Interim Hydrogeomorphic Functional Assessment Model for Low-Gradient, Fine Substrate Riverine Wetlands with Defined Channels and Intermittent (Seasonal) Flow Regimes in Eastern South Dakota

Version 1.1

By

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I. Introduction

General

Wetlands have properties of both aquatic and terrestrial ecosystems. Their most widely valued function is providing habitat for fish, birds, animals, and macro- and microorganisms. They contribute to the maintenance of biological diversity. In addition to this "food chain support" function, wetlands carry out hydrologic functions and biogeochemical "processing" functions, all of which are important to society as a whole. They also provide recreational, educational, research, and aesthetic functions.

Wetland Functions

Wetland functions are the normal or characteristic activities that take place in wetland ecosystems. Wetlands perform a wide variety of functions in a hierarchy from simple to complex as a result of their physical, chemical, and biological attributes. Not all wetlands perform the same functions. A specific class of wetland will perform similar functions, but it is usually at the subclass or more defined level (such as low gradient, fine substrate) at which a group of wetlands perform the same functions. Even at this level, similar wetlands do not always perform functions to the same degree of magnitude. The functions selected for assessment should reflect the characteristics of the wetland ecosystem and landscape under consideration and the assessment objectives. By narrowing the focus to a regional subclass, it is possible to identify the functions that are most likely to be performed and of greatest benefit to the public interest.

The hydrogeomorphic system of wetland classification recognizes three broad categories of functions wetlands perform. They include functions related to hydrology, biogeochemical processing, and wildlife/biological habitat. Specific wetland functions have been identified within the three broad categories. Storage of surface water is an example of a riverine wetland function as identified in this model. This function can be defined as "the ability of the wetland to retain, store, and subsequently release excess surface water, as from flood events." Effects on-site include contribution to the maintenance of characteristic soils and vegetation, and providing a mechanism for the recharge of ground water. Effects off-site include reduction in the amount of water delivered to downstream ecosystems during flood events.

Functional Profile of Riverine Wetlands

Riverine ecosystems include the zone adjacent to a stream that receives additional moisture from flooding or from runoff from the surrounding uplands. This zone, also referred to as the riparian zone, includes the active stream channel and flood plain (Rosgen, 1996). In the larger riverine systems with perennial flow and biennial or less flooding, this zone may also include first level terraces that no longer receive additional moisture from flooding but receive runoff from the surrounding uplands. They have characteristic hydrology, soils, and vegetation that differ from adjacent upland landforms. The width of the riparian ecosystem is typically a function of the drainage area of the associated stream; the larger the contributing drainage area, the wider the riparian zone.

Not all riparian ecosystems contain wetlands, although most do; however, riverine-class wetlands all occur within some type of riparian ecosystem. Wetlands within riverine ecosystems occur in several topographic positions. In addition to the stream channel itself, the most common position on which these wetlands occur is in the zone immediately adjacent to the active channel. This includes the zone from periods of low flow (otherwise referred to as base flow), to that of bank full discharge. Bank full discharge is the flow rate that forms and controls the shape and size of the active channel. This discharge is expected to occur every 1.5 years on average. Riverine wetlands can also occur on the flood plain. Flood plains that receive additional moisture from annual flood events may be wetlands in and of themselves. Most flood plains within the reference domain for this model do not flood as frequently or of sufficient duration to qualify as wetlands in and of themselves. Instead, they contain depressional areas that, when flooding occurs, traps and store excess water for sufficient time to develop characteristic wetland soils and vegetative communities. These depressions include oxbows and non-channel depressions formed by natural processes associated with flood events.

The area of initial application for this model is eastern South Dakota (east of the Missouri River). Similar physiographic and climatic conditions occur in eastern North Dakota, western Minnesota, and northeastern Nebraska, and this model may have applicability there. This model is intended to address wetlands that occur within low gradient, fine substrate riverine ecosystems that have intermittent or seasonal flow regimes within defined channels. These generally include the lower segments of first order streams and second order streams with the characteristic flow regime. These ecosystems typically convey surface water within a defined channel. In normal precipitation years, their flow regime is seasonal and typically occurs in the spring and summer. Surface flow will cease, usually in late summer or early fall. During years of above-normal precipitation, they may exhibit year-round flow. Conversely, these stream systems may be dry for extended periods during years of drought.

The surficial geology of riverine ecosystems in this region consists of alluvium, derived primarily from loess and/or glacial till. The alluvium may be a few feet to as many as tens of feet in thickness. Glacial till typically underlies the alluvium at some point, providing a restrictive layer to downward movement of water. Where the alluvium is only a few feet in thickness, water may “perch” on top of the alluvial/till interface, or water may move laterally underground. Either instance may result in creation of a wetland at some point within the riverine ecosystem.

The following summary describes the hydrologic, soil, and vegetative features that should be considered characteristic for the assessment of this subclass of wetlands.

Hydrology

The hydrodynamics of riverine wetlands are dominated by downstream, unidirectional water flow. Surface water, derived from precipitation and snowmelt, is the dominant source of supply to these wetlands. Riverine wetlands occurring along the fringe of the channel may receive shallow ground water discharge during dry periods. Wetlands occurring in depressions and oxbows within the riverine flood plain typically receive water from flooding. During flood events, they trap and store excess water that eventually evaporates, is utilized by plants, or infiltrates into the ground, recharging local aquifers. Shallow aquifers may supply water to some flood plain depressions, particularly in the spring and early summer. Riverine wetlands lose water by surface flow, evaporation of surface water, transpiration by plants, and by percolation and seepage into the ground.

Soils

Soils associated with riverine ecosystems are alluvial in nature, are typically poorly or weakly developed, and highly stratified. They form in sediment deposited during high flow events. Within the reference domain for this model, the sediment is typically derived from a mixture of loess and glacial till. The rate of deposition in a given area depends on: (1) the frequency of flooding; (2) flow velocity; (3) the topographic roughness of the flood plain surface, and; (4) vegetative conditions. The stratigraphy of flood plain soils is usually variable and dependent upon landscape position, sediment source, and characteristics associated with flood events. Wetland soils associated with flood plain depressions within the reference domain are usually medium (loamy or silty) or fine textured. They are typically high in organic matter. Wetland soils adjacent to stream channels are not as well defined in terms of texture and organic matter content.

Vegetation

The vegetative community in riverine wetlands normally has herbaceous and woody components. Within the reference domain, the herbaceous component is dominant. The herbaceous plant community is similar in composition and abundance to communities found on other classes of wetlands. Probably the most significant difference between this class of wetlands is in the presence of a woody component. Although inferior in composition to herbaceous species, woody plants provide added attributes in terms of hydrologic modification and wildlife habitat that herbaceous species lack. Willows (Salix spp.) are the dominant woody component.

Fish and Wildlife Service National Wetland Inventory (NWI) classification of this subclass is typically PEMA, PEMB, PEMC, PFOA, PFOC, PSSA, R4UB, or R4SB.

II. Discussion of Riverine Wetland Functions and Associated Functional Indices

Wetlands associated with riverine ecosystems have complex hydrologic, morphologic, and biologic characteristics. They occur on different physiographic positions within the riverine landscape. These wetlands receive most or all of their recharge from high flow events. Some wetlands are disconnected from the stream channel and receive moisture as runoff from surrounding uplands. Wetlands that are disconnected from the stream channel, such as oxbows, typically function as recharge wetlands. Those adjacent to the channel can function as either recharge or discharge wetlands, depending on the stratigraphy of the flood plain, the time of year, frequency of high flow events, or a combination of these.

For purposes of this model, two basic wetland types will be considered when performing functional assessments. The first type of wetland is that which is associated with, or along the fringe of, the stream channel. This type of wetland is located adjacent and parallel to the channel. These types of wetlands may function as recharge wetlands during high flow events; they may also function as discharge wetlands during normal flow, low flow, or dry periods. They do not have the ability to store surface water in the same manner as depressional wetlands do since they are inundated only during high flow events which are usually of short duration (see discussion of function 1.0, Storage of Surface Water). The second type of wetland is found in depressions on the riverine flood plain. They are disconnected from the active channel. These wetlands commonly occur in oxbows, or old segments of stream channel. Although not as common as fringe wetlands in this particular reference subclass, they are nonetheless significant when present. They typically have a surface portal to the channel, which is only accessible during high flow events. They may have subsurface connections to the channel or to other wetlands in the riverine system which allow for subsurface flow during longer periods of time. They can act as recharge wetlands in that they may supply subsurface water to the stream system, particularly during dry periods, via subsurface conduits and pathways.

The following are a discussion of functions associated with this subclass of riverine wetlands.

1.0 STORAGE OF SURFACE WATER

DEFINITION: The ability of the wetland to retain and store water from overbank flow and runoff from uplands during precipitation events, and subsequently releasing it to the stream system via surface and/or subsurface pathways.

EFFECTS ON-SITE: This function contributes to the maintenance of characteristic soils and vegetation; replenishes soil moisture and provides a mechanism for the recharge of ground water; and maintains habitat essential for aquatic organisms.

EFFECTS OFF-SITE: This function aids in the reduction of the volume of water delivered to downstream sites during high flow events. It also provides for a source of recharge to feed local and downstream aquatic ecosystems during periods of low flow.

Discussion of Function

Geology, geomorphology, and precipitation affect the surface and subsurface water flow network within riverine ecosystems. The water source for these systems is from precipitation, and may reach these wetlands in the form of surface runoff and/or subsurface flow. During periods of high flow (flood events), variability in the geomorphic surface of riverine ecosystems captures more water from high flows. Generally, the greater the variability, the more water that is captured and stored within the system. Surface water storage provides a mechanism for ground water recharge. It also provides for a temporary reduction in the volume of water that is delivered to downstream ecosystems during high flow events. This variability in storage capacity supports the wide diversity of vegetation found in these wetlands, in turn providing the habitat aquatic and terrestrial organisms need to survive. This function also facilitates biogeochemical processing within riverine wetlands.

Riverine wetlands that occur adjacent and parallel to the stream channel (i.e. fringe wetlands) do not perform this function, or at best perform it to a very limited extent during high flow events. In order for this function to occur, the wetland must be disconnected from the stream channel and have the ability to retard and contain water. These types of wetlands do not have the ability to store surface water in the same manner as depressional wetlands do since they are inundated only during high flow events, which are usually of short duration, and they have no closed topography required to withhold and retain excess moisture. The function, therefore, is not rated when assessing this type of riverine wetland.

Discussion of Variables

Indicators associated with the performance of this function focus on the geomorphology of the riverine system, hydrology, and land use. Cultural activities within and in close proximity to the wetland and the watershed affect the rate and quantity of water moving into and through these wetlands. Changes to the natural topographic variability (V_{topog}) found in these wetlands directly impacts their water storage capacity. Wetland use (V_{wetuse}) can have an effect on topography, especially in areas of intensive agricultural and other uses, as well as vegetative characteristics of a site. Similarly, alterations to the flood plain and wetland hydrology (V_{hydalt}) can increase the rate of surface or subsurface drainage that lowers the water storing capacity of the wetland, and may affect the frequency and duration of. Land use activities also affect erosion and sediment import (V_{sed}) into riverine wetlands by water and wind. Soil porosity (V_{soil}) within the wetland affect water storage and the ability of the soil to transmit and hold water interstitially.

Index of Function

$$= [V_{topog} \text{ x } V_{hydalt} \text{ x } (V_{sed} + V_{soil} + V_{wetuse})/3]^{1/3}$$

2.0 VELOCITY REDUCTION OF SURFACE WATER FLOW

DEFINITION: The ability of the wetland to reduce the velocity of excess surface runoff (out of channel flow) from storm events and/or snowmelt.

EFFECTS ON-SITE: This function contributes to the maintenance of the characteristic soils, vegetation, and vertebrate and invertebrate populations. It also provides for erosion reduction in the riverine wetland ecosystem, and aids in biogeochemical processing.

EFFECTS OFF-SITE: Erosion reduction and retention of nutrients, elements, and compounds on-site decreases the probability of the export of these to aquatic ecosystems downstream, resulting in improved water quality downstream and within the stream system.

Discussion of Function

This function pertains not only to the rate of flow through the wetland, but also to the energy that water expresses as it moves into, through, and out of the wetland. As a result of velocity reduction and energy dissipation within wetlands, pressure on channel beds and banks is lower so the system is more stable. Vegetation and topographic variability within riverine wetlands provide structural roughness and resistance that reduces the velocity of overland flow during periods of high flow. This reduction in the flow velocity allows time for the settlement of water-borne sediment, nutrients, and other contaminants within the wetland. Water velocity reduction during periods of high flow contributes to a decrease in the energy and the erosive force that these waters possess.

Discussion of Variables

The variables within this function reflect land use and the physical condition of the wetland watershed, and vegetative cover. Wetland use (V_{wetuse}) directly influences the velocity of surface water movement through the wetland. Wetland use also influences a host of other attributes that affect surface water movement through riverine systems. As the size and number of obstacles to surface flow increase, the potential for velocity reduction and energy dissipation increases. When water flows over surfaces and around obstacles, friction and shear forces create turbulent flow and reduce velocities. These gross features of site roughness are reflected in the topographic complexity (V_{topog}) and vegetation density (V_{denhw}) variables. Alterations to hydrology within or in close proximity to the wetland (V_{hydalt}) affect the rate of surface water movement through it. In addition, dominant use of the uplands (V_{upuse}) has an affect on the amount of runoff delivered to the ecosystem from precipitation events and from snowmelt. An intact wetland buffer (V_{buffer}) also aids in slowing the rate of flow from uplands into the wetland, and in slowing the flow rate through wetlands during high flow events.

Index of Function

$$= [V_{topog} + V_{hydalt} + V_{denhw} + V_{wetuse} + (V_{upuse} + V_{buffer})/2]/5$$

3.0 STORAGE AND RELEASE OF SUBSURFACE WATER

DEFINITION: The ability of the wetland to retain excess water within the soil profile and release it gradually to the stream channel, thereby moderating stream flow.

EFFECTS ON-SITE: This function contributes to the maintenance of the characteristic soils and vegetation within the wetland ecosystem, and provides a mechanism for the moderation of ground water flow.

EFFECTS OFF-SITE: This function modifies the hydrology of riverine wetland systems downstream, and provides water input into the stream system during periods of low flow.

Discussion of Function

Geology, geomorphology, and precipitation affect the surface and subsurface water flow network within riverine ecosystems (Boschee, et. al. 1999). The principal water source for these systems is from excess precipitation producing upstream runoff and from ground water discharge. Principle losses are through runoff downstream, evapotranspiration, and deep percolation. These hydrological elements produce an inter- and intra-annual cycle of water storage within the wetland boundaries. The cyclic nature of riverine wetland water regimes supports the diverse plant communities' characteristic of these ecosystems, particularly during dry periods. It also aids in the biogeochemical processing cycle. In some instances, ground water is released to the stream system during dry cycles, providing the only source of surface flow through the system.

Discussion of Variables

The variables associated with the performance of this function focus on land use and on the physical integrity of soil conditions. Cultural activities within and in close proximity to the wetland, as well as activities within the riverine watershed, affect the rate and quantity of water moving into and through these wetlands. Hydrologic alterations within or adjacent to the wetland (V_{hydalt}) can change the rate of surface or subsurface drainage, which in turn changes the subsurface rate of flow and the water storing capacity of the wetland. Alterations to the flood plain and wetland hydrology also act as a surrogate indicator of the expected frequency of high flow events. Wetland use (V_{wetuse}), upland use (V_{upuse}), and hydrologic alterations within the watershed (V_{source}) are used to describe and rate any potential alterations to the natural rate of water flow to and through the wetland. Wetland soil porosity (V_{soil}) affect water storage and the ability of the soil to transmit and hold water interstitially.

Index of Function

$$= \{V_{hydalt} \text{ x } [(V_{source} + V_{upuse})/2 + (V_{soil} + V_{wetuse})/2]/2\}^{1/2}$$

4.0 REMOVAL OF IMPORTED ELEMENTS AND COMPOUNDS

DEFINITION: The ability of the wetland to store and cycle elements and compounds. Considers abiotic and biotic processes that convert elements and compounds (such as nutrients, heavy metals, and pesticides) from one form to another.

EFFECTS ON-SITE: The net effects of this function are the balancing of gains of elements and compounds through importation processes and losses through hydrologic export, efflux to the atmosphere, and long term retention in persistent biomass and sediment.

EFFECTS OFF-SITE: The retention of elements, compounds, and nutrients on-site results in a decrease in the probability of export to aquatic ecosystems downstream, and an increase in water quality.

Discussion of Function

Wetlands function as interceptors of non-point source pollution (Johnston, 1991). Riverine wetlands, particularly those in headwater positions, are strategically located to intercept nutrients and contaminants before they reach streams (Brinson, 1988). This function involves the annual turnover of nutrients and the long-term retention or accumulation of elements and compounds from incoming water sources. Conversion of elements and compounds within the wetland ecosystem generally results in a reduction in the amount of these that are exported to downstream ecosystems and water supplies. Elements include macronutrients that are essential to plant growth (such as nitrogen, phosphorus, and potassium), micronutrients (such as iron, sulfur, and magnesium), and heavy metals (such as chromium, molybdenum, and zinc). Compounds include herbicides, pesticides, fertilizers, and other imported inorganic materials. Mechanisms of removal of imported contaminants include sorption, sedimentation, denitrification, burial, decomposition and decay, uptake and incorporation into short- and long-lived, annual and perennial, herbaceous and woody biomass, and similar processes (Brinson, et. al. 1985].

Discussion of Variables

The variables that affect the performance of this function deal with soil (abiotic) and vegetative (biotic) properties and land use. Abiotic components assist in the reduction and oxidation processes that biogeochemically cycle and retain elements and compounds. Biotic components of the wetland ecosystem cycle and retain elements and compounds through biomass accumulation and litter production. Elements and compounds are recycled annually through decay and decomposition. Neely and Baker (1989) report decay rates for some emergent plants in the Prairie Pothole region to be greater than one year, indicating retention. These decomposition rates facilitate nutrient cycling on an annual and longer-term basis. Soil organic matter (V_{som}) provides one of the most important mechanisms by which these processes occur. Detritus ($V_{detritus}$) is important in nutrient cycling as it is the primary source of organic matter supply to the wetland soil. Detritus is also used as a surrogate or indirect measure of the vegetative health of the wetland in this function.

Land use activities influence the magnitude at which elements and compounds enter the wetland ecosystem, as well as the natural cycling and removal processes. Upland use (V_{upuse}) and wetland use (V_{wetuse}) are important considerations in the cycling process.

Consideration should also be given to the hydrologic regime, and impacts to that regime, both within the wetland ecosystem and the riverine watershed. Impacts to wetland hydrology (V_{hydalt}) and the contributing watershed area (V_{source}) affect the ability of the wetland to function and provide suitable biotic components for the cycling of elements and compounds.

Index of Function

$$= \{[(V_{som} + V_{detritus})/2] \times [V_{wetuse} + (V_{hydalt} + V_{source} + V_{upuse})/3]/2\}^{1/2}$$

5.0 RETENTION OF PARTICULATES AND ORGANIC MATERIALS

DEFINITION: The deposition and retention of inorganic and organic particulates (>45um) from the water column, primarily through physical processes.

EFFECTS ON-SITE: Sediment and organic matter accumulation contributes to the nutrient capital of an ecosystem. Sediment deposition increases surface elevation and changes the wetland topographic complexity. Organic matter is retained for decomposition or exported to downstream systems. Natural rates of accumulation are slow as compared to accelerated rates.

EFFECTS OFF-SITE: If properly functioning, wetlands help to reduce potential export of sediment and organic particulates to downstream wetlands and other aquatic ecosystems, including ground water systems.

Discussion of Function

Flooding from overbank flow of alluvial streams is a major source of inorganic particulates for floodplain wetlands. Floodplains of smaller streams also receive sediments due to overland flow from adjacent uplands. Once water-borne sediment has been transported to a floodplain, velocity reductions normally occurs due to surface roughness and increasing cross-sectional area of discharge (Nutter and Gaskin, 1989). This leads to a reduction in the capacity of water to transport suspended sediments, so particulates settle. The best evidence of this function is the presence of retained sediments in depositional layers. This evidence is particularly diagnostic when deposition is recent and can be related to a specific flood event.

Wetlands act as filters, trapping and holding water-borne material. Retention applies to particulate material arising from both on-site and off-site sources, but excludes in situ production of peat. This function contrasts with function 4.0, Retention, Conversion, and Release of Elements and Compounds, in that the emphasis is more dependent on physical processes such as sedimentation and particulate removal. Sediment retention facilitates burial of imported materials, and aids in biogeochemical processes such as chemical precipitation (as in the case of phosphorus precipitation by Fe^{+++}). Dissolved forms may be transported as particles after undergoing sorption and chelation, such as happens when heavy metals are mobilized with organic compounds such as organic acids. Imported sediment can undergo renewed pedogenesis on-site, which potentially involves weathering and release of elements that were previously inaccessible to mineral cycling (Brinson, 1995).

Discussion of Variables

The variables associated with the performance of this function focus primarily on components of the system that affect the physical processes of particulate removal (mineral and organic) and sedimentation. One of the critical factors in the life of a wetland is the rate at which sediment is delivered to the wetland, as evidenced by the amount of accumulation that has taken place. Natural rates of sediment accumulation are slow as compared to accelerated rates that commonly occur in areas of intensive agricultural use. Accelerated sedimentation, if left unchecked, can reduce the ability of the wetland to perform many of the hydrologic, biogeochemical, and vegetative/habitat functions. This accelerated accumulation is represented by the sedimentation (V_{sed}) variable. These types of wetlands occupy landscape positions within the riparian corridor and hence are subject to periodic high flow (V_{flood}) events. This periodic flooding contributes to the geomorphology of the riverine system, and provides for the cyclic deposition and removal of water-borne sediment. Use of the uplands (V_{upuse}) has a direct influence on the potential delivery of sediment to these ecosystems. Similarly, use of the wetland (V_{wetuse}) has an effect on the natural rate of sedimentation and sediment export.

As water flows over surfaces, friction and shear forces created by irregularities in the surface create turbulent flow and reduce velocities, both of which are conducive to sediment deposition. Three variables contribute to regulating flow velocities and rates of deposition. Density of the herbaceous and woody vegetation present (V_{denhw}) provides an indication of the kinds and amount of vegetation present in the wetland. The topographic complexity (V_{topog}) variable provides a method of indexing the condition (or roughness) of the wetland surface. An established buffer zone (V_{buffer}) around the margin of the wetland affects surface flow into the wetland, and acts as a filter during periods of peak flow.

Index of Function

$$= [V_{sed} + (V_{topog} + V_{denhw})/2 + (V_{buffer} + V_{upuse} + V_{wetuse})/3]/3$$

6.0 ORGANIC CARBON EXPORT

DEFINITION: The export of dissolved and particulate organic carbon and detritus from the wetland through leaching, flushing, displacement, and erosion.

EFFECTS ON-SITE: The decomposition of living biomass and detritus provides organic carbon essential for food web support and biogeochemical processing and contributes to carbon cycling.

EFFECTS OFF-SITE: This function provides support for food webs and biogeochemical processing in downstream aquatic and terrestrial ecosystems.

Discussion of Function

Wetlands export organic carbon at higher rates per unit area than do terrestrial ecosystems (Mulholland and Kuenzler, 1979), in part because surface water has greater contact time with organic matter in litter and in the soil surface. While the molecular structure of most organic material is not well known because of its chemical complexity (Stumm and Morgan, 1981), organic matter nevertheless plays important roles in geochemical and food web dynamics. For example, organic carbon complexes with a number of relatively immobile metallic ions that facilitate transport in soil (Schiff et.al., 1990). Organic carbon is a primary source of energy for microbial food webs (Dahm, 1981; Edwards, 1987; Edwards and Meyer, 1986) which form the base of the detrital food web in aquatic ecosystems. These factors, in combination with the proximity of wetlands to aquatic ecosystems, make wetlands critical sites for supplying both dissolved and particulate organic carbon.

Discussion of Variables

There are two primary requirements that need to be met in order for riverine wetlands to function as a source of organic carbon. Source material is required in order to supply organic material available for decomposition into organic carbon, and a source of water as a vehicle for carbon transportation. Most organic carbon comes from the decay of plant material produced within and adjacent to the wetland. Native, permanently vegetated wetlands produce more organic material than do wetlands that are disturbed, as from agricultural activities. The vegetation density (V_{denhw}) and stratification/canopy (V_{veg}) variables reflect the health and productivity of the perennial plant community within the wetland. Vegetative production directly influences the amount of detritus ($V_{detritus}$) which can accumulate on the soil surface and become available for further breakdown. Some of the organic carbon produced on decomposition of the plant litter is incorporated into the surface layer of the wetland soil (V_{som}) and becomes available for transportation with sediment or in solution. The movement of water through the wetland accomplishes transportation of organic carbon. Surface flow, such as is evident during high flows, is the common mode of transportation. Subsurface inflow also contributes to organic carbon export. The movement of soil water within alluvium may create outflow through surface and subsurface pathways to downstream localities. Restrictions in or alterations to wetland hydrology (V_{hydalt}) may affect the ability of water to move through the wetland, thereby altering the movement of organic carbon.

Index of Function

$$= [V_{detritus} + V_{som} + (V_{denhw} + V_{veg})/2 + (V_{hydalt} + V_{topog})/2]/4$$

7.0 MAINTAINS CHARACTERISTIC PLANT COMMUNITY

DEFINITION: The maintenance of vegetation in the wetland by mechanisms such as seed dispersal, seed banks, and vegetative propagation which respond to variations in hydrology and disturbances such as fire and herbivores.

EFFECTS ON-SITE: This function creates microclimatic conditions that support plants and animals. Plants convert solar radiation and carbon dioxide into complex organic carbon that provides energy to drive food webs. Plants also provide habitat for feeding, nesting, resting, escape, and breeding for resident and migratory vertebrates and invertebrates. Production of plant material provides the primary source of organic material necessary for biologic processing functions. A well maintained, healthy plant community also serves to modify riverine ecosystem hydrology.

EFFECTS OFF-SITE: This function provides a source of vegetative propagules available for export to downstream ecosystems. This assists in revegetation following drought or other disturbances and provides for gene flow between populations. It provides habitat for vertebrates and invertebrates in adjacent ecosystems.

Discussion of Function

Herbaceous and woody vegetation accounts for most of the above-ground biomass of riverine systems. The physical characteristics of living and dead plants are closely related to ecosystem functions associated with hydrology, nutrient cycling, and the abundance and diversity of animal species (Lillie and Evard, 1994). Vegetation is not static, however, and species composition and physical characteristics can change in space and time in response to natural and cultural influences (Weller, 1987).

The importance of plant communities to riverine ecosystems can be understood by considering what happens when vegetation is removed or highly disturbed (Harris and Gosselink, 1990). Removal or severe disturbance of riparian vegetation can lead to a change in the structure of macroinvertebrate communities (Hawkins, Murray, and Anderson, 1982), a decrease in the species diversity of stream ecosystems, a decline in the local and/or regional diversity of animals associated with riverine corridors, and a significant change in river/stream hydrology (Gosselink et. al., 1990).

Discussion of Variables

Variables associated with this function address plant community characteristics and potential cultural disturbances. The elements of a healthy plant community may be compromised by cultural activities. Land use within the wetland (V_{wetuse}) directly impacts plant communities. Plant community characteristics change as disturbances occur within and surrounding the wetland ecosystem. The ratio of native to non-native species (V_{pratio}) is an indicator of the health of a community. A healthy plant community is comprised of a high percentage of native, non-invasive plants. As a system is degraded, invasive species (native and non-native) out-compete sensitive native species. A healthy, native plant community consists of components measuring vegetative strata and canopy coverage. Undisturbed riverine ecosystems often contain both herbaceous and woody species. Cultural activities, whether from overuse by livestock, farming, or urbanization, typically result in a decrease in the abundance of herbaceous and/or woody species. Since woody and herbaceous components are commonly present in the riverine plant community, defined vegetative strata provide vegetative characteristics not found on slope wetlands or on prairie potholes.

Upland use (V_{upuse}) indirectly affects wetland communities, particularly when activities on the uplands have caused increased or decreased runoff or increased sediment movement (V_{sed}) into the wetland. An established buffer (V_{buffer}) provides protection from excess sedimentation from adjacent uplands, particularly in areas of intensive agricultural use. Periodic high flow of water is common within riverine ecosystems and has contributed over time to the characteristic plant community found on these wetlands. Changes in the frequency of high flow events impacts the characteristic subsurface and surface water regimes, and hence the soil moisture regime. Alterations to the flood plain and wetland hydrology (V_{hydalt}) impacts ground water and surface water regimes within these types of wetlands.

Index of Function

$$= \{V_{wetuse} \text{ x } [V_{pratio} + (V_{buffer} + V_{upuse})/2 + (V_{hydalt} + V_{sed})/2]/3\}^{1/2}$$

8.0 MAINTAINS HABITAT STRUCTURE WITHIN WETLAND

DEFINITION: Soil, vegetation, and other aspects of ecosystem structure within the wetland, and among wetlands in the same and different classes and subclasses, that would support animal populations for resting, feeding, hiding, and reproduction.

EFFECTS ON-SITE: Riverine wetlands contribute to habitat features for aquatic and terrestrial vertebrates and invertebrates by virtue of their position on the landscape.

EFFECTS OFF-SITE: Riverine wetlands contribute to the overall landscape diversity of habitat types for aquatic and terrestrial organisms.

Discussion of Function

Wetlands provide water, habitat, food, and other life requirements for motile species. In addition, the variation and diversity of vegetative strata commonly associated with riverine wetland ecosystems provide unique habitat not found in other classes of wetlands. This function compares the suitability of vegetation structure for sustaining animal populations.

Vegetation of mature, intact riverine ecosystems reflects the constraints imposed by environmental parameters (climate, hydrologic regime, edaphic factors, geomorphology, etc.) and the competitive interactions of its plants. Wetland vegetation patterns of altered riverine systems are affected by current and past disturbances, in addition to the constraints previously listed. Most larger river systems and many smaller ones in the continental United States have been dramatically altered by dams, levees, diversions, and abstractions (Stanford and Ward, 1979). Therefore, present vegetation patterns in riverine wetlands often reflect past and ongoing anthropogenic alterations in hydrogeomorphic conditions.

Discussion of Variables

Intact vegetation is critical for optimum habitat functions for wildlife. Wetlands function as habitat for wildlife by providing food, shelter, and reproductive cover. The functionality of a wetland to provide these needs for wildlife can be disturbed through cultural alterations both within and around the wetland area. The extent of these disturbances is represented by wetland use (V_{wetuse}), and use and condition of the buffer (V_{buffer}). Wildlife normally prefer the habitat qualities that a diverse stand of native plant species offer. Quite often with time, introduced, non-native species tend to dominate sites. The ratio of native to non-native species (V_{pratio}) gives an indication of the potential habitat quality the vegetation offers native wildlife populations. Density and condition of the native vegetation within the wetland gives an indication of the ability of the wetland to provide necessary habitat elements. Wetland vegetation within riverine ecosystems provides habitat for wildlife relative to the cover it provides. Cover is, in turn, relative to the presence of vegetative strata for the site. Vegetative cover and stratification (V_{veg}) and vegetation density (V_{denhw}) capture this aspect of the quality of habitat that the plant species present on the site offer. In addition to the cover that actively growing vegetation offers, plant litter ($V_{detritus}$) on or near the wetland surface provides habitat for invertebrate species and many small vertebrates, such as small mammals and birds.

Maintenance of water levels and soil moisture in the wetland is importance to the maintenance of vegetation for habitat. Alterations within the flood plain and wetland (V_{hydalt}) can affect the characteristic hydrologic regime associated with periodic high flows. These alterations also serve to reduce ground and surface water levels.

Index of Function

$$= [V_{denhw} + V_{veg} + V_{wetuse} + V_{pratio} + (V_{buffer} + V_{detritus} + V_{hydalt})/3]/5$$

9.0 MAINTAINS HABITAT INTERSPERSION AND CONNECTIVITY AMONG WETLANDS

DEFINITION: The capacity of a wetland to permit aquatic organisms to enter and leave the wetland via permanent or ephemeral surface channels or overbank flow, and to permit access of terrestrial or aerial organisms to contiguous areas of food and cover.

EFFECTS ON-SITE: Provides habitat diversity. Contributes to secondary production and complex trophic interactions. Provides access to and from wetland for reproduction, feeding, rearing, and cover. Contributes to completion of life cycles and dispersal between habitats.

EFFECTS OFF-SITE: Riverine wetlands contribute to the overall landscape diversity and linking of habitat types for aquatic and terrestrial organisms. They provide corridors for wide-ranging or migratory species, and conduits for dispersal of plants and animals to other areas.

Discussion of Function

Riverine floodplains and the wetlands associated with them are used extensively by both terrestrial and aquatic animals to complete portions of their life histories (Minshall, Jensen, and Platts, 1989; Welcomme, 1979; Wharton et. al., 1982). Adequate habitat corridors are required for connecting wetlands to other ecosystems. Aquatic vertebrates enter floodplain wetlands during high flow events, most often via small connections from side or main channels. Natural or man-made barriers (such as levees) between wetlands and the stream channel may restrict surface connections during years without high flow events.

Wetlands of riverine floodplains often support a heterogeneous mosaic of habitat types at a variety of temporal and spatial scales. For example, depressions on a floodplain surface may hold water for long periods between floods, thus supporting aquatic organisms and more flood-intolerant plants than nearby, less wet sites. Likewise, links between the floodplain and the main channel provide important conduits for seed dispersal to and from wetlands.

Wetlands provide water and other life requirements for motile species that primarily exploit upland habitats. In addition, all vegetative strata in riverine wetlands provide wildlife corridors between different wetland types, between uplands and wetlands, and between uplands (Sedell et. al., 1990). Such connections between habitats help maintain higher animal and plant diversity across the landscape than would be the case if habitats were more isolated from one another.

Discussion of Variables

Intact vegetation is critical for optimum habitat functions for wildlife. Similarly, uninterrupted corridors are critical for movement of animals within and between wetlands, between wetlands and uplands, and between uplands. Continuity of vegetation, connectivity of specific vegetation types, the presence and scope of corridors between upland and wetland habitats, and corridors among wetlands all have a direct bearing on the movement and behavior of animals that use wetlands (Pautou and Decamps, 1985). This effect is reflected by the use of the wetland (V_{wetuse}), and by the use and condition of the upland (V_{upuse}) and the buffer (V_{buffer}). Wetland vegetation within riverine ecosystems provides the cover necessary for wildlife to feel safe in using it as a travel corridor. Cover is, in turn, relative to the presence of vegetative strata for the site. These elements are reflected in the variable (V_{veg}).

Topographic complexity (V_{topog}) is an important factor contributing to the interspersion of habitat types and connections between river and flood plain wetlands. Elevated structures (such as hummocks) and low areas (channels and small depressions) direct the flow of water through wetlands, and affect the direction and duration of flows. Wetlands with a mosaic of interspersed habitat types provide conditions suitable for a higher diversity of plant and animal species that do wetlands with uniform topography.

Index of Function

$$= (V_{topog} + V_{upuse} + V_{buffer} + V_{veg} + V_{wetuse})/5$$

Flood Plain/Wetland Hydrology Alterations
(V_{hydalt})

Definition: The presence of man-made, surface and/or subsurface alterations that are on the flood plain immediately adjacent to the wetland assessment area, or within the wetland assessment area, that impact wetland hydrology.

Subsurface alterations may include tile drainage, ditches, or channelization greater than two feet in depth.

Note: This variable also serves as a surrogate indicator of the frequency flooding, or high flow events, occurs in the system.

Methodology for Rating V_{hydalt}: This variable considers the effects manipulations on the flood plain (H_{fp}) and within the wetland (H_w) have on wetland hydrology. Flood plain alterations and wetland alterations are assessed separately and then combined to produce a summary rating. Flood plain alterations should be considered as significant to wetland hydrology if present within a distance of 1,000 feet parallel to or upstream from the wetland assessment area. Wetland alterations include any manipulations that have occurred within the wetland. Both components are equally significant when dealing with the wetland water regime, and therefore are rated exponentially; in other words, a low score for one of these components will result in a correspondingly lowered overall rating for V_{hydalt}. Types of flood plain and wetland alterations are described in Table 1 and 2, respectively. A variable rating is calculated using the following equation:

$$V_{hydalt} = (H_{fp} \times H_w)^{1/2}$$

Table 1. Flood Plain Hydrology Alterations (H_{fp})	
Measurement or Condition	**Index**
Flood plain has not been physically manipulated. No surface alterations (such as constructed channels, dams, dikes, diversions, dugouts, or fill) or subsurface alterations (such as tile drainage) present.	1.0
A water impoundment structure is situated **downstream** from the wetland such that wetland hydrology has been enhanced or degraded beyond what it would normally be. No structures are present **parallel to or upstream** that would affect hydrology.	0.75
One or more surface alterations (constructed channels, dams, dikes, diversions, dugouts, or fill) are present at a distance of 500 to 1000 feet **parallel to or upstream from** the wetland. Such alteration(s) partially divert or retard the flow of surface water, particularly water from high flow events, away from the wetland. No subsurface alterations are present.	0.5
(No measurement for this index.)	0.25
One or more surface alterations (constructed channels, dams, dikes, diversions, dugouts, or fill) are present within 500 feet **parallel to or upstream from** the wetland. Such alteration(s) are designed to divert or retard >75% of the surface water flow, particularly water from high flow events, away from the wetland, -AND/OR- A subsurface drainage feature (such as drain tile) is adjacent and parallel to the wetland.	0.1
Flood plain hydrology has been altered such that all surface and/or subsurface flow to the wetland has been eliminated. (Alterations include channelization and lining, or complete diversion or drainage of surface and/or subsurface water sources.)	0.0

Table 2. Wetland Hydrology Alterations (H_w)	
Measurement or Condition	**Index**
Wetland has not been physically manipulated. No surface alterations (such as drainage ditches, dams, dikes, dugouts, or fill) or subsurface alterations (such as tile drainage) present.	1.0
A surface alteration is present within the wetland as follows: (1) a drainage ditch with a bottom elevation at or above the hydric boundary; (2) a dam, dike, dugout, or any fill material affecting 25% or less of the wetland area, -AND- No subsurface alterations are present within the wetland.	0.75
A surface alteration is present within the wetland as follows: (1) a drainage ditch with a bottom elevation at or below the hydric boundary but above the bottom of the wetland; (2) a dam, dike, dugout, or any fill material affecting 26% to 50% of the wetland area, -AND- No subsurface alterations are present within the wetland.	0.5
A surface alteration (such as a dam, dike, dugout, or fill) is present within the wetland, and impacts from 51 to 75% of the wetland area.	0.25
A surface alteration is present within the wetland as follows: (1) a drainage ditch with a bottom elevation at or below the bottom of the wetland, effectively draining static water; (2) a dam, dike, dugout, or any fill material affecting 76% to 99% of the wetland area; (3) a constructed channel in lieu of the natural watercourse, vegetated, -AND/OR- Subsurface alterations (such as drain tile) into and through wetland, with some saturation remaining as evidenced by the presence of remnant hydrophytes.	0.1
Cultural alterations to the wetland are present such that all wetland hydrology has been eliminated. Alterations include channelization and lining, or complete diversion or drainage of surface and/or subsurface water sources.	0.0

Flood Plain/Wetland Topographic Complexity (V_{topog})

Definition: The topographic roughness of the surface of the wetland and surrounding flood plain, ***excluding*** the effects vegetation and other biotic factors have on that surface.

Methodology for Rating V_{topog}: There are two components to the topography variable. The first considers the topographic roughness of the wetland surface. The second considers the topography of the surrounding flood plain. Both components are important in terms of velocity reduction of surface water flow and surface water storage. During the assessment, both components are rated separately using conditions described in Table 3 and 4. An estimate of the size of the wetland assessment area compared to the surrounding flood plain area is made (to the nearest 5 percent). A variable score is calculated using the following equation:

$$V_{topog} = \frac{(T_w \text{ x \% of area})}{100} + \frac{(T_{fp} \text{ x \% of area})}{100}$$

Table 3. Topographic Roughness of the Wetland Surface (T_w)

Measurement or Condition	Index
Natural conditions occur within the wetland as evidenced by irregular, uneven surfaces (undulating conditions from meander scars, sediment bars, or hummocks). No evidence of any manipulations that would result in a smooth surface (such as cut/fill activities, cultivation, etc.).	1.0
Evidence of manipulations or activities within the wetland that have had a smoothing effect on the surface (such as cut and/or fill activities, cultivation, etc.), -AND- 1 to 25% of the wetland area is affected; -OR- Excessive "hoof action" (trampling) by livestock has occurred throughout the wetland, such that naturally-occurring features have been obscured.	0.75
Evidence of manipulations or activities within the wetland that have had a smoothing effect on the surface (such as cut and/or fill activities, cultivation, etc.), -AND- 26 to 50% of the wetland area is affected.	0.5
Evidence of manipulations or activities within the wetland that have had a smoothing effect on the surface (such as cut and/or fill activities, cultivation, etc.), -AND- 51 to 75% of the wetland area is affected.	0.25
Evidence of manipulations or activities within the wetland that have had a smoothing effect on the surface (such as cut and/or fill activities, cultivation, etc.), -AND- 76 to 95% of the wetland area is affected.	0.1
Greater than 95% of the wetland has been manipulated such that the surface is smooth and regular (as from fill and leveling in urban areas, channel lining, etc.)	0.0

Table 4. Topographic Complexity of the Flood Plain Surface (T_{fp})	
Measurement or Condition	**Index**
Natural conditions occur in the flood plain area as evidenced by irregular, uneven surfaces (undulating conditions from meander scars, sediment bars, or hummocks). No evidence of any manipulations that would result in a smooth surface (such as cut/fill activities, cultivation, etc.).	1.0
Evidence of manipulations or activities in the flood plain area that have had a smoothing effect on the surface (such as cut and/or fill activities, cultivation, etc.), -AND- 1 to 25% of the flood plain area is affected; -OR- Excessive "hoof action" (trampling) by livestock has occurred throughout the flood plain, such that naturally-occurring features have been obscured.	0.75
Evidence of manipulations or activities in the flood plain area that have had a smoothing effect on the surface (such as cut and/or fill activities, cultivation, etc.), -AND- 26 to 50% of the flood plain area is affected.	0.5
Evidence of manipulations or activities in the flood plain area that have had a smoothing effect on the surface (such as cut and/or fill activities, cultivation, etc.), -AND- 51 to 75% of the flood plain area is affected.	0.25
Evidence of manipulations or activities in the flood plain area that have had a smoothing effect on the surface (such as cut and/or fill activities, cultivation, etc.), -AND- 76 to 95% of the flood plain area is affected.	0.1
Greater than 95% of the flood plain has been manipulated such that the surface is smooth and regular (as from fill and leveling for pavement, channel lining, etc.)	0.0

Watershed Hydrology Alterations (V_{source})		
Model Variable	**Measurement or Condition**	**Index**
Definition: The physical alterations that exist within the wetland watershed source area. The source area is considered to be the uplands, excluding the flood plain, which contribute surface and subsurface water to the flood plain and wetland. **Note:** For watershed areas in excess of 1000 acres (+ or -), use remote sensing techniques, input from local specialists, or information from other sources.	No surface or subsurface alterations within the wetland watershed source area.	1.0
	Surface structures (primarily dams or diversions) are present within the wetland watershed source area that divert water from, or slow the flow of water to, the wetland, -AND/OR- Depressional and/or slope wetland drainage activities (surface or subsurface) exist in the uplands, -AND- Less than 25% of the watershed area is affected by these alterations.	0.75
	Surface structures (primarily dams or diversions) are present within the wetland watershed source area that divert water from, or slow the flow of water to, the wetland, -AND/OR- Depressional and/or slope wetland drainage activities (surface or subsurface) exist in the uplands, -AND- 25 to 50% of the watershed area is affected by these alterations.	0.5
	Surface structures (primarily dams or diversions) are present within the wetland watershed source area that divert water the wetland, -AND/OR- Depressional and/or slope wetland drainage activities (surface or subsurface) exist in the uplands, -AND- 51 to 75% of the watershed area is affected by these alterations.	0.25
	The dominant surface and subsurface flow paths of water in the upland watershed source area has been altered or eliminated, thus affecting the flow of water to the wetland (such as by diversions, dams, drainage, or terraces). Greater than 75% of the watershed source area is impacted.	0.1
	The upland watershed source area has been extremely altered such that almost all water flow to the wetland has been eliminated.	0.0

Upland Use
(V_{upuse})

This variable attempts to rate the use and condition of the majority of the upland within the wetland watershed. To do this, a maximum of three upland use types should be considered. Visual observations, aerial photography, local specialists, or other sources should be used to determine the three dominant land types and their approximate percentage occurrence (to the nearest 10 percent) in the landscape. The index value for each condition can be found in the table below. Numbers can be inserted in the following equation to calculate a relative value for this variable.

$$\frac{[\text{Land use 1 (\% area) x Index value}] + [\text{Land use 2 (\% area) x Index value}] + [\text{Land use 3 (\% area) x Index value}]}{\text{Sum \% area}}$$

If two-thirds or more of the upland watershed area is of one or two use types, score this variable based on those types.

Model Variable	Measurement or Condition	Index
Definition: The use and condition of the majority of the upland watershed area. **Note:** For watershed areas in excess of 1000 acres (+ or -), use remote sensing techniques, input from local specialists, or information from other sources.	Well managed, permanently vegetated native prairie. Management allows for adequate plant recovery time between grazing periods.	1.0
	Permanent vegetation under a system of management such as: Native species under season-long grazing with moderate use; -OR- Idle non-native grassland; -OR- Permanent native or non-native hayland.	0.75
	Permanent native or non-native pasture which has been historically over-grazed, with some (<50%) bare ground and low plant vigor; -OR- No-till small grain; -OR- Minimum till small grain in a grass/legume rotation.	0.5
	Permanent native or non-native pasture which has been severely over-grazed, with significant (<50%) bare ground, low plant vigor, and evidence of soil erosion; -OR- No-till or minimum till row crop, continuous minimum till small grain.	0.25
	Conventional tillage small grain or row crop; -OR- Inputs/overflow from cultural activities (such as from industry and urbanization).	0.1
	Urban, semi-pervious, or impervious surface resulting in maximum overland flow and a high rate of delivery to the wetland.	0.0

Detritus[1]
($V_{detritus}$)

Model Variable	Measurement or Condition	Index
Definition: ***Previous years'*** vegetative remnants (from both herbaceous and woody species) within the wetland that are prostrate and in contact with the soil surface. This includes partially buried debris that is exposed at the surface. **Note [1]:** Use this measure of detritus when assessing depressional or linear-type wetlands that are not adjacent to the channel but are within the riverine ecosystem.	The litter layer thickness in: Winter/spring (Dec.-May) is 2.5 to 4 inches; Summer (June-August) is 1.5 to 2.5 inches; Fall (Sept.-Nov.) is .75 to 2 inches. (Indicator: A continuous, uniform mat of litter occurs throughout the wetland. Less than 1 percent of the soil surface in the wetland is exposed.)	1.0
	The litter layer thickness in: Winter/spring (Dec.-May) is 1.25 to <2.5 inches or >4 inches; Summer (June-August) is 1 to <1.5 inches or >2.5 inches; Fall (Sept.-Nov.) is .5 to <.75 inches or >2. (Indicator: Litter occurs throughout the wetland. It is relatively continuous, with up to 15% bare ground; thickness may be uniform or slightly variable; or, the litter layer is overly thick, consisting primarily of cattail remnants.)	0.75
	The litter layer thickness in: Winter/spring (Dec.-May) is .75 to <2.25 inches; Summer (June-August) is .5 to <1 inches; Fall (Sept.-Nov.) is .2 to <.5 inches. (Indicator: Litter occurrence is variable. There may be from 15 to 50% bare ground. The thickness may be uniform or variable.)	0.5
	The litter layer thickness in: Winter/spring (Dec.-May) is >0 but <.75 inches; Summer (June-August) is >0 but <.5 inches; Fall (Sept.-Nov.) is >0 but <.2 inches; -OR- If cultivated, no-till practices are in use. (Indicator: Litter occurrence is highly variable and relatively thin. There is generally 50 to 90% bare ground.)	0.25
	There is no measurable litter present in the assessment area. However, the wetland is relatively intact and has vegetation present (or is able to support vegetation) capable of producing detritus; -OR- If cultivated, minimum or conventional tillage practices are in use.	0.1
	There is no detritus present, and the wetland has been altered or eliminated such that there is no potential for recovery.	0.0

Detritus[2]
($V_{detritus}$)

Model Variable	Measurement or Condition	Index
Definition: ***Previous years'*** vegetative remnants (from both herbaceous and woody species) within the wetland that are prostrate and in contact with the soil surface. This includes partially buried debris that is exposed at the surface. **Note [2]:** Use this measure of detritus when assessing fringe wetlands associated with the channel in the riverine ecosystem.	The litter layer thickness in: Winter/spring (Dec.-May) is ≥1 inch; Summer (June-August) is >.75 inches; Fall (Sept.-Nov.) is .5 inches.	1.0
	The litter layer thickness in: Winter/spring (Dec.-May) is .75 to 1 inch; Summer (June-August) is .5 to .75 inches; Fall (Sept.-Nov.) is .25 to .5 inches.	0.75
	The litter layer thickness in: Winter/spring (Dec.-May) is .5 to .75 inches; Summer (June-August) is ..25 to .5 inches; Fall (Sept.-Nov.) is .1 to .25 inches.	0.5
	The litter layer thickness in: Winter/spring (Dec.-May) is >0 but <.5 inches; Summer (June-August) is >0 but <.25 inches; Fall (Sept.-Nov.) is >0 but <.1 inches;	0.25
	There is no measurable litter present in the assessment area. However, the wetland is relatively intact and has vegetation present (or is able to support vegetation) capable of producing detritus.	0.1
	There is no detritus present, and the wetland has been altered or eliminated such that there is no potential for recovery.	0.0

Sedimentation Within the Wetland (V_{sed})

Model Variable	Measurement or Condition	Index
Definition: Evidence of culturally accelerated (excessive) sedimentation within the wetland. **Note:** Partial fill in wetland does not count as sediment. If the wetland has been partially filled, evaluate that part of the wetland that is intact.	No visual evidence of culturally accelerated sedimentation within the wetland.	1.0
	Evidence of sedimentation within less than half of the wetland area in the form of small rills, sediment fans or bars, or thin silt deposits on detritus, -AND/OR- Sediment thickness is <3 inches.	0.75
	Evidence of sedimentation throughout most (50 to 75%) of the wetland, as evidenced by the presence of rills, sediment fans or bars, partial burial of detritus, or accumulations along plant stems, -AND/OR- Sediment thickness is 3 to <6 inches. (Indicator: Dominant land use adjacent to the wetland, or within the watershed area, is cropland. Tillage may be into or through buffer and into the outer edge of the wetland.)	0.5
	Significant evidence of sedimentation throughout most (>75%) of the wetland, as evidenced by the presence of rills, sediment fans or bars, partial to nearly complete burial of detritus, or burial of plant crowns and partial burial of stems, -AND/OR- Sediment thickness is 6 to <9 inches. (Indicator: Dominant land use adjacent to the wetland, or within the watershed area, is cropland. A buffer is typically absent. Tillage may occur throughout most (>50%) of the wetland in most years.)	0.25
	Significant evidence of sedimentation throughout the wetland, as evidenced by the presence of rills, sediment fans or bars, and nearly complete burial of detritus and plants, -AND/OR- Sediment thickness is 9 to 12 inches. (Indicator: Dominant land use adjacent to the wetland, or within the watershed area, is cropland. Conventional tillage is common, and ephemeral or perennial gullies may be present on uplands. Best management practices lacking to control erosion.)	0.1
	Pronounced rise in bottom elevation of wetland due to sedimentation, resulting in the loss of wetland vegetation and/or hydrology. Typical thickness of sediment is >12 inches; -OR- Wetland has been completely filled (such as in or around urban areas).	0.0

Soil Organic Matter
(V_{som})

Model Variable	Measurement or Condition	Index
Definition: A surrogate measure of the organic matter content of the ***wetland soil***, which aids in nutrient and elemental cycling and in organic carbon export.	**For loamy and clayey soils:** Soil colors in 50% or more of the upper 12 inches have either - value of 3 or less and chroma of 0, or - value of 2.5 or less and chroma of 1, or - value of 2 and chroma of 2 (Soil organic matter content, measured, is ≥4 percent); -OR- **For sandy soils:** Soil colors in the upper 6 inches have either - a neutral hue with value of 2 or 3, or - value of 2 or less and chroma of 1 or less, and no A horizon with darker color occurs immediately or contiguously below 6 inches. (Soil organic matter content, measured, is ≥2 percent.) (Indicator: The assessment area has not been drained or cropped.)	1.0
	(No measurement for this index.)	0.75
	For loamy and clayey soils: Soil colors in 50% or more of the upper 12 inches have value of 3 or 4 and chroma of 1 or 2 (Soil organic matter content, measured, is 1.5 to 4 percent); -OR- **For sandy soils:** Soil colors in the upper 6 inches have value of 3 or 4 and chroma of 2 or less. (Soil organic matter content, measured, is 0.5 to 2 percent.) (Indicator: The assessment area has been partially drained, or there is evidence of intermittent or historical tillage.)	0.5
	(No measurement for this index.)	0.25
	For all textural classes, soil colors in the surface layer (50% or more of the upper 12 inches for loamy and clayey soils, and the upper 6 inches for sandy soils) have value >4 and chroma >2. (Soil organic matter content is <1.5% for loamy and clayey soils, and <0.5% for sandy soils.) (Indicator: The assessment area has been "effectively" drained and frequently tilled.)	0.1
	The surface lacks soil or natural substrate properties (such as with asphalt, concrete, buildings, etc.)	0.0

Soil Porosity[3] (V_{soil})		
Model Variable	**Measurement or Condition**	**Index**
Definition: The physical integrity of the soil in the ***upper 18 inches*** of the soil profile. **NOTE [3]:** The conditions described are for loamy and clayey soils (i.e. soils with textures of sandy loam and finer). For soils with sandy textures, refer to the description of this variable on the following page.	Many medium, fine, and/or very fine, continuous pores, -AND/OR- Soil structure is one or more of the following: weak or moderate prismatic, and/or; moderate or strong, medium and fine, angular or subangular blocky, and/or; moderate or strong granular, -AND- Rupture resistance is friable or very friable. (Indicator: Wetland has not been disturbed within past 50 years. No evidence of an Ap horizon, or plow layer, within the hydric soil boundary.)	1.0
	(No measurement for this index.)	0.75
	Common fine and very fine, few to no medium, continuous and/or discontinuous pores, -AND/OR- Soil structure is one or more of the following: weak or moderate, medium and/or fine, angular or subangular blocky, and/or; weak or moderate granular, -AND/OR- Rupture resistance is firm. (Indicator: An Ap horizon is present in wetland. Wetland may be partially tilled, or has been restored but for less than 20 years.)	0.5
	(No measurement for this index.)	0.25
	Few fine and very fine discontinuous pores, -AND/OR- Soil structure is weak coarse subangular blocky or plate-like, massive, or structureless, -AND/OR- Rupture resistance is very firm or harder. (Indicator: A plow pan is present in the wetland, evidenced by roots growing horizontally along the pan rather than vertically through it. Wetland is tilled throughout most years.)	0.1
	The wetland substrate consists of a non-porous medium, such as asphalt or concrete (as from urbanization).	0.0

Soil Porosity[4]
(V_{soil})

Model Variable	Measurement or Condition	Index
Definition: The physical integrity of the soil in the ***upper 18 inches*** of the soil profile. **NOTE [4]:** The conditions described are for sandy soils (i.e. soils with textures of loamy fine sand and coarser).	Many fine and very fine, continuous pores (if observable), -AND/OR- Soil structure is any one of the following: weak medium or fine subangular blocky, and/or; moderate or strong granular, -AND- Rupture resistance is very friable or loose. (Indicator: Wetland has not been disturbed within past 50 years. No evidence of an Ap horizon, or plow layer, within the hydric soil boundary.)	1.0
	(No measurement for this index.)	0.75
	Common fine and very fine, continuous or discontinuous pores (if observable), -AND/OR- Soil structure weak subangular blocky and/or weak granular, -AND/OR- Rupture resistance is friable. (Indicator: An Ap horizon is present in wetland. Wetland may be partially tilled, or has been restored but for less than 20 years.)	0.5
	(No measurement for this index.)	0.25
	Few fine and very fine discontinuous pores (if observable), -AND/OR- Soil structure is one or more of the following: weak coarse subangular blocky, and/or; medium or coarse plate-like, below a plow layer, and/or; massive (structureless), -AND/OR- Rupture resistance is firm or harder. (Indicator: A plow pan is present in the wetland, evidenced by roots growing horizontally along the pan rather than vertically through it. Wetland is tilled throughout most years.)	0.1
	The wetland substrate consists of a non-porous medium, such as asphalt or concrete (as from urbanization).	0.0

Buffer Condition, Continuity, and Width
(V_{buffer})

Definition: An assessment of the condition, continuity, and width of the permanently vegetated buffer adjacent to the wetland.

Methodology for Rating V_{buffer}: There are three components to the buffer variable. These components are buffer condition, buffer continuity, and buffer width. Buffer continuity and width are interrelated components of the buffer variable. A summary rating has been developed (Table 5) based on various combinations of these two components. An average wetland buffer width should be determined in the field, along with the continuity of the buffer surrounding or adjacent to the wetland. The point at which these figures intersect in Table 5 is the summary rating (B_1) to use for these components. Table 6 lists buffer conditions and associated index ratings. When determining condition of the buffer, consider the area from the jurisdictional wetland boundary outward a distance of 100 feet. When a condition index (B_2) has been determined, an index rating for V_{buffer} can be determined using the formula:

$$V_{buffer} = [(B_1) \times (B_2)]^{1/2}.$$

Note: If there is no buffer, then the index rating for the variable is 0.

Table 5. Summary Rating for Buffer Continuity and Width (B_1)

Width (Ft.) \ Cont. (%)	100	80-99	60-79	40-59	20-39	1-20
≥100	1.0	.9	.7	.5	.3	.15
75-99	.8	.75	.6	.4	.25	.1
50-74	.6	.5	.5	.3	.2	.1
25-49	.4	.3	.3	.2	.15	.05
10-24	.2	.2	.15	.1	.1	.05
1-9	.1	.1	.1	.05	.05	.01

(Buffer condition values can be found in Table 6, following page.)

Table 6. Buffer Condition (B_2) Rating Guide	
Measurement or Condition	**Rating**
Native canopy is 90 to 100 percent and consists primarily of herbaceous and woody species..	1.0
Tillage disrupts 1 to 25% of the buffer area, -AND/OR- Native vegetative canopy present is 75 to 89 percent; -OR- Introduced perennial species (smooth brome, intermediate wheatgrass, etc.) provide the dominant vegetative canopy throughout the buffer.	.75
Tillage disrupts 26 to 50% of the buffer area, -AND- No-till or minimum till practices are used on the buffer area, -AND/OR- Native vegetative canopy present is 50 to 74 percent.	.5
Tillage disrupts 51 to 75% of the buffer area, -AND- No-till or minimum till practices are used on the buffer area, -AND/OR- Native vegetative canopy present is 25 to 49 percent.	.25
Tillage has disrupted 75 to 90% of the buffer area, -AND- No-till or minimum till practices are used on the buffer area, -AND/OR- Native vegetative canopy present is 1 to 24 percent.	.1
Tillage has disrupted >90% of the buffer area, -AND- Conventional tillage is in use on the buffer area, -AND/OR- Native vegetative canopy is < 1 percent.	0

Density of Perennial Herbaceous and Woody Vegetation (V_{denhw})

This variable considers the herbaceous and woody species present in the assessment area, and the basal density they occupy. Any method of measurement can be used to determine the basal area of these components. For purposes of rapid assessment, an ocular estimation of basal area is adequate. The index for this variable is obtained by joining the herbaceous density (in percent) with the woody density on the chart, below.

Not all riverine wetlands defined in this model contain a woody vegetative component in their natural state. For the most part, it is assumed first-order streams, and the upper segments of second-order streams, lack a significant woody component. Data or other information may be used to validate or invalidate this assumption in any given situation. This does not change the significance this variable has in the performance of the functions that it influences. If the assessed wetland, because of its hydrologic regime, does not typically contain woody species in its natural state, use the first row of figures (6-10% woody density) to rate the herbaceous component of this variable.

Model Variable	**Measurement/Index**					
Definition: The measured or estimated density of perennial herbaceous and woody species present in the wetland that are appropriate for the site. **Note:** If there is no perennial vegetation present in the wetland, then the variable index is **0**.	% Herb. Density / % Woody Density	50-65	40-49 -or- >65	30-39	15-29	1-15
	6-10	1.0	0.75	0.5	0.25	0.1
	4-5 or >10	0.8	0.6	0.4	0.2	0.1
	2-3	0.6	0.4	0.2	0.15	0.1
	1	0.5	0.3	0.2	0.1	0.1
	0	0.3	0.25	0.2	0.1	0.05

Ratio of Native to Non-native Plant Species (V_{pratio})		
Model Variable	**Measurement or Condition**	**Index**
Definition: The ratio of native to non-native species present in the wetland, as indicated by the top four dominants, or by a more extensive species survey.	Native species comprise 76 to 100 percent of the total species present in the wetland.	1.0
	Native species comprise 51 to 75 percent of the total species present in the wetland.	0.75
	Native species comprise 26 to 50 percent of the total species present in the wetland.	0.5
	Native species comprise 11 to 25 percent of the total species present in the wetland.	0.25
	Native species comprise 1 to 10 percent of the total species present in the wetland; -OR- A single dominant plant species (native or non-native) comprise a monotypic invasive stand within the wetland (such as cattails, reed canarygrass, etc.)	0.1
	Wetland is unvegetated.	0.0

Vegetative Strata and Canopy Coverage
(V_{veg})

Model Variable	**Measurement/Index**					
Definition: The vegetative index (rating), based on the number of vegetative strata present that are appropriate for the site and the measured or estimated canopy coverage these strata provide within the wetland. **Note:** If all vegetative strata have been removed and there is no vegetative canopy coverage in the wetland, then the variable index is **0**.	% Vegetative Cover / Vegetative Strata (5)	75-125	50-74 -or- >125	25-49	10-24	1-9
	All appropriate strata are present for the site[5]	1.0	0.75	0.5	0.25	0.1
	One strata absent	0.8	0.6	0.4	0.2	0.1
	Two strata absent	0.6	0.4	0.2	0.1	0.1
	More than two strata absent	0.2	0.15	0.15	0.1	0.1

[5] Vegetative Strata

Riverine wetlands, as defined in this model, may contain from one to three vegetative strata, depending upon stream hydrology and the position/location of the wetland within the hydrologic unit. These strata, for purposes of simplicity, are defined as follows:

1. Herbaceous layer -- the layer consisting of grasses, sedges, forbs, etc.
2. Shrub layer -- the layer consisting of shrubs such as
3. Tree layer -- the layer consisting of mature willows, cottonwoods, etc.

Vegetative stratification and composition within riverine ecosystems is more complex than this model will address. For evaluating this variable, the following guidelines can be used to determine the number of strata that should be present under natural conditions in a given wetland in a given position in the hydrologic unit, unless other data is available indicating different stratification.

Stream Order	No. Strata	Vegetative Type
1st, Upper 20% 2nd	1	Herb
Mid 20 to 50% 2nd	2	Herb/Shrub
Lower 50% 2nd and below	3	Herb/Shrub/Tree

Wetland Use
(V_{wetuse})

Model Variable	Measurement or Condition	Index
Definition: The dominant land use and condition of the ***wetland*** area.	No evidence of tillage in the wetland (adapted vegetation intact), -AND/OR- If wetland is grazed or hayed, no evidence of disruption to the wetland system (such as by compaction or rutting by equipment, or excessive trampling by livestock).	1.0
	Wetland is in permanent vegetation. Evidence of historic tillage through wetland, -AND/OR- Evidence of minor disruption to the wetland system from light grazing or infrequent haying (every other year or less often).	0.75
	Tillage occurs in <50% of the wetland area in most years; -OR- Over-grazing is evident through <50% of the wetland area; -OR- Wetland is hayed or burned annually.	0.5
	Tillage occurs in 50 to 90% of the wetland area in most years; -OR- Over-grazing is evident through ≥50% of the wetland area; -OR- Wetland is hayed or burned twice annually or more often.	0.25
	Tillage occurs through >90% of the wetland area in most years. If recently tilled, crop and hydrophytic vegetation remnants may be observed.	0.1
	Wetland more severely disturbed than indicated above (devoid of vegetation due to urbanization, feedlots, etc.) -OR- Non-wetland (upland) area (for mitigation purposes).	0.0

Variable Score Field Form

Field Office	Assessment Area ID. ____________________ (If more than one WAA)
County	
Date	Wetland Acres (Pre-)
Producer/Landowner	Wetland Acres (Post-)
Yellow flag? (Y/N) _____ If Y, what? ________________ Red flag? (Y/N) _____ If Y, what? __________________	Type of wetland (fringe adjacent to stream channel, or dissociated depressional or linear, such as an abandoned channel)? ____________________________

Variable	**Measurement or Condition Results**	**Variable Score**		**Discussion/Rationale**
		Pre-	**Post-**	
$\mathbf{V_{hydalt}}$	Alterations to flood plain hydrology (H_{fp})? ______ If so, what? ________________________________ (H_{fp}) = __________ Alterations to wetland hydrology (H_w)? ________ If so, what? ________________________________ (H_w) = __________			$V_{hydalt} = (H_{fp} \times H_w)^{1/2}$
$\mathbf{V_{topog}}$	Alterations to wetland topography (T_w)? ________ If so, what? ________________________________ % of area ________ (T_w) = ________ Alterations to flood plain topography (T_{fp})? _____ If so, what? ________________________________ % of area ________ (T_{fp}) = ________			V_{topog} = [(T_w x % of area)/100] + [(T_{fp} x % of area)/100]
$\mathbf{V_{source}}$	Watershed alterations present (Y/N)? __________ If so, what? ________________________________ % of watershed area _________			
$\mathbf{V_{upuse}}$	Dominant upland uses (3 maximum): (1)______________ Index ______ % area______ (2)______________ Index ______ % area______ (3)______________ Index ______ % area______			V_{upuse} = {[Index (1) x % area] + [Index (2) x % area] + [Index (3) x % area]}/ sum % area
$\mathbf{V_{detritus}}$	Detritus thickness __________			

Variable Score Field Form (Continued)				
Variable	**Measurement or Condition Results**	**Variable Score**		**Discussion/Rationale**
		Pre-	**Post-**	
V_{sed}	Evidence of accelerated sedimentation present in wetland (Y/N)? __________ If so, what? ________________________________ Sediment thickness __________			
V_{som}	Soil texture upper 18" __________ Observed color upper 12" (value) _________			
V_{soil}	Soil texture upper 18" __________ Soil pores observed _________________________ Soil structure ______________________________ Rupture resistance __________________			
V_{buffer}	Buffer continuity (%) ________ Buffer width (ave., ft.) ________ Continuity/Width rating (B_1) ________ Buffer condition ____________________________ Condition rating (B_2) ________			$V_{buffer} = [(B_1) \text{ x } (B_2)]^{1/2}$
V_{denhw}	Is a woody component present in the assessment area (Y/N)? ________ If not, score this variable based on the herbaceous component. Herbaceous density (%) __________ Woody density (%, if applicable) __________			
V_{pratio}	Native species present in wetland (% of total dominants) ____________			
V_{veg}	Vegetative canopy coverage (%) __________ No. vegetative strata present __________ Deviation from normal (no. strata believed absent) __________			
V_{wetuse}	Dominant use of wetland _____________________			

Table 7. Association of Model Functions and Variables[6]									
Variable	Function								
	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
V_{hydalt}	P1	P2	P1	S		S	S	S	
V_{source}			S	S					
V_{topog}	P1	P2			S	S			P2
V_{upuse}		S	S	S	S		S		P2
$V_{detritus}$				P1		P2		S	
V_{sed}	S				P2		S		
V_{som}				P1		P2			
V_{soil}	S		P2						
V_{buffer}		S			S		S	S	P2
V_{denhw}		P2			S	S		P2	
V_{pratio}							S	P2	
V_{veg}						S		P2	P2
V_{wetuse}	S	P2	S	S	S		P1	P2	P2

[6] Legend

P1 -- Primary indicator of function (trigonometric equation)
P2 -- Primary indicator of function (linear equation)
S -- Secondary indicator of function