contiguous United States, approximately 53% of all wetlands have been lost in the last century (NRC 1995, Mitsch and Gosselink 2000). The U.S. government actually encouraged the widespread destruction of wetlands via established policies until the 1970s (NRC 1995). Currently, wetlands are the only ecosystem type that is comprehensively regulated across all public and private lands within the United States (NRC 1995). Nevertheless, wetland losses have continued over the past two decades (Dahl 2000). Urban development, rural development, and agriculture accounted for 30, 21, and 23%, respectively, of these recent losses (Dahl 2000).

Numerous definitions and classifications have been developed for wetlands, but the system adopted by the U.S. Fish and Wildlife Service and the National Park Service (Cowardin et al. 1979) is the one most commonly used by scientists worldwide (Mitsch and Gosselink 2000). This classification system is hierarchical and all-encompassing and SOPN will adopt also use this

classification system. There are at least three general types of wetlands within the SOPN according to Cowardin et al. (1979).

Emergent Wetland, Persistent (Freshwater Marshes)

This class and subclass belongs to palustrine wetlands group as classified by Cowardin et al. (1979). Palustrine systems are wetlands dominated by persistent vegetation (Figure 1). Wetlands without persistent vegetation are also included in this system if they are< 20 acres (8 ha), < 6.5 feet (2 m) deep during low water times, and no portion of the boundary contains wave-formed or bedrock shoreline (Cowardin et al. 1979).

Freshwater marshes include a very diverse group of wetlands that are characterized by: 1) emergent, soft-stemmed aquatic plants such as cattails, arrowheads, reeds, and other species of grasses and sedges; 2) a shallow water regime; and 3) generally shallow deposits of peat. This wetland type is the most ubiquitous in North America and includes places like the prairie potholes and Florida Everglades. Freshwater marshes are the ecosystem used for the development of this model. Within the SOPN, they are present at Bent's Old Fort National Historic Site (BEOL), Sand Creek Massacre National Historic Site (SAND), Chickasaw National Recreation Area (CHIC), Pecos National Historical Park (PECO), and Lake Meredith National Recreation Area (LAMR).

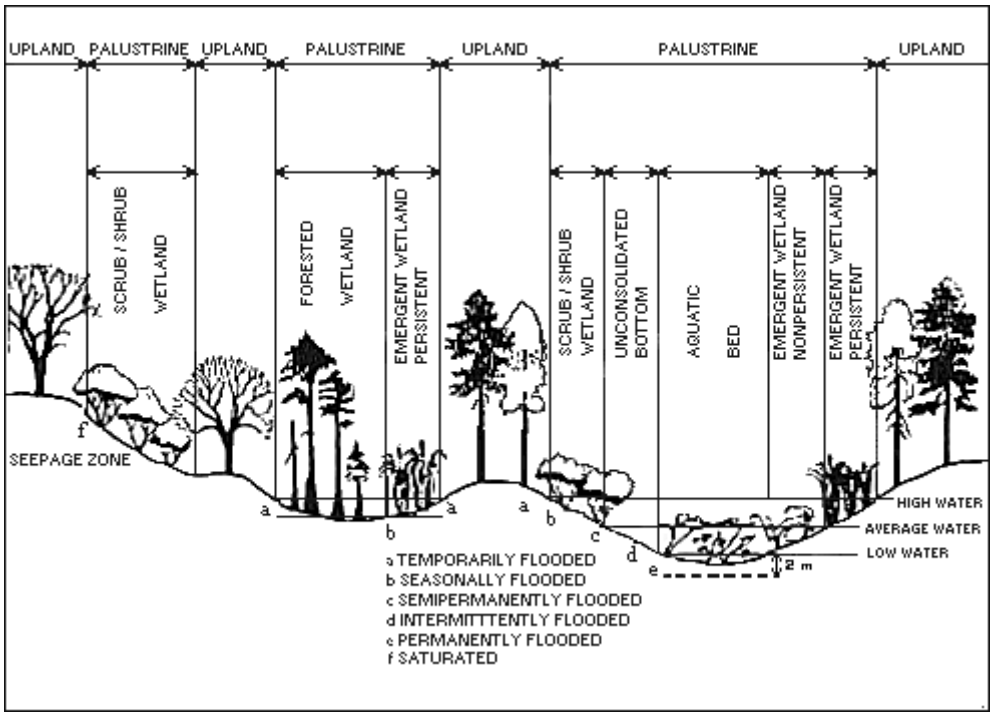

Figure 1. Distinguishing features and examples of habitats in the Palustrine System (from Cowardin et al. 1979).

Riverine Ecosystems

Riverine ecosystems generally include all wetlands and deepwater habitats contained within a channel. They are bounded by uplands, by wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, or where the channel enters a lake or reservoir. Water is usually, but not always, flowing in this system. Upland islands or Palustrine wetlands may occur in the channel, but they are not included in the Riverine System (Cowardin et al. 1979). Riverine ecosystems are present at Lyndon B. Johnson National Historical Park (LYJO), Washita

Battlefield National Historic Site, Fort Larned National Historic Site, LAMR, CHIC, BEOL, SAND, and PECO. These ecosystems are modeled for SOPN by Sue Braumiller of NPS.

Lacustrine Ecosystems

The Lacustrine System includes permanently flooded lakes and reservoirs, intermittent lakes, and tidal lakes with ocean-derived salinities below 0.5 %. Typically, there are extensive areas of deep water and there is considerable wave action. The lacustrine system includes wetlands and deepwater habitats with all of the following characteristics: (1) situated in a topographic depression or a dammed river channel; (2) lacking trees, shrubs, persistent emergents, emergent mosses or lichens with greater than 30% areal coverage; and (3) total area exceeds 20 acres (b ha) (Cowardin et al. 1979). Similar wetland and deepwater habitats totaling less than 20 acres (8 ha) are also included in the lacustrine system if an active wave-formed or bedrock shoreline feature makes up all or part of the boundary, or if the water depth in the deepest part of the basin exceeds 6.5 feet (2 m) at low water. Lacustrine systems formed by damming a river channel are bounded by a contour approximating the normal spillway elevation or normal pool elevation, except where palustrine wetlands extend lakeward of that boundary (Cowardin et al. 1979). Lacustine ecosystems are present at LAMR, LYJO, and CHIC. These ecosystems are modeled for SOPN by Sue Braumiller of NPS.

DRIVERS

All ecosystems are influenced by natural and anthropogenic forces. By virtue of being wetlands, hydrology is the major driver for freshwater marsh ecosystems. The periodic drying and inundation is crucial to the ecosystem function of freshwater marshes (Figure 2). Variation in climate, succession, herbivory, and fire are also all important natural processes controlling all wetlands.

Climatic fluctuations over the past century have resulted in changes in local watershed hydrology which directly affect the condition of freshwater marsh ecosystems. Long-term droughts not only reduce water levels but they diminish groundwater supplies. Human accelerated climate change may create more erratic climatic fluctuations and could potentially produce extended droughts.

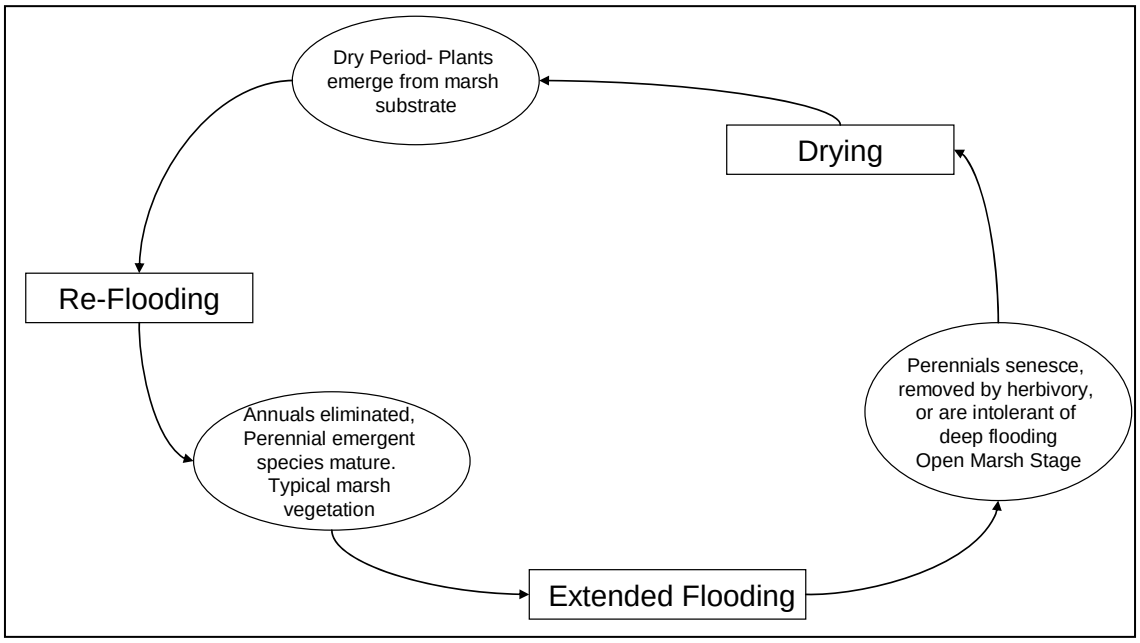

Figure 2. Typical hydrologic cycle of a freshwater marsh.

STRESSOR TYPES

The definition of stress offered by Barrett et al. (1976) is used in this model. Specifically, “Stress is defined here as a perturbation (stressor) applied to a system (a) which is foreign to that system or (b) which is natural to that system but applied at an excessive [or deficient] level.” (Barrett et al. 1976). Hence, agricultural pesticides are a stressor foreign to wetlands. Similarly, nutrients and fire suppression are stressors applied at unnaturally high and low levels respectively.
For the purposes of this model, there are three major stressors that influence wetland ecosystems. They are represented by rectangles in Figure 3.

Natural Processes

Hydrology is the most important factor in wetland ecosystem maintenance and processes. The hydrologic regime is defined as the magnitude, frequency, duration, timing, and rate of change of water level fluctuation (Poff et al. 1997). The hydrologic regime affects soil bio-geochemical processes, nutrient cycling, and nutrient availability. These processes, in turn, influence the biological communities that can be supported in a wetland. Wetland biological communities exert strong influences on the hydrologic regime. For example, accumulation of senesced plants can hinder water circulation. Similarly, beavers (*Castor canadensis*) are considered “ecosystem engineers” because they directly alter water levels and circulation. Duration, frequency, and timing of water level fluctuations are the primary determinants of hydroperiod, which is characteristic of different wetland types. Climatic variation can cause large seasonal and annual fluctuations of the hydroperiod, leading to profound changes in wetland ecosystem structure and function.

The dynamics of succession, or ecosystem development, have been documented in a variety of wetlands. Although alternative theories of succession exist, the collective evidence suggests that wetland biological communities undergo natural changes due to external influences on the hydrologic regime (e.g., climate change) and internal processes that alter environmental conditions (e.g., accumulation of organic matter) (Mitsch and Gosselink 2000).

Urbanization

Urbanization is the leading cause of wetland loss in the United States (Dahl 2000), and directly or indirectly threatens emergent wetlands at LAMR, CHIC and BEOL. Compared to land converted to agriculture, wetland losses to urban and suburban development are small. Nevertheless, wetlands that are not directly affected (e.g., removed or altered) by development are subject to a variety of indirect influences. Drainage and physical disturbance are stressors directly to wetlands if development occurs on the wetland itself. Adjacent development and navigation corridors may alter wetland hydrology, usually by means of hydrologic stabilization. Polluted runoff from urban areas contains toxicants, nutrients, and sediments that potentially enter nearby wetlands. Water diversion, flood control, and reservoir projects often associated with local human population growth, cause permanent flooding in wetlands. Finally, fire suppression generally accompanies urban development due to fears of property loss.

A*griculture*

Conversion to agricultural land is the major cause of wetland loss worldwide (Mitsch and Gosselink 2000). In fact, some of the world’s most fertile soils were once wetlands in the present states of Iowa, Illinois, and southern Minnesota. Although most land conversion occurred prior to the 1970s, current losses can be attributed to farm programs and economic conditions. Agricultural activities outside park boundaries pose threats to wetlands with SOPN parks. Runoff contaminated with sediment, nutrients, and pesticides reach park wetlands through waterways and drainages that have inadequate buffer zones. Aerial deposition of pesticides and nutrients

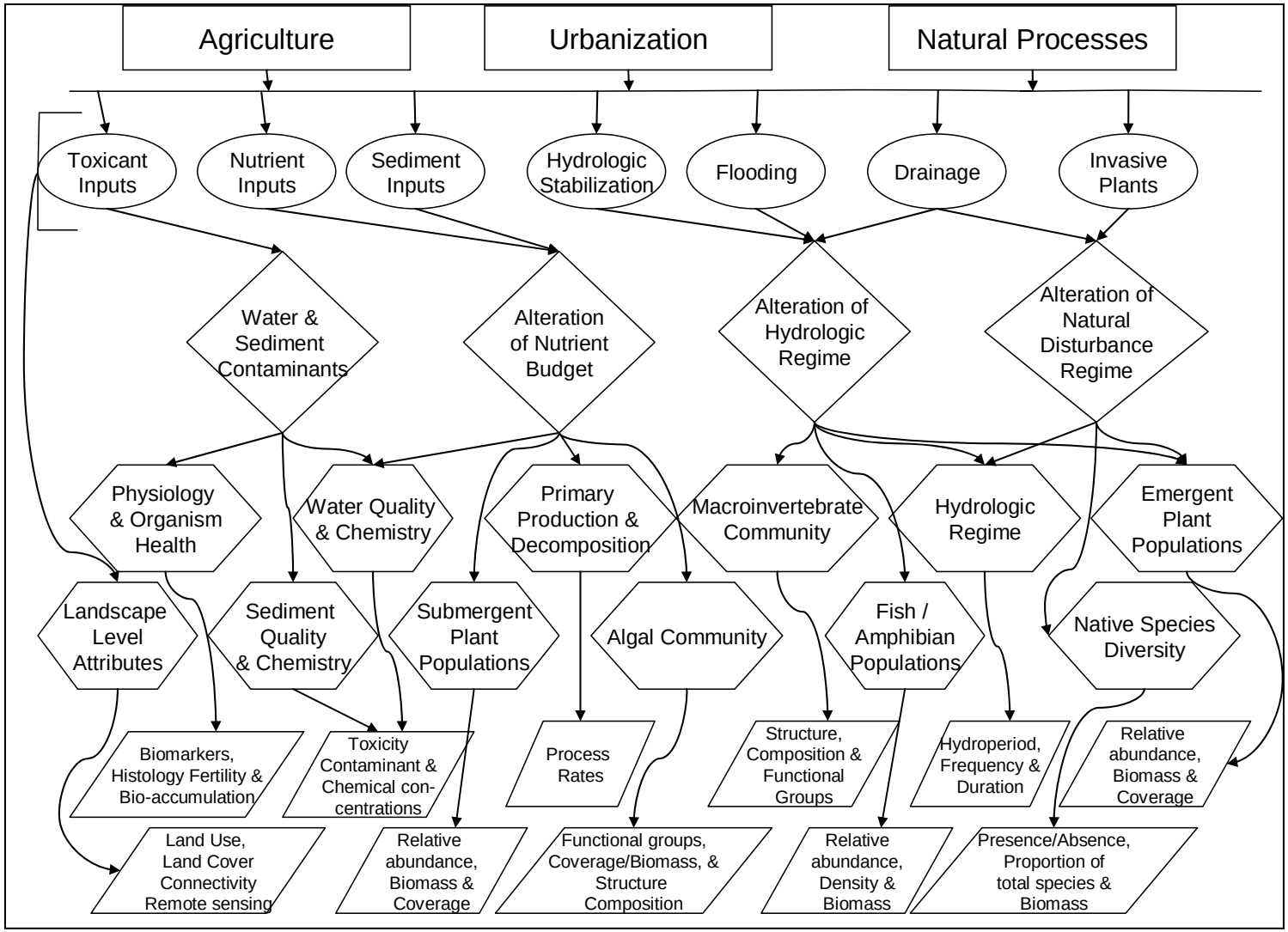

Figure 3. Freshwater Marsh Conceptual Model.

has been documented in wetlands downwind of agricultural areas. Wetland destruction and fragmentation on adjacent lands threatens wetland species dependent on migration or dispersal corridors. The primary stressors associated with agricultural activity are drainage, sediments, nutrients, and toxicants. With the discovery of atmospheric contaminant deposition and global climate change, it appears likely that every ecosystem in the biosphere is or will be influenced by humans (Vitousek et al. 1997).

INDIVIDUAL STRESSORS

All of these individual stressors are a direct or indirect result of one of the major stressor types. The individual stressors are represented in Figure 3 by ovals. All of these stressors affect one or more of the major processes (represented by diamonds) of freshwater marsh ecosystems.

Toxicants

"Toxicants" in this model refers to any anthropogenic chemical that reaches wetlands and potentially elicits toxic effects on organisms, communities, or the ecosystem (Rand 1995). Wetlands receive toxicant inputs from upstream water sources, direct releases, and deposition. Polluted streams, runoff, and groundwater transport toxicants from adjacent or distant sources. Natural or artificial wetlands are often used specifically for filtering contaminants that are released directly into the system. Finally, wetlands receive toxicant inputs from aerial deposition, which has become recognized by widespread mercury contamination of water bodies (Wiener et al. 2002).

The well-known ability of wetlands to assimilate contaminants and "purify" water (Mitsch and Gosselink 2000) is largely due to the perception that contaminants entering wetlands are eventually "locked-up" in sediments, and therefore benign to organisms. However, there is mounting evidence that contaminants buried in wetland soils and sediments are still available to biota and therefore threaten aquatic and terrestrial ecosystems (Landrum and Robbins 1990, McIntosh 1991). For example, up to 2% of the total amount of organochlorines present in lake's sediments were removed from the lake as sediment-dwelling insects emerged into the terrestrial environment. The contaminated insects became a source of contamination to aquatic and terrestrial food webs (Fairchild et al. 1992).

Toxicants influence biota at varying levels of ecological organization. Typically, toxicant exposure is first manifested by the presence of detoxifying enzymes or toxicant metabolites in organism tissues. These so-called "bio-markers" are an active area of research and have the potential to signal early warnings of toxicant exposure. As toxicant exposure time or levels increase, organisms suffer malformations, tumors, stunted growth, lost reproduction, and eventually death. Populations are therefore affected when sufficient individuals suffer toxic effects and alter population abundance, biomass, and productivity. Disproportionate losses of populations lead to changes in community composition, and conceivably alterations in ecological processes.

Nutrients

The most common reason for impairment of U.S. surface waters is eutrophication caused by excessive inputs of nitrogen and phosphorus from non-point sources. More than half of the rivers and lakes that currently fail to meet water quality standards are impaired by nutrients (United States Environmental Protection Agency [USEPA] 1998). The dominant source of nutrients in U.S. surface waters is non-point runoff from agricultural and urban areas (Carpenter et al. 1998). Excessive nitrogen and phosphorus can cause drastic changes in plant communities. The most prominent effect of nutrient enrichment is a proliferation of algae, which can lead to a wide array of additional problems. Algal blooms cause fish kills as decomposition and respiration consume large amounts of oxygen. High algal biomass reduces water transparency, which hinders growth of submergent plants. Aesthetic, recreational, and drinking water values are also reduced by eutrophication.

Sediment

Sediment considered in this model is comprised of mostly inorganic particles <2 mm in diameter, thus emcompassing sand, silt, and clays (Wood and Armitage 1997). Although sediments are a natural part of most aquatic ecosystems, human activities have dramatically increased sediment inputs to lakes, streams and wetlands. Most sediment enters wetlands through urban and agricultural runoff. When suspended in water, fine sediments increase turbidity, decrease light penetration, and alter primary productivity. Sediment particles < 63 micrometers (µm) in size are frequently adsorbed to by a variety of contaminants, especially nutrients and heavy metals (Wood and Armitage 1997). Consequently, sediments are an integral part of nutrient- and toxicant-related effects in wetlands. In some cases, excessive sediment accumulation can alter the hydrologic regime.

Drainage

Draining, dredging, filling, and ditching are human modifications specifically designed to dry out wetlands. By removing the source of water influx, wetlands are desiccated and the land used for urban development, highway construction, or agriculture. Levees are often constructed with the primary goal of preventing water from entering the former wetland area. This practice has led to farming and development in the floodplains of many rivers, which has also caused widespread property damage and loss of life when rivers flood. Wetland removal and subsequent fragmentation of remaining habitats is associated with declines in the diversity wetland organisms (Lehtinen et. al. 1999).

Flooding

Wetlands are sometimes flooded as part of water development and management programs. The most common scenario is the loss of riparian wetlands by reservoir construction. A related human impact is the stabilization of wetland hydrology, typically a result of dams designed to reduce flooding. Because the hydrologic regime is unquestionably the most important controller of wetland ecosystems, human alterations of water flow have damaged wetlands on a grand scale. The effects of drainage, flooding, or any other hydrologic alteration are variable. On one extreme, wetlands are drained and entirely obliterated. On the other hand, many wetlands are cut off from their water source by roads or levees, but remain physically in tact. The loss or alteration of water influx reduces inputs of sediments, nutrients, and propagules. Consequently, long-term changes in plant and animal community composition are the most common effects of hydrologic alteration.

Invasive Exotic Plants

The invasion of non-indigenous species seriously threatens wetland ecosystems nationwide (U.S. Congress 1993). Most invasive species in wetlands have escaped landscaping cultivation or were intentionally planted to stabilize sites already disturbed by human activities. Lacking natural enemies, many exotic species rapidly infest wetlands and displace native flora and fauna. Historically, climate, fire, and grazing controlled the diversity and abundance of vegetation in prairie wetlands. Changes in grazing patterns and animals and altered hydrology often favor the survival of introduced species (e.g., tamarisk [*Tamarix spp.*]) and allows thriving non-natives to displace native species. Russian-olive (*Elaeagnus angustifolia*) and tamarisk are two non-native species that have greatly altered western riparian communities (Brock 1984; Shafroth et al. 1998). Not only have they altered the communities they have invaded, they are difficult to remove. For example, tamarisk can repeatedly resprout after fire, cutting, or browsing, and it survives in very wet, very dry, or very salty soils (Gladwin and Roelle 1998; Smith et al. 1998).

In prairie wetlands, disruption of natural processes such as fire has led to domination by robust, emergent plants, particularly in the prairie pothole region. Cattail (*Typha spp.*) and purple loosestrife (*Lythrum salicaria*), once rare on the Great Plains, have spread across thousands of prairie wetlands and threatening waterways across the United States (U.S. Congress 1993;

Malecki and Blossey 1994). Exotic plants such as tamarisk may be increasing fire frequencies and subsequently increasing in dominance after fire (Busch 1995).

ECOSYSTEM ATTRIBUTES

The twelve attributes shown in Figure 3 are represented by hexagons and are characteristics of the physical (e.g. hydrologic regime), biological (e.g. macroinvertebrates) and chemical (e.g. water chemistry) environment. Potential vital signs are shown in parellograms below each attribute in Figure 3.

Physiology and Organism Health

Some attributes of physiological processes and organism health are indicative of stress on ecosystems and therefore useful in long-term monitoring. Contaminant-induced biochemical processes provide evidence that organisms are being exposed to contaminants in their environment. For example, exposure to heavy metals stimulates cellular production of metallothionein, a protein used to regulate essential metals in most organisms. Cellular damage is minimized because the toxic metal is sequestered by metallothionein and effectively removed from circulation (Klaverkamp et al. 1991). Similarly, analyses for contaminants that accumulate in the tissues of organisms provide important information exposure. Finally, growth and reproduction, which are essential for all organisms, are often indicative of anthropogenic stress (e.g., Beyers et al. 1999).

Sediment Quality and Chemistry

Sediment is defined here as the organic and inorganic soils and substrates of wetlands. Sediments are a major part of biogeochemical cycling in wetland ecosystems (Mitsch and Gosselink 2000) and provide habitat for many organisms. Most anthropogenic chemicals eventually accumulate in sediments due to a variety of hydrological and chemical processes (Ingersoll 1995). Sediment contamination is a widespread problem in aquatic ecosystems of the U.S. and poses significant threats to ecological and human health (NRC 1989). Contaminated sediments may be directly toxic to organisms or can be a source of contamination in the food chain. The most common contaminants found in sediments are heavy metals, pesticides, persistent organic chemicals, and hydrocarbons.

Primary Production and Decomposition

Ecosystem processes, and the biogeochemical cycles they control, are fundamental attributes of all ecosystems. Primary production, which is the rate of plant biomass accumulation, is sensitive to anthropogenic alteration of the nutrient budget, hydrologic regime, and natural disturbance processes. Primary production in freshwater marshes often equals or exceeds cultivated crops (Mitsch and Gosselink 2000). Primary production in freshwater swamps is highly influenced by the duration and timing of flooding, and therefore sensitive to anthropogenic alterations of wetland hydrology.

Decomposition, which is the rate at which carbon from organic matter is metabolized and released as carbon dioxide, is a significant part of wetland ecosystems. Decomposition is slow in anaerobic or permanently wetted environments (Mitsch and Gosselink 2000). Wetlands are therefore a major carbon sink in the biosphere because they tend to accumulate dead organic matter (Mitsch and Gosselink 2000). Hence, much of the food webs supported in these ecosystems are ultimately dependent on detritus and microbes.

Submergent Plant Populations

Submergent plants have their photosynthetic tissues completely submerged, but flowering structures often extend above the water surface (Richardson and Vymazal 2001). Submerged

plant communities are important habitat for numerous wetland animals. For example, many fish species rely on submergent beds for spawning and larval development (Tiner 1999). The productivity and distribution of submergents is strongly influenced by light penetration to the benthic environment. Consequently, anthropogenic increases in suspended inorganic particles or phytoplankton biomass are detrimental to submergent plant populations.

Water Quality and Chemistry

Water quality is fundamental to the functioning of all aquatic and semi-aquatic ecosystems. Although water quality standards for lakes and streams are well-established, chemical and biological criteria for wetlands are still under development. The U.S. Environmental Protection Agency mandated that states would have water quality standards for wetlands by 1993 (USEPA 1990). However, most states are still developing standards and criteria (Apfelbeck 2001).

Macroinvertebrate Community

Insects, crustaceans, and other invertebrates are highly diverse and abundant, and play central roles in aquatic food webs. Within most taxonomic groups there are typically many species with a variety of environmental requirements and sensitivity to stressors. As a result, macroinvertebrate communities have been used for over three decades in ecological evaluations of aquatic systems (Rosenberg and Resh 1993) and are currently being used by the Heartlands Network and Prairie Cluster Prototype (Peterson et al. 1999).

Algal Community

Algae occur in most wetlands that contain standing water for even short periods. Algae are important sources of wetland primary production, transform and retain nutrients, stabilize substrates, provide habitat for other taxa, and are an important food source for many animals (Stevenson 2001). Algae are useful for wetland biological assessments because they are diverse, abundant, and have a wide range of known tolerance to environmental (e.g., water quality) factors (Mayer and Galatowitsch 1999). Taxonomy is sufficiently developed to ensure consistency and relative ease in identifying most common algal genera.

Emergent Plant Populations

Emergent macrophytes are the dominant form of plant life in most wetlands (Richardson and Vymazal 2001). In general, they produce aerial stems and leaves and an extensive root system. These plants are morphologically and physiologically adapted to growing in waterlogged environments, and are therefore used to delineate wetlands (NRC 1995). Emergent macrophytes are a major component in wetland food webs and nutrient cycles. Because many emergent plants have narrow tolerances of hydrologic conditions, salinity, water chemistry, and nutrient levels, population and community-level monitoring can be used to detect changes in environmental conditions (Tiner 1999).

Hydrologic Regime

As discussed above, the hydrologic regime is the dominant environmental control of wetland ecosystems. Consequently, the hydrologic regime itself is an important ecosystem component and requires monitoring in addition to other physical, chemical, and biological attributes. This model adopts the definition of hydrologic regime given by Poff et al. (1997), which includes magnitude, frequency, duration, timing, and rate of change of flows in river systems. Each of these attributes of river hydrology apply to wetland ecosystems as well, and are briefly described below.

The magnitude refers to the water that inundates a wetland, and can be measured by water depth or volume. The frequency refers to how often a wetland is inundated. Seasonal inundation is most

common, but annual time scales are relevant for many wetlands. The duration is the period of time associated with a specific inundation level and may be weeks or years depending on the type of wetland and climate. The timing refers to the regularity with which inundation occurs. For example, although many wetlands are predictably inundated during specific seasons, others may be inundated intermittently and unpredictably based on weather conditions. The rate of change refers to how quickly water levels change and strongly influences the water residence time in wetlands. This, in turn, has important implications for numerous ecological processes. Lent et al. (1997) developed indicators for monitoring wetland hydrologic regimes.

Fish and Amphibian Populations

Although small, ephemeral wetlands rarely support fish, deeper wetlands that are hydrologically connected to larger water bodies may support great varieties and abundance of fish species. The relatively warm, productive habitat with abundant plants provides ideal nursery habitat for many fish species. Population monitoring of such fish species would provide an important linkage between vegetation communities and vertebrate populations (Mitsch and Gosselink 2000).

Amphibian species are currently in a global decline (Blaustein and Wake 1990), and have therefore received much attention in scientific and public dialogue. Because their life cycle integrates aquatic and terrestrial systems amphibians are excellent indicators of overall watershed condition. Amphibians are also an important trophic link between aquatic invertebrates and birds, reptiles, and mammals.

Native Species Diversity

The Endangered Species Act is a legislative affirmation that the preservation of native species is a long-standing priority in the United States. The NRC (2000) also identified native species diversity as an important indicator of ecosystems. In general, native species diversity is negatively associated with the degree of human disturbance in ecosystems, and therefore represents a useful indicator of the human imprint on the land (NRC 2000). This indicator would undoubtedly be useful in wetland ecosystem monitoring.

Landscape Level Attributes

The size, position, and number of wetlands, as well as land use and land characteristics in the vicinity of wetlands are examples of this category. These attributes, often measurable through an analysis of a series of remote sensing or aerial images, can affect all of the other attributes described above. Sediment supply (e.g., through erosion), concentration of nutrients and toxins (e.g., through nonpoint and point source pollution), changes in hydrology (e.g., through dams, shoreline stabilization, dredging, diking, and flooding), introduction of invasive species, and metapopulation dynamics (e.g., through vicinity of and corridors between wetlands) may all be affected by landscape level attributes.

Increasing the percent cover of impervious surfaces within a watershed will increase runoff and the sediments, nutrients, and toxins carried by runoff. Shoreline stabilization may decrease the areal extent of a wetland. Invasive species may be introduced to a wetland more readily if the wetland is surrounded by urban or agricultural land use. Fewer wetlands and loss of connective corridors between wetlands may contribute to population extinctions or genetic bottlenecks through restricted gene flow.

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