WI/MN Wetland Rapid Assessment Method Science Support Document

Version 1.0, September 2025

Version Information

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This document provides the scientific basis and background for the Wisconsin/Minnesota Wetland Rapid Assessment Method (*Wisconsin/Minnesota Wetland Rapid Assessment Method Steering Committee. 2025. Wetland Rapid Assessment Method Tool. Version 1.0*).

MN/WI RAM Science Support Document

Contents

Introduction

The Minnesota and Wisconsin wetland rapid assessment tool (RAM) is a collaborative effort between the two states. The RAM steering committee that was formed to develop the tool reviewed numerous similar tools developed by other states including Idaho, New Hampshire, Ohio, Oregon, Louisiana, and Washington. In addition, the steering committee considered existing wetland rapid assessment tools for Wisconsin and Minnesota as well as concepts and methods contained in recently developed stream quantification tools for both states.

Wetland Functional Groups

As wetlands perform many functions, it is necessary to identify the specific functions to be evaluated by this RAM according to the needs of both states. Both Minnesota and Wisconsin state statutes and associated rules (MN) and administrative code (WI) specify wetland functions that require evaluation in their respective wetland regulatory programs. As such, all functions requiring evaluation by each state are combined and grouped in broad functional categories as follows:

Water Quality – This functional group focuses on the ability of a wetland to improve water quality of downstream resources. Specific functions within this group include:

- Nitrate removal
- Phosphorous retention
- Sediment and Pollutant retention

- Shoreline stabilization
- Thermoregulation

Hydrologic – This functional group focuses on the ability of a wetland to affect the movement and distribution of water on the landscape, including the interface between surface and groundwater functions. Specific functions within this group include:

- Surface water attenuation
- Surface water supply
- Groundwater recharge

Ecological – This functional group focuses on the ability of a wetland to affect the natural relationships of organisms in the wetland and its surrounding landscape. Specific functions within this group include:

- Native plant habitat
- Wildlife habitat
- Fish habitat

Climate – This functional group focuses on the ability of a wetland to mitigate the negative effects of excess atmospheric carbon and methane gas. Specific functions within this group include:

- Water regime
- Catchment Characteristics
- Soils
- Vegetation

Anthropogenic – This functional group focuses on the ability of a wetland to provide various types of direct human uses. Specific functions in this group include:

- Historic or cultural uses
- Scientific or educational importance
- Commercial uses
- Recreational uses
- Scenic beauty

General Approach

Wetlands are evaluated in this RAM in terms of their effectiveness to perform a specific function, the potential to maintain the function into the immediate future, and the value of that function to society. The importance of a wetland's functioning also depends on the opportunity (i.e., the physical relationship between the wetland and the needs of society) to provide a function and the social significance or value (i.e., direct benefits to society). Value as used in this RAM refers to the value of the function to the public as opposed to the value to specific individuals. Value is considered in terms of the opportunity to perform the function and the significance of the function in area/watershed. This RAM considers the effectiveness and value of each function at the time of the evaluation.

Each function has one or more drivers which are primary factors that determine how well the function is performed. For example, the vertical structure and stem density of the plant community and the susceptibility of the wetland to flooding are primary drivers of a wetland's ability to slow floodwater. Various indicators of these drivers are used in this RAM evaluation. These indicators can be onsite (within the wetland) or offsite (within the surrounding landscape). Indicators can be positive or negative. A positive functional indicator is a characteristic that by its presence indicates increased effectiveness, opportunity, and/or significance of a function. A negative functional indicator is a characteristic or "stressor" that by its presence diminishes the effectiveness, opportunity, and/or significance of a function.

Functional Group Rationales

General

Each metric associated with a function is used in combination with other metrics to determine a functional ranking of lower, moderate, or higher. Metric values vary from simple yes/no questions to tables requiring quantitative inputs. These metric values are used in formulas or a decision matrix to arrive at a qualitative ranking. The formulas and decision matrices can be found in the RAM spreadsheet under the tab for each functional group. The basis for the metrics and ranking formulas, and decision matrices are described for each function within each functional group below.

Ecological

The presence of water interacting with soils and vegetation drives ecological processes at all trophic levels from microbial activity in the soil to use of the wetland by characteristic megafauna. The trophic structure of wetlands proceeds from plant detritus to micro-organisms, to invertebrate consumers, and then on to vertebrate consumers (Hook, et al. 1988).

The ecological role of wetlands in providing habitat for fish, wildlife, and native plant communities as well as their contribution to biological diversity is well established. Most wetland functional assessment methods evaluate some aspect of a wetland's ecological functioning as it relates to use by fauna. However, faunal use of wetlands is particularly difficult to assess given that use by many species' changes between years and within seasons. Given this variability, long-term surveys of faunal diversity and abundance would be required to adequately assess faunal use of a wetland which are impractical for a rapid assessment (Gilbert, et al. 2006). Therefore, indicators of faunal use of wetlands are typically based on observable characteristics of the wetland and its surrounding landscape. These indicators are a combination of intrinsic wetland characteristics and extrinsic factors (Preston and Bedford 1988), (CWMW 2008). Examples of intrinsic characteristics include plant community structure and composition, soil texture, and water regime. Extrinsic factors are primarily related to a wetland's position in the landscape mosaic and its relationship to other habitats across the landscape.

The approach to evaluating faunal use of wetlands is highly variable among different wetland functional assessment methods. Some methods focus on specific guilds of species while others focus on diversity and abundance. Some examples of different types of faunal evaluations from various assessment methods are as follows:

- Wildlife and aquatic diversity/abundance (Adamus, et al. 1991)
- Fish and wildlife habitat (Hohn, et al. 2019), (Wisconsin Department of Natural Resources 2014)

- Habitat condition (U.S. Army Corps of Engineers 2016)
- Ecological integrity and fish/wildlife habitat (West Virginia Department of Environmental Protection 2020), (Stone, et al. 2015)
- Maintenance of characteristic wildlife, fish, and amphibian habitat (Minnesota Board of Water and Soil Resources 2010)
- Habitat and maintaining food webs (Hruby 2012)
- Faunal habitat (Gilbert, et al. 2006)
- Anadromous fish, resident fish, amphibian/reptile, waterbird nesting, waterbird feeding, aquatic invertebrates, pollinators, and songbird/raptor/mammals (Adamus and Verble 2016)
- Native fish habitat, waterfowl habitat, wetland-dependent bird habitat, wildlife movement corridors, and woodland amphibian habitat (Prusila, et al.2020)

Focusing on the ability of a wetland to provide habitat for specific guilds of species is problematic if the intent of assessment is to have an overall rating for faunal use. No single species guild can serve as an all-inclusive indicator of wetland habitat functions (Gilbert, et al. 2006). Choosing multiple species guilds to assess tends to increase the complexity and length of the assessment while compromising the goal of keeping it rapid. Additionally, a different rating for each species guild assessed can make it difficult to interpret and use the information effectively in a regulatory context as it requires more consideration as to which rating for which species guild is more valuable in a particular context.

Some methods focus on the ability of the wetland to maintain its “characteristic” faunal habitat and its overall ecological integrity rather than specific species guilds. Others focus on assessment habitat diversity and the contribution of the wetland to overall biodiversity. Focusing the assessment solely on faunal diversity may result in devaluing wetlands that are less diverse but provide critical habitat components for a narrow range of species. However, it is also important that the assessment recognizes the importance of a wetland in providing a diversity of habitats.

Most methods assess land use, human disturbance, travel corridors, habitat fragmentation, and/or natural habitats within a certain distance of the assessed wetland. Stone et al (2015) assesses factors affecting wildlife use within 500 feet of the wetland edge. Hruby (2012) assesses land use and habitat disturbance within a one-kilometer circle of the wetland. West Virginia Department of Environmental Protection (2020) assesses a contiguous natural buffer within 300 meters of a wetland. Faber-Langendoen, et al (2016) assesses contiguous natural land cover within 500 meters and buffer within a 100-meter zone. CWMW (2008) surmises that 500 meters is the maximum distance between wetlands and other water-dependent habitats that does not by itself function as a barrier to regular movements of terrestrial animals. Environmental Law Institute (2008) and Emmons and Olivier Resources (2001) suggest a range of potentially effective buffer distances for wildlife protection to be 100 to greater than 300 feet.

The evaluation of the ecological functioning of wetlands in this RAM is based in part on the assumption that wetlands in better condition will tend to support more natural biological processes at all trophic levels leading to a more natural array of habitat types and use by characteristic fauna. Wetland condition is based on its floristic quality which reflects the impact of anthropogenic stressors on biological processes. Wetlands that are in exceptional to good condition are considered high functioning for wildlife capacity. This RAM also considers the ability of a wetland to provide a variety of habitat conditions. The assumption is that wetlands that are not necessarily in exceptional to good condition can still have a higher ranking if they are particularly diverse. Diversity metrics include the number of plant community strata, interspersion of those strata, and the abundance of downed trees that provide niches for decomposers and invertebrates which drive many biological processes.

This RAM also considers two extrinsic factors that relate to a wetland's location in the surrounding landscape mosaic and the resulting opportunity for faunal recruitment to and utilization of the wetland. Wetlands that are surrounded by more natural land cover are assumed to provide more opportunity for wildlife to access and use them as part of their life cycle. Natural land cover is assessed within 0.1 miles (528 feet) of the wetland edge. Secondly, wetlands that are within or near core areas of natural cover have more connectedness to other habitats and thus more opportunities for faunal recruitment and habitat utilization. This RAM utilizes the EPA's EnviroAtlas core area data of natural landcover, core fragmentation, and patterns of connectivity amount core patches. The EnviroAtlas connectivity framework is considered a structural framework because its connectivity patterns are independent of species' habitat requirements. The scoring matrix for ranking wildlife habitat opportunity gives the most weight to wetlands that occur within core areas of natural cover, and secondly the amount of identified core areas within a 2-mile radius.

Although this RAM does not focus on specific faunal species guilds, it separately assesses the capacity and opportunity for the wetland to provide habitat for fish because it is addressed as such in state statute/code/rules. Nearly all fish require shallow water provided by wetlands at some stage of their lives for spawning, predator avoidance, shelter, and/or feeding (Adamus, et al. 1991). In general, the longer a wetland is inundated, the more likely a complex array of water-dependent organisms will be present that support fish (Stone, et al. 2015). Wetlands with at least seasonal inundation and preferably permanent to semi-permanent water regimes are most favorable for fish (Adamus and Verble 2016), (Prusila, et al. 2020). No water depth is better than another for fish as preferred water depth depends on fish species and at what stage of development the species is in. However, shallower depths tend to support larger macrophyte growth which in turn provide cover and dense concentrations of invertebrate foods used by fish (Adamus, et al. 1991).

To support fish, isolated wetlands must have at least some permanently flooded areas, but it is unlikely that such wetlands would be deep enough to not freeze solid during typical winters in both states. Otherwise, only wetlands with some surface water connection to a lake or stream could potentially support fish depending on the type of connection. Vegetation and woody material in the wetland provide critical defense against predators, shade, and microhabitat diversity to support invertebrate food sources for fish (Stone, et al. 2015), (Adamus and Verble 2016).

This RAM requires that the wetland have a surface water connection to a lake or stream that can support native fish populations before the fisheries habitat function is applicable. The opportunity for a wetland to support fish is then based on the extent to which the connection poses barriers to fish movement. The capacity for the wetland to support fish is assessed based on the relative abundance of flooded water regimes with vegetation and the abundance of woody vegetation and debris, higher amounts resulting in higher ratings for both metrics. The opportunity and capacity scores are combined for an overall rating for fisheries habitat. The scoring places more emphasis on the opportunity portion of the rating.

Hydrologic

Wetlands play an important role in the hydrologic cycle – influencing and controlling surface water flows in watersheds and are often an interface between surface and groundwater. The Hydrologic Group is divided and summarized into surface water attenuation, surface water supply, and groundwater recharge.

Surface Water Attenuation Functional Capacity

Wetlands can receive surface water in a variety of ways including precipitation, direct inputs from streams and ditches, overbank flooding from adjacent streams and lakes, saturation overland flow from surrounding uplands or wetlands, and groundwater discharge. Similarly, a wetland can attenuate surface water through different processes including storing surface water within physical topographic contours (e.g., physical depressions, beaver dams, manmade structures), providing a topographically flat area that allows floodwaters to spread out, slowing surface water flows through vegetation, and removing surface water from the system via groundwater recharge and evapotranspiration.

Wetland hydrogeomorphic (HGM) classification broadly integrates physical landform, water source, and hydrodynamics (Smith, et al. 1995). Wetlands also lie on a continuum of surface water connectivity with downstream waters (Marton, et al. 2015), (Cohen, et al. 2016), (Lane, et al. 2018), (Evenson, et al. 2018). The less direct and slower the connection a wetland has to downstream waters, the greater the lag and storage effects to attenuate downslope/downstream flow. Riverine and lacustrine fringe wetlands have bi-directional flow dynamics (i.e., direct and fast connections), whereas depressional wetlands that lack a perennially flowing outlet must go through a fill and spill process before surface water can move downgradient (van der Kamp and Hayashi 2009), (Shaw, et al. 2012), (Vanderhoof, et al. 2016). HGM class and surface water outflow characteristics combined provide the primary surface water attenuation functional capacity indicators.

Water regime describes the long-term surface water conditions in a wetland (Federal Geographic Data Committee 2013). Wetlands that lack permanent standing water are more likely to alter surface water flows, and soil moisture status can control the absorption capacity of soils at the start of flood producing events (Adamus, et al. 1991), (Acreman and Holden 2013). In addition, the greater the level of throughflow complexity, the more time it takes for surface water to flow through a wetland. This results in desynchronization of downstream surface water flow and allows for evapotranspiration and/or groundwater recharge to remove water from the system. Wetlands that lack distinct channels, where surface water moves via sheet flow, have greater surface water attenuation than wetlands with channels (Acreman and Holden 2013). In riverine systems, woody vegetation can provide greater friction during overbank flood flows, thereby slowing floodwaters (Arcement, Jr. and Schneider 1989). These within wetland processes (water regime, throughflow complexity, and woody vegetation in riverine wetlands) serve as secondary surface water attenuation functional capacity indicators.

Surface soil permeability (the rate of water movement when soils are in an unsaturated condition) in combination with water regime can qualitatively indicate wetland soil water storage potential. The greater the surface soil permeability of the wetland (for wetlands that have temporarily flooded, seasonally saturated or continuously saturated water regimes) the greater the potential soil water storage and groundwater recharge (Vepraskas and Richardson 2001), (Acreman and Holden 2013). Soil texture corresponds to soil permeability and is applied as the indicator, with organic and sandy soil texture classes having greater permeability than loamy and clay texture classes. To simplify, the more general US EPA's National Wetland Condition soil texture classes (n= 6) that incorporate organic soil types (USEPA 2021) are used in the RAM as opposed to the more detailed NRCS soil texture classes (n = 12) that consider only mineral soils (Schoeneberger, et al. 2012).

Evapotranspiration, manmade impacts that retain surface water, and catchment characteristics were also evaluated as potential drivers/indicators of surface water attenuation functional capacity but were ultimately excluded from this RAM. Evapotranspiration is a major process within wetlands that can remove large quantities of water from watersheds; however, potential evapotranspiration tends to be relatively homogenous over large regions and generalizations regarding evapotranspiration by plant community or water regime type have not yet been established (Drexler et al. 2004). Manmade impacts that retain water (e.g., roadbeds, dikes, excavations) are effectively accounted for within the HGM classification and outflow characteristics, thus a specific indicator relating to this factor was not used. Catchment characteristics are considered in terms of surface water attenuation opportunity-value.

Surface water attenuation functional capacity indicators have been scored according to the preceding rationale. Wetlands with more restrictive outflow characteristics and secondary attenuation indicators are rated as having a higher surface water attenuation functional capacity and vice versa. For example, a depressional HGM class wetland with a highly restricted outflow, no natural or artificial channels, a seasonally flooded water regime, and muck surface soil texture has a higher rating for surface water attenuation functional capacity. A slope-groundwater HGM wetland with a 1st order stream flowing through and out of the wetland, a continuously saturated water regime, and mucky peat surface soil texture has a lower surface water attenuation functional capacity rating. Wetlands with a combination of intermediate characteristics will tend to have a moderate rating. For example, a riverine-lower perennial HGM class wetland with a temporarily flooded water regime, sandy surface soil texture, and emergent vegetation has a moderate surface water attenuation functional capacity rating.

Surface Water Attenuation Opportunity-Value

Landscape context is considered the primary surface water attenuation opportunity-value driver in the RAM. Wetlands within developed landscapes (including agriculture) have greater opportunity and social significance to attenuate surface water flows due to the overall wetland loss, altered hydrology, and relatively greater generation of stormwater flows in these landscapes (Adamus and Verble 2020). Percent developed National Land Cover Database classes within the catchment area is the indicator used in this RAM. For riverine HGM class wetlands, the catchment area is defined as the approximate total catchment for the stream system with the AA as the pour point (*sensu* the streamflow contributing area in the Oregon Rapid Wetland Assessment Protocol, Adamus and Verble 2020). For all other HGM classes, the catchment area is the immediate catchment at topographic breaks where precipitation can possibly drain towards the Assessment Area (*sensu* the runoff contributing area in the Oregon Rapid Wetland Assessment Protocol, Adamus and Verble 2020).

Secondary surface water attenuation opportunity-value drivers include the primary surface water input and wetland-catchment ratio. Wetlands that receive direct surface water from stream or lake flooding (i.e., bi-directional flow dynamics) have greater opportunity and societal importance to attenuate surface water flow due to direct surface water connection to a stream/lake network compared to wetlands not directly adjacent to lakes and streams (Acreman and Holden 2013). Similarly, wetlands receive surface water via man-made conveyances (e.g., ditching, stormwater) have greater opportunity-value to attenuate surface water flow due to the enhanced (and intentional) connection to the immediate surrounding drainage network. Additionally, the greater the catchment area relative to the wetland area, the greater the opportunity the wetland can attenuate surface water flows as larger watersheds would yield greater water flows (Adamus, et al. 1991). AA area divided by catchment area and expressed as a percentage is the specific wetland-catchment ratio indicator in this RAM. The indicator is only applied to non-riverine HGM classes as the catchment area is typically much larger in riverine HGM class wetlands compared to other classes, and riverine wetlands would already have moderate to higher surface water attenuation opportunity-value ratings based on surface water input and catchment land use scores.

Surface water attenuation opportunity-value have been scored to reflect the preceding rationale. Wetlands in developed landscapes that directly receive stream/lake flooding or where surface waters are received via man-made conveyances and have a small size relative to catchment area are rated as having higher surface water attenuation opportunity-value. Conversely, wetlands in intact landscapes that do not receive stream/lake flooding or lack man-made conveyances and have large AA area relative to catchment area are rated as having lower surface water attenuation opportunity-value. For example, a riverine-lower perennial HGM class wetland in a catchment where agriculture land use is high (>75%) will have a “higher” surface water attenuation opportunity-value rating. A moderately sized depressional HGM class wetland with a small catchment within a natural landscape will have a “lower” surface water attenuation opportunity-value rating. Wetlands with a combination of intermediate characteristics will tend to have a moderate rating.

Surface Water Supply Functional Capacity

Surface water can exit a wetland in a variety of ways and thereby act as a surface water source for a receiving downgradient waterbody such as a stream, lake, or another wetland. Specific hydrological processes include groundwater discharge, saturation overland flow during and immediately following precipitation events, fill and spill dynamics where surface water fills a wetland basin and leaves via a relatively discrete outflow, and return flow when flooding recedes back to adjacent streams and lakes.

Like surface water attenuation, the effect of one or more of these hydrological processes in a wetland in terms of supplying surface water depends primarily on surface water connectivity, wetland landform, and hydrodynamics. The more direct and faster the connection a wetland has to downstream waters, the greater capacity a wetland has to supply surface water (Marton, et al. 2015), (Lane, et al. 2018). This is the opposite of how surface water outflow characteristics affect surface water attenuation. Groundwater discharge is a relatively more important process in terms of surface water supply as groundwater is typically a continuous rather than a seasonal or sporadic source of water (Minnesota Boar of Water and Soil Resources 2012), (NRCS 2021). Saturation overland flow occurs when precipitation mixes with water within the upper surface of the soil and the excess water runs off. Saturation overland flow is often difficult (and beyond the scope of this RAM) to distinguish from groundwater discharge and (similar to groundwater) it can be a relatively slow and continuous process (Acreman and Holden 2013). Return flow to adjacent streams/lakes from riverine and lacustrine fringe wetlands following flooding events is presumably relatively less important in terms of surface water supply to the receiving stream/lake as the predominate wetland water source is from the stream/lake itself (Smith, et al. 1995) as hydrological processes for the stream/lake operate at larger watershed scales. Depressional wetlands subject to fill and spill dynamics can vary more broadly in terms of surface water supply as they often have a variety of significant water sources including precipitation, overland flow, and groundwater inflow (Smith, et al. 1995), (Shaw, et al. 2012), (Minnesota Board of Water and Soil Resources 2012). Given this, surface water outflow characteristics and HGM class (which broadly integrates physical landform, water source, and hydrodynamics) are the primary surface water supply functional capacity indicators in this RAM.

Secondary surface water supply indicators focus on within wetland characteristics including throughflow complexity, water regime, and soil surface texture. The lower the level of throughflow complexity the less time it takes for surface water to flow through a wetland and ultimately to another downgradient waterbody. Wetlands that have distinct channels increase water loss (Acreman and Holden 2013) and provide direct/faster surface water outflow connections thereby increasing surface water supply functional capacity (Marton, et al. 2015), (Lane, et al. 2018). Soils that are saturated to the surface or inundated (i.e., flooding) for prolonged periods of time often indicate that the wetland is intersecting the water table (Adamus, et al. 1991), (Mitsch, et al. 2023). In addition, wetland soils that are saturated or inundated at the surface at the time of precipitation event lack the capacity to store water (Acreman and Holden 2013), (Mitsch, et al. 2023). Water regime describes the long-term surface water conditions for a wetland (Federal Geographic Data Committee 2013) and is used as the indicator in this RAM with “wetter” water regimes indicating greater surface water supply functional capacity. Finally, the greater the surface soil permeability of the wetland (for wetlands with temporarily flooded, seasonally saturated, or continuously saturated water regimes that often have periods where the soil is typically not saturated at the surface for at least some of the growing season) the greater the potential soil water storage (Vepraskas and Richardson 2001) which can reduce surface water supply downstream.

Surface water supply functional capacity indicators have been scored to reflect the preceding rationale. Wetlands with less restrictive throughflow and outflow characteristics, HGM classes and water regimes that indicate groundwater discharge and/or saturation overland-flow conditions are rated as having a higher level of surface water supply functional capacity and vice versa. For example, an HGM slope-groundwater class wetland with a 1st order stream flowing through and exiting the wetland, a continuously saturated water regime, and mucky peat soil texture has a “higher” rating for surface water supply functional capacity. Conversely, an HGM riverine-lower perennial class wetland adjacent to river with a temporarily flooded water regime and sand soil texture has a “lower” rating for surface water supply functional capacity. Combinations of intermediate indicator levels typically results in a “moderate” surface water supply functional capacity rating. For example, a depressional HGM class wetland with a moderately restricted outflow (i.e., surface water exits seasonally/sporadically), that lacks channels within the wetland, has a seasonally flooded water regime and mucky peat surface soil texture has a “moderate” surface water supply functional capacity rating.

Surface Water Supply Opportunity-Value

Wetlands can act as a significant surface water source to downgradient waters including streams, lakes, and other wetlands. The influence of wetlands on downgradient hydrology is partially dependent on wetland size (Lane, et al. 2018). Also, most stream network miles are headwater/low order streams where flows are often strongly regulated by non-floodplain wetlands (NRCS 2021). Conversely, riverine and lacustrine fringe HGM wetlands (where the pre-dominate water source is flooding from a stream/lake; Smith et al. 1995) provide relatively less hydrological supply to adjacent waters.

Given that, the receiving waterbody extent relative to the wetland is considered the primary surface water supply opportunity-value driver in this RAM. The greater the relative extent of the wetland compared to the receiving waterbody extent, the greater the importance the wetland is assumed to have in supplying the receiving waterbody. For wetlands with stream (or ditch) outflows, the primary indicator applied is the Strahler stream order of the receiving stream/ditch, with surface water supply opportunity-value rated at the highest level for 1st and 2nd order streams. For wetlands that outflow to lakes or other wetlands, the size of the Assessment Area divided by the size of the receiving lake/wetland (expressed as a percentage) is the primary indicator applied. The larger the Assessment Area relative to the receiving lake/wetland size the greater the surface water supply opportunity value rating.

The secondary surface water supply opportunity-value driver is wetland-catchment ratio. The greater the wetland area relative to the catchment, the greater hydrological influence the wetland has to downstream waters relative to broader watershed scales (Adamus, et al. 1991). AA area divided by catchment area and expressed as a percentage is the specific wetland catchment ratio indicator in this RAM, with the larger the wetland relative to the catchment the higher level of surface water supply opportunity-value. Like other applications of the indicator, it only applies in wetlands that are non-riverine HGM classes.

Surface water supply opportunity-value indicators have been scored to reflect the preceding rationale. Wetlands that discharge to low order streams or are comparable in size or larger than a receiving lake or wetland and have a relatively small catchment are rated as having “higher” surface water supply opportunity-value and vice-versa. For example, an HGM slope-groundwater class wetland with a 1st order stream flowing through and exiting the wetland with a catchment smaller than the wetland has a surface water supply opportunity-value rating of “higher”. An HGM slop-groundwater class wetland that outflows directly to a river (e.g., 7th order stream) with a relatively large catchment has a surface water supply opportunity-value rating of “lower”. Combinations of intermediate indicator levels results in a “moderate” surface water supply opportunity-value rating. For example, a moderately sized depressional wetland with a moderately sized relative catchment area outflows into a larger depressional wetland has a “moderate” surface water opportunity-value rating.

Groundwater Recharge Functional Capacity

Groundwater recharge is the downward movement of surface water into the soil. Depending on the setting and conditions, a wetland may provide groundwater recharge. More often, however, wetlands are an intersection of the land surface with the water table and/or form due to groundwater discharge and whether a wetland provides net groundwater recharge can often be a dynamic process that depends on climatic cycles in addition wetland characteristics (Winter 1999), (NRCS 2011), (Siegel 1988), (Minnesota Board of Water and Soil Resources 2012) (Mitsch, et al. 2023).

The RAM groundwater recharge functional capacity rates the likelihood that a wetland potentially provides long-term net groundwater recharge (i.e., a “higher” rating) versus wetlands that intersect the groundwater table and/or are more likely to alternate between recharge/discharge states or be net-neutral in terms of recharge (i.e., a “moderate” rating) versus wetlands that form due to net groundwater discharge (i.e., a “lower” rating).

For groundwater recharge to occur, there must be a gradient for surface water to be absorbed into the soil. The primary drivers that allow for favorable groundwater recharge conditions are HGM class and water regime. Depressional HGM class wetlands pond precipitation, snowmelt, and/or flooding behind a topographic contour allowing for infiltration (van der Kamp and Hayashi 2009), (NRCS 2011), (Mitsch, et al. 2023) particularly at the upland margins when surface water exceeds the water table elevation (Weller 1981), (Minnesota Board of Water and Soil Resources 2012). The primary water source for organic and mineral soil flat HGM classes is precipitation (Smith, et al. 1995). Groundwater recharge can occur following precipitation events when the soil surface is not saturated (Acreman and Holden 2013) but can be removed from the system relatively quickly via evapotranspiration. Riverine and lacustrine fringe HGM class wetlands alternate between groundwater recharge and discharge depending on flooding dynamics (i.e., bank storage, Chen and Chen 2003), (Minnesota Board of Water and Soil Resources 2012). HGM slope class wetlands have relatively low net groundwater recharge as they typically form due to groundwater discharge and the elevation gradient within the wetland that allows surface water to quickly runoff to an adjacent waterbody (Smith, et al. 1995). In all cases, soil moisture status largely controls the absorption capacity at the start of flood producing events (Acreman and Holden 2013). Wetlands with seasonally saturated or temporarily flooded water regimes (i.e., “drier” wetlands), will be able to absorb surface water more often during the growing season compared to continuously saturated or flooded water regimes that more likely indicate that a wetland is supported by groundwater inflow (Adamus, et al. 1991), (Adamus and Verble 2020).

Secondary groundwater recharge functional capacity drivers include outflow characteristics, soil surface texture, watershed position, and wetland-catchment ratio. The less direct and slower the surface water connection a wetland has to downstream waters, the greater the lag effects to attenuate flow and allow for groundwater recharge (Marton, et al. 2015), (Cohen, et al. 2016), (Lane, et al. 2018). Wetlands with more restricted outflows will thus have greater groundwater recharge functional capacity. Soil surface textures that have greater permeability (i.e., the rate of water movement when soils are in an unsaturated condition) also have greater potential to provide groundwater recharge (Acreman and Holden 2013). This indicator only applies in water regimes that are expected to have unsaturated surface soil conditions at least by the end of the growing season in typical years. Additionally, wetlands at higher watershed positions have a greater potential to provide groundwater recharge compared to wetlands at lower positions where it is more likely that groundwater discharge contributes to hydrology (Winter 1999). The water table is often a subdued replica of the ground surface and can be used as a qualitative proxy of local-intermediate groundwater flow systems with local topographic highs (e.g., a HUC-12 watershed boundary) and local topographic lows (e.g., a stream, lake, or large wetland) which can often be assumed to be local-intermediate groundwater flow system divides (Alley, et al. 1999), (Winter 1999). Finally, the larger the catchment relative to the wetland, the greater the ability that the wetland captures surface water flows (Adamus et al. 1991) and potential for groundwater recharge to occur. As with the surface water attenuation and supply specific functions, the indicator is the Assessment Area divided by the catchment area expressed as a percentage and it is only applied to non-riverine HGM classes.

Groundwater recharge functional capacity indicators have been scored to reflect the preceding rationale. Depressional wetlands with more restricted outflows that capture and pond surface water, with “drier” water regimes that allows for infiltration, organic or sandy soil surface textures, located at relatively higher watershed positions and have relatively large catchments are rated as having a higher level of groundwater recharge functional capacity. Wetlands with opposing characteristics will tend to be rated at a “lower” groundwater recharge functional capacity level. For example, a small depressional wetland with a moderately sized catchment, temporarily flooded water regime, no surface water outlet, mucky-sandy soil texture, near to the HUC 12 boundary elevation has a groundwater recharge functional capacity rating of “higher”. A ditched large organic soil flat with a relatively small catchment (due to being in a flat landscape), continuously saturated water regime, and peat soil texture has a groundwater recharge functional capacity rating of “lower”. Combinations of intermediate indicator levels result in a “moderate” groundwater recharge functional capacity rating. For example, a moderately sized depressional wetland with a seasonally flooded water regime, moderately restricted outflow, mucky peat surface soil texture, with an elevation approximately midway between the HUC 12 boundary and a nearby stream has a “moderate” groundwater recharge functional capacity rating.

Groundwater Recharge Opportunity-Value

Whether or not a wetland is located within an area with notable groundwater use and the broader landscape context are considered the primary groundwater recharge opportunity-value drivers in this RAM. A notable groundwater use area is where there is clear evidence of groundwater use by people and thus a wetland has greater opportunity and societal importance to provide groundwater recharge. Additionally, wetlands within developed landscapes (including agriculture) have greater opportunity and social significance to provide groundwater recharge due to the overall historic wetland loss and greater groundwater usage. Like surface water attenuation opportunity-value, the percent developed and agricultural landcover within the catchment is the applied indicator.

Watershed baseflow maintenance is the secondary groundwater recharge opportunity-value driver in this RAM. Baseflow is the streamflow that is sustained between precipitation events by delayed (typically groundwater discharge) pathways (Price 2011). The opportunity and societal importance for a wetland to provide watershed baseflow maintenance via groundwater recharge is assumed to be equal as baseflow processes and sources operate at larger watershed scales.

Groundwater recharge opportunity-value indicators have been scored to reflect the preceding rationale. Wetlands located in a notable groundwater use area and in a predominately developed catchment are rated “higher” for groundwater recharge opportunity-value and vice-versa.

Water Quality

Wetlands provide a variety of water quality functions. The Water Quality Group is divided and summarized into nitrate removal, phosphorus retention, sediment and general pollutant retention, shoreline stabilization, and thermoregulation.

Wetlands are often retentive ecosystems but their ability to do so largely depends on their hydrology which controls the source and amount of sediment, nutrient, and pollutant inputs they receive (Johnston 1991). In addition, wetlands lie on a continuum of surface water connectivity with downstream waters (Marton, et al. 2015), (Cohen, et al. 2016), (Lane, et al. 2018), (Evenson, et al. 2018). The less direct and slower the connection a wetland has to downstream waters, the greater the lag and storage effects to attenuate downslope/downstream flow and thereby provide physical retention and allow for biogeochemical processes to occur.

Given this, surface water isolated wetlands (i.e., wetlands that lack a surface water outflow except during the most extreme high-water conditions) are important in this RAM. While it is understood that almost all wetlands are hydrologically connected to groundwater or other surface waters in some capacity, isolated wetlands provide a high level of water quality function as all surface water is essentially retained (Whigham and Jordan 2003). Downstream connectivity serves as primary indicator for Nitrate Removal, Phosphorus Retention, and

Sediment and General Pollutant Retention functional capacity in this RAM, with isolated wetlands given the highest scores.

In addition, surface water input (e.g., directed inputs from constructed conveyances vs. overland flow from surrounding upland) in combination with the percent developed/agricultural landcover within the catchment are primary opportunity-value indicators for the Nitrate Removal, Phosphorus Retention, and Sediment and General Pollutant Retention specific functions in this RAM. Where wetlands in developed landscapes that receive surface water flows have a greater opportunity-value to provide water quality functions.

Nitrate Removal Functional Capacity

Nitrogen is one of the primary nutrients for all living organisms, but an excess of nitrogen (e.g., from agricultural or home-use fertilizers, non-point source runoff, wastewater discharge, septic systems, manure applications, etc.) can be detrimental to surface water quality (Bernhard 2010). Nitrogen goes through a complex cycle with abundant nitrogen gas in the atmosphere, natural and artificial nitrogen fixation (conversion of nitrogen gas to ammonia), ammonification from decomposition, nitrification (conversion of ammonia to nitrate in aerobic conditions), and denitrification (conversion of nitrate to nitrogen gas in anoxic conditions).

While wetlands can physically retain particulate nitrogen from incoming surface waters (e.g., intercepting incoming organic material and allowing to settle) or through vegetation uptake of soluble forms and subsequent storage in the soil (Kizewski, et al. 2019), the most important nitrogen cycle process in wetlands to improve water quality is through denitrification. Wetlands are often net nitrogen sinks with little to no decreased capacity to reduce nitrate over time via denitrification (Johnston 1991).

Surface outflow characteristics are the primary nitrate removal functional capacity indicator in this RAM, as the less direct a connection a wetland has to downstream waters the greater lag time and biogeochemical processing (Whigham and Jordan 2003), (Cohen, et al. 2016). Given that there is potential for nitrate to leach into the groundwater in high level groundwater recharge wetlands, nitrate removal functional capacity scoring is capped (50 out of 100 points) for isolated wetlands.

Secondary nitrate removal functional capacity indicators relate to wetland characteristics that promote denitrification. Soil saturation (and or surface water inundation), as well as a source of organic material are typically required to foster the anoxic conditions for denitrification to occur. The organic material provides a source of carbon for microbial activity to consume oxygen and water saturation/inundation slows gas exchange such that oxygen is not replenished. Wetland water regime is a primary factor in terms of promoting anoxic/denitrifying conditions (Winikoff and Finlay 2023) with continuously saturated and seasonally to semi-permanently flooded water regimes (that support emergent vegetation) producing the most frequent surface anoxic conditions (Rose and Crumpton 1996). Organic surface soil textures (e.g., muck, mucky peat, etc.) indicate that a carbon source for microbial activity is present. Finally, increased through-flow complexity of surface water through a wetland increases surface water residence time and the likelihood of anoxic/denitrifying conditions (Nilsson, et al. 2023). Water flow through characteristics (e.g., overland flow vs. natural channels) and density of vegetation material are through-flow complexity indicators.

Nitrate removal functional capacity indicators have been scored according to the preceding rationale. Wetlands with more restrictive outflow characteristics, continuously saturated or flooded water regimes that are associated with emergent vegetation, organic soils, and dense vegetation/rooted leaf litter are rated as having higher nitrate removal functional capacity and vice versa. For example, a depressional HGM class wetland with a moderately restricted outflowing low order stream, a seasonally flooded water regime, dense shallow marsh vegetation (e.g., non-native invasive cattail), muck surface soil texture, and lacking natural or ditched channels will have a "higher" nitrate removal functional capacity rating. Whereas a lacustrine fringe HGM class wetland that is permanently flooded open water with scattered aquatic vegetation and muck soils will have a "moderate" nitrate removal functional capacity rating.

Phosphorus Retention Functional Capacity

Similar to nitrogen, an excess of phosphorus can cause water quality problems, and wetlands can retain incoming phosphorus via physical settling of particulates, as well as plant uptake and subsequent storage in organic forms in the soil (Mitsch, et al. 2023). Unlike nitrogen, phosphorus can be released from adhered mineral sediments and organic material under anoxic conditions (Johnston 1991), (Winikoff and Finlay 2023). This remobilization of phosphorus during anoxic conditions is the opposite of nitrate removal (i.e., denitrification), thus warranting individual treatment of nitrogen and phosphorus as specific functions in this RAM. In addition, while denitrification in wetlands appears to be sustainable, wetlands can variably serve as net sources or sinks for phosphorus from year to year, and wetlands can become overloaded from human sources becoming a consistent source (Johnston 1991). Also, streams located in wetland dominant watersheds with little human development often have elevated total phosphorus indicating that intact wetlands can often act as a phosphorus source (Stroom 2024), Diggelen, et al. 2020).

Surface outflow characteristics are the primary phosphorus retention functional capacity indicator in this RAM, as the less direct a connection a wetland has to downstream waters the greater lag time and biogeochemical processing (Whigham and Jordan 2003), (Cohen, et al. 2016). As phosphorus does not leach via groundwater recharge, surface water isolated wetlands are rated as having higher phosphorus retention functional capacity.

Secondary phosphorus removal functional capacity indicators relate to wetland characteristics that further promote physical filtering of incoming surface water and maintaining aerobic conditions and phosphorus adherence. Wetlands with temporarily flooded water regimes typically lack surface saturation/flooding such that the soil surface is aerobic much of the growing season in most years. Permanently flooded open water wetlands (particularly when they have abundant aquatic vegetation) often maintain diel oxygen patterns during the growing season, such that anoxic conditions are limited in the water column when not frozen (Rose and Crumpton 1996), thereby also limiting phosphorus remobilization. Continuously saturated and seasonally - semipermanently flooded water regimes on the other hand, promote anoxic conditions (Rose and Crumpton 1996) and subsequent phosphorus remobilization (Winikoff and Finlay 2023). In addition, soil surface texture relates to wetland phosphorus retention as phosphorus readily adheres to clay particles (i.e., greater phosphorus retention in loamy/clayey textures) and organic textures indicate anoxic conditions at the soil surface (i.e., less likely to provide phosphorus retention when organic soils are present due to anoxic conditions). Increased through-flow complexity of surface water through a wetland (via a lack of surface water channels and dense vegetation) increases filtration and settling of phosphorus adhered to particulates. Finally, groundwater discharge wetlands are also associated with elevated phosphorus in receiving streams (Stroom 2024), (Diggelen, et al. 2020). Local watershed position (where wetlands are closer in elevation to the local groundwater system low are more likely to have net groundwater discharge compared to wetlands closer to the local groundwater system high elevation which have more potential to provide groundwater recharge) and direct observation of springs and seeps are the two groundwater discharge indicators. Slope, Riverine, and Lacustrine Fringe HGM wetland classes are assumed to be located at the local groundwater flow system elevation low in this RAM as they are directly adjacent to streams or lakes.

Phosphorus retention functional capacity indicators have been scored according to the preceding rationale. Wetlands with more restrictive outflow characteristics, water regimes that promote aerobic conditions in the soil surface or the water column, loamy/clayey soil textures, lacks channels and has high density vegetation, and lack groundwater discharge are rated as having higher phosphorus retention functional capacity and vice versa. For example, a depressional HGM class wetland that lacks a surface water outlet has a “higher” phosphorus retention functional capacity rating. Whereas an extensive organic flat with a 1st order stream outflow (i.e., no restricted outflow, organic soils present, channel through the wetland, wetland located near the local elevation low), continuously saturated water regime, dense vegetation, and no springs observed has a “lower” phosphorus retention functional capacity rating. Wetlands with intermediate characteristics have a “moderate” rating. For example, a depressional HGM wetland with a moderately restricted outflowing low order stream, a seasonally flooded water regime, dense shallow marsh vegetation (e.g., non-native invasive cattail), muck surface soil texture, lacking natural or ditched channels, and lacking observed springs/seeps has a “moderate” phosphorus retention functional capacity rating.

Sediment and General Pollutant Retention Functional Capacity

Sediments are the suspended mineral and organic particulates found in surface water, saturation overland flow runoff waters, and directed stormwater/drainage. Sediments originate from the surrounding catchment, bank erosion, and internal algal production. The suspension of sediments in a water column depends on the velocity of the water relative to the size of the particles being transported (Johnston 1991). Deposition occurs when velocity falls below the critical erosion velocity for a given particle size. When sediment laden water enters wetlands, velocity is often greatly decreased allowing for deposition and retention. The retention benefits downstream water quality by reducing turbidity and retaining phosphorus and contaminants that are sorbed to the particles (Johnston 1991). Except for resuspension of sediment in floodplains and in open water wetlands (e.g., turbid water state wetlands), sediment retention is a relatively irreversible mechanism (Boto and Patrick 1979).

Initially, the efficacy of wetlands to retain many different pollutants commonly found in Wisconsin and Minnesota’s surface waters was considered to include chlorides, microcystin toxins, sulfate, metals, pesticides, and PFAS compounds. It was ultimately determined that developing specific functions for individual pollutants (beyond nitrogen and phosphorus) was beyond the scope of this RAM. As many of the pollutants are either of larger size or may bind to sediments (Johnston 1991), a combined sediment and general pollutant retention specific function was adopted for this RAM. In other words, the same processes that increase the functional capacity of wetlands to retain sediment, likely also increase retention for many pollutants.

Unlike the nitrate removal and phosphorus retention specific functions which rely on a combination of physical deposition and anoxic condition indicators to describe functional capacity, the sediment and general pollutant retention function relies primarily on physical deposition processes. The primary indicator is wetland outflow characteristics with surface water isolated wetlands providing the greatest level of functional capacity. Secondary sediment and general pollutant indicators include throughflow complexity within the wetland, vegetation material density, presence and type of woody vegetation for riverine wetlands (i.e., presence of trees and large woody debris in floodplains provides greater friction thereby slowing floodwaters (Arcement and Schneider 1989), local watershed position (i.e., wetlands in higher water positions have greater potential to retain sediment), and surface soil texture (i.e., wetlands in finer soil textures have greater potential to retain adhered pollutants).

Sediment and general pollutant functional capacity indicators have been scored according to the preceding rationale. Wetlands with more restrictive outflow characteristics, dense vegetation (and woody vegetation if a riverine HGM class wetland), lacking channels or ditches, and loamy/clayey soils are rated as having “higher” sediment and general pollutant retention functional capacity and vice versa. For example, a depressional HGM class wetland with a moderately restricted outflowing low order stream, a seasonally flooded water regime, dense shallow marsh vegetation (e.g., non-native invasive cattail), muck surface soil texture, and lacking natural or ditched channels has a “higher” sediment and general pollutant retention functional capacity rating. Whereas a partially drained depressional HGM class wetland with a ditch running through and exiting the basin, dense reed canary grass, and muck surface soil texture has a “lower” sediment and general pollutant retention functional capacity rating. Wetlands with intermediate characteristics will typically receive moderate ratings. For example, an open water depressional HGM class wetland with a moderately restricted outflowing low order stream, sparse aquatic vegetation, and muck surface soil texture will have a “moderate” sediment and general pollutant retention functional capacity rating.

Nitrate Removal, Phosphorus Retention, and Sediment and General Pollutant Retention Opportunity-Value

The core RAM water quality functions (nitrate removal, phosphorus retention, and sediment and general pollutant retention) share the same opportunity-value concepts and rationale. Wetlands that are located within developed landscapes (Adamus and Verble 2020) and wetlands that receive a relatively greater share of surface water (e.g., via streams, ditches, etc.; Johnston 1991) are assumed to have greater opportunity and social significance to provide these functions compared to wetlands located within intact landscapes or receive relatively less surface water.

In terms of landscape context, the percent developed National Land Cover Database classes within the catchment area is the primary indicator (and is the same as described in the surface water attenuation opportunity-value section). The remaining secondary indicators focus on surface water inputs as hydrology largely controls the source, amount, spatial and temporal distribution of sediment and nutrients that wetlands receive (Johnston 1991). Wetlands that receive direct surface water from stream or lake flooding or via man-made conveyances should receive a relatively higher load of sediments and nutrients compared to wetlands that only receive surface water via precipitation and saturation overland flow from an immediate catchment (Acreman and Holden 2013). Additionally, the greater the catchment area relative to the wetland area, the greater the opportunity for the wetland to receive surface water sediment and nutrients as larger watersheds would yield greater water flows (Adamus, et al. 1991). The catchment ratio indicator is only applied to non-riverine HGM classes (see the surface water attenuation opportunity-value section). Finally, wetlands located on floodplains receive surface water flows, and whether a wetland is within a mapped floodplain or not is included as a core water quality specific function opportunity-value indicator to reinforce the other indicators.

Opportunity-value indicators for the nitrate retention, phosphorus removal, and sediment and general pollutant retention specific functions have been scored to reflect the preceding rationale. Wetlands in developed landscapes, that directly receive stream/lake flooding or man-made conveyances, are small relative to their catchment area, and are located on a mapped floodplain are rated as having “higher” opportunity-value for these core water quality functions. For example, a depressional HGM class wetland, located in a suburban landscape, that receives multiple stormwater inputs and road ditches, is small relative to its immediate catchment, but is not on a mapped floodplain will have a “higher” rating for nitrate removal, phosphorus, sediment, and general pollutant retention opportunity-value. Whereas a depressional HGM class wetland located within a forested landscape, where the wetland is greater in size than the immediate catchment, and surface water is received via overland flow will have a “lower” opportunity-value rating for these water quality functions. Wetlands with a combination of intermediate characteristics will tend to have a “moderate” rating.

Shoreline Stabilization Functional Capacity

Wetlands are often located at the interface between uplands and streams or lakes. When wetlands are on the shores or banks of surface waters they can reduce erosional forces through soil stabilization and by dissipating wave energy. This occurs primarily from vegetation stabilizing the soils, either by slowing down surface water flow or by the plant roots acting as a binding agent (Ford, et al. 2016). Holding the soil in place helps prevent sediment and associated pollutants and nutrients from being eroded into downstream waters.

As shoreline stabilization can only occur if the wetland is immediately adjacent to (and has bi-directional flooding dynamics with) a stream or lake, this function is only applicable for riverine and lacustrine fringe HGM class wetlands. This is a qualifying condition for the shoreline stabilization specific function in this RAM and essentially serves as the opportunity-value component. As such, there is no stand-alone opportunity-value component to the function.

The active shoreline or “bank” in this RAM is defined as approximately 75 feet landward from the edge of the water (roughly uphill from the ordinary high water mark line) or until the shoreline experiences a topographic break (Wisconsin State Legislature 2004).

Two indicators are applied in terms of shoreline stabilization functional capacity: percent of the shoreline that is bare ground and the slope of the shoreline. Greater density of vegetation at the shoreline provides greater root binding of the soil and stems to dissipate energy and shallower slopes are less erodible compared to steeper slopes.

The shoreline stabilization indicators have been scored according to the preceding rationale. Riverine or lacustrine fringe HGM class wetlands with less bare ground and shallower slopes are rated as having higher shoreline stabilization functional capacity and vice versa. For example, a lacustrine fringe wetland with dense emergent and submerged aquatic vegetation lakeward, transitioning to sedges landward, with a very moderate slope will have a “higher” shoreline stabilization functional capacity rating.

Thermoregulation Functional Capacity

In some contexts, wetlands may be able to help moderate water temperature in adjacent streams during the warmest months of the year. This is done primarily through two processes: groundwater discharge and shading. A thermoregulation wetland function is most likely to occur in low order streams where groundwater may be a more prevalent water source and stream widths are narrower thereby allowing the vegetation of the adjacent wetland to shade the stream channel.

The thermoregulation specific function is applied only for wetlands that are immediately adjacent (and having bi-directional flow dynamics with) a stream or wetlands that have a stream outlet. This is a qualifying condition for the function in this RAM and essentially serves as the opportunity-value component. As such, there is no stand-alone opportunity-value component for the function.

Four functional capacity thermoregulation indicators are applied equally in this RAM when a wetland outlets to a stream: stream order, HGM class, observed springs/seeps, tree and tall shrub cover. Low order streams are assumed to have a greater prevalence of groundwater sources and are more readily shaded from adjacent vegetation. HGM classes associated with groundwater discharge (e.g., slope-groundwater) provide greater thermoregulation functional capacity and observed springs or seeps in a wetland are a direct indication of groundwater discharge. Finally, trees and tall shrubs provide more shade than emergent vegetation. The tree plus shrub cover metric excludes cover from ericaceous shrubs (e.g., leatherleaf) which are diminutive in stature and provide little shade.

Thermoregulation functional capacity indicators have been scored according to the preceding rationale. Wetlands with observed groundwater discharge and/or HGM classes that indicate groundwater discharge, high tree and tall shrub cover, and that are adjacent to low order streams will have higher thermoregulation functional capacity ratings and vice versa. For example, a slope-groundwater HGM class wetland with a first order stream flowing through and out, that supports a mature and dense canopy of Black ash trees, and has numerous seeps will have a “higher” thermoregulation functional capacity rating. Whereas a riverine-lower perennial HGM wetland, adjacent to a 4th order river, dominated by reed canary grass, and lacks any springs or seeps will have a “lower” thermoregulation functional capacity rating. Wetlands with a combination of intermediate characteristics will have a “moderate” rating. For example, if a riverine-lower perennial wetland with the same characteristics as the previous example except that the vegetation consists of a mature silver maple floodplain forest that can provide much more shade will have a “moderate” thermoregulation functional capacity rating.

Considered But Not Included in Water Quality

The idea of hydraulic loading rate (HLR) was considered for inclusion into the tool. HLR in wetlands is a measure of the volume of water applied to a wetland's surface area over a specific time. It directly influences the wetland's ability to treat pollutants, as HLR affects microbial communities and residence time, thereby impacting removal efficiency for substances like phosphorus, nitrogen, and organic matter. Eventually this concept was abandoned due to complications with reaching accurate HLR calculations and because the data sources that could be utilized to generate HLR metrics were unreliable and inconsistent between states. Instead, the tool uses other, similar questions with reliable data sources to assess the ratio of the wetland size to the watershed or catchment area.

In addition, using algal growth as an indicator of phosphorus and/or sediment loading was considered but not pursued after conversations with experts in this field (LaLiberte 2024). There are many types of algal blooms and not all blooms are indicative of excess phosphorus or sedimentation. In addition, many assessors are unlikely to be able to discern various algae species to determine which of those are indicative of eutrophication and which are not.

Climate

A wetland's ability to mitigate climate warming and the destabilization effects of anthropogenic greenhouse gas emissions is assessed in this RAM based on the predicted effectiveness of a wetland to sequester (store) carbon in quantities greater than what is emitted through greenhouse gas emissions. This RAM also considers existing wetland carbon stores that are and continue to be sequestered in the wetland.

Available oxygen in the soil leads to the decomposition of organic matter by microbes (aerobic decomposition) and the release of carbon dioxide. Anaerobic decomposition is a much slower process of breaking down organic matter in the absence of oxygen. Wetland soils typically contain considerably more carbon than uplands due to a decreased rate of decomposition associated with anaerobic soil conditions. Anaerobic soil conditions in wetlands result from prolonged periods of soil saturation and drive relatively higher rates of organic matter accumulation in the upper soil surface as compared to uplands (USGCRP 2018). The amount of carbon storage depends on factors such as wetland type and size, the depth of wetland soils, groundwater and nutrient levels, and pH (USGCRP 2018). The depth of organic content provides a relative indicator of current soil carbon storage within the existing soil profile. Overall, the burial of organic matter remains the largest carbon sequestering process on the planet (Temmink, et al. 2022) with wetlands being a major contributor. Plants also store carbon in woody tissues resulting in large amounts of carbon stored in forested wetlands. Wetland soils can also store carbon that washes in from upland areas, through soil erosion or movement of organic matter such as leaves or woody debris (USGCRP 2018). Both the organic content of wetland soils and the amount of plant biomass in the wetland are used as indicators of carbon stores in this RAM.

Anaerobic soil conditions also influence greenhouse gas emissions, and methane emissions from wetlands potentially offsetting any positive benefits of carbon sequestration in soils and plants (Bridgham, et al. 2006), (USGCRP 2018). Methane is produced in wetlands because of the depletion of oxygen and a continuous supply of carbon that enables microbial methane synthesis and release of methane gas (Lohila, et al. 2016). While methane is many times stronger than carbon dioxide in its ability to trap heat and affect climate warming, it will eventually breakdown in the atmosphere. Carbon dioxide on the other hand, which is released from aerobic decomposition of plant material, does not break down and persists in the atmosphere. Therefore, on a longer time scale, the benefit of decreased carbon dioxide release from saturated restored wetlands generally outweighs the sometimes-higher methane releases (Gunther, et al. 2020).

The fluctuation of methane releases from wetlands (methane flux) is highly variable between and within wetlands. Differences in topography, vegetation, temperature, water table position, and other factors regulate these fluxes (USGCRP 2018). Methane flux is generally highest under increasing inundation time where oxygen becomes depleted (Yuan, et al. 2021), (Altor 2008), (Crill, et al. 1988), (Nykänen, et al. 1998). Saturation at or near the soil surface slows decomposition of organic matter while allowing for some oxygen availability to lessen methane production. Methane emissions are kept to a minimum when water levels are near the surface (Beyer and Höper 2015), (Zou, et al. 2022). Evans et al (2021) found that the mean annual effective water table depth was the overriding factor controlling greenhouse gas emissions and that raising water table levels in drained peatlands reduced greenhouse gas emissions until the water table is within 10 centimeters of the ground surface. Water regime is an indicator used in this RAM to approximate the relative level of methane releases.

Nitrous oxide is another powerful greenhouse gas released from wetlands, yet the processes and influences on its release are poorly understood and not directly assessed in this tool. Emissions are generally higher in drained and warmer wetland soils and increase substantially when drainage leads to land use changes such as deforestation and conversion to agricultural land (Bahram, et al. 2022). Some of the same characteristics of wetlands that influence methane fluxes also influence nitrous oxide emissions in a similar manner.

Surface vegetation plays a large role in carbon flux with the presence of sphagnum associated with decreased methane emissions and positive carbon balance (Pelletier, et al. 2007), (Purre and Ilomets 2021), (Waddington and Warner 2001), (Tuittila, et al. 2004). One study found that carbon fluxes were largely determined by plant community type where a positive carbon balance was found when original peatland species were present despite hydrologic alterations (Urbanová, et al. 2012). Invasive and exotic species in a wetland compared to native species often have a higher capacity to acquire resources, grow more rapidly, increase carbon substrates in the soil, and promote increased methane production when favorable conditions exist (Yuan, et al. 2021), (Lawrence, et al. 2016), (Ehrenfeld 2010). In contrast, sphagnum-dominated wetlands inhibit microbial decomposition of plant detritus and foster accumulation of metal-bound organic carbon in the soil (Zhao, et al. 2023).

Broadly, peatlands tend to store more carbon than mineral soil wetlands. Forested wetlands tend to store more carbon in vegetation than non-forested wetlands. Non-forested mineral soil wetlands tend to be larger sources of carbon dioxide. All wetland types are typically sources of methane (USGCRP 2018).

Very few contemporary rapid functional assessment methods attempt to rate the ability of a wetland to store carbon and contribute to reduced greenhouse gas emissions. The Oregon Rapid Wetland Assessment Protocol (ORWAP) (Adamus and Verble 2016) evaluates the effectiveness of a wetland for retaining carbon on a net annual basis for long periods while emitting little or no methane. The basic assumptions behind ORWAP's carbon sequestration model for non-tidal wetlands were used as a starting point for assessment of this function. In ORWAP, both the existing carbon stores of wetlands (soil organic matter, woody vegetation) and the wetland's ability to produce and retain carbon that is either generated in the wetland (plant growth) or received from upgradient sources (decaying plant debris and eroded soil particles carried by overland water flow) are considered. Plant cover and temperature are considered as proxies for plant productivity and the availability of carbon for sequestration. Methane limitation is assessed by a variety of factors including salinity, permanent surface water, coniferous tree cover, and moss cover.

Given the complexity and variety of factors affecting a wetland's ability to store carbon and contribute to the mitigation of global warming, this RAM focuses on broad factors that are relatively easy to assess, overlap with characteristics being assessed for other functions, and can be reasonably associated with known factors influencing carbon storage and greenhouse gas emissions. Although temperature influences methane emissions, it is not used as a metric for this RAM. The temperature ranges across Wisconsin and Minnesota vary by a third as indicated by the number of growing degree days. However, there are often other characteristics associated with the northern areas of the states where temperatures are lower that correlate with other metrics used in the tool such as high organic matter soils and sphagnum/forested wetlands. More specific ORWAP metrics related to water regime and vegetation composition as well as salinity and sediment indicators were determined to be too difficult to assess accurately for an entire AA and are not used in this RAM.

This function is examined in terms of the following indicators:

- Existing Carbon Storage
- Carbon Deposition Capacity
- Methane Emissions Limitation Capacity

Existing carbon storage capacity is assessed by the organic matter content of the soil (more organic matter, higher carbon storage), the percentage of the wetland with woody vegetation (more woody vegetation, higher carbon storage in vegetation), and the percent cover of sphagnum (more sphagnum, higher carbon content and increased peat-forming capacity). Organic matter stored below (soils) and above ground (trees and shrubs) are assigned equal weight in scoring (0-35 points), while sphagnum is slightly lower (0-30 points). Sphagnum will likely not be a factor in areas of the states that lack peatlands.

The ability of wetlands to receive and store carbon from upstream watershed sources is assessed by catchment size (larger catchment to wetland size ratios have the potential to deliver more carbon), catchment gradient (steeper catchment slope have the potential to deliver more carbon), and catchment land use (catchments with natural/perennial vegetation cover tend to inhibit carbon runoff to wetlands where it can accumulate). The relative size and cover class of the catchment are assigned equal weight in scoring, while the catchment gradient is half the weight of the overall score. It was assumed that catchment cover and size have a greater influence on the amount of carbon deposition in the wetland as compared to the catchment slope.

The relative degree of methane release is assessed by the water regime and floristic quality of the wetland. Wetlands with more of a continuously saturated water regime tend to have lower methane releases in relation to carbon storage. Wetlands with a lower floristic quality rank will tend to have more exotic and invasive vegetation resulting in increased primary productivity which tends to increase methane release. Water regime is assumed to be the primary driver of methane release and assigned the most weight in scoring. Floristic quality contributes up to one-third of the score.

The overall rank for carbon sequestration is a combination of existing carbon stores, methane limitation, and carbon deposition in the wetland. Existing carbon stores and methane limitation have the greatest influence on the overall rank. When existing carbon stores are low, higher carbon deposition is assumed to partially compensate and slightly increase the overall rank except when methane releases are high (i.e. methane limitation rank is low).

Anthropogenic

The anthropogenic function revolves around the physical attributes of wetlands that affect both passive and active human uses of wetlands.

Statutory requirements are focused on the development of drivers and questions. In Wisconsin, NR 103, Wis. Adm Code, requires protection of recreational, cultural, educational, scientific, and natural scenic beauty values in wetlands. Minnesota regulations require evaluation and protection of education, recreation, and commercial benefits. Hence, this RAM evaluates the anthropogenic function of wetlands in terms of:

- Commercial use
- Public recreation

- Education and scientific uses
- Historic and cultural values
- Natural scenic beauty

Initial development of drivers and indicators split education and scientific study and treated land use (public or private) as a stand-alone driver. As the process developed the technical team chose to combine scientific study and educational use into a single driver. Additionally, the land use and ownership factored into several drivers regarding accessibility, so it was dropped as a driver. During development, inclusion of a question about wetland interspersion of vegetation types as an indicator for the natural scenic beauty value was considered. This question was dropped due to the difficulty of generalizing scenic beauty values based on a wetland's intrinsic characteristics.

Scoring considerations were limited from the start due to the nature of the drivers. The uses and considerations were either present or not, so the questions were developed to affirm the presence or absence. The Anthro questions do not result in a Functional Capacity Rank, as these attributes provide Opportunity Value only for the assessed wetlands.

Commercial Use

Commercial use refers to whether a wetland or part of it is used for producing wetland dependent products. Wetland dependent implies that the activity's location in a wetland, and its persistence, is essential to producing the commercial product. Examples of wetland dependent commercial uses include wild rice production, horticultural peat mining, and certain types of aquaculture. Wetland dependent commercial uses do not include uses that require the conversion to non-wetland or uses that can and are preferably conducted in non-wetlands (e.g., row crop corn and soybean production).

Wetlands with a high commercial use ranking are those currently being used for commercial purposes, while those with a moderate ranking have similar characteristics as and are adjacent to or in the same region as wetlands that are commonly used for a specific commercial purpose.

Public Recreation

Public, nature-based recreation implies the public can use the wetland for wetland dependent recreation opportunities such as personal watercraft use, hunting, trapping, fishing, bird watching, or general wildlife/nature viewing.

A wetland with a high public recreation value is assumed to be specifically managed for wetland dependent recreation, have infrastructure that supports wetland dependent public recreation, and/or is located within a typical travel distance for the casual recreation user. This RAM assumes that wetlands under private ownership are not accessible for public recreational uses unless public access has overtly been provided. Consequently, this RAM assumes wetlands that grant access to the public provide greater recreation opportunities than wetlands that do not grant access to the public. Access to the public means a person does not need to ask a landowner's permission for access.

Educational and Scientific Uses

Educational and scientific uses relate to whether the wetland is used for education purposes or for academic or applied research. A wetland rated as "high" for educational and scientific uses is located on a property that provides superior educational and scientific research opportunities, and that provide safe public access for such uses, including parking and accessibility for a wide range of user groups.

Academic or applied research means evidence, such as signage or the wetland's location, that indicates it is currently used for research purposes. Properties designated for education or scientific use mean nature preserves or centers, school property, college campuses, or other lands emphasizing environmental education. Wetlands located on private lands that lack education infrastructure are rated low for this function.

Historic and Cultural Values

Historic and cultural values relate to attributes of the wetland that provide intrinsic value due to cultural or historic significance, or resource sensitivity or rarity. Indicators of these values include state archeological sites and historic sites identified on agency or historic preservation office mapping which provide intrinsic cultural benefits to society. Also included are wetland areas or wetland components valued by tribes which may be used for sustaining tribal cultural practices, culturally important plant harvesting, teaching tribal practices, or that have ceremonial importance. Cultural values may also include wetlands that support threatened, endangered, or special concern plant and animal species, and wetlands in publicly protected areas such as parks, recreation areas, fish and wildlife areas, natural areas, tribal reservations, or ceded territory.

Natural Scenic Beauty

Natural scenic beauty refers to viewable attributes of the wetland that allow the public to appreciate the intrinsic value of wetland-oriented beauty in the landscape. This value is indicated by publicly accessible viewing areas of natural wetlands. Wetland viewing areas that are unobstructed by the built environment or dense vegetation would provide scenic beauty value. Also providing value is a wetland area with a natural character, where trash, dumping, or other human-made materials and structures are not distracting from the view. Finally, infrastructure that supports viewing can increase the opportunity-value for scenic beauty, including platforms, benches, trails, and the like.

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