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# Ecological Performance Standards for Wetland Mitigation

## An Approach Based on Ecological Integrity Assessments

# APPENDICES

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November 2008

NatureServe

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# Appendices

# Appendix I: Template for Metrics Protocols

**Metric A**

**Definition**:

**Background**:

**Metric Type**:

**Tier**:

**Rationale for Selection of the Variable**:

**Measurement Protocol**:

**Metric Rating**: Specify the narrative and numerical ratings for the metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| | **Metric Rating** | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| | | | |

**Data**:

**Scaling Rationale:**

**Confidence that reasonable logic and/or data support the index:**

# Appendix II: Protocols for Rapid (Level 2) Field Metrics

## ▪ A. Landscape Context Metrics

### Landscape Connectivity

**Definition:** A measure of the percent of unfragmented landscape within 1 km area (non-riverine), or degree to which the riverine corridor above and below a floodplain area exhibits connectivity with adjacent natural systems (riverine).

**Background:** The non-riverine metric rating is taken from McIntyre and Hobbs (1999); the riverine is adapted from Collins et al. (2007; CRAM 4.5.2).

**Metric Type**: Condition

**Tier:** 2 (rapid field measure)

**Rationale for Selection of the Variable:**
Non-riverine**:** The intensity of human activity in the landscape often has a proportionate impact on the ecological processes of natural systems. The percentage of altered landscape (e.g., anthropogenic patches) provides an indirect estimate of connectivity among natural ecological systems. The metric is fairly simple, treating the landscape in a binary fashion (either natural or non-natural), and for a level 1 metric this may be sufficient. But a more sophisticated metric should accommodate the idea that landscape types having varying degrees of connectivity, depending on the variety of natural and non-natural ecosystem types.

The integrity of the landscape context of wetlands can be important to certain biota Amphibians and reptiles are especially sensitive to the matrix of habitats surrounding a wetland because they spend the majority of their lives foraging, resting, and hibernating in the surrounding terrestrial habitat (Semlitsch 1998). Upland habitats immediately surrounding wetlands serve as important dispersal corridors and are also used as foraging and aestivation areas for many amphibian species (Semlitsch 1998). Total unaltered area around the wetland also seems to be an important landscape component in the maintenance of wetland fauna. Guerry and Hunter (2002) found that wood frogs, green frogs, eastern newts, spotted salamanders, and salamanders of the blue-spotted/Jefferson's complex (*Ambystoma laterale*/*A. jeffersonianum*) were more likely to occupy ponds in unaltered landscapes (in their study, unaltered landscape corresponded to intact forested areas).

Riverine: Riverine areas are typically comprised of a continuous corridor of intact natural vegetation along the stream channel and floodplain (Smith 2000). These corridors allow uninterrupted movement of animals to up- and down-stream portions of the riparian zone as well as access to adjacent uplands (Gregory et al. 1991). These corridors also allow for unimpeded movement of surface and overbank flow, which are critical for the distribution of sediments and nutrients as well as recharging local alluvial aquifers. Fragmentation of the riverine corridor can occur as a result of human alterations such as roads, power and pipeline corridors, agriculture activities, and urban/industrial development (Smith 2000). See additional rationale in Collins et al. (2007). Note that Collins et al. (2007) have considerably refined this metric from earlier versions. However, their rationale for developing separate scoring procedures for upstream versus downstream connectivity (they score degradation in downstream connectivity less severely than upstream connectivity) is not used here.

**Measurement Protocol:** Non-riverine**:** This metric is measured by estimating connectivity either based on a fixed absolute area around the wetland occurrence or an area based on a fixed distance around the wetland. The distance is measured from the edge of the wetland. For either approach, it may be desirable to remove areas that are outside the watershed of the occurrence.

For the first method, assess the amount of unfragmented natural habitat in a one km area surrounding the wetland (1 $km^2$ or 100 ha; 0.38 $mi^2$ or 247 ac), preferably within the watershed of the wetland. This measure can be completed in the office using aerial photographs or GIS, then, if possible or desirable, verifying the natural cover in the field.

For the second method, use a fixed 500 m fixed distance around the wetland perimeter. This would allow for more consistent assessment of the connectivity around both small and large wetlands, as a 1 $km^2$ area around a large, 50 ha wetland, would only have a 399 m radius, compared to a 1 $km^2$ area around a 1 ha wetland, which would have a radius of 564 meters. The fixed 500 m distance would be comparable to the fixed area approach for small to medium wetlands. Riverine: See Collins et al. (2007; CRAM manual)

**Metric Rating**: Specify the narrative and numerical ratings for a metric, from Excellent to Poor.

| | | **Metric** | **Rating** | |
|---|---|---|---|---|
| | **Excellent** | **Good** | **Fair** | **Poor** |
| *Non-Riverine* | Intact: Embedded in 90-100% natural habitat of around wetland, preferably within the watershed | Variegated: Embedded in 60-90% natural habitat; | Fragmented: Embedded in 20-60% natural habitat; | Relictual: Embedded in < 20% natural habitat; |
| *Riverine –* | The combined total length of all non-buffer segments is less than 200 m (<10%) for wadable (2-sided) sites, 100 m (<10%) for non-wadable (1-sided) sites. | Combined length of all non-buffer segments is between 200 m and 800 m (10-40%) for "2-sided" sites; between 100 m and 400 m (10-40%) for "1-sided" sites. | Combined length of all non-buffer segments is between 800 and 1800 m (40-90%) for "2-sided" sites; between 400 m and 900 m (40-90%) for "1-sided" sites. | Combined length of all non-buffer segments is greater than 1800 m for "2-sided" (>90%) sites, greater than 900 m f or "1-sided" sites (>90%). |

**Data**:
Non-riverine: McIntyre and Hobbs (1999).
Riverine: Collins et al. (2007; CRAM 4.5.2), but thresholds of percent buffer are adjusted to match the non- riverine ratings for connectivity.

**Scaling Rationale:**
Non-riverine: Less fragmentation increases connectivity between natural ecological systems and thus allow for natural exchange of species, nutrients, and water. The categorical ratings are based on McIntyre and Hobbs (1999). Their scaling rationale is summarized as follows:

| Excellent | Good | Fair | Poor |
|---|---|---|---|
| Definition:<br>Intact: Embedded in 90-100% natural habitat;<br>Rationale: Connectivity is expected to be high; remaining natural habitat is in good condition (low modification); and a mosaic with gradients. | Definition:<br>Variegated: Embedded in 60-90% natural habitat;<br>Rationale:<br>Connectivity is generally high, but lower for species sensitive to habitat modification; remaining natural habitat with low to high modification and a mosaic that may have both gradients and abrupt boundaries | Definition:<br>Fragmented: Embedded in 20-60% natural habitat;<br>Rationale:<br>Connectivity is generally low, but varies with mobility of species and arrangement on landscape; remaining natural habitat with low to high modifications and gradients shortened. | Definition:<br>Relictual: Embedded in < 20% natural habitat;<br>Rationale:<br>Connectivity is essentially absent; remaining natural habitat generally highly modified and generally uniform |

In addition, the Heinz Center (2002) used <10% non-forest as a measure of unfragmented (core = 100%, interior=90-99%) forest, and between 10-40% as "connected forested. The data on which these breakpoints were established needs to be investigated. The Heinz Center is also investigating the use of a fragmentation index that takes into account roads that occur within the neighborhood area. (Cavender-Bares, pers. comm. 2005).

Riverine: As continuous buffer decreases, the continuity of natural vegetated patches in the riparian decreases, along with corresponding changes in species, sediment, nutrient, and water movement. The ratings are partly based on the CRAM rating of Collins et al. (2007), but their scaling is very conservative; that is, buffer widths of between 5 and 10% non-natural are ranked C, and >10% non-natural is D. Here the scaling is modified to correspond to that of the non-riverine metric. Further review is needed of the scaling for this buffer.

**Confidence that reasonable logic and/or data support the index:** Medium/High.

## Buffer Index

**Definition:** A measure of the overall area and condition of the buffer immediately surrounding the wetland, using 3 measures: Percent of Wetland with Buffer, Average Buffer Width, and Buffer Condition. Wetland buffers are vegetated, natural (non-anthropogenic) areas that surround a wetland.

**Background:** Metric is taken from Collins et al. (2006). The buffer of wetlands can be important to biotic and abiotic aspects of the wetland. The Environmental Law Institute (2008) has also recently reviewed the role of buffers for wetlands.

**Metric Type**: Condition

**Tier:** 1 (remote sensing) or 2 (rapid field measure)

**Rationale for Selection of the Variable:** Semlitsch (1998) monitored terrestrial migrations for six Ambystomid salamander species and concluded buffer areas 164 m from wetland edges were needed to encompass 95% of population forays.

**Measurement Protocol:** Metric is taken from Collins et al. (2006), who provide an equation to integrate the three measures into an overall index. The table below provides additional guidance on buffer definitions (from Table 4.3, Collins et al. 2006). There is also value in adjusting the rating of buffer width based on slope. The following slope Adjustment should be used (Environmental Law Institute 2008, based on data from Island County, Washington).

Slope Gradient Additional Buffer Length Multiplier
5-14% 1.3
15-40% 1.4
>40% 1.5

**Metric Rating**: Specify the narrative and numerical ratings for a metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| | Metric | Rating | | |
|---|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** | **Very Poor** |
| Buffer is > 75 – 100% of occurrence perimeter. | Buffer is > 50 – 74% of occurrence perimeter. | Buffer is 25 – 49% of occurrence perimeter. | Buffer is < 25% of occurrence perimeter. | - |
| Average buffer width of occurrence is > 200 m, adjusted for slope. | Average buffer width is 100 – 199 m, after adjusting for slope. | Avg. buffer width is 50 – 99 m, after adjusting for slope. | Avg. buffer width (m) is 10-49, after adjusting for slope. | Avg. buffer width (m) is < 10 m, after adjusting for slope |
| Buffer for occurrence is characterized by abundant (>95%) cover of native vegetation and little to no (<5%) cover of non-native plants, with intact soils, and little or no trash or refuse. | Buffer for occurrence is characterized by substantial (75-95%) cover of native vegetation, low (5-25%) cover of non-native plants, intact or moderately disrupted soils, moderate or lesser amounts of trash or refuse, and minor intensity of human visitation or recreation. | Buffer for occurrence is characterized by a moderate (25-50%) cover of non-native plants, and either moderate or extensive soil disruption, moderate or greater amounts of trash or refuse, and moderate intensity of human visitation or recreation. | Buffer for occurrence is dominated by non-native plant cover (>50%) characterized by barren ground and highly compacted or otherwise disrupted soils, with moderate or greater amounts of trash or refuse, and moderate or greater intensity of human visitation or recreation; OR there is no buffer present. | |

**Data**: See Environmental Law Institute (2008).

**Scaling Rationale:** See Collins et al. (2006). There is abundant evidence on the value of even short buffers between 10 to 50 m (Environmental Law Institute 2008); thus the CRAM Buffer width scale is extended to have an A-E rating.

**Confidence that reasonable logic and/or data support the index:** Medium/High

Table 1. Guidelines for identifying wetland buffers and breaks in buffers (from CRAM manual; Collins et al. 2006, Table 4.3).

| Examples of Land Covers Included in Buffers | Examples of Land Covers Excluded from Buffers | Examples of Land Covers Crossing and Breaking Buffers |
|---|---|---|
| natural upland habitats and plant communities, roads not hazardous to wildlife, vegetated levees, rough meadows or greenbelts, swales and ditches, foot trails, horse trails, bike trails, pastures subject to open range grazing pressure, dry-land farming areas, plantations, Conservation Reserve Program pastures. | open water (see note below), parking lots, commercial and private developments, very active roadways and bike trails, intensive agriculture, railroads pastures subject to heavy grazing pressure (e.g., horse paddock, feedlot, turkey ranch), lawns, sports fields, traditional golf courses. | large paved roads (two lanes or larger), residential areas, bridges, culverts, paved creek fords, railroads, sound walls, fences that interfere with movements of water, sediment, or wildlife species that are critical to the overall functions of the wetland. |

Open Water: [from Collins et al. 2006] Open water adjacent to the wetland site, such as a lake, large river, or lagoon is not considered part of the buffer. There are three reasons for excluding open water from wetland buffers. First, a significant portion of the adjacent environment of lacustrine, lagoon, and estuarine wetlands usually consists of open water. These areas of open water are commonly wider than 200 m. Assessments of buffer extent around a wetland and of buffer width are therefore inflated by including open water as a part of the buffer. Second, while there may be positive correlations between wetland stressors and the quality of open water, quantifying water quality generally requires laboratory analyses beyond the scope of rapid assessment. Third, open water can be a direct source of stress (i.e., water pollution, waves, boat wakes) or an indirect source (i.e., promotes visitation by livestock and people, provides access for non-native plant species). Because open water is excluded from buffers, in wetland classes that are typically adjacent to open water, only the terrestrial portion of the perimeter of the site is considered in the calculation of percent buffer.

## Surrounding Land Use

**Definition:** This metric addresses the intensity of human dominated land uses within a specified landscape area. Landscape area is defined as a small landscape area of 1,000 ha (2,500 ac) area surrounding the stand or polygon, for polygons up to 500 ha, or 2x the size of the polygon for all polygons larger than 500 ha. If the polygon is identified as a wetland, use a landscape area of 100 ha ($1 km^2$) or ~250 ac (~0.4 $mi^2$) or use a local watershed area equivalent to this scale. Each land use type occurring in the landscape area is assigned a coefficient ranging from 0.0 to 1.0 indicating its relative impact to the polygon of the target system.

**Background:** This metric is one aspect of the landscape context of specific stands or polygons of ecosystems and is taken from Hauer et al. (2002). See also Mack (2006) for a related version of this metric.

**Metric Type**: Stressor

**Tier:** 2 (rapid field measure)

**Rationale for Selection of the Variable:** The intensity of human activity in the landscape has a proportionate impact on the ecological processes of natural ecosystems. Assessing land use incorporates both the aspect of "habitat destruction" and "habitat modification" (sensu McIntyre and Hobbs 1999), at least for the non-natural habitats. That is, in addition to the effect of converting natural habitat to agricultural, urban and other land use modifications, there is the additional aspect of the intensity of that land use.

Typically, the specification of "landscape area" varies depending on the spatial scale of the system under study. For matrix types, a 10,000 ha (25,000 ac) "large landscape" area can be used. Alternatively, a large landscape of 4,000 ha (10,000 ac) landscape area can also be justified, based on Anderson (2006). Large patch types could use a "small landscape" of 1000 ha (10 $km^2$) or ~2,500 ac (4 $mi^2$), and the "local landscape" of 100 ha (1 $km^2$ area) or 250 ac (0.4 $mi^2$). Small patch communities could use the "local landscape" of 100 ha (1 $km^2$ area) or 250 ac (0.4 $mi^2$). But when a level 1 assessment is applied to broadly classified types (e.g. deciduous forest, evergreen shrubland, perennial grassland), it is hard to know what the appropriate scale of the landscape area should be.

**Measurement Protocol:** We recommend using the small landscape area of 1,000 ha (2,500 ac) area surrounding the stand or polygon, for polygons up to 500 ha, or 2x the size of the polygon for all polygons larger than 500 ha. If the polygon is identified as a wetland, use a landscape area of 100 ha (1$km^2$) or ~250 ac (~0.4 $mi^2$), or a local watershed equivalent to this scale.

This metric is measured by documenting surrounding land use(s) within the large or small landscape area surrounding the center of the stand or polygon. This should be completed in the office using aerial photographs or GIS, then verified in the field, using roads or transects to verify land use categories. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use within the landscape area, but remotes sensing alone can be used.

To calculate a Total Land Use Score estimate the % of each Land Use type and then plug the corresponding coefficient (Table 1; the coefficients in this table are derived from Hauer et al. (2002) with some manipulation to account for regional application) into the following equation:

*Sub-land use score* = ∑ LU x PC/100

where**:** LU = Land Use Score for Land Use Type; PC = % of adjacent area in Land Use Type.

Do this for each land use within 100 m of the stand or polygon edge, then sum Sub-Land Use Score to arrive at a Total Land Score. For example, if 30% of the adjacent area was under moderate grazing (0.3 * 0.6 = 0.18), 10% composed of unpaved roads (0.1 * 0.1 = 0.01), and 40% was a natural area (e.g. no human land use) (1.0 * 0.4 = 0.4), the Total Land Use Score would = 0.59 (0.18 + 0.01 + 0.40).

**Metric Rating:** Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

| **Metric Rating** | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| Average Land Use Score = 1.0-( | Average Land Use Score = 0.80-0.95 | Average Land Use Score = 0.4-0.80 | Average Land Use Score = <0.4 |

**Data**: See Tables 1, 2 and 3, below.

Table 1. Current Land Use and Corresponding Land Use Coefficients (adapted from Table 21 in Hauer et al. (2002).

| Current Land Use | Coefficient |
|---|---|
| Paved roads/parking lots/domestic or commercially developed buildings/mining (gravel pit, quarry, open pit, strip mining). | 0 |
| Unpaved Roads (e.g., driveway, tractor trail) / abandoned mines | 0.1 |
| Agriculture (tilled crop production) / intensively developed vegetation (golf courses, lawns, etc). | 0.2 |
| Vegetation conversion (chaining, cabling, rotochopping, clearcut) | 0.3 |
| Heavy grazing on rangeland or pastures | 0.3 |
| Heavy logging or tree removal with 50-75% of trees >30 cm dbh removed | 0.4 |
| Intense recreation (ATV use/camping/sport fields/popular fishing spot, etc.) / Military training areas (armor, mechanized) | 0.4 |
| Agriculture - permanent crop (vineyards, orchards, nurseries, berry production, introduced hay field and pastures etc) | 0.4 |
| Commercial tree plantations / Christmas tree farms | 0.5 |
| Dam sites and flood disturbed shorelines around water storage reservoirs | 0.5 |
| Recent old fields and other disturbed fallow lands dominated by ruderal and exotic species. | 0.5 |
| Moderate grazing on rangeland | 0.6 |
| Moderate recreation (high-use trail) | 0.7 |
| Mature old fields and other fallow lands with natural composition | 0.7 |
| Selective logging or tree removal with <50% of trees >30 cm dbh removed | 0.8 |
| Light grazing / light recreation (low-use trail) / haying of native grassland | 0.9 |
| Natural area / land managed for native vegetation | 1 |

**Scaling Rationale:** Land uses have differing degrees of potential impact on ecological patterns and processes. Some land uses have minimal impact, such as simply altering the integrity of native vegetation (e.g., recreation and grazing), while other activities (e.g., hay production and agriculture) may replace native vegetation with nonnative or cultural vegetation yet still provide potential cover for species movement. Intensive land uses (i.e., urban development, roads, mining, etc.) may completely destroy vegetation and drastically alter ecological processes. The coefficients were assigned according to best scientific judgment regarding each land use's potential impact (Hauer et al. 2002, NatureServe and Network ecology staff, pers. comm. 2008). See also Mack (2006).

**Confidence that reasonable logic and/or data support the index:** Medium.

Table 2. Current Land Use and Corresponding Land Use Coefficients, based on Mack (2006).

TABLE II

Florida land use classes and emergy coefficients, the NLCD land use classes equated to those land uses, and emergy coefficients used to calculate the LDI scores in this study

| Florida land use classes | NLCD land use classes | FL LDI coefficients | OH LDI coefficients |
|---|---|---|---|
| Natural system | Forest, wetland (forest, emergent) | 1.00 | 1.00 |
| Natural open water | Water | 1.00 | 1.00 |
| Pine plantation | | 1.58 | |
| Recreational/open space (low intensity) | | 1.83 | |
| Woodland pasture (with livestock) | | 2.02 | |
| Pasture (without livestock) | | 2.77 | |
| Low intensity pasture (with livestock) | Pasture | 3.41 | 3.41 |
| Citrus | | 3.68 | |
| High intensity pasture (with livestock) | | 3.74 | |
| Row crops | | 4.54 | |
| Single family residential (low density) | | 6.79 | |
| Recreational/open space (high intensity) | Urban forests, highly managed | 6.92 | 6.92 |
| High intensity agriculture (dairy farm) | Row crop | 7.00 | 7.00 |
| Single family residential (medium density) | | 7.47 | |
| Single family residential (high density) | Suburban | 7.55 | 7.55 |
| Mobile home (medium density) | | 7.70 | |
| Highway (2 lane) | | 7.81 | |
| Low intensity commercial | | 8.00 | |
| Institutional | | 8.07 | |
| Highway (4 lane) | | 8.28 | |
| Mobile home (high density) | | 8.29 | |
| Industrial | Rock, transitional | 8.32 | 8.32 |
| Multi-family residential (low rise) | | 8.66 | |
| High intensity commercial | | 9.18 | |
| Multi-family residential (high rise) | | 9.19 | |
| Central business district (average 2 stories) | Urban | 9.42 | 9.42 |
| Central business district (average 4 stories) | | 10.00 | |

Original Hauer et al. table is provided in Table 3.

Table 3. Current Land Use and Corresponding Land Use Coefficients, modified from Table 21 in Hauer et al. (2002).

| Current Land Use | Coefficient |
|---|---|
| Paved roads/parking lots/domestic or commercially developed buildings/gravel pit operation | 0.0 |
| Surface mining, mountaintop removal mining | 0.0 |
| Unpaved Roads (e.g., driveway, tractor trail) / Underground mining | 0.1 |
| Agriculture (diking, ditching, tide gates, tilled crop production) | 0.2 |
| Peat extraction, peat mining | 0.3 |
| Heavy grazing by livestock / intense recreation (ATV use/camping/popular fishing spot, etc.) | 0.3 |
| Logging or tree removal with 50-75% of trees >50 cm dbh removed | 0.4 |
| Hayed | 0.5 |
| Aquaculture -- fish, shrimp, oyster farming | 0.5 |
| Moderate grazing | 0.6 |
| Moderate recreation (high-use trail) | 0.7 |
| Selective logging or tree removal with <50% of trees >50 cm dbh removed | 0.8 |
| Light grazing / light recreation (low-use trail) | 0.9 |
| Fallow with no history of grazing or other human use in past 10 yrs | 0.95 |
| Natural area / land managed for native vegetation | 1.0 |

## ▪ B. Size

### Patch Size

**Definition:** A measure of the current size (ha) of the occurrence or stand. The metric is assessed relative to reference stands of a type, globally.

**Background:** This metric is one aspect of the size of specific occurrences of a wetland type. The metric rating is taken from NatureServe's Ecological Integrity Assessment Working Group.

**Metric Type**: Condition

**Tier:** 1 (remote sensing); 2 (rapid field measure)

**Rationale for Selection of the Variable:** The role of absolute size in assessing integrity is complex (NatureServe Ecological Integrity Working Group 2008). First, higher ratings for size may not always indicate increased integrity. For some types absolute size can vary widely for entirely natural reasons (e.g., a forest type may have very large occurrences on rolling landscapes, and be restricted to small occurrences on north slopes or ravines in other landscapes).

Second, size overlaps with landscape context as a metric, depending on the scale of the analysis. Both size and landscape context are dealing with spatial aspects of the occurrence. Very large sized, matrix occurrences essentially define the landscape context, particularly. For example, a wetland of 1,000 ha will have a landscape connectivity assessed of 100 ha, (using the fixed area method of that metric). Criteria for establishing the size metric ratings are sometimes can be confounded with criteria for Landscape Context. For example, the use of Minimum Dynamic Area (MDA) as the basis for the Size criteria is misleading, at least at the system or natural/community level, because MDA is really assessing the landscape area within which an occurrence is embedded. MDA is typically applied to types at very broad classification levels (e.g., northern hardwood landscapes, boreal forest landscapes, etc.). There, information on MDA is lacking for many types.

Nonetheless size can be an important aspect of integrity. For some types, diversity of animals or plants may be higher in larger occurrences than in small occurrences that are otherwise similar. For occurrences in mosaics, the larger occurrences often have more micro-habitat features. Larger wetlands are more resistant to hydrologic stressors, larger uplands more resistant to invasion by exotics, since they buffer their own interior portions. Thus size can serve as a readily measured proxy for some ecological processes and the diversity of interdependent assemblages of plants and animals.

N.B. For NatureServe's methodology for assigning an "Element Occurrence Rank" integrates integrity and conservation values, so with respect to size, larger EOs are generally presumed to be more value for conservation purposes, as they provide a better representation of the type being conserved. Because of its importance for assessing conservation value, NatureServe keeps the size metric separate from other metrics within a Size Rank Factor. Some consideration had been given to combining size metrics with a broader "landscape context and size Rank Factor," so that interactions between size and landscape context could be dealt with first, before considering their joint interaction with condition. Users focused strictly on ecological integrity may find this an appealing option.

**Measurement Protocol:** Absolute Size can be measured in GIS using aerial photographs, orthophoto quads, National Wetland Inventory maps, etc. Size can also be estimated in the field using 7.5 minute topographic quads, NPS Vegetation Mapping maps, National Wetland Inventory maps, or a global positioning system. Wetland boundaries are not delineated using jurisdictional methods (U.S. Army Corps of Engineers 1987); rather, they are delineated by ecological guidelines for delineating the boundaries of the wetland type, based on the International Vegetation Classification, equivalent National Vegetation Classifications, Cowardin or other wetland classifications.

**Metric Rating**: Specify the narrative and numerical ratings for a metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| Metric Rating | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| Patch size is very large compared to other examples of the same type (e.g., top 10% based on known and historic occurrences, or area-sensitive indicator species very abundant within occurrence). | Patch size is large compared to other examples of the same type (e.g. within 10-30%, based on known and historic occurrences, or most area-sensitive indicator species moderately abundant within occurrence). | Patch size is moderate compared to other examples of the same type, (e.g., within 30-70% of known or historic sizes; or many area-sensitive indicator species are able to sustain a minimally viable population, or many characteristic species are but present). | Patch size is too small to sustain full diversity and full function of the type. (e.g., smallest 30% of known or historic occurrences, or both key area-sensitive indicator species and characteristic species are sparse to absent). |

**Data:** N/A

**Scaling Rationale:** Scaling criteria are based on the NatureServe Ecological Integrity Assessment Working Group (2008).

**Confidence that reasonable logic and/or data support the index:** Medium.

## Patch Size Condition

**Definition:** A measure of the current size of the wetland (in hectares) divided by the historic (within most recent period of intensive settlement or 200 years) size of the wetland, multiplied by 100.

**Background:** This metric is one aspect of the size of specific occurrences of a wetland type. The metric rating is taken from Rondeau (2001) and best scientific judgment. It is an optional metric.

**Metric Type**: Condition

**Tier:** 1 (remote sensing); 2 (rapid field measure)

**Rationale for Selection of the Variable:** Relative size is an indication of the amount of the wetland change caused by human-induced disturbances. It provides information that allows the user to calibrate the current size to the historic area of the wetland. For example, if a wetland has a current size of 1 hectare but the historic size was 2 hectares, this indicates that half (50%) of the original wetland has been lost or severely degraded. Complicating the use of this metric is that wetland size may either increase or decrease due to human disturbances.

**Measurement Protocol:** Relative size can be measured in GIS using aerial photographs, orthophoto quads, National Wetland Inventory maps, etc. However, field calibration of size may be required since it can be difficult to discern the historic area of the wetland from remote sensing data. However, the reverse may also be true, since old or historic aerial photographs may indicate a larger wetland than observed in the field. Relative size can also be estimated in the field using 7.5 minute topographic quads, NPS Vegetation Mapping maps, National Wetland Inventory maps, or a global positioning system. Wetland boundaries are not delineated using jurisdictional methods (U.S. Army Corps of Engineers 1987); rather, they are delineated by ecological guidelines for delineating the boundaries of the wetland type, based on the International Vegetation Classification, equivalent National Vegetation Classifications, Cowardin or other wetland classifications.

The definition of the "historic" timeframe will vary by region, but generally refers to the intensive Euro-American settlement that began in the 1600s in the eastern United States and extended westward into the 1800s. If the historic time frame is unclear, use a 200 yr time period, long enough to ensure that the effects of wetland loss are well-established.

**Metric Rating**: Specify the narrative and numerical ratings for a metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| **Metric Rating** | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| Occurrence is at, or only minimally reduced from, its full original, natural extent (<95%), and has not been artificially reduced in size. Reduction can include destroyed or severely disturbed; (e.g., large changes in hydrology due to roads, impoundments, development, human-induced drainage; or changes caused by recent clearcutting) | Occurrence is only modestly reduced from its original natural extent (80-95% or more). Reduction can include...(see A) | Occurrence is substantially reduced from its original, natural extent (50-80%). Reduction can include...(see A) | Occurrence is heavily reduced from its original, natural extent (>50%). Reduction can include... (see A) |

**Data:** N/A

**Scaling Rationale:** Scaling criteria are based on Rondeau (2001), NatureServe Ecological Integrity Assessment Working Group (2008) and best scientific judgment.

**Confidence that reasonable logic and/or data support the index:** Medium.

## C. Vegetation Metrics

### Vegetation Structure

**Definition:** An assessment of the overall structural complexity of the vegetation layers, including presence of multiple strata, age and structural complexity of canopy layer, and evidence of the effects of disease or mortality on structure.

**Background:** This metric has been drafted by NatureServe's Ecological Integrity Assessment Working Group, with the forested wetlands part adapted from Schafale (2005).
The biotic structure of a wetland includes all of its organic matter that contributes to its material construct or architecture. Living vegetation and coarse detritus are examples of biotic structure. In many wetlands, including bogs and tidal marshes, much of the sediment pile is organic. Evaluation of the fine and coarse organic material is included as biotic structure. The physical condition of the sediment is captured in other metrics, such as hydroperiod, physical patch richness, and topographic complexity. Plants strongly influence the quantity, quality, and spatial distribution of water and sediment within wetlands. For example, vascular plants entrap suspended sediment and contribute organic matter to the sedimentary pile. Plants reduce wave energies and decrease the velocity of water flowing through wetlands. Plant detritus is a main source of essential nutrients. Vascular plants and large patches of macroalgae function as habitat for wetland wildlife.

**Metric Type**: Condition

**Tier:** 2 (rapid field measure)

**Rationale for Selection of the Variable:** In wetlands, vegetation structure can have an important controlling effect on composition and processes. The patch structure is an important reflection of vegetation dynamics and for creating heterogeneity within the community. Plants strongly influence the quantity, quality, and spatial distribution of water and sediment within wetlands. For example, vascular plants entrap suspended sediment and contribute organic matter to the sedimentary pile. Plants reduce wave energies and decrease the velocity of water flowing through wetlands. Vascular plants and large patches of macroalgae function as habitat for wetland wildlife (Collins et al 2006).

The patch structure is often homogenized by disturbance such as logging of wetland forests, soil compaction, or heavy grazing by livestock and geese of fresh and salt marshes.

**Measurement Protocol:** This metric consists of evaluating the horizontal structure of the canopy relative to the reference condition of fine-scale heterogeneity in density and size or age. The protocol is an ocular evaluation of variation in overall structure, including age/size and density, overall canopy cover, abundance of canopy gaps with regeneration, and number of different age/size patches represented. A field form should be used that describes structure using either strata or growth forms (Jennings et al. 2008). For the strata method, list all major strata - tree, shrub, field, non-vascular, floating, submerged – then estimate strata cover and cover of dominant (>5% cover), characteristic, and exotic species. For the growth form approach, list major growth forms - tree (subdivided into overstory and regeneration), shrub (subdivided by tall, and medium/low), herb, nonvascular, floating, submerged, epiphyte, and liana – then estimate strata cover and cover of dominant (>5%), characteristic, and exotic species. Only the maximum or modal height of any vegetation type is used to determine its height class. For example, although a tall tree might span the entire range of all the height classes, it can only represent one height class, based on its overall height.

Field survey method for estimating structure may be either a (1) Site Survey (semi-quantitative) method where the observers walks the entire occurrence, or assessment area within the occurrence, and make notes on vegetation strata, their cover, and exotic species. (2) Quantitative Plot Data, where a fixed area is surveyed, using either plots or transects. The plot or transect is typically a "rapid" plot, but a single intensive plot can also be taken. See Appendix X.2.

**Metric Rating**: Specify the narrative and numerical ratings for the metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| **VEGETATION STRUCTURE** | **Measure** | **(Metric)** | **Rating** | |
|---|---|---|---|---|
| | **Excellent** | **Good** | **Fair** | **Poor** |
| *Bog & Fen* | Peatland is supporting vegetation to its reference standard condition. Some very wet peatlands may not have any woody vegetation or only scattered stunted individuals. Woody vegetation mortality is due to natural factors and is not being influenced by anthropomorphic factors. Tree diameters and heights are near reference standard condition. | Generally, peatland vegetation has only minor anthropogenic influences present or the site is still recovering from major past human disturbances. Mortality or degradation due to grazing, limited timber harvesting or other anthropomorphic factors may be present although not widespread. The site can be expected to meet reference standard condition in the near future if negative human influence does not continue. | Peatland vegetation has been moderately influenced by anthropogenic factors. Expected structural classes or species are not present. Human factors may have diminished the standard condition for woody vegetation. The site will recover to reference standard condition only with the removal of degrading human influences and moderate recovery times. | Expected peatland vegetation is absent or much degraded due to anthropogenic factors. Woody regeneration is minimal and existing vegetation is in poor condition, unnaturally sparse, or depauperate in expected species. Recovery to reference standard condition is questionable without restoration or will take many decades. |
| *Floodplain & Swamp Forest, Mangrove* | Canopy a mosaic of small patches of different ages or sizes, including old trees and canopy gaps containing regeneration. Overall density moderate and average tree cover generally greater than 25%. | Canopy largely heterogeneous in age or size, but with some gaps containing regeneration or some variation in tree sizes AND overall density moderate and greater than 25% tree cover. | Canopy somewhat homogeneous in density and age, AND extremely dense or very open. Canopy cover may be very high or very low (>90%, <25%) | Canopy extremely homogeneous, sparse, or absent (<10% cover). |
| *Freshwater Marsh, [separate out vernal pools, prairie potholes]* | Vegetation is at or near reference standard condition in structural proportions. No structural indicators of degradation evident. | Vegetation is moderately altered from reference standard condition in structural proportions. Several structural indicators of degradation evident. | Vegetation is greatly altered from reference condition in structural proportions. Many structural indicators of degradation evident. | Vegetation is greatly altered from reference condition in structural proportions. Many structural indicators of degradation evident. |

| VEGETATION STRUCTURE | Measure | (Metric) | Rating | |
|---|---|---|---|---|
| | **Excellent** | **Good** | **Fair** | **Poor** |
| *Aquatic Vegetation* | Vegetation is at or near reference standard condition in structural proportions. No structural indicators of degradation evident. | Vegetation is moderately altered from reference standard condition in structural proportions. Several structural indicators of degradation evident. | Vegetation is greatly altered from reference condition in structural proportions. Many structural indicators of degradation evident. | Vegetation is greatly altered from reference condition in structural proportions. Many structural indicators of degradation evident. |

**Data**: N/A

**Scaling Rationale:** This metric has been scaled based on scientific judgment of NatureServe's Ecological Integrity Assessment Working Group and, for forested wetlands, from work by Schafale (2005). The metric is scaled based on the similarity between the observed vegetation structure and what is expected based on reference condition. Reference conditions reflect the accumulated experience of field ecologists, studies from sites where natural processes are intact, regional surveys and historic sources (Collins et al. 2006).

Assessing structure is more challenging in herbaceous wetlands, e.g., aquatic freshwater vegetation can have multiple layers, freshwater marshes can have high, medium, or low structure, not just dense, tall layer. And there are some very structurally simple natural types, such as the Everglades sawgrass types, freshwater bulrush marshes. In peatlands in the western U.S., some woody species (e.g., *Spiraea douglasii*, *Myrica gale*, *Pinus contorta*) often expand rapidly in degraded peatlands (hydrologic change, nutrient loading, fire suppression) (J. Christy pers. comm. 2008).

**Confidence that reasonable logic and/or data support the index:** Medium

## Organic Matter Accumulation

**Definition:** An assessment of the overall organic matter accumulation, whether both fine and coarse litter (non-forested wetlands) or coarse woody debris and snags (primarily forested wetlands)

**Background:** This metric is adapted from the CRAM manual (Collins et al. 2006) by the NatureServe Ecological Integrity Assessment Working Group.

**Metric Type**: Condition

**Tier:** 2 (rapid field measure)

**Rationale for Selection of the Variable:** See Collins et al. (2006).
The accumulation of organic material and an intact litter layers are integral to a variety of wetland functions, such as surface water storage, percolation and recharge, nutrient cycling, and support of wetland plants. Intact litter layers provide areas for primary production and decomposition that are important to maintaining functioning food chains. They nurture fungi essential to the growth of rooted wetland plants. They support soil microbes and other detritivores that comprise the base of the food web in many wetlands. The abundance of organic debris and coarse litter on the substrate surface can significantly influence overall species diversity and food web structure. Fallen debris serves as cover for macroinvertebrates, amphibians, rodents, and even small birds. Litter is the precursor to detritus, which is

a dominant source of energy for most wetland ecosystems. However, organic matter accumulation can be a problem in vernal pools and playas because it encourages biological invasions and can lead to deleterious algal blooms.

**Measurement Protocol:** This metric consists of evaluating the organic matter accumulation  The protocol is an evaluation of variation in overall organic matter size and number of standing snags, downed logs, and their decay, or amount of fine litter accumulation, including litter layers, duff layers, and leaf piles in pools. A field form should be used that describes the organic matter accumulation. Collins et al (2006) recommend that for estuarine habitats (salt marsh and mangrove) the metric should be assessed in areas that would typically support sedimentation of fine-grained, organic-rich substrates, such as back bays, off-channel basins, or on the surface of the main salt marsh plain. Areas that are hydro-dynamically active, including tidal channels or areas near the inlet to water, should not be used to evaluate this metric.

Field survey method for estimating organic matter accumulation may be either a (1) Site Survey (semi-quantitative) method where the observers walks the entire occurrence, or assessment area within the occurrence, and make notes on organic matter accumulation, or (2) Quantitative Plot Data, where a fixed area is surveyed, using either plots or transects. The plot or transect is typically a “rapid” plot, but a single intensive plot can also be taken. See Appendix X.2.

Coarse woody debris methods have been outlined by Brown (1974. [James K. Brown. 1974. Handbook for inventorying downed woody material. of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 24 p.] They may be more appropriate for a Tier 3 metric, including multiple data collection points and a repeatable methodology.

**Metric Rating**: Specify the narrative and numerical ratings for the metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| **Organic Matter Accumulation** | **Measure** | **(Metric)** | **Rating** | |
|---|---|---|---|---|
| | **Excellent** | **Good** | **Fair** | **Poor** |
| *Floodplain & Swamp Forest, Mangrove* | | A wide size-class diversity of downed coarse woody debris (logs) and standing snags, with 5 – 9 or more logs and snags exceeding 30 cm dbh and 2 m in length, and logs in various stages of decay. [An Excellent rating could be based on: with > 10 logs and snags exceeding 30 cm dbh and 2 m in length]. | A moderately wide size-class diversity of downed coarse woody debris (logs) and standing snags, with 1-4 logs and snags exceeding 30 cm dbh and 2 m in length, and logs in various stages of decay. | A low size-class diversity of downed coarse woody debris (logs) and standing snags, with logs and snags absent to rarely exceeding 30 cm dbh and 2 m in length, and logs in mostly early stages of decay (if present). |
| *Bog& Fen* | | The site is characterized by an accumulation of peaty, hummocky, organic matter. There is some matter of various sizes, some very old. | The site is characterized by some areas lacking an accumulation of peaty hummocky, organic matter. Size of materials does not vary greatly, nor do any appear old. | The site is characterized by large areas without peaty, hummocky organic matter (e.g., peat mining). Size of materials does not vary greatly, nor do any appear old. |

| Organic Matter Accumulation | Measure | (Metric) | Rating | |
|---|---|---|---|---|
| | **Excellent** | **Good** | **Fair** | **Poor** |
| *Freshwater Marsh, Salt Marsh, and Aquatic Vegetation* | | The site is characterized by a moderate amount of fine organic matter. There is some matter of various sizes, but new materials seem much more prevalent than old materials. Litter layers, duff layers, and leaf piles in pools or topographic lows are thin. In North American Pacific Salt Marsh, with 5-9 or more logs and snags exceeding 30 cm dbh and 2 m in length, and logs in various stages of decay. [An Excellent rating could be established using: > 10 logs and snags exceeding 30 cm dbh and 2 m in length.] | The site is characterized by occasional small amounts of coarse organic debris, such as leaf litter or thatch, with only traces of fine debris, and with little evidence of organic matter recruitment, or somewhat excessive littler. In North American Pacific Salt Marsh, with 1-4 logs and snags exceeding 30 cm dbh and 2 m in length, and logs in various stages of decay. | The site contains essentially no significant amounts of coarse plant debris, and only scant amounts of fine debris. OR too much debris. In North American Pacific Salt Marsh, with logs and snags absent to rarely exceeding 30 cm dbh and 2 m in length, and logs in mostly early stages of decay |

**Data**: Salt marshes include both brackish / deltaic and marine. Some wetlands don't have organic matter. The time of year that a salt marsh is visited affects how much fine debris may be found. Coastal plain ponds depend on fire and herbaceous ground cover. The California vernal pool option from CRAM was eliminated, as it is too fine a level for a national assessment, but it could be used at a System or Macrogroup level.

Ratings for number of logs in North American Pacific Salt Marshes are adapted from Adamus (2006: Appendix A, code 33). They may not be appropriate North American Atlantic Salt Marsh.

In cypress ponds the accumulated organic matter is occasionally reduced by wildland fire, which is followed by an increase of herbaceous cover. Perhaps this metric is best applied to appropriate wetlands at the new IVC and NVC "Group" level. More detailed information and reviews could provide guidance for the application of this metric to different new hierarchy groups (C. Nordman pers. comm. 2007).

**Scaling Rationale:** Revised from Collins et al. (2006), with input from Adamus (2006).
The metric is scaled based on the similarity between the observed organic matter accumulation and what is expected based on reference condition. Reference conditions reflect the accumulated experience of field ecologists, studies from sites where natural processes are intact, regional surveys and historic sources (Collins et al. 2006).

Salt marshes include both brackish / deltaic and marine. Some wetlands don't have organic matter. The time of year that a salt marsh is visited affects how much fine debris may be found. Coastal plain ponds depend on fire and herbaceous ground cover. The California vernal pool option from CRAM was eliminated, as it is too fine a level for a national assessment, but it could be used at a System or Macrogroup level. Ratings for number of logs in Pacific salt marshes is adapted from Adamus (2006: Appendix A, code 33).

**Confidence that reasonable logic and/or data support the index:** Medium

## Vegetation Composition

**Definition**: An assessment of the overall species composition and diversity, including by layer, and evidence of specific species diseases or mortality.

**Background**: This metric has been drafted by NatureServe's Ecological Integrity Assessment Working Group (2008).

**Metric Type**: Condition

**Tier:** 2 (rapid field measure)

**Rationale for Selection of the Variable**: Trees, shrubs, herbs, and alga play an important role in providing wildlife habitat, and they are the most readily surveyed aspect of wetland biodiversity. Vegetation is also the single, largest component of net primary productivity. The functions of wetland systems are optimized when a rich native flora dominates the plant community, and when the botanical structure of the wetland is complex due to species diversity and recruitment, and resulting in suitable habitat for multiple animal species. Much of the natural microbial, invertebrate, and vertebrate communities of wetlands are adjusted to the architectural forms, phenologies, detrital materials, and chemistry of the native vegetation. Furthermore, the physical form of wetlands is partly the result of interactions between plants and physical processes, especially hydrology. A sudden change in plant-community dominance, such as that which results from plant invasions, can have cascading effects on system form, structure, and function (Collins et al. 2006).

**Measurement Protocol**: This metric consists of evaluating the species composition of the vegetation. The protocol is an ocular evaluation of variation in overall composition. These metrics require the ability to recognize the major-dominant aquatic, wetland, and riparian plants species of each layer or stratum. The required level of botanical expertise to assess a wetland based on these metrics is about the same as what is required to conduct a legal jurisdictional delineation of a wetland. When a field team lacks the necessary botanical expertise, voucher specimens will need to be collected using standard plant presses and site documentation. This can greatly increase the time required to complete an assessment.

A field form should be used that describes composition using either strata or growth forms (Jennings et al. 2008). For the strata method, list all major strata - tree, shrub, field, non-vascular, floating, submerged – then estimate strata cover and cover of dominant (>5% cover), characteristic, and exotic species. For the growth form approach, list major growth forms - tree (subdivided into overstory and regeneration), shrub (subdivided by tall, and medium/low), herb, nonvascular, floating, submerged, epiphyte, and liana – then estimate strata cover and cover of dominant (>5%), characteristic, and exotic species.

Field survey method for estimating structure may be either a (1) Site Survey (semi-quantitative) method where the observers walks the entire occurrence, or assessment area within the occurrence, and make notes on vegetation strata, their cover, and exotic species. (2) Quantitative Plot Data, where a fixed area is surveyed, using either plots or transects. The plot or transect is typically a "rapid" plot, but a single intensive plot can also be taken. See Appendix X.2.

**Metric Rating**: Specify the narrative and numerical ratings for the metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| Vegetation Composition | Measure | (Metric) | Rating | |
|---|---|---|---|---|
| | **Excellent** | **Good** | **Fair** | **Poor** |
| | Vegetation is at or near reference standard condition in species present and their proportions. Lower strata composed of appropriate species, and regeneration good. Native species sensitive to anthropogenic degradation are present, functional groups indicative of anthropogenic disturbance (ruderal or "weedy" species) are absent to minor, and full range of diagnostic / indicator species are present. | Vegetation is close to reference standard condition in species present and their proportions. Upper or lower strata may be composed of some native species reflective of past anthropogenic degradation (ruderal or "weedy" species). Some indicator/diagnostic species may be absent. | Vegetation is different from reference standard condition in species diversity or proportions, but still largely composed of native species characteristic of the type. This may include ruderal ("weedy") species. Regeneration of expected native trees may be sparse. Many indicator/diagnostic species may be absent. | Vegetation severely altered from reference standard in composition. Expected strata are absent or dominated by ruderal ("weedy") species, or comprised of planted stands of non-characteristic species, or unnaturally dominated by a single species. Regeneration of expected native trees minimal or absent. Most or all indicator/diagnostic species are absent. |

**Data**: In progress

**Scaling Rationale:** The metric is scaled based on the similarity between the dominant species composition of the vegetation and what is expected based on reference condition. Reference conditions reflect the accumulated experience of field ecologists, studies from sites where natural processes are intact, regional surveys and historic sources (Collins et al. 2006.

**Confidence that reasonable logic and/or data support the index:** Medium/High

## Relative Total Cover of Native Plant Species

**Definition:** A measure of the relative percent cover of all plant species that are native to the region. Typically calculated by estimating total absolute cover of all vegetation, subtracting total exotic species cover, and expressing the total native species cover as a percentage of the total vegetative cover.

**Background:** This metric has been developed by the NatureServe's Ecological Integrity Assessment Working Group, building on a variety of related metrics that assess relative species richness of exotic species (Miller et al. 2006).

**Metric Type**: Condition

**Tier:** 2 (rapid field measure)

**Rationale for Selection of the Variable:** Native species dominate this system when it has excellent ecological integrity. This metric is a measure of the degree to which native plant communities have been altered by human disturbance. With increasing human disturbance, non-native species invade and can dominate the wetland.

**Measurement Protocol:**
This metric consists of evaluating the exotic and native species composition of the vegetation. The protocol is an ocular evaluation of exotic species cover. A field form should be used that describes exotic

species composition using either strata or growth forms (Jennings et al. 2008). For the strata method, list all major strata - tree, shrub, field, non-vascular, floating, submerged – then estimate strata cover and cover of exotic species. For the growth form approach, list major growth forms - tree (subdivided into overstory and regeneration), shrub (subdivided by tall, and medium/low), herb, nonvascular, floating, submerged, epiphyte, and liana – then estimate strata cover and cover of exotic species.

Field survey method for estimating structure may be either a (1) Site Survey (semi-quantitative) method where the observers walks the entire occurrence, or assessment area within the occurrence, and make notes on vegetation strata, its cover and the cover of exotics. (2) Quantitative Plot Data, where a fixed area is surveyed, using either plots or transects. The plot or transect is typically a "rapid" plot, but a single intensive plot can also be taken. See Appendix X.2.

The metric is calculated by first estimating the total cover of the vegetation, [preferably by layer – tree, shrub, herb, and non-vascular- thus the total could easily exceed 100%], then estimating the total cover of the exotic species, by layer, subtracting the total exotic species cover from the total species cover to get the percent native species cover, then dividing the native cover by the total and multiplying by 100.

**Metric Rating**: Specify the narrative and numerical ratings for a metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| | | Metric | Rating | | |
|---|---|---|---|---|---|
| | **Excellent** | **Good** | **Fair** | **Poor** | **Very Poor** |
| *All wetlands* | >99% relative cover of native plant species. | 95-99% relative cover of native plant species. | 80-94% relative cover of native plant species. | 50-79% relative cover of native plant species. | <50% relative cover of native plant species. |

**Data**: N/A

**Scaling Rationale:** The criteria are based on extrapolated thresholds from ecological site descriptions from NRCS (2005), Cooper (1990), Windell et al. (1996), CNHP (2005), and best scientific judgment. These criteria need further validation. Scaling of this metric using exotic species richness rather than cover is an alternative approach (Miller et al. 2006).

**Confidence that reasonable logic and/or data support the index:** High

## Invasive Exotic Plant Species

**Definition:** The percent cover of a selected set of exotic species that are considered invasive.

**Background:** This metric has been drafted by NatureServe's Ecological Integrity Assessment Working Group, based in part on work by Tierney et al. 2008) and Miller et al. (2006).

**Metric Type**: Stressor

**Tier:** 2 (rapid field measure)

**Rationale for Selection of the Variable:** As viable populations of invasive plants become established in novel habitats, they inflict a suite of ecological damage to native species including loss of habitat, loss of biodiversity, decreased nutrition for herbivores, competitive dominance, overgrowth, struggling, and shading, resource depletion, alteration of biomass, energy cycling, productivity, and nutrient cycling (Dukes and Mooney 1999). Invasive plant species can also affect hydrologic function and balance, making water scarce for native species.

Wetland invasive plant species in the United States presently include, but are not limited to the following:
Northeast: purple loosestrife (*Lythrum salicaria*), reed canary grass (*Phalaris arundinacea*), Japanese knotweed (*Polygonum cuspidatum*), water chestnut (*Trapa natans*), flowering rush (*Butomus umbellatus*), yellow iris (*Iris pseudacorus*), Chinese tallow tree (*Triadica sebifera*), Chinese privet (*Ligustrum sinense*), and exotic biotype of giant reed (*Phragmites australis*). Narrow cattail (*Typha angustifolia* and *T. latifolia × angustifolia* hybrid) is also an increasing problem.
Southeast: water hyacinth (*Eichhornia crassipes*)
Midwest: reed canary grass (*Phalaris arundinacea*), purple loosestrife (*Lythrum salicaria*)
West: reed canary grass (*Phalaris arundinacea*), purple loosestrife (*Lythrum salicaria*), parrotfeather (*Myriophyllum aquaticum*), cordgrass (*Spartina alterniflora, S. anglica, S. densiflora, S. patens*), hydrilla (*Hydrilla verticillata*), Brazilian waterweed (*Egeria densa*), Eurasian water-milfoil (*Myriophyllum spicatum*).

These species can cause a substantial management effort to control and reduce wetland condition. Invasive plants significantly alter species composition and diversity and often form monotypic stands.

**Measurement Protocol:** This metric consists of evaluating the exotic and native species composition of the vegetation. The protocol is an ocular evaluation of exotic species cover. A field form should be used that describes exotic species composition using either strata or growth forms (Jennings et al. 2008). For the strata method, list all major strata - tree, shrub, field, non-vascular, floating, submerged – then estimate strata cover and cover of exotic species. For the growth form approach, list major growth forms - tree (subdivided into overstory and regeneration), shrub (subdivided by tall, and medium/low), herb, nonvascular, floating, submerged, epiphyte, and liana – then estimate strata cover and cover of exotic species.

Field survey method for estimating structure may be either a (1) Site Survey (semi-quantitative) method where the observers walks the entire occurrence, or assessment area within the occurrence, and make notes on vegetation strata, its cover and the cover of exotics. (2) Quantitative Plot Data, where a fixed area is surveyed, using either plots or transects. The plot or transect is typically a "rapid" plot, but a single intensive plot can also be taken. See Appendix X.2.

**Metric Rating**: Specify the narrative and numerical ratings for a metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| Metric Rating | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| No key invasive exotic species present in area. | Total abundance of key invasive exotic species less than 3%. | Total abundance of key invasive exotic species 3-5% | Total abundance of key invasive exotic species greater than 5% |

**Data**: NatureServe (2006)
NatureServe. 2006. International Ecological Classification Standard: Terrestrial Ecological Classifications. Classification and Integrity Indicators for Selected Forest Types of Office Depot's Sourcing Areas of the Southeastern United States. NatureServe Central Databases. Arlington, VA. Data current as of 29 March 2006.

**Scaling Rationale:** In progress

**Confidence that reasonable logic and/or data support the index:** Medium/High

## ▪ D. Hydrology Metrics

### Water Source

**Definition:** An assessment of the extent, duration, and frequency of saturated or ponded conditions within a wetland, as affected by the kinds of direct inputs of water into, or any diversions of water away from, the wetland.

**Background:** Water Sources encompass the forms, or places, of direct inputs of water to the AA as well as any unnatural diversions of water from the AA. Diversions are considered a water source because they affect the ability of the AA to function as a source of water for other habitats while also directly affecting the hydrology of the AA. Metric is taken from Collins et al. (2006).

"A water source is direct if it supplies water mainly to the AA, rather than to areas through which the water must flow to reach the AA. Natural, direct sources include rainfall, ground water discharge, and flooding of the AA due to high tides or naturally high riverine flows. Examples of unnatural, direct sources include stormdrains that empty directly into the AA or into an immediately adjacent area. For seeps and springs that occur at the toe of an earthen dam, the reservoir behind the dam is an unnatural, direct water source. Indirect sources that should not be considered in this metric include large regional dams or urban storm drain systems that do not drain directly into the AA but that have systemic, ubiquitous effects on broad geographic areas of which the AA is a small part. For example, the salinity regime of an estuarine wetland near Napa is affected by dams in the Sierra Nevada, but these effects are not direct. But the same wetland is directly affected by the nearby discharge from the Napa sewage treatment facility. Engineered hydrological controls, such as tide gates, weirs, flashboards, grade control structures, check dams, etc., cans serve to demarcate the boundary of an AA (see Section 3.5), but they are not considered water sources."

**Metric Type**: Condition

**Tier:** 2 (rapid field measure)

**Rationale for Selection of the Variable:** See Collins et al. (2006).
"Wetlands, by definition, depend on constant or recurrent, shallow inundation or saturation at or near the surface of the substrate (National Research Council 2001). Consistent, natural inflows of water to a wetland are important to their ability to perform and maintain most of their intrinsic ecological, hydrological, and societal functions. The flow of water into a wetland also affects sediment processes and the physical structure/geometry of the wetland. Sudol and Ambrose (2002) found that one of the greatest causes of failed wetland mitigation or restoration projects is inadequate, or inappropriate hydrology. "

**Measurement Protocol:** See Collins et al. (2006).
"The assessment of this metric is the same for all wetland classes. It is assessed initially in the office using the site imaging, and then revised based on the field visit. For all wetlands, including fringe habitat for estuaries and lagoons, this metric focuses on *direct* sources of non-tidal water as defined above (see Figure 4.1). The natural sources will tend to be more obvious than the unnatural sources. Evaluation of this metric should therefore emphasize the identification of the unnatural sources or diversions that directly affect the AA. Permanent or semi-permanent features that affect water source at the overall watershed or regional level should not be considered in the evaluation of this metric.

The office work should initially focus on the immediate margin of the AA and its wetland, and then expand in focus to include the smallest watershed or storm drain system that directly contributes to the AA or its immediate environment, such as another part of the same wetland or adjacent reach of the same riverine or riparian system. Landscape indicators of unnatural water sources include adjacent intensive development or irrigated agriculture, nearby wastewater treatment plants, and nearby reservoirs (see Table 4.7b). The office work will yield a preliminary assessment based on the schedule of scores provided below. These scores are applicable to all wetland classes.

Estuarine: The water for estuarine wetlands is by definition a combination of marine and riverine (i.e., fluvial) sources. This metric is focused on the non-tidal water sources. To assess water source, the plant species composition of the wetland should be compared to what is expected, in terms of the position of the wetland along the salinity gradient of the estuary, as adjusted for the overall wetness of the water year. In general, altered sources are indicated by vegetation that is either more tolerant or less tolerant than would be expected. If the plant community is unexpectedly salt-tolerant, then an unnatural decrease in freshwater supply is indicated. Conversely, if the community is less salt-tolerant than expected, than an unnatural increase in freshwater is indicated.

Seeps and Springs: Ground water is the source of water for seep, spring, and slope wetlands. It is generally expected that the source is perennial and relatively constant in volume throughout most years. The water source can be assessed, therefore, based on plant indicators of its permanence and consistency. The hydrologic needs of many plant species commonly found in wetlands have been determined (Reed, 1988). A data column indicating whether each of these species is a wetland obligate, facultative, or considered to be restricted to upland habitat, is provided in the plant species table in Appendix 4.

Riverine, Depressional, Lacustrine, Lagoons, and Playas: Natural sources of water for these wetlands include rainfall, groundwater, riverine flows, and (for lagoons) ocean water. Whether the wetlands are perennial or seasonal, alterations in the water sources result in changes in either the high water or low water levels. Such changes can be assessed based on the patterns of plant growth along the wetland margins or across the bottom of the wetlands.

Vernal Pools: The hydrology of vernal pools and pool systems depends mainly on direct rainfall and runoff from the adjacent upland. Sub-surface flows between pools and swales can be subtle, multi-directional, and difficult to assess, but significant during wet years. Interannual variations in water sources can affect the hydrology. The effects of changes in water sources can be assessed according to distribution, abundance, and size of individual pools and pool systems, as well as the pattern of vegetation zonation and interspersion

Table 1. Appropriate landscape positions for each wetland class (Table 4.7b in CRAM manual, from Collins et al. 2006).

| Wetland Type | Natural Landscape Position | Unnatural Landscape Position |
|---|---|---|
| **Riverine Wetlands** | **Along valley bottoms and canyon bottoms with at least seasonal flow.** | **Along unnatural channels (e.g., abandoned paleo-channels, flumes, ditches and canals).** |
| **Slope Wetlands** | **Along the bases or middle reaches of hillslopes or dunes, typically at breaks in the slope, transitions between one slope and another, in landslide topography, or at contacts between geological strata.** | **In flat, "mesa-like" areas or along tops of hills or ridges where water in the dry season must be pumped in order to reach the site.** |
| **All other Freshwater Wetlands** | **Topographic low points in basins, on natural topographic saddles, or on bedrock or other impermeable substrate. The basins may be distinct or diffuse and subtle.** | **At elevations above the topographic low point of a basin, on hillslopes or high ground lacking adequate catchment and runoff such that water in dry season must be pumped in order to reach the site.** |
| **Salt marsh wetlands.** | **At the terminus of watersheds or coastal catchments, in the transition zone between tidal and freshwater areas, at or near sea level.** | **Alkaline or saline marsh developed in artificial impoundments above tidal influence, with salts derived from soils rather than marine-sources.** |

**Metric Rating**: Specify the narrative and numerical ratings for a metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| | Metric Rating | | | |
|---|---|---|---|---|
| | **Excellent** | **Good** | **Fair** | **Poor** |
| *All wetland types* | Water source for site is precipitation, groundwater, tidal, natural runoff from an adjacent freshwater body, or system naturally lacks water in the growing season. There is no indication of direct artificial water sources. Land use in the local drainage area of the site is primarily open space or low density, passive uses. No large point sources discharge into or adjacent to the site. | Water source is mostly natural, but site directly receives occasional or small amounts of inflow from anthropogenic sources. Indications of anthropogenic input include developed land or agricultural land (< 20%) in the immediate drainage area of the site, or the presence of small stormdrains or other local discharges emptying into the site, road runoff, or the presence of scattered homes along the wetland. that probably have septic systems. No large point sources discharge into or adjacent to the site. | Water source is primarily urban runoff, direct irrigation, pumped water, artificially impounded water, or other artificial hydrology. Indications of substantial artificial hydrology include > 20% developed or agricultural land adjacent to the site, and the presence of major point sources that discharge into or adjacent to the site. | Water flow exists but has been substantially diminished by known impoundments or diversions of water or other withdrawals directly from the site, its encompassing wetland, or from areas adjacent to the site or its wetland, OR water source has been several altered) to the point where they no longer support wetland vegetation (e.g., flashy runoff from impervious surfaces). |

**Data**: The poor rating may need further work to apply to the non-arid parts of the East.

**Scaling Rationale:** Metric ratings are taken from Collins et al. (2006)

**Confidence that reasonable logic and/or data support the index:** Medium/High

## Hydroperiod or Channel Stability

**Definition:** An assessment of the characteristic frequency and duration of inundation or saturation of a wetland during a typical year.

**Background:** Metric is taken from Collins et al. (2006), but adapted to include Bog & Fen variant of the metric.

"For tidal wetlands, there are many hydroperiod cycles that correspond to different periodicities in the orbital relationships among the Earth, Moon, and Sun. Other hydro-periodicities for tidal wetlands are semi-daily, daily, semi-weekly, monthly, seasonal, and annual. Depressional, lacustrine, and riverine wetlands typically have daily cycles that are governed by diurnal increases in evapotranspiration and seasonal cycles that are governed by wet season rainfall and runoff, and dry season consumption. Seep and spring wetlands that depend on groundwater may have relatively slight seasonal variations in hydroperiod. Lagoons and lacustrine systems have similar hydroperiods, except that lagoons can be episodically subjected to tidal inundation.

The concept of channel stability only pertains to riverine wetlands. It refers to the degree to which a riverine channel is either aggrading (i.e., there is a net and chronic accumulation of sediment on the channel bed such that it is rising over time), or degrading (i.e., there is a net and chronic loss of sediment from the bed such that it is being lowered over time). There is much interest in channel entrenchment (i.e., the inability of flows in a channel to exceed the channel banks) and this is addressed in the Hydrologic Connectivity metric."

**Metric Type**: Condition

**Tier:** 2 (rapid field measure)

**Rationale for Selection of the Variable:** See Collins et al. (2006). A basic understanding of the natural hydrology or channel dynamics of the type wetland being evaluated is needed to apply this metric. For instance high gradient riparian areas in mountainous areas have very different dynamics from those in flat coastal plains, especially in terms of aggradation or degradation.

"For all wetlands except riverine wetlands, hydroperiod is the dominant aspect of hydrology. The pattern and balance of inflows and outflows is a major determinant of wetland functions Mitch and Gosselink (1993). The patterns of import, storage, and export of sediment and other water-borne materials are functions of the hydroperiod. In most wetlands, plant recruitment and maintenance are dependent on hydroperiod. The interactions of hydroperiod and topography are major determinants of the distribution and abundance of native wetland plants and animals. Natural hydroperiods are key attributes of successful wetland projects (National Academy of Sciences 2001).

For riverine systems, the patterns of increasing and decreasing flows that are associated with storms, releases of water from dams, seasonal variations in rainfall, or longer term trends in peak flow, base flow, and average flow are more important that hydroperiod. The patterns of flow, in conjunction with the kinds and amounts of sediment with which the flow interacts, largely determine the form of riverine systems, including their floodplains, and thus also control their ecological functions. Under natural conditions, the opposing tendencies for sediment to stop moving and for flow to move the sediment tend toward a dynamic equilibrium, such that the form of the channel that contains the sediment and the flow remains relatively constant over time (Leopold 1994). Large and persistent changes in either the flow regime or the sediment regime tend to destabilize the channel and cause it to change form. Such regime changes are associated with upstream land use changes, alterations of the drainage network of which the channel of interest is a part, and climatic changes. A riverine channel is an almost infinitely adjustable complex of interrelations between flow, width, depth, bed resistance, sediment transport, and riparian vegetation. Change in any one will be countered by adjustments in the others. The degree of channel stability can be assessed based on field indicators."

**Measurement Protocol:** See Collins et al. (2006).
This metric evaluates recent changes in the hydroperiod, flow regime, or sediment regime of a wetland and the degree to which these changes affect the structure and composition of the wetland plant community or, in the case of riverine wetlands, the stability of the riverine channel. Common indicators are presented for the different wetland classes. This metric focuses on changes that have occurred in the last 2-3 years.

<u>Riverine:</u> See Collins et al. (2006).
"Every stable riverine channel tends to have a particular form in cross section, profile, and plan view that is in dynamic equilibrium with the inputs of water and sediment. If these supplies change enough, the channel will tend to adjust toward a new equilibrium form. For example, an increase in the supply of sediment, relative to the supply of water, can cause a channel to aggrade (i.e., the elevation of the channel bed increases), which might cause simple increases in the duration of inundation for existing wetlands, or complex changes in channel location and morphology through braiding, avulsion, burial of wetlands, creation of new wetlands, spray and fan development, etc. An increase in water relative to sediment might cause a channel to incise (i.e., the bed elevation decreases), leading to bank erosion, headward erosion of the channel bed, floodplain abandonment, and dewatering of riparian habitats. For most riverine systems, chronic incision (i.e., bed degradation) is generally regarded as more deleterious than aggradation because it is more likely to cause significant decreases in the extent of riverine wetland and riparian habitats (Kondolf *et al.* 1996). There are many well-known field indicators of equilibrium conditions, or deviations from equilibrium, that can be used to assess the existing mode of behavior of a channel and hence the degree to which its hydroperiod can sustain wetland and riparian habitats."

"To score this metric, visually survey the AA for field indicators of aggradation or degradation (listed in Table 4.8). After reviewing the entire AA and comparing the conditions to those described in the table, determine whether the AA is in equilibrium, aggrading, or degrading, then assign a rating score using the alternative state descriptions in Table 4.9"

Table 1a. Suggested field indicators for evaluating Hydroperiod Metric for riverine Wetlands (from CRAM manual, Table 4.8, Collins et. al. 2006).

| Condition | Field Indicators |
|---|---|
| **Indicators of Channel Equilibrium** | - The channel (or multiple channels in braided systems) has a well-defined usual high water line, or bankfull stage that is clearly indicated by an obvious floodplain, topographic bench that represents an abrupt change in the cross-sectional profile of the channel throughout most of the site.<br>- The usual high water line or bank full stage corresponds to the lower limit of riparian vascular vegetation.<br>- Leaf litter, thatch, wrack, and/or mosses exist in most pools.<br>- The channel contains embedded woody debris of the size and amount consistent with what is available in the riparian area.<br>- There is little or no active undercutting or burial of riparian vegetation.<br>- There is little evidence of recent deposition of cobble or very coarse gravel on the floodplain, although recent sandy deposits may be evident.<br>- There are no densely vegetated mid-channel bars and/or point bars.<br>- The spacing between pools in the channel tends to be 5-7 channel widths.<br>- The larger bed material supports abundant periphyton. |
| **Indicators of Active Degradation** | - The channel through the site is characterized by deeply undercut banks with exposed living roots of trees or shrubs. There are abundant bank slides or slumps, or the banks are uniformly scoured and unvegetated.<br>- Riparian vegetation may be declining in stature or vigor, and/or riparian trees and shrubs may be falling into the channel.<br>- Abundant organic debris has accumulated on what seems to be the historical floodplain.<br>- The channel bed appears scoured to bedrock or dense clay.<br>- The channel bed lacks any fine-grained sediment.<br>- Recently active flow pathways appear to have coalesced into one channel (i.e. a previously braided system is no longer braided).<br>- There are one or more nick points along the channel, indicating headward erosion of the channel bed. |
| **Indicators of Active Aggradation** | - The channel through the site lacks a well-defined usual high water line.<br>- There is an active floodplain with fresh splays of sediment covering older soils or recent vegetation.<br>- There are partially buried tree trunks or shrubs.<br>- Cobbles and/or coarse gravels have recently been deposited on the floodplain.<br>- There is a lack of in-channel pools, their spacing is greater than 5-7 channel widths, or many pools seem to be filling with sediment.<br>- There are partially buried, or sediment-choked, culverts.<br>- Transitional or upland vegetation is encroaching into the channel throughout most of the site.<br>- The bed material is loose and mostly devoid of periphyton. |

Table 1b. Alternative ORAM Checklist (adapted from Mack 2001, Metric 3e)

**The Rater may check one or several of these possible disturbances, yet still determine that the natural hydrologic regime is intact. Check all that are observed present in or near the wetland.**

**Ditch(es), in or near the wetland point source discharges to the (non-stormwater)**
**Tile(s), in or near the wetland filling/grading activities in or near the wetland**
**Dike(s), in or near the wetland road beds/RR beds in or near the wetland**
**Weir(s), in or near the wetland dredging activities in or near the wetland**
**Stormwater inputs (addition of water) other (specify)**

**Have any of the disturbances identified above caused or appear to have caused more than trivial alterations to the wetland's natural hydrologic regime, or have they occurred so far in the past that current hydrology should be considered to be "natural."?**

**Select a rating:**
**A (EXCELLENT) There are no modifications or no modifications that are apparent to the rater.**
**B (GOOD). The wetland appears to have recovered from past modifications.**
**C. (FAIR). The wetland appears to be in the process of recovering from past modifications.**
**D. (POOR). The modifications have occurred recently occurred, and/or the wetland has not recovered from past modifications, and/or the modifications are ongoing.**

Depressional, Lacustrine, Playas, Seeps and Springs: See Collins et al. (2006).
"Assessment of the hydroperiod for these kinds of wetlands should be initiated with an office-based review of diversions or augmentations of flows to the wetland. Field indicators for altered hydroperiod include pumps, spring boxes, ditches, hoses and pipes, encroachment of terrestrial vegetation, excessive exotic vegetation along the perimeter of the wetland, and desiccation during periods of the year when comparable wetlands are typically inundated or saturated (Table 4.10). "

Table 4.10: See Collins et al. (2006). Field Indicators of Altered Hydroperiod for Depressional, Lacustrine, Playas, Seeps and Spring Wetlands, and Vernal Pools and Pool Systems.

***Direct Engineering Evidence Indirect Ecological Evidence***

*Reduced Extent and Duration of Inundation or Saturation*
Upstream spring boxes, diversions, impoundments, pumps, ditching or draining from the wetland
Evidence of aquatic wildlife mortality
Encroachment of terrestrial vegetation
Stress or mortality of hydrophytes
Compressed or reduced plant zonation

*Increased Extent and Duration of Inundation or Saturation*
Berms, dikes, or other water control features that increase duration of ponding: pumps, diversions, ditching or draining into the wetland.
Late-season vitality of annual vegetation
Recently drowned riparian or terrestrial vegetation
Extensive fine-grain deposits on the wetland margins

Lagoon: See Collins et al. (2006).
"The hydroperiod of a natural lagoon can be highly variable due to interannual variations in freshwater inputs and occasional breaching of the tidal barrier. For the purposes of CRAM, the wetland fringe of a "lagoon" that is breached and experiencing significant tidal action is classified as either estuarine (if it is significantly affected by fluvial inputs), or marine (if it lacks significant fluvial inputs). Here we assume that the wetlands of interest are in fact associated with a lagoon, meaning an impoundment of freshwater

with marine or estuarine influences being mostly restricted to wind-driven over-wash across the tidal barrier, aeolian deposition of salts, seepage of saline water through the tidal barrier, etc. The Hydroperiod Metric for lagoon wetlands therefore focuses on freshwater influences and the evidence of the dynamic nature of lagoon hydroperiods.

Alteration of the hydroperiod can be inferred from atypical wetting and drying patterns along the shoreline (e.g., a preponderance of shrink-swell cracks or dried pannes in inappropriate locations within the lagoon and/or that do not occur in similar, un-impacted lagoons). Inadequate tidal flushing, or, in arid systems, excessive freshwater input during the dry season may be indicated by algal blooms or by encroachment of freshwater vegetation. Dikes, levees, ponds, ditches, and tidecontrol structures are indicators of an altered hydroperiod resulting from management for flood control, salt production, waterfowl hunting, boating, etc. "

Estuarine: See Collins et al. (2006).
"The volume of water that flows into and from an estuarine wetland due to the changing stage of the tide is termed the "tidal prism". This volume of water consists of inputs from both tidal (i.e., marine) and non-tidal (e.g., fluvial or upland) sources. The timing, duration, and frequency of inundation of the wetland by these waters is termed the tidal hydroperiod. Under natural conditions, increases in tidal prism result in increases in sedimentation, such that increases in hydroperiod do not persist. For example, estuarine marshes tend to build upward in quasi-equilibrium with sea level rise. A decrease in tidal prism usually results in a decrease in hydroperiod. A change in the hydroperiod of an estuarine wetland (i.e., a change in the tidal prism) can be inferred based on changes in the relative abundance of plants indicative of either high or low marsh. A preponderance of shrink cracks or dried pannes is indicative of decreased hydroperiod. In addition, inadequate tidal flushing may be indicated by algal blooms or by encroachment of freshwater vegetation. Dikes, levees, ponds, or ditches are indicators of an altered hydroperiod resulting from management for flood control, salt production, waterfowl hunting, etc. Table 4.13 provides narratives for rating Hydroperiod for estuaries."

**Metric Rating**: Specify the narrative and numerical ratings for a metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| | Excellent | Good | Fair | Poor |
|---|---|---|---|---|
| *All Non-riverine freshwater wetlands, except Bog & Fen)* | Hydroperiod of the site is characterized by natural patterns of filling or inundation and drying or drawdown. | The filling or inundation patterns in the site are of **greater** magnitude (and greater or lesser duration than would be expected under natural conditions, but thereafter, the site is subject to **natural drawdown or drying.** | The filling or inundation patterns in the site are characterized by **natural** conditions, but thereafter are subject to **more rapid or extreme drawdown or drying**, as compared to more natural wetlands.<br>OR<br>The filling or inundation patterns in the site are of substantially **lower magnitude or duration** than would be expected under natural conditions, but thereafter, the site is subject to **natural drawdown or drying.** | Both the filling/inundation and drawdown/drying of the site deviate from natural conditions (either increased or decreased in magnitude and/or duration). |
| *Bog & Fen (non-riverine)* | Hydroperiod of the site is characterized by stable, saturated hydrology, or by naturally damped cycles of saturation and partial drying. | Hydroperiod of the site experiences minor altered inflows or drawdown/drying, as compared to more natural wetlands (e.g., ditching). | Hydroperiod of the site is somewhat altered by greater increased inflow from runoff, or experiences moderate drawdown or drying, as compared to more natural wetlands (e.g., ditching). | Hydroperiod of the site is greatly altered by greater increased inflow from runoff, or experiences large drawdown or drying, as compared to more natural wetlands (e.g., ditching). |
| *Riverine* | Most of the channel through the site is characterized by equilibrium conditions, with no evidence of severe aggradation or degradation (based on the field indicators listed in Table 4.8). | Most of the channel through the site is characterized by some aggradation or degradation, none of which is severe, and the channel seems to be approaching an equilibrium form (based on the field indicators listed in Table 4.8). | There is evidence of severe aggradation or degradation of most of the channel through the site (based on the field indicators listed in Table 4.8) | D: Concrete, or otherwise artificially hardened, channels through most of the site (based on the field indicators listed in Table 4.8). |
| *Salt Marsh, Mangrove* | Area is subject to the full tidal prism, with two daily tidal minima and maxima. <u>Lagoons:</u> Area subject to natural interannual tidal fluctuations (range may be severely muted or vary seasonally), and is episodically fully tidal by natural breaching due to either fluvial flooding or storm surge. | Area is subject to reduced, or muted, tidal prism, although two daily minima and maxima are observed. <u>Lagoons</u>: Area is subject to full tidal range more often than would be expected under natural circumstances, because of artificial breaching of the tidal barrier. | Area is subject to muted tidal prism, with tidal fluctuations evident only in relation to extreme daily highs or spring tides. <u>Lagoons:</u> Area is subject to full tidal range less often than would be expected under natural circumstances due to management of the breach to prevent its opening. | Area is subject to muted tidal prism, plus there is inadequate drainage, such that the marsh plain tends to remain flooded during low tide. <u>Lagoons</u>: Area probably has no episodes of full tidal exchange |

**Data:** N/A

**Scaling Rationale:** Metric ratings are taken from Collins et al. (2006), except for Bog & Fen, which were drafted by the NatureServe Ecological Integrity Assessment Working Group.

**Confidence that reasonable logic and/or data support the index:** Medium/High

## Hydrologic Connectivity

**Definition:** An assessment of the ability of the water to flow into or out of the wetland, or to inundate adjacent areas.

**Background:** Metric is taken from Collins et al. (2006, CRAM manual 4.0, but cf 4.2.3.). A salt marsh, mangrove, and Bog & Fen variant of the metric was added.

**Metric Type**: Condition

**Tier:** 1 (remote sensing); 2 (rapid field measure)

**Rationale for Selection of the Variable:** See Collins et al. (2006).
"Hydrologic connectivity between wetlands and adjacent uplands supports ecologic function by promoting exchange of water, sediment, nutrients, and organic carbon. Inputs of organic carbon are of great importance to ecosystem function. Litter and allochthonous input from adjacent uplands provides energy that subsidizes the aquatic food web (Roth 1966). Connection with adjacent water bodies promotes the import and export of water-borne materials, including nutrients. Surface and subsurface hydrologic connections, including connections with shallow aquifers and hyporheic zones, influence most wetland functions. Plant and animal communities are affected by these hydrologic connections. Plant diversity tends to be positively correlated with connectivity between wetlands and natural uplands and negatively correlated with increasing inter-wetland distances (Lopez 2002). Diversity of amphibian communities is directly correlated with connectivity between streams and their floodplains (Amoros and Bornette, 2002). Linkages between aquatic and terrestrial habitats allow wetland-dependent species to move between habitats to complete life cycle requirements."

The number of junctions in tidal channels (Adamus 2005: 76; 2006: Appendix A, code 54A) provides a measure of the number of branches in typically dendritic networks of channels in tidal marsh, and provides an indication of existing tidal connectivity or potential connectivity at proposed restoration sites. Occurrences are determined by channels visible in 1:24,000 air photos. Time elapsed since restoration of tidal circulation and extent of restoration (Adamus 2005: 54; Adamus 2006) provides a measure of rate and extent of sediment accretion.

**Measurement Protocol:** See Collins et al. (2006).
"Scoring of this metric is based solely on field indicators. No office work is required. This metric pertains only to Riverine, Estuarine, Lagoon, Vernal Pool and Playas and individual Vernal Pools.

<u>Riverine:</u> See Collins et al. (2006).
"For riverine wetlands and riparian habitats, Hydrologic Connectivity is assessed based on the degree of channel entrenchment (Leopold *et al.* 1964; Rosgen 1996; MacDonald and Montgomery 2002). Entrenchment is a field measurement calculated as the flood-prone width divided by the bankfull width. Bankfull width is the channel width at the height of bankfull flow. The flood-prone channel width is measured at the elevation of twice the maximum bankfull depth. The process for estimating entrenchment in outlined below.

Entrenchment varies naturally with channel confinement. Channels in steep canyons naturally tend to be confined, and tend to have small entrenchment ratios indicating less hydrologic connectivity. Assessments of hydrologic connectivity based on entrenchment must therefore be adjusted for channel confinement, according to the following worksheets."

### *Riverine Wetland Entrenchment Ratio Calculation Worksheet*

*Step 1: Identify bankfull contour.* This is a critical step requiring experience. If the stream is entrenched, the height of bankfull flow is identified as a scour line, narrow bench, or the top of active point bars well below the top of apparent channel banks. If the stream is not entrenched, bankfull stage can correspond to the elevation of a broader floodplain with indicative riparian vegetation.

*Step 2: Estimate maximum bankfull depth.* Once the bankfull contour is identified, estimate its height above the nearest point along the channel bottom.

*Step 3: Estimate flood prone height.* Double the estimate of maximum bankfull depth from Step 2, and note the location of the new height on the channel bank.

*Step 4: Estimate flood prone width.* Estimate the width of the channel at the flood prone height.

*Step 5: Calculate entrenchment ratio.* Divide the flood prone width (results of Step 4) by the maximum bankfull depth Result of Step 2)

*Result (enter here and use in Tables 4.14b, c).*

### *Riverine Wetland Confinement Calculation Worksheet*

*Step 1: Estimate bankfull width of AA.* Estimate channel width at bankfull based on the Step 1 of the entrenchment worksheet immediately above.

*Step 2: Estimate effective valley width for AA.* Estimate the maximum distance from the top of either bank to the adjacent land that is at least 10 feet higher than the bank top.

*Step 3: Determine confinement of AA.* Channel is confined if valley width (Step 2) is less than twice bankfull width (Step 1).

**Metric Rating**: Specify the narrative and numerical ratings for a metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| | A | B | C | D |
|---|---|---|---|---|
| **HYDROLOGIC CONNECTIVITY** *All non-riverine wetlands, excluding Bog and other isolated wetlands, Salt Marsh and Mangrove (see below)* | Rising water in the site has unrestricted access to adjacent upland, without levees, excessively high banks, artificial barriers, or other obstructions to the lateral movement of flood flows. | Lateral excursion of rising waters in the site is partially restricted by unnatural features, such as levees or excessively high banks, but less than **50%** of the site is restricted by barriers to drainage. Restrictions may be intermittent along the site, or the restrictions may occur only along one bank or shore. Flood flows may exceed the obstructions, but drainage back to the wetland is incomplete due to impoundment. | Lateral excursion of rising waters in the site is partially restricted by unnatural features, such as levees or excessively high banks, and **50-90%** of the site is restricted by barriers to drainage. Flood flows may exceed the obstructions, but drainage back to the wetland is incomplete due to impoundment. | All water stages in the site are contained within artificial banks, levees, sea walls, or comparable features, or **greater than 90%** of wetland is restricted by barriers to drainage. There is essentially no hydrologic connection to adjacent uplands. |
| *Bog and other isolated wetlands* | | No connectivity | Partial connectivity. (e.g., ditching or where duripan is intentionally broken by drilling or blasting] | Substantial to full connectivity |
| *Salt Marsh* | Average tidal channel sinuosity >4.0; absence of channelization. Marsh receives unimpeded tidal flooding. Total absence of tide gates, flaps, dikes culverts, or human-made channels. | Average tidal channel sinuosity = 2.5 - 3.9. Marsh receives essentially unimpeded tidal flooding, with few tidal channels blocked by dikes or tide gates, and human-made channels are few. Culvert, if present, is of large diameter and does not significantly change tidal flow, as evidenced by similar vegetation on either side of the culvert. | Average tidal channel sinuosity = 1.0 – 2.4. Marsh channels are frequently blocked by dikes or tide gates. Tidal flooding is somewhat impeded by small culvert size, as evidenced in obvious differences in vegetation on either side of the culvert. | Average tidal channel sinuosity <1.0. Tidal channels are extensively blocked by dikes and tide gates; evidence of extensive human channelization. Tidal flooding is totally or almost totally impeded by tidal gates or obstructed culverts. |
| *Mangrove* | Excellent connectivity to other estuarine communities (e.g. marsh-mangrove, lagoon-bay estuaries, freshwater marshes) to ensure wide salinity gradients. Tidal flow is unimpeded. | Good connectivity to other estuarine communities (e.g. marsh-mangrove, lagoon-bay estuaries, freshwater marshes), with minimally reduced salinity gradients. Tidal flow is only minimally impeded by un-natural barriers. | Fair connectivity to other estuarine communities (e.g. marsh-mangrove, lagoon-bay estuaries, freshwater marshes) with moderately reduced salinity gradients. Tidal flow is moderately impeded by un-natural barriers. | Poor connectivity to other estuarine communities (e.g. marsh-mangrove, lagoon-bay estuaries, freshwater marshes) with little gradient in salinity Tidal flow is extensively impeded by un-natural barriers. |
| *Riverine – Unconfined* | Entrenchment ratio is > 4.0. Completely connected to floodplain (backwater sloughs and channels) | Entrenchment ratio is 1.4 – 2.2. Minimally disconnected from floodplain by dikes, tide gates, elevated culverts, etc. | Entrenchment ratio is < 1.4. Moderately disconnected from floodplain by dikes, tide gates, elevated culverts, etc. | Extensively disconnected from floodplain by dikes, tide gates, elevated culverts, etc. |
| *Riverine – Confined* | Entrenchment ratio is > 1.4. | Entrenchment ratio is 1.0 – 1.4. | Entrenchment ratio is < 1.0. | - |

**Data:** N/A

**Scaling Rationale:** Metric ratings are taken from Collins et al. (2006). A salt marsh, mangrove, and Bog & Fen variant of the metric was added, and scaling rationale needed. Number of channel junctions adapted from Adamus (2006: Appendix A, code 54A). Time elapsed since restoration of tidal flooding adapted from Adamus (2006: Appendix A, code 13D). Page: 34

It's tempting to borrow the "wide salinity gradient and connectivity" metric from mangroves. It applies to many estuaries but not lagoons on west coast that may have restricted tidal access in summer and restricted salinity gradients, so can't use unless we make a separate metric for lagoons (J. Christy pers. comm. 2008).

Depressional wetlands often have outlets, so they may not equate to isolated wetlands.

**Confidence that reasonable logic and/or data support the index:** Medium/High

## Upstream Surface Water Retention

**Definition:** A measure of the percentage of the contributing watershed which drains into water storage facilities (e.g., reservoirs, sediment basins, retention ponds, etc.) which are capable of storing surface water from several days to months.

**Background:** This metric is taken from Smith (2000). It addresses hydrologic stressors on riverine associated wetlands.

**Metric Type**: Stressor

**Tier:** 1 (remote-sensing)

**Rationale for Selection of the Variable:** Ecological processes of riparian areas are driven to a large degree by the magnitude and frequency of peak flows and the duration and volume of base flows (Poff et al. 1997). The biotic and physical integrity of riparian areas are dependent on the natural variation associated with these flow characteristics (Gregory et al. 1991, Poff et al. 1997). The amount of water retained in upstream facilities has a direct effect on these flows and subsequent effects on the continued biotic and physical integrity of the riparian area (Poff et al. 1997). For example, retention of surface water can decrease or eliminate episodic, high intensity flooding, decrease seasonal high flows (e.g., spring snowmelt) and increase base flows during seasonal dry periods causing a shift in channel morphology and altering the dispersal capabilities, germination, and survival of many plant species dependent on those flows (Poff et al. 1997; Patten 1998).

**Measurement Protocol:** This metric is measured as the percent of the contributing watershed to the riparian area that occurs upstream of a surface water retention facility. First the total area of the contributing watershed needs to be determined. Next, the area of the contributing watershed which is upstream of the surface water retention facility furthest downstream is calculated for each stream reach (e.g., main channel and/or tributaries) then summed, divided by the total area of the contributing watershed, then multiplied by 100 to arrive at the metric value. For example if a dam occurs on the main channel, then the entire watershed upstream of that dam is calculated whereas if only small dams occur on tributaries then the contributing watershed upstream of each dam on each of the tributaries would be calculated then summed.

These calculations can be conducted using GIS themes of surface water retention facilities, USGS 7.5 minute topographic maps, and/or Digital Elevation Models. The contributing watershed can be calculated or digitized using Digital Elevation Models in a GIS. The percentage of the contributing watershed upstream of surface water retention facilities is simply "cut" from the original contributing watershed layer and its area is then calculated then compared to the total area.

**Metric Rating**: Specify the narrative and numerical ratings for a metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| Metric Rating | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| < 5% of drainage basin drains to surface water storage facilities | >5 - 20% of drainage basin drains to surface water storage facilities | >20 - 50% of drainage basin drains to surface water storage facilities | > 50% of drainage basin drains to surface water storage facilities |

**Data**: A GIS layer of surface water retention facilities is needed to calculate this metric. E.g., for Colorado wetlands, see the Colorado Division of Water Resource's Decision Support Systems website: http://cdss.state.co.us/

**Scaling Rationale:** The scaling is based on Smith (2000) and best scientific judgment. Additional research may suggest changes to the scaling criteria.

**Confidence that reasonable logic and/or data support the index:** Medium.

## Upstream/Onsite Water Diversions

**Definition:** A measure of the number of water diversions (e.g., ditch, well, reservoir, spring, mine, pipeline, pump, power plant) and their impact in the contributing watershed and in the wetland relative to the size of the contributing watershed.

**Background:** This metric addresses hydrologic stressors on riverine associated wetlands.

**Metric Type**: Stressor

**Tier:** 1 (remote-sensing), 2 (rapid field measure)

**Rationale for Selection of the Variable:** Ecological processes of riparian areas are driven to a large degree by the magnitude and frequency of peak flows and the duration and volume of base flows (Poff et al. 1997). The biotic and physical integrity of riparian areas are dependent on the natural variation associated with these flow characteristics (Gregory et al. 1991, Poff et al. 1997). The amount of water imported, exported, or diverted from a watershed can affect these processes by decreasing episodic, high intensity flooding, seasonal high flows (e.g., spring snowmelt), and base flows (Poff et al. 1997, Patten 1998).

**Measurement Protocol:** This metric can be measured by calculating the total number of water diversions occurring in the upstream contributing watershed as well as those onsite. The number of diversions relative to the size of the contributing basin is considered and then compared to the scorecard to determine the rating. Examples of water diversions include ditch, well, reservoir, spring, mine, pipeline, pump, power plant.

Since the riparian area may occur on a variety of stream orders and since the corresponding upstream or contributing watershed differs in area, it is difficult to set standard guidelines. Thus, the user must use their best scientific judgment regarding the number of diversions and their impact relative to the size of the contributing watershed. If available, attributes such as capacity (cubic feet/second) of each diversion can be considered in the assessment.

**Metric Rating**: Specify the narrative and numerical ratings for a metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| Metric Rating | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| No upstream, onsite, or nearby downstream water diversions present | Few diversions present or impacts from diversions minor relative to contributing watershed size. Onsite and nearby downstream diversions, if present, appear to have only minor impact on local hydrology. | Many diversions present or impacts from diversions moderate relative to contributing watershed size. Onsite and nearby downstream diversions, if present, appear to have a major impact on local hydrology. | Water diversions are very numerous or impacts from diversions high relative to contributing watershed size. Onsite and nearby downstream diversions, if present, have drastically altered local hydrology. |

**Data**: A GIS layer of surface water diversions is needed to calculate this metric. E.g., for Colorado wetlands, see the Colorado Division of Water Resource's Decision Support Systems website: http://cdss.state.co.us/

**Scaling Rationale:** The scaling is based on best scientific judgment. Additional research is needed and may suggest changes to the scaling criteria.

**Confidence that reasonable logic and/or data support the index:** Low/Medium.

## Groundwater Diversions

**Definition:** A measure of the number of groundwater diversions and their impact in the contributing watershed and in the wetland relative to the size of the contributing watershed.

**Background:** Metric has been proposed by NatureServe's Ecological Integrity Assessment Working Group, as the non-riverine version of the Surface Water metrics above, but it has not yet been developed.

**Metric Type**: Stressor

**Tier:** 1 (remote-sensing), 2 (rapid field measure)

**Rationale for Selection of the Variable:** Not available

**Measurement Protocol:** Not available

**Metric Rating**: Specify the narrative and numerical ratings for a metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| Metric Rating | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| Under development | Under | development | Under |

**Data**: Not available

**Scaling Rationale:** Not available

**Confidence that reasonable logic and/or data support the index:** Not available

## ▪ E. Soils (Physicochemistry) Metrics

### Physical Patch Types

**Definition:** A checklist of the number of different physical surfaces or features that may provide habitat for species.

**Background:** Metric is adapted from Collins et al. (2006), but has been greatly simplified by NatureServe's Ecological Integrity Assessment Working Group.

**Metric Type**: Condition

**Tier:** 2 (rapid field measure)

**Rationale for Selection of the Variable:** The rationale for this variable as used by CRAM tended to connect increasing physical complexity with increasing ecological functions, beneficial uses, as well as overall condition. Here we revise the metric to primarily emphasize condition. For each wetland class, there are visible patches of physical structure that typically occur at multiple points along the hydrologic / moisture gradient. But not all patch types will occur in all wetland types. Therefore, the rating is based on the percent of total expected patch types for a given wetland class.

**Measurement Protocol:** Prior to fieldwork, the imagery of the site should be reviewed to survey the major physical features or patch types present. The office work must be field-checked using the Structural Patch Worksheet below, by noting the presence of each of the patch types expected for a given wetland type, and calculating the percentage of expected patch types actually found in the site. Table 4.16 contains narratives for rating the Physical Patch Richness Metric for each wetland class.

**Metric Rating**: Specify the narrative and numerical ratings for a metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| | A - B | C | D |
|---|---|---|---|
| *All wetland types* | Physical patch types typical of reference standard condition are present (see checklist). | Some physical patch types typical of reference standard condition are lacking (see checklist). | Many physical patch types typical of reference standard condition are lacking (see checklist). |

**Data**: See table below from Collins et al. (2006). Refinement is needed before applying as a general ecological integrity metric.

**Physical Patch Type Worksheet for All Wetland Classes, Except Vernal Pool Systems**
Circle each type of patch that is observed in the AA and calculate the percentage of its maximum possible number of patch types. In the case of riverine wetlands and riparian habitats, their status as confined or unconfined must first be determined (see discussion on previous page).

| **PHYSICAL PATCH TYPE (check for presence)** | Riverine (Unconfined) | Riverine (Confined) | Estuarine | Coastal Lagoon | Depressional | Seeps and Springs | Lacustrine | Individual Vernal Pools | Playas |
|---|---|---|---|---|---|---|---|---|---|
| Minimum Patch Size | $3m^2$ | $3m^2$ | $3m^2$ | $3m^2$ | $3m^2$ | $1m^2$ | $3m^2$ | $1m^2$ | $3m^2$ |
| Secondary channels on floodplains or along shorelines | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| Swales | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 |
| Pannes or pools on floodplain | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Islands (exposed at high-water stage) | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| Pools in channels | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| Riffles | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Unvegetated flats/mudflats | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Point bars and in-channel bars | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| Debris jams or wrackline in channel or on floodplain | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| Hummocks and/or sediment mounds | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| Bank slumps, boulders, or undercut banks in channels or along shoreline | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 |
| Variegated shoreline | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Animal mounds and burrows | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 |
| Standing snags | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| Macroalgae | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 |
| Shellfish beds | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| Prograding vegetated bank (no undercut) | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Concentric or parallel high water marks | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Soil cracks | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| Cobble | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| Boulders | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | | | | | | | | |
| **No. Observed Patch Types** | | | | | | | | | |

Patch Type Definitions: See Collins et al. (2006).

***Secondary channels on floodplains or along shorelines***

Channels represent the physical confine of riverine or estuarine flow. A channel consists of a bed and its opposing banks, plus its functional floodplain. Wetlands can have a primary channel that conveys most flow, and secondary channels that convey flood flows. Short tributary channels that originate in the wetland and that only convey flow between the wetland and the primary channel are also regarded as secondary channels. Secondary channels may be located in the main channel basin or on the floodplain and may be dry or wetted at the time of assessment.

***Swales***

Swales are broad, elongated, sometimes-vegetated, tributaries that convey seasonal runoff and lack a well defined bed and bank, obvious deeps and shallows, or other characteristics of channels. Swales can act as zones of infiltration, as well as groundwater discharge.

***Pannes or pools on floodplain***

A panne is a broad, shallow depression composed of very fine sediments, and surrounded by a vegetated wetland plain. Pannes fill with water at least seasonally, and differ from vernal pools by lacking an abundance of emergent vegetation of any kind.

***Islands (exposed at high-water stage)***

An island is an area of land above the usual high water level and, at least at times, surrounded by water in a river, lake, lagoon, or estuary. Islands differ from hummocks and other mounds by being large enough to support multiple trees or large shrubs.

***Pools in channels***

Pools are areas along tidal and fluvial channels that fill with water at least seasonally, and that tend to retain water when the rest of the channel or plain is drained. Pools in channels are generally too deep to support emergent vegetation.

***Riffles***

Riffles are areas of relatively shallow, rapid, turbulent flow in fluvial channels. Riffles add oxygen to the water, as water is churned, and provide habitat for many invertebrates.

***Unvegetated flats***

A flat is an area lacking vascular vegetation that consists of silt, clay, sand, shell hash, gravel or cobble. Flats are similar to bars (see ***Point Bars and in-channel bars*** definition), except that flats extend below the usual low-water contour.

***Point bars and in-channel bars***

Bars are sedimentary features within intertidal and fluvial channels. They are patches of transient bedload sediment that form along the inside of meander bends or in the middle of straight channel reaches. They are formed above the low water contour and are seldom covered with vegetation. They can consist of silt, sand, gravel, and/or cobble.

***Debris jams or wrack line in channel or on floodplain***

Wrack is an accumulation of natural or unnatural floating debris along the high water line of a wetland. A jam is an accumulation of floating debris, across a channel that partially obstructs water flow.

***Hummocks or sediment mounds***

Hummocks are mounds created by plants in slope wetlands, depressions, and along the banks and floodplains of fluvial and tidal systems. Hummocks are typically less than 1m high. Sediment mounds are similar to hummocks without the vegetated cover.

***Bank slumps, boulders, or undercut banks in channels or along shoreline***

Bank slumps form when a chunk of bank material breaks off and slides into the channel in a fluvial or tidal system, where it becomes cemented in place. Both bank slumps and boulders are durable objects that are intransient except under extremely high-powered flow events. Boulders (rocks with a diameter of more than 10" (256mm)) and hardened bank slumps within the channel or along the shoreline can influence channel formation and create microhabitats. Undercut banks are concave features created when strong currents scour earthen banks. Bank erosion below the water line creates "shelves" that provide habitat for fish and other aquatic organisms.

*Variegated shoreline*

As viewed from above, the shoreline or edge of a wetland or water body can be straight, curved, or variegated. A variegated shoreline can be sketched as a sequence of s-shaped curves of varying amplitude and asymmetry, such that the line seems to meander or wander.

*Animal mounds and holes*

Many vertebrates make mounds or holes as a consequence of their foraging, denning, predation, predator avoidance, or other common behaviors. The disturbance to the upper part of the soil horizon redistributes soil nutrients and influences plant species composition and abundance. To be considered a patch type there should be evidence that a population of burrowing animals occupies or recently occupied the Assessment Area. Such evidence includes recently tilled soil mounds, scat, or footprints associated with the burrow. A single burrow or mound does not constitute a patch.

*Standing snags*

Tall, woody vegetation, such as trees and tall shrubs, can take many years to fall to the ground after dying. As these standing "snags" decompose, they provide habitat for birds and many other organisms. Any standing, dead woody vegetation that is at least 12 feet tall is considered a snag.

*Macroalgae*

Benthic macroalgae attach to the bottom sediments or other substrates in fresh, brackish, and saline water bodies. Macroalgae also occur in surface layers of soils and porous rocks, on the bark and leaves of trees, and in symbiotic association with fungi to form lichens. These organisms are important primary producers, representing the base of the food chain in some wetlands. They also contribute to the fertility of the soil in providing habitat for benthic and soil organisms.

*Shellfish beds*

Oysters, clams and mussels are common bivalves that create beds on the banks and bottoms of wetland systems. Shellfish beds influence the condition of their environment by affecting flow velocities, providing three-dimensional structure and habitat for plant and animal life, and playing particularly important roles in the uptake and cycling of nutrients and other water-borne materials.

*Prograding vegetated bank (no undercut)*

Sedimentation on the inside of channel bends can cause the formation of point bars that can later be colonized by vegetation to form a prograding vegetated bank. In essence, it is a vegetated point bar. Such areas can be important nurseries for fish and amphibians.

*Concentric or parallel high water marks*

Repeated, seasonal and interannual variation in water level in a wetland can cause concentric zones in soil moisture, topographic slope, and chemistry that translate into visible zones of different vegetation types and soils, greatly increasing overall ecological diversity.

*Soil cracks*

Repeated wetting and drying of fine grain soil that typifies some wetlands can cause the soil to crack and form deep fissures that increase the mobility of heavy metals and promote subsidence while providing refuge for amphibians and breeding sites for mosquitoes and other macroinvertebrates.

*Cobble and Boulders*

Cobble and boulders are rocks of different size categories. The long axis of cobble ranges from about 2.5" to 10.0". A boulder is any rock having a long axis greater than 10". Submerged cobbles and boulders provide abundant habitat for aquatic macroinvertebrates and small fish. Emergent or exposed cobbles and boulders provide roosting habitat for birds, shelter for amphibians, and they contribute to patterns of shade and light and air movement near the ground surface that affect soil moisture gradients, aeolian deposition of seeds and organic debris, and overall substrate complexity.

**Scaling Rationale:** Scaling rationale focuses more on a range of variability of physical path types, rather than a presumption that more physical patch types is better than less.

**Confidence that reasonable logic and/or data support the index:** Low/Medium

## Water Quality

**Definition**: An assessment of water quality based on visual evidence of water clarity and eutrophic species abundance.

**Background**: Metric was developed by the NatureServe Ecological Integrity Assessment Working Group.

**Metric Type**: Condition

**Tier**: 1 (remote sensing), 2 (rapid field measure)

**Rationale for Selection of the Variable**: In progress. Implicit here are observations on pollutants, nutrient and sediment loads, which are not always observable in field. Remote sensing and other research are more likely sources of info on those stressors (through Tier 1 metrics).

**Measurement Protocol**: Some of the data on water quality available from rivers an lakes could be very relevant to riverine and lakeshore wetland types.

**Metric Rating**: Specify the narrative and numerical ratings for the metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| | | **Metric Rating** | | |
|---|---|---|---|---|
| | **Excellent** | **Good** | **Fair** | **Poor** |
| *All wetlands* | There is no visual evidence of degraded water quality. Wetland species that respond to high nutrient levels are minimally present, if at all. Water is clear with no strong green tint or sheen. Sources of significant nutrient or toxics loading (septic systems, lawns, industrial or sewage plant outfalls, feedlots, boatyards) 2 miles or more distant. | Some negative water quality indicators are present, but limited to small and localized areas within the wetland. Wetland species that respond to high nutrient levels may be present but are not dominant. Water may have a minimal greenish tint or cloudiness, or sheen. Sources of significant nutrient or toxics loading 1 miles or more distant. | Negative water quality indicators or wetland species that respond to high nutrient levels are common. Wetland is not dominated by these vegetation species. Sources of water quality degradation are typically apparent. Water may have a moderate greenish tint, sheen or other turbidity with common algae. Sources of significant nutrient or toxics loading 1/2 mile or more distant. | Wetland is dominated by vegetation species that respond to high nutrient levels or there is widespread evidence of other negative water quality indicators. Algae mats may be extensive. Sources of water quality degradation are typically apparent. Water may have a strong greenish tint, sheen or turbidity. The bottom will be difficult to see during the growing season. Surface algal mats and other vegetation block light to the bottom. Sources of significant nutrient or toxics loading within 1/4 mile. |

**Data**: Not available

**Scaling Rationale:** In progress.

**Confidence that reasonable logic and/or data support the index:** Low/Medium

## Soil Surface Condition

**Definition**: An indirect measure of soil condition based on stressors that increase the potential for erosion or sedimentation of the soils, assessed by evaluating intensity of human dominated land uses on the site.

**Background**: This metric is partly based on a metric developed by Tierney and Faber-Langendoen (2005), Mack (2001), and the NatureServe Ecological Integrity Working Group

**Metric Type:** Condition

**Tier**: 2 (rapid field measure)

**Rationale for Selection of the Variable**: In progress.

**Measurement Protocol**: In progress

**Metric Rating**: Specify the narrative and numerical ratings for the metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| | | **Metric Rating** | | |
|---|---|---|---|---|
| | **Excellent** | **Good** | **Fair** | **Poor** |
| *- All freshwater wetlands* | Bare soil areas are limited to naturally caused disturbances such as flood deposition or game trails. | Some amount of bare soil due to human causes is present but the extent and impact is minimal. The depth of disturbance is limited to only a few inches and does not show evidence of ponding or channeling water. Any disturbance is likely to recover within a few years after the disturbance is removed. | Bare soil areas due to human causes are common and will be slow to recover. There may be pugging due to livestock resulting in several inches of soil disturbance. ORVs or other machinery may have left some shallow ruts. Damage is not excessive and the site will recover to potential with the removal of degrading human influences and moderate recovery times. | Bare soil areas substantially degrade the site due to altered hydrology or other long-lasting impacts. Deep ruts from ORVs or machinery may be present, or livestock pugging and/or trails are widespread. Water will be channeled or ponded. The site will not recover without restoration and/or long recovery times. |
| *- salt marsh and mangrove* | Excluding mud flats, bare soils are limited to salt panes. | Limited exposure of bare soils caused by erosion of marsh and channel banks due to excavation or marine traffic. | Frequent exposure of bare soils caused by erosion of marsh and channel banks due to excavation by marine traffic. [excessive animal grazing?] | Extensive bare soils caused by erosion of marsh and channel banks due to excavation by marine traffic. [excessive animal grazing?] |

**Data**: Not available.

**Scaling Rationale:** In progress. Percentages of bare soil due to human disturbance adapted from Adamus (2006: Appendix A, code 5).

**Confidence that reasonable logic and/or data support the index:** Medium

## On-Site Land Use

**Definition:** A measure of the intensity of human dominated land uses within the stand or polygon.

**Background:** This metric is one aspect of the condition of specific stands or polygons of an stand or polygon, and is adapted from Hauer et al. (2002)

**Metric Type**: Stressor

**Tier:** 1 (remote-sensing), 2 (rapid field measure)

**Rationale for Selection of the Variable:** The intensity of human activity in the stand or polygon often has a proportionate impact on the ecological processes occurring onsite. Each land use type is assigned a coefficient ranging from 0.0 to 1.0 indicating its relative impact to the stand or polygon (Hauer et al. 2002).

**Measurement Protocol:** This metric is measured by documenting land use(s) within the stand or polygon. This should be completed in the field then verified in the office using aerial photographs or GIS. However, with access to current aerial photography and/or GIS data a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use within 100 m of the stand or polygon edge.

To calculate a Total Land Use Score estimate the % of the stand or polygon under each Land Use type and then plug the corresponding coefficient (Table A) with some manipulation to account for regional application) into the following equation:

*Sub-land use score* = ∑ LU x PC/100

where**:** LU = Land Use Score for Land Use Type; PC = % of adjacent area in Land Use Type.

Do this for each land use, then sum the Sub-Land Use Score(s) to arrive at a Total Land Score. For example, if 30% of the stand or polygon was under moderate grazing (0.3 * 0.6 = 0.18), 10% composed of unpaved roads (0.1 * 0.1 = 0.01), and 40% was a natural area (e.g. no human land use) (1.0 * 0.4 = 0.4), the Total Land Use Score would = 0.59 (0.18 + 0.01 + 0.40).

**Metric Rating**: Specify the narrative and numerical ratings for a metric, from Excellent to Poor.

| **Metric Rating** | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| Average Land Use Score = 1 0.95 | Average Land Use Score = 0.80-0.95 | Average Land Use Score = ( 0.80 | Average Land Use Score = < 0.4 |

**Data**:

Table A. Current Land Use and Corresponding Land Use Coefficients (adapted from Table 21 in Hauer et al. (2002)

| Current Land Use | Coefficient |
|---|---|
| Paved roads/parking lots/domestic or commercially developed buildings/mining (gravel pit, quarry, open pit, strip mining). | 0 |
| Unpaved Roads (e.g., driveway, tractor trail) / abandoned mines | 0.1 |
| Agriculture (tilled crop production) / intensively developed vegetation (golf courses, lawns, etc). | 0.2 |
| Vegetation conversion (chaining, cabling, rotochopping, clearcut) | 0.3 |
| Heavy grazing on rangeland or pastures | 0.3 |
| Heavy logging or tree removal with 50-75% of trees >30 cm dbh removed | 0.4 |
| Intense recreation (ATV use/camping/sport fields/popular fishing spot, etc.) / Military training areas (armor, mechanized) | 0.4 |
| Agriculture - permanent crop (vineyards, orchards, nurseries, berry production, introduced hay field and pastures etc) | 0.4 |
| Commercial tree plantations / Christmas tree farms | 0.5 |
| Dam sites and flood disturbed shorelines around water storage reservoirs | 0.5 |
| Recent old fields and other disturbed fallow lands dominated by ruderal and exotic species. | 0.5 |
| Moderate grazing on rangeland | 0.6 |
| Moderate recreation (high-use trail) | 0.7 |
| Mature old fields and other fallow lands with natural composition. | 0.7 |
| Selective logging or tree removal with <50% of trees >30 cm dbh removed | 0.8 |
| Light grazing / light recreation (low-use trail) / haying of native grassland | 0.9 |
| Natural area / land managed for native vegetation | 1 |

**Scaling Rationale:** The coefficients were assigned according to best scientific judgment regarding each land use's potential impact (Hauer et al. 2002, and NatureServe and Network ecology staff pers. comm. 2008). Land uses have differing degrees of potential impact. Some land uses have minimal impact, such as simply altering the integrity of native vegetation (e.g., recreation and grazing), while other activities (e.g., grazing by cattle in forest ground layers) may replace native vegetation with nonnative or cultural vegetation yet still provide potential cover for species movement. Intensive land uses (i.e., roads) may completely destroy vegetation and drastically alter hydrological processes.

Original Hauer et al. table.

Table 1. Current Land Use and Corresponding Land Use Coefficients, modified fromTable 21 in Hauer et al. (2002).

| Current Land Use | Coefficient |
|---|---|
| Paved roads/parking lots/domestic or commercially developed buildings/gravel pit operation | 0.0 |
| Surface mining, mountaintop removal mining | 0.0 |
| Unpaved Roads (e.g., driveway, tractor trail) / Underground mining | 0.1 |
| Agriculture (diking, ditching, tide gates, tilled crop production) | 0.2 |
| Peat extraction, peat mining | 0.3 |
| Heavy grazing by livestock / intense recreation (ATV use/camping/popular fishing spot, etc.) | 0.3 |
| Logging or tree removal with 50-75% of trees >50 cm dbh removed | 0.4 |
| Hayed | 0.5 |
| Aquaculture -- fish, shrimp, oyster farming | 0.5 |
| Moderate grazing | 0.6 |
| Moderate recreation (high-use trail) | 0.7 |
| Selective logging or tree removal with <50% of trees >50 cm dbh removed | 0.8 |
| Light grazing / light recreation (low-use trail) | 0.9 |
| Fallow with no history of grazing or other human use in past 10 yrs | 0.95 |
| Natural area / land managed for native vegetation | 1.0 |

**Confidence that reasonable logic and/or data support the index:** Medium.

## ▪ F. Stressor Checklists

### Guidelines for Completing the Stressor Checklist

(from Collins et al. 2006)

**A. Definition:** Wetlands are connected by physical and biological mechanisms to a terrestrial watershed; the characteristics of this watershed, and, in particular, the human activities that take place there, greatly influence wetland structure and function (Frissell *et al.*, 1986; Scott 2002, Roth 1996). A stressor, as defined for the purposes of the CRAM, is an anthropogenic perturbation within a watershed that can negatively affect the condition and function of a wetland.

**B. Rationale:** The purpose of this metric is to develop a checklist of stress associated with human activities surrounding the wetland to be assessed. The overarching purpose of this checklist is to identify likely anthropogenic causes for poor wetland conditions as assessed by CRAM. A list of potential stressors corresponds to each of the major attributes of wetland condition. Thus, relationships between stressors, attributes, and their component metrics might be surmised. In some cases, a single stressor may cause deviation from "good" condition, but in most cases multiple stressors interact to affect wetland condition (EPA, 2002).
There are four underlying assumptions of the Stressor Checklist: (1) deviation from a "good" condition can be explained by a single stressor or multiple stressors acting on the wetland; (2) increasing the number of stressors acting on the wetland causes a decline in its condition (there is no assumption as to whether this decline is additive (linear), multiplicative, or is best represented by some other non-linear mode); (3) increasing either the intensity or the proximity of the stressor results in a greater decline in condition; and (4) continuous or chronic stress increases the decline in condition.

**C. Seasonality:** The Stressor Checklist is not sensitive to seasonality.

**D. Office and Field Indicators:** The assessment of this attribute is the same across all wetland classes. For each CRAM attribute, a variety of human actions that are likely sources of stress are listed, and their presence, and likelihood of affecting the AA in question, are recorded in Table5.1, below. The hydrology, physical, and biotic structure stressor checklists should be scored for those visible within the AA itself. Adjacent land use should be scored only for those land uses outside the AA. In addition to the potential stressors relating to the CRAM attributes, stress relating to adjacent land use is also assessed.

## G. References for Level 2 Metrics


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# Appendix III: Protocols for Intensive (Level 3) Field Metrics (Examples)

In the course of compiling a rapid, level 2 assessment protocol, a number of intensive metrics were identified that may be relevant to a wide variety of wetlands. These are described here, but their role in an intensive assessment needs further review.

## Biotic Metrics

### Floristic Quality Assessment (Mean $C_n$)

**Definition:** The mean conservatism of all the native species growing in the wetland.

**Background:** This metric is one aspect of the vegetation condition of specific occurrences of wetland or terrestrial ecological systems. There are a variety of indices available to assess floristic quality, of which Mean $C_n$ is one. It is the average coefficient of conservatism across all native species for a give sample unit or site.

The concept of species conservatism is the foundation of the Floristic Quality Assessment (FQA) approach to monitoring and assessing ecological communities (Rocchio 2007). The core of the FQA method is the use of "coefficients of conservatism" (C value), which are assigned to all native species in a flora following the methods described by Swink and Wilhelm (1994) and Wilhelm and Masters (1996). C values range from 0 to 10 and represent an estimated probability that a plant is likely to occur in a landscape relatively unaltered from natural or historical range of variation (sometimes using pre-European settlement conditions as the reference). A C value of 10 is assigned to species which are obligate to high-quality natural areas and can't tolerate any habitat degradation whereas a 0 is assigned to species with a wide tolerance to human disturbance. The proportion of conservative plants in a plant community provides a powerful and relatively easy assessment of the integrity of both biotic and abiotic processes and as such is indicative of the ecological integrity of a site (Wilhelm and Ladd 1988). The mean $C_n$ is the average C value across all native species. Mean $C_{all}$ , which includes both native and non-native species, where all non-natives are given a value of 0, is sometimes encouraged as providing a more realistic account of the integrity of the vegetation within a site (Taft et al. 2006).

A Floristic Quality Index (FQI) can be derived from the C values (Swink and Wilhem 1994, Lopez and Fennessy 2002). After each species has been assigned a C value, the average C value (mean C) of all native species can be multiplied by the square root of site or total plot (or native) richness ($\sqrt{S}$) to produce the Floristic Quality Index (FQI) index, (also called the Floristic Quality Assessment Index, or FQAI). Larger areas will typically support more species than smaller areas and since there may be cases when a large and a small area share the same *C* value, accounting for species richness by multiplying it with the *C* value adds a discriminating factor to the floristic quality assessment (Taft et al. 1997). Area is not the only factor affecting species richness, as habitat heterogeneity and the presence of anthropogenic patches can have an impact on richness, regardless of size (Wilhelm and Masters 1996). Thus, to limit the influence of area alone on the index, the square root of species richness is used (Swink and Wilhelm 1994; Taft et al. 1997). Still, interpretation of the index is more straightforward if a fixed area is used, as species-area relationships can be directly interpreted, along with the index.

The index can be calculated using only native species, all species, species by cover, and other permutations (see Table 2 in Rocchio 2), including the Adjusted Floristic Quality Index, which eliminates the sensitivity of the index to species richness (Miller and Wardrop 2006). There is a FQA version that relies on other field measures (wetland affinity status, exotic/native, and species richness) that are more widely available than are C values (Ervin et al. 2006)

**Metric Type**: Condition

**Tier:** 3 (intensive field method)

**Rationale for Selection of the Variable:** Plants grow in habitats to which they are adapted, including biotic and abiotic fluctuations associated with that habitat (Wilhelm and Masters 1995). However, when disturbances to that habitat exceed the natural range of variation (e.g. many human-induced disturbances), only those plants with wide ecological tolerance will survive and conservative species (those with strong fidelity to habitat integrity) will decline or disappear according to the degree of human disturbance (Wilhelm and Master 1995, Wilhelm pers. comm. 2005).

Although *Cn* can be a useful independent metric of floristic quality, it is recommended that practitioners use additional FQA or other vegetation metrics along with Mean C to provide a more comprehensive and clear assessment (Taft et al. 1997). This could be accomplished using a multi-metric index such as a vegetation index of biotic integrity (e.g. Rocchio 2007) or simply by reporting and making conclusions based on multiple, independent vegetation metrics.

**Measurement Protocol:** Species presence/absence data need to be collected from the wetland. Although plot-based or area-based measurements are preferred, depending on time and financial constraints, this metric can also be measured using plot-less techniques. The two methods are described as follows: (1) Site Survey (semi-quantitative): walk the entire occurrence of the community type at the site and make notes of each species encountered. A thorough search of each macro- and micro-habitat is required. (2) Quantitative Plot Data: Use a fixed area method. A variety of techniques are available, including line transects, transects with 20 or more small 0.25 – 1 $m^2$ quadrats laid along them, or fixed-area plot methods of 100 to 1000 $m^2$.

Studies by Yorks and Dabydeen (1998) and Rocchio (2006) found that the transect method did not pick up most non-dominant species (making richness based metrics less accurate and comprehensive) and therefore was biased toward dominant species and resulted in biased proportions for some guilds (graminoids, forbs, etc.). This can result in metrics which are less sensitive to changes resulting from human disturbances. Thus, the plot (or reléve) method is preferred.

The plot method described by Peet et al. (1998) is a recommended approach for collecting quantitative data for this metric. This method uses a 20 x 50 m plot which is typically established in a 2 x 5 arrangement of 10 x 10 m modules, and provides a standard 0.1 ha sample area, a widely used standard for assessing species richness. However, the array of modules can be rearranged or reduced to meet site conditions (e.g. 1 x 5 for linear areas or 2 x 2 for small, circular sites). Species presence (with cover if desired) is recorded in each of four modules. If time permits, the reset of the 50 x 20 m area can be surveyed for additional species to obtain a 0.1 ha sample. The method is suitable for most types of vegetation, provides information on species composition across spatial scales, is flexible in intensity and effort, and compatible with data from other sampling methods (Peet et al. 1998, Mack 2004).

The metric is calculated by referencing only native species C value from a given state FQA Database, summing the C value, and dividing by the total number of native species (Mean C). The Mean $C_n$ is then used to determine the metric status in the scorecard. The metric can also be calculated using all species.

**Metric Rating:** Specify the narrative and numerical ratings for the metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| Metric Rating | | |
|---|---|---|
| **Good-Excellent** | **Fair** | **Poor** |
| $C_n$ = 5.0 | $C_n$ 3.5 – 5.0 | $C_n$ < 3.5 |
| $C_{all}$ = ? | $C_{all}$ ? | $C_{all}$ ? |
| | | |

**Data**: FQA methods have been developed and successfully tested in Illinois (Swink and Wilhelm 1979), Missouri (Ladd 1993), Ohio (Andreas and Lichvar 1995), southern Ontario (Oldham et al. 1995), Michigan (Herman et al. 1996), Indiana (Coffee Creek Watershed Conservancy 2001), North Dakota (Northern Great Plains Floristic Quality Assessment Panel 2001), and Colorado (Rocchio 2007). The exact form of the equation is still debated. Various authors have criticized the approach of combining the C value with the square root of richness to calculate an FQI, and recommend treating each separately, as done here (Bowles and Jones 2006). Others have adjusted the FQI to account for effects of species richness (Miller and Wardrop 2006). Various state and provincial FQA Databases are available that have C values assigned to all species in the jurisdiction.

**Scaling Rationale:** It is recommended that mean C and FQA index scores only be compared between similar plant community or ecological system types, but it is not yet clear what level of typing will produce a satisfactory result. Can they be fairly broad types (such as wet meadow, bog, fen, marsh, forested swamp, etc), more narrow types (Rocky Mountain Montane Fen, Laurentian-Acadian Alkaline Fen, etc) (Rocchio 2007), or specific natural community or association types (Bowles and Jones 2006)? In the Midwest, field studies using FQA have determined that a site with a Mean C of 3.0 or less is unlikely to achieve higher C values (Wilhelm and Masters 1995). In other words, those sites have been disturbed to the degree that conservative species are no longer able to survive and or compete with the less conservative species as a result of the changes to the soil and or hydrological processes on site. Sites with a Mean C of 3.5 or higher are considered to have at least marginal quality or integrity thus this value was used as the Minimum Integrity Threshold (between Fair and Poor) (Wilhelm and Masters 1995). The threshold between Fair and Good was assigned based on best scientific judgment upon reviewing the FQA literature. Given that values for FQI are somewhat sensitive to the type of wetland being sampled, we did not divide the FQI into Excellent versus Good. In addition, mean C (and FQI) may not be a sensitive metric to detect these differences. For example, Bowles and Jones (2006) found that A and B ranked dry to mesic prairies could be not discriminated based on mean C (or on FQI). The minimum C value of 3.5 requires greater testing, since Rocchio (2007) found that heavily impacted sites still had values above 5.5.

In central Pennsylvania, Miller and Wardrop found that for headwater wetlands, mean $C_n$ for low impacted sites ranged from 4.55 to 6.13 (mean = 5.48 $\pm$ 0.46 S.D.), for moderately impacted sites from 2.87 to 5.27 (mean = 4.17 $\pm$ 0.74) and for highly impacted sites, from 2.0 to 4.78 (mean = 3.37 $\pm$ 0.25). In the prairie pothole region, DeKeyser et al. (203) found mean $C_n$ for low impacted sites $\geq$ 4.01, for moderately impacted sites from 3.16-4.00, and for highly impacted sites, from 0-.3.15.

In West Virginia, Byers (pers. comm. 2007) found that the following C values (though all exotics were assigned a value of "0", rather than being dropped from the calculations, which reduces the mean C of C lower than if just natives are used). Data on the mean Coefficient of Conservation for 315 palustrine plots throughout West Virginia for which EO Rank values have been assigned (EO Rank from Natural Heritage Methodology):

Table. Coefficient of Conservatism Values ($C_{all}$) for wetland plots in West Virginia (Byers pers. comm. 2007)

| Rating | Condition Ranking | Mean C | Number of Plots |
|---|---|---|---|
| **Excellent** | **A** | **5.7** | **52** |
| | **AB** | **5.7** | **24** |
| **Good** | **B** | **5.6** | **194** |
| | **BC** | **4.7** | **11** |
| **Fair** | **C** | **5.0** | **31** |
| | **CD** | **3.8** | **3** |

In Colorado, mean $C_n$ for highly impacted wetland sites had a mean approximately = 5.6, and for reference, impacted sites, a mean of approximately = 6.7. The effectiveness of mean $C_n$ was best in The effectiveness of Mean C (natives) for each ecological system type in Colorado Rocky Mountain wetlands was very strong for fens, riparian shrublands, and slope wet meadows, though variability of the index for fens and riparian shrublands increased substantially as human disturbance increased. The index was weakly effective in detecting human disturbance in extremely rich fens, and showed no utility for riverine wet meadows.

**Confidence that reasonable logic and/or data support the index:** High

## Invasive Exotic Species

See Neckles et al. (2006)

**Rationale**: Invasion of native habitats by invasive exotic species or native species whose densities are becoming unnaturally high (e.g., white-tailed deer) is presently recognized as second only to direct habitat loss and fragmentation as a threat to biodiversity. Pimentel et al. (2001) estimated that invasive species cost the United States $138 billion annually making the reduction of these species a shared priority of many agencies and organizations in the United States (National Invasive Species Council 2001). Once viable populations of invasive plants become established in novel habitats, they inflict a suite of ecological damage to native species including loss of habitat, loss of biodiversity, decreased nutrition for herbivores, competitive dominance, overgrowth, struggling, and shading, resource depletion, alteration of biomass, energy cycling, productivity, and nutrient cycling (Dukes and Mooney 1999). Invasive plant species can also affect hydrologic function and balance, making water scarce for native species.

Wetland invasive plant species vary by region. In the Northeast they include, but are not limited to, purple loosestrife (*Lythrum salicaria*), Japanese knotweed (*Polygonum cuspidatum*), water chestnut (*Trapa natans*), flowering rush (*Butomus umbellatus*), yellow iris (*Iris pseudacorus*) and Phragmites (*Phragmites australis*). These species have been detected in most parks and cause a substantial management effort to control and reduce wetland condition. Invasive plants significantly alter species composition and diversity and often form monotypic stands.

## ▪ Hydrology Metrics

### Index of Hydrological Alteration

**Definition:** This metric uses daily streamflow data to determine trends at one site or determine differences between pre- and post-impacts of sites.

**Background:** This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

**Metric Type:** condition

**Tier:** 3 (intensive field method)

**Rationale for Selection of the Variable:** The Index of Hydrological Alteration (IHA) is an easy to use tool for calculating the characteristics of natural and altered hydrologic regimes using any type of daily hydrologic data, such as streamflows, river stages, ground water levels, etc. Rather that review the entire method here, please refer to http://www.freshwaters.org/tools to download the IHA software as well as supporting documentation, including numerous published papers.

**Measurement Protocol:** Long-term daily streamflow data are required for this metric. If those are not available daily flow data may be generated using a hydrologic model or other simulation method (see Richter et al. 1997). The IHA statistics will be meaningful only when calculated for a sufficiently long hydrologic record. The length of record necessary to obtain reliable comparisons is currently being researched, however it is recommended that at least twenty years of daily records be used (see Richter et al. 1997).

Some lake level and ground water well data are also available from the USGS, but much of this type of data is collected and managed by other local governmental entities.

**Metric Rating**: Specify the narrative and numerical ratings for a metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| Metric Rating | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| No significant change from Reference Hydrographs | Slight change from Reference Hydrographs | Moderate change from Reference Hydrographs | Large change from Reference Hydrographs |

**Data**:
Index of Hydrologic Alteration Software and Supporting Documentation:
http://www.freshwaters.org/tools [website obsolete?]

U.S. Geological Survey Streamflow Data: http://water.usgs.gov/usa/nwis. (data can be imported directly in the IHA)

The U.S. Forest Service, U.S. Bureau of Land Management, and local government agencies may have streamflow data for some of the streams located on the lands they manage.

**Scaling Rationale:** The scaling is based on best scientific judgment of deviation from the reference standard. Additional research may suggest changes to the scaling criteria.

**Confidence that reasonable logic and/or data support the index:** Medium/High.

## Soils (Physicochemistry) Metrics

### Bank Stability

**Definition:** This metric assesses the stability and condition of the streambanks.

**Background:** This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

**Metric Type:** condition

**Tier:** 3 (intensive field method)

**Rationale for Selection of the Variable:** Unstable or eroding banks are often the results of local and/or upstream impacts associated with channel incision induced by over grazing and/or upstream alterations in the hydrological and/or sediment regimes. The local impact from eroding or unstable banks is typically a drop in the local water table along with a change in composition of plant species growing along the streambanks.

**Measurement Protocol:** This metric is measured by walking along the streambanks in the riparian area and observing signs of eroding and unstable banks. These signs include crumbling, unvegetated banks, exposed tree roots, exposed soil, as well as species composition of streamside plants (Prichard et al. 1998, Barbour et al. 1999). Stable streambanks are vegetated by native species that have extensive root masses (*Alnus incana*, *Salix* spp., *Populus* spp., *Betula* spp., *Carex* spp., *Juncus* spp., and some wetland grasses) (Prichard et al. 1998). In general, most plants with a Wetland Indicator Status of OBL (obligate) and FACW (facultative wetland) have root masses capable of stabilizing streambanks while most plants with FACU (facultative upland) or UPL (upland) do not (Reed 1988, Prichard et al. 1998).

Each bank is evaluated separately then averaged to assign the metric rating.

**Metric Rating**: Specify the narrative and numerical ratings for a metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| Metric Rating | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| Banks stable; evidence of erosion or bank failure absent or minimal; < 5% of bank affected.<br><br>Streambanks dominated (> 90% cover) by Stabilizing Plant Species (OBL & FACW) | Mostly stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.<br><br>Streambanks have 75-90% cover of Stabilizing Plant Species (OBL & FACW) | Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.<br><br>Streambanks have 60-75% cover of Stabilizing Plant Species (OBL & FACW) | Unstable; many eroded areas; "raw". Areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.<br><br>Streambanks have < 60% cover of Stabilizing Plant Species (OBL & FACW) |

**Data**:
Wetland Indicator Status: U.S. Fish and Wildlife Service, National Wetlands Inventory website: http://www.nwi.fws.gov/plants.htm or USDA PLANTS Database: http://plants.usda.gov/

The Colorado Floristic Quality Assessment Database will also have Wetland Indicator Status information.

**Scaling Rationale:** The scaling is based on Barbour et al. (1999), Prichard et al. (1998), and best scientific judgment of deviation from the reference standard. Additional research may suggest changes to the scaling criteria.

**Confidence that reasonable logic and/or data support the index:** Medium.

## Soil Organic Carbon

**Definition:** This metric measures the amount of soil organic carbon present in the soil.

**Background:** This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

**Metric Type:** condition

**Tier:** 3 (intensive, field-based)

**Rationale for Selection of the Variable:** Soil organic matter or carbon generally refers to the organic fraction of the soil, including plant and animal residues at various stages of decomposition, as well as substances synthesized by the soil organisms (Neue 1984). Organic matter plays an extremely important role in the soil environment, including increases water holding capacity, encouraging soil structure, has a high cation exchange capacity, and supplies essential nutrients (Brady 1990).

Soil organic carbon is a strong metric of soil quality due to its sensitivity to environmental disturbance (NRC 2000 *in* Fennessy et al. 2004). Given that soil organic carbon contributes to critical hydrologic, biogeochemical, and physical processes, a reduction in soil organic carbon from reference conditions serves as a strong indicator of loss of soil quality.

**Measurement Protocol:** Multiple soil pits should be dug in the wetland to a depth of at least 40 cm. If quantitative vegetation data are being collected, soil pits should be located within these plots to allow correlations with vegetation data. For example, if using the 20 x 50 m plots described by Peet et al. (1998), soil pits would be located within each of the intensive modules. At least five replicate soil samples should be taken within the top 10 cm of the soil surface in each pit. The replicates are mixed together as "one" sample from the site. Each soil sample should be placed in their own individual plastic bag, packed on ice, and sent to a laboratory for analysis of soil organic carbon (e.g., CHN Analyzer).

**Metric Rating**: Specify the narrative and numerical ratings for the metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| Metric Rating | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| Soil C is equivalent to natural range of variability | Soil C is nearly equivalent to natural range of variability | Soil C is significantly lower than natural range of variability | Soil C is significantly lower than natural range of variability |

**Data**: N/A

**Scaling Rationale:** Reference soil organic carbon levels need to be established in undisturbed wetlands. Thereafter, the scaling is based on best scientific judgment and an assumed linear relationship of the amount of deviation from the reference standard to level of disturbance. If data are collected from wetlands across a disturbance gradient, quantitative criteria could be established. Alternatively, if "baseline" soil organic carbon levels are known (from "pre-impact" conditions or from adjacent unaltered sites) then this metric can be used to determine change of soil organic carbon with time.

**Confidence that reasonable logic and/or data support the index:** Medium/High.

## Soil Bulk Density

**Definition:** Soil bulk density is a ratio of the mass/volume of the soil. This metric is a measure of the compaction of the soil horizons.

**Background:** This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

**Metric Type:** Condition

**Tier:** 3 (intensive field method)

**Rationale for Selection of the Variable:** Bulk density is a measure of the weight of the soil divided by its volume and provides an indication of the level of compaction. Compaction can result from any activity which compresses soil particles thereby increasing the weight to volume ratio. This can reduce the soil's water holding capacity, infiltration rate, water movement through the soil, and limit plant growth by physically restricting root growth (NRCS 2001). Bulk density of organic soils are typically much less than those of mineral soils, however as decomposition increases and/or organic soils are compacted from human activity, bulk density of organic soils will increase. This has corresponding negative impacts on ecological processes such as water movement through the peat body, decomposition, and nutrient cycling.

**Measurement Protocol:** Multiple soil pits should be dug in the wetland to a depth of at least 40 cm. If quantitative vegetation data are being collected, soil pits should be located within these plots to allow correlations with vegetation data. For example, if using the 20 x 50 m plots described by Peet et al. (1998), soil pits would be located and samples collected within each of the intensive modules.

The samples are collected by taking a core sample within the top 15 cm of the soil. A cylinder of known volume should be used to collect samples. A PVC pipe of known dimensions will suffice. The cylinder is simply inserted into the soil profile, extracted, then shaved to eliminate any soil which is not contained within the cylinder. The soil remaining in the cylinder can then be placed into a plastic bag and then sent to a laboratory for analysis. Bulk density and soil texture (e.g., particle distribution) should be analyzed. Alternatively, texture can be determined in the field using the "field hand method", however lab analysis is preferable.

Once texture and bulk density are determined, use the information below to determine whether the soil's bulk density is less than, equal to, or greater then the minimum root-restricting bulk density values listed for the corresponding texture of the soil and assign the metric rating accordingly in the scorecard.

There are no root restricting values given for organic soils, thus if the wetland is dominated by organic soil, reference bulk density measurements need to be established in undisturbed areas.

**Metric Rating**: Specify the narrative and numerical ratings for the metric, from Excellent to Poor (see Master Table of Metrics and Ratings).

| **Metric Rating** | | | |
|---|---|---|---|
| **Excellent** | **Good** | **Fair** | **Poor** |
| Bulk density value for wetland is at least 0.2 (g/cm3) less than Root Restricting Bulk Density value for the soil texture found in the wetland. | Bulk density value for wetland is at least 0.2 (g/cm3) less than Root Restricting Bulk Density value for the soil texture found in the wetland. (same as Very Good) | Bulk density for wetland is between 0.2 to 0.1 (g/cm3) less than Root Restricting Bulk Density value for the soil texture found in the wetland. | Bulk density for wetland is = or > than Root Restricting Bulk Density value for the soil texture found in the wetland. |

**Data**: The data below are derived from a Natural Resource Conservation Service, Soil Quality Information Sheet — Compaction which can be found online at:

http://soils.usda.gov/sqi/publications/sqis.html
http://www.urbanext.uiuc.edu/soil/sq_info/RSQIS4.pdf
http://soils.usda.gov/sqi/management/files/RSQIS4.pdf

These texture classes have the following Root Restricting Bulk Density values (g/cm3):

1. Coarse, medium, and fine sand AND loamy sand other than loamy very fine sand = 1.8 g/cm3
2. Very fine sand, loamy very find sand = 1.77 g/cm3
3. Sandy loam = 1.75 g/cm3
4. Loam, sandy clay loam = 1.7 g/cm3
5. Clay loam = 1.65 g/cm3
6. Sandy clay = 1.6 g/cm3

7. Silt, silt loam = 1.55 g/cm3
8. Silty clay loam = 1.5 g/cm3
9. Silty clay = 1.45 g/cm3
10. Clay = 1.4 g/cm3

**Scaling Rationale:** The scaling is based on best scientific judgment and an assumed linear relationship of the amount of deviation from the reference standard to level of disturbance. However, no distinction was made between Excellent and Good as there is no information to suggest that threshold. Alternatively if "baseline" bulk density levels are known (from "pre-impact" conditions or from adjacent unaltered areas) then this metric can be used to determine change of bulk density with time.

**Confidence that reasonable logic and/or data support the index:** Medium/High.

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# Appendix IV: Comparison of Wetland Classifications

The following tables compare the NVC classification used here, to that of the National Wetland Inventory (NWI) classification (Cowardin 1979), and to the Hydrogeomorphic (HGM) Classification, first drafted by Brinson (1993). There have been various modifications of the main classes by various authors (Collins et al. 2006, etc.).

Given the existence of the two major classifications that are widely used for various wetlands projects, NWI for inventory and HGM for functional assessments, it may be asked why another set of classifications should be introduced. Briefly they may be stated as follows:

1. The NVC and Ecological Systems classifications are comprehensive for all ecosystems, not just wetlands; thus they provide a comprehensive set of types for all ecological integrity or condition assessments. Thereby they can also provide comprehensive mapping and assessment approaches to the landscape.
2. Both classifications rely on a suite of ecological criteria to define types, not just hydrologic drivers; thus they are more general classifications, less focused on single technical criteria. The NVC emphasizes vegetation, but correlates vegetation with ecological and biogeographic criteria. Ecological systems emphasize vegetation, soils, climate and other criteria to define types, with vegetation response used as a major criterion for assessing the role of other criteria.
3. The NVC is a federal standard for all federal agencies; using it directly in wetland assessments will encourage cross-walking of information among agencies that need wetland condition assessments. For example, the status and trends of forested wetlands are regularly reported by the USFS FIA program, as part of their assessment of all forests, and the status and trends of forested wetlands are regularly surveyed by the NWI wetlands survey, as part of their assessment of all wetlands. But no one has evaluated the similarities and differences between these two evaluations. The NVC can facilitate such a comparison.
4. The NVC Formations are very similar to NWI types and a fairly straightforward linkage can be created (See Appendix D and Dahl 2006). Thus, it should be possible to use both NWI and the NVC to report on the nations wetlands; the latter being important when wetlands are reported on along with other ecosystems (such as forests or rangelands).
5. HGM is less consistent in how wetlands are treated; many HGM classes extend well beyond any ecological or jurisdictional definition of wetlands, particularly for riparian treatments. Using the NVC in conjunction with HGM will facilitate a better understanding of both the wetland and non-wetland components of HGM applications.
6. The NVC is a cooperative venture with non-federal partners, including the Ecological Society of America, NatureServe, and the Network of Natural Heritage Programs. Thus, it brings together federal, academic, state, and private ecologists, and enhances tracking wetland types at the state level.
7. Ecological Systems increasingly are being used for large-scale mapping, and can provide a comprehensive view of wetland distribution.

## IV. A. Major Wetland Formation Types Recognized in the NVC and IVC

Brief descriptions of wetland formations, organized by common wetland categories (swamp, marsh etc,). Wetland formations are coded based on their hierarchy position in the overall U.S. National Vegetation Classification (FGDC 2008).

| Wetland Formation | Brief Description |
|---|---|
| FOREST & WOODLAND | |
| Swamp (wooded) | |
| Mangrove (1.A.4) | Mangrove swamps (mangal, mangle) are tidal, estuarine forested wetlands that occur along the (sheltered) coasts of tropical and subtropical latitudes of the Earth. Their adaptations to cope with seawater include methods of salt secretion, exclusion and accumulation. Physiognomically, they vary in size from dwarf shrubs to tall trees. They are commonly found on the intertidal mud flats along the shores of estuaries, usually in the region between the saltmarshes and seagrass beds. Where tidal amplitude is relatively low they form narrow bands along the coastal plains, and rarely penetrate inland more than several kilometers along rivers. Where tidal amplitude is greater, mangroves extend further inland along river courses, forming extensive stands in the major river deltas. Mangrove cays occur also within the lagoon complex of barrier reefs. In general, mangroves fall within two categories: mangroves of oceanic islands and inland mangroves. The latter type needs to adapt to a pronounced variation in salinity due to the variations in freshwater carried from the interior streams, whereas the former type has a salinity gradient driven by the rate of evaporation in the shallow ponds and mudflats and the rainfall on site, especially in the case of small to very small islands. |
| Tropical Flooded & Swamp Forest (1.A.3) | Tropical Flooded & Swamp Forest is a forested or wooded wetland and peatland. Structural characteristics that recur in flooded forests are presence of monospecific stands such as palm swamp, even-canopied forests, and sharp vegetation zonations. It is common to find that trees in flooded tropical forests develop sclerophylly (firm, thickened leaf) due to poor nutrition or water limitations, or gas exchange structures such as pneumatophores, lenticels, knees, aerial roots, swelling of base of trees, surface or aerial roots in order to overcome poor soil aeration, or support structures, e.g., plank buttresses and stilt roots to provide stability in muddy or steep conditions. Tree heights can vary greatly, from 1 to 50 m. Tropical swamp forests can be divided into freshwater swamp or floodplain forest (along rivers and lakes) and peat swamp forest (formed behind natural floodplain levees), where peat layers may be well in excess of 1 m. The floodplain forests are found along rivers, streams and lakes. They have a dynamic water table, with seasonal flooding inundating the vegetation for short (< 7 days) to long (> 1 month) periods, leading to an influx of sediment and mineral enrichment during high water periods. |
| Temperate Flooded & Swamp Forest (1.C.3) | Temperate Flooded & Swamp Forest is a forested or wooded wetland and peatland. It is defined as a treed or tall shrub (also called *thicket*) dominated wetland that is influenced by minerotrophic groundwater, either on mineral or organic (peat) soils. The essential features of this type are the dominance of tall woody, either broadleaf or needleleaf trees or broadleaf shrubs, generally over 10-20% cover, and either a wood-rich peat, more common in depressions, or a mineral soil on floodplains. In swamp forests, the water table is often below the major portion of the ground surface, and the dominant ground surface is at the hummock ground surface, that is, 20 cm or more above the average summer groundwater level. It is the aerated (or partly aerated) zone of substrates above the water that is available for root growth of trees and/or tall shrubs. Flooded forests (sometimes called riverine or riparian swamps) have a more dynamic water table, with seasonal flooding inundating the vegetation for short (< 7 days) to long (> 1 month) periods. They are found along rivers, streams and lakes. They are subject to dramatic water fluctuations, seasonal flooding, and an influx of sediment and mineral enrichment during high water periods. Peat accumulation is usually shallow (less than 40 cm). The nutrient regime in swamps is highly variable, ranging from base-rich conditions with pH above 7.0, to base-poor conditions where pH can be in the range of 4.5 or lower. |
| Boreal Flooded & Swamp Forest (1.D.2) | Boreal Flooded & Swamp Forest is a forested or wooded wetland and peatland. These swamps are defined as a treed or tall shrub (also called *thicket*) dominated wetland that is influenced by minerotrophic groundwater, either on mineral or organic (peat) soils; less commonly they occur in transitional floodplain habitats. The vegetation is dominated by tall woody, mostly needleleaf trees, with broadleaf shrubs, generally over 10-20% cover, and the wood-rich peat laid down by this vegetation. The water table is below the major portion of the ground surface, and the dominant ground surface is at the hummock ground surface, that is, 20 cm or more above the average summer groundwater level. It is the aerated (or partly aerated) zone of substrates above the water that is available for root growth of trees and/or tall shrubs. The nutrient regime in swamps is highly variable ranging from base-rich conditions with pH above 7.0, to base-poor conditions where pH can be in the range of 4.5 or lower. One may recognize swamp forms based on the base-rich/pH gradient, i.e. calcareous rich (eutrophic), intermediate (mesotrophic), and poor (oligotrophic). Poor minerotrophic swamps may be transitional to treed ombrotrophic bog. |
| SHRUBLAND & GRASSLAND | |
| Bog & Fen (Peatland) | |

| | |
|---|---|
| Tropical Bog & Fen (2.A.4) | In tropical regions of the world, peat accumulating conditions occur in the cold, wet mountain highlands and in most of the flood plains of the lowlands, where peatlands have a fluctuating water table, with groundwater and surface water movements being common. "True" tropical bogs and fens, however, with sedge or moss peat are relatively rare. Tropical bogs occur in high, rainy regions, on flat to gently sloping, water-soaked ground with nearly impervious clay beneath peat of depths varying from <0.1 m to > 3 m. They are covered by a mixed vegetation of sedges and grasses, with scattered or clumped growth of dwarfed trees or shrubs. |
| Temperate & Boreal Bog & Fen (2.C.4) | A temperate & boreal bog is a sphagnum peatland type. Bogs may be treed or treeless, and they are usually covered with *Sphagnum* spp. and ericaceous shrubs. The driest bogs, especially in permafrost terrain may be covered in dwarf shrubs and lichens. The bog surface, which is raised or level with the surrounding terrain, is virtually unaffected by runoff waters or groundwaters from the surrounding mineral soils. Precipitation, fog and snowmelt are the primary water sources and, thus, all bogs are ombrogenous.<br>A temperate and boreal fen is a peatland with a fluctuating water table. The waters in fens are rich in dissolved minerals and, therefore, are minerotrophic. Groundwater and surface water movement is a common characteristic of fens. Surface flow may be directed through channels, pools, and other open water bodies that can form characteristic surface patterns. The dominant materials are moderately decomposed sedge and brown moss peats of variable thickness. The vegetation on fens is closely related to the depth of the water table and the chemistry of the waters present. The composition of vegetation may also reflect regional geographic variations. In general, graminoid vegetation and some bryophytes dominate wetter fens where the water table is above the surface. Shrubs are prominent in drier fens where the water table is lower. Trees appear on the driest fen sites where microtopographic features such as moss hummocks provide habitats as much as 20 cm above the water table. |
| Marsh | |
| Salt Marsh (2.C.6) | Salt Marsh is a wetland that has shallow water, and has levels that usually fluctuate due primarily to tides. It is found primarily in temperate and boreal coastal regions of temperate and boreal climates, but extends into the Arctic and Tropics. Coastal salt marshes are primarily intertidal; that is, they are found in areas at least occasionally inundated by high tide but not flooded during low tide. The vegetation is comprised of emergent aquatic macrophytes, especially saline or halophytic species, chiefly graminoids such as rushes, reeds, grasses and sedges, and shrubs and other herbaceous species such as broad-leaved emergent macrophytes, floating-leaved and submergent species (aquatic vegetation), and macroscopic algae. The vegetation is usually arranged in distinct zones of parallel patterns in response to gradients of tidal flooding frequency and duration, water chemistry or disturbance, sometimes described simply as "high marsh" (limits of high tide) and "low marsh" (intertidal marsh) Salt marshes have gradients that include, barren salt flats at the tidal edge, rushes, and then halophytic herbs and grasses at the outer edge. Daily drawdowns may expose mudflats which contain a sparse mix of pioneering herb and grass species. Salt marsh chemistry is dominated by salinity. Salinity levels vary depending on a complex of factors, including frequency of inundation, rainfall, soil texture, freshwater influence, fossil salt deposits, and other factors. The lower limits of salinity are defined as at least 0.5 ppt, below which it is considered freshwater. |
| Tropical Freshwater Marsh (2.A.5) | Tropical Freshwater Marsh includes wet meadows, shallow and deep emergent marshes. These wetlands have shallow water, and has levels that usually fluctuate daily, seasonally or annually due to tides (freshwater tidal), flooding, evapotranspiration, groundwater recharge, or seepage losses. The vegetation comprises evergreen emergent aquatic macrophytes, chiefly graminoids such as rushes, reeds, grasses and sedges, and shrubs and other herbaceous species such as broad-leaved emergent macrophytes, floating-leaved and submergent species, and non-vascular plants such as brown mosses, liverworts, and macroscopic algae. Vegetation is usually arranged in distinct zones of parallel or concentric patterns in response to gradients of water depths, frequency of drawdowns, water chemistry or disturbance. Saline or brackish non-tidal marshes are included here. Seasonal drawdowns may expose mudflats which are revegetated by pioneering herb and grass species. Plant communities of seasonal marshes are dynamic. They shift spatially with water levels, and change in composition over a short time, whereas communities of semi-permanent marshes usually are more stable, represented by stands of reeds which may persist for many years in the absence of severe drought. |
| Temperate & Boreal Freshwater Marsh (2.C.5) | Temperate Freshwater Marsh includes wet meadows, wet prairies, shallow and deep emergent marshes. These wetlands have shallow water, with levels that usually fluctuate daily, seasonally or annually due to tides (freshwater tidal), flooding, evapotranspiration, groundwater recharge, or seepage losses. The vegetation is comprised of seasonal green emergent aquatic macrophytes, chiefly graminoids such as rushes, reeds, grasses and sedges, and shrubs and other herbaceous species such as broad-leaved emergent macrophytes, floating-leaved and submergent species, and non-vascular plants such as brown mosses, liverworts, and macroscopic algae. The vegetation is usually arranged in distinct zones of parallel or concentric patterns in response to gradients of water depths, frequency of drawdowns, water chemistry or disturbance. Saline or brackish non-tidal marshes are included here. Seasonal drawdowns may expose mudflats which are revegetated by pioneering herb and grass species. Plant communities of seasonal marshes are dynamic. They shift spatially with water levels, and change in composition over a short time, whereas communities of semi-permanent marshes usually are more stable, represented by stands of reeds which may persist for many years in the absence of severe drought. |
| Tundra Wet Meadow (4.C.2) | Tundra wet meadow are low sedge and moss dominated communities. Comparisons of these circumpolar Arctic sedge meadows with Boreal sedge meadows (and marshes) are needed. They are called "Graminoid-moss tundra," being dominated by both sedges and grasses, along with an abundance of bryophytes, but few lichens. Hydrology varies from drier sites to saturated soils and standing water (50-60 cm deep). |
| AQUATIC VEGETATION | |
| Marine and Estuarine | Saltwater Aquatic Vegetation wetlands are distinct wetlands transitional along the coast between the intertidal |

| | |
|---|---|
| Aquatic Vegetation (5.A.1) | salt marshes or other intertidal areas, and permanent, deep water oceans. Submerged or floating aquatic plants usually dominate the vegetation, with less than 25% of the surface water area occluded by standing emergent or woody plants. Macroalga may be common. Open surface water at a range of depths is present for all or most of the year. |
| Freshwater Aquatic Vegetation (5.B.1) | Freshwater Aquatic Vegetation wetlands are distinct wetlands transitional between those wetlands that are saturated or seasonally wet (i.e. bog, fen, marsh or swamp) and permanent, deep water bodies (i.e. lakes) usually with a developed profundal zone. Submerged or floating aquatic plants usually dominate the vegetation, with less than 25% of the surface water area occluded by standing emergent or woody plants. Open surface water up to 2 m deep is present for all or most of the year. Water levels are seasonally stable, permanently flooded, or intermittently exposed during droughts, low flows or intertidal periods. |

## IV. B. National Wetland Inventory (Cowardin) Classification

The wetland classification system of Cowardin et al. (1979) forms the basis for the National Wetlands Inventory (NWI) Classification and Mapping Program across the United States. This classification was designed to be used as an inventory tool for wetlands and deepwater habitats. In this classification, the four hierarchical levels (System, Subsystem, Class, Subclass) are defined by water body types (e.g., marine, riverine, palustrine), substrate materials, flooding regimes, and vegetation life forms. A fifth level, the Dominance Type, which is named for the dominant plant or animal forms, is unstructured and must be developed by the user. One advantage of the NWI system is that it can be mapped using aerial photography and ground-truthing. Limitations are that not all features of the system can be observed from aerial photography, and some features, such as flooding, are very dynamic and not consistently observable. In addition, because the development of the user-defined types has not been coordinated, they are (by definition) not comparable among users. The NWI system has been widely used for reporting on the status and trends of wetland acres across the U.S. (e.g. Dahl 2006), but has not been used for functional or ecological integrity assessments.

Appendix D also shows how the NWI classification can be structured to link fairly directly to the NVC, by nesting the NVC formation level within the Cowardin class level. One can then work downwards within the NVC to get to a comprehensive list of wetland types at multiple scales (from Division to Association), providing the much needed solution to the Dominance Types list that has never been competed by NWI. It is also possible to link to the NatureServe Ecological Systems classification, which provides a robust set of tools for both classification and mapping at multiple spatial and thematic scales.

Table D.1.1 Relation of NVC Formations to NWI Systems, sub-Systems and Classes (Cowardin 1979).

| NWI Levels | | | NVC Formation |
|---|---|---|---|
| System | Sub-System | Class | Formation |
| 1. Marine | Intertidal | Aquatic Bed | 5.A.1. Marine and Estuarine Saltwater Aquatic Vegetation |
| | | Reef | See Coastal Marine Classification (CMESC) |
| | | Rocky Shore | 5.A.1. Marine and Estuarine Saltwater Aquatic Vegetation |
| | | Unconsolidated Shore | In NVC, not developed. (Tidal mud flats, sandy beaches, cobble-gravel etc); See also CMESC. |
| | Subtidal | Aquatic Bed | 5.A.1. Marine and Estuarine Saltwater Aquatic Vegetation |
| | | Reef | See Coastal Marine Classification (CMESC) |
| | | Rock Bottom | See Coastal Marine Classification (CMESC) |
| | | Unconsolidated Bottom | See Coastal Marine Classification (CMESC) |
| 2. Estuarine | Intertidal | Emergent | 2.A.6. Tropical Salt Marsh*<br>2.C.6. Temperate & Boreal Salt Marsh * |
| | | Forested | 1.A.4. Mangrove* |
| | | Reef | See Coastal Marine Classification (CMESC) |
| | | Rocky Shore | In NVC, see - Marine, Intertidal, Rocky Shore, and see CMESC |
| | | Scrub-Shrub | See Estuarine, Intertidal, Forested (tall shrubs >2 m), or Estuarine, Intertidal, Emergent (short shrubs < 2 m). |
| | | Streambed | See Coastal Marine Classification (CMESC) |
| | | Unconsolidated Shore | In NVC, see: Marine, Intertidal, Unconsolidated Shore; Undeveloped in NVC, and see CMESC |
| | Subtidal | Aquatic Bed | In NVC, see: Marine, Subtidal, Aquatic Bed |
| | | Reef | See Coastal Marine Classification (CMESC) |
| | | Rock Bottom | See Coastal Marine Classification (CMESC) |
| | | Unconsolidated Bottom | See Coastal Marine Classification (CMESC) |
| 3. Riverine | All subsystems | All classes | See Freshwater Classification (review Emergent - non-persistent subclass, and Aquatic Bed class) |
| 4. Lacustrine | All subsystems | All classes | See Freshwater Classification (review Emergent - non-persistent subclass, and Aquatic Bed class) |
| 5. Palustrine | n/a | Aquatic Bed | 5.B.1. Freshwater Aquatic Vegetation * |
| | | Emergent | 2.A.5. Tropical Freshwater Marsh *<br>2.C.5. Temperate & Boreal Freshwater Marsh*<br>5.B.1. Freshwater Aquatic Vegetation * |
| | | Forested | 1.A.3. Tropical Flooded & Swamp Forest *<br>1.C.3. Temperate Flooded & Swamp Forest |

| | | | |
|---|---|---|---|
| | | | 1.D.2. Boreal Flooded & Swamp Forest * |
| | | Moss-Lichen | 2.A.4. Tropical Bog & Fen *<br>2.C.4. Temperate & Boreal Bog & Fen* |
| | | Scrub-Shrub | See Palustrine, Forested (tall shrubs >2 m), or Palustrine, Emergent (short shrubs < 2 m). |
| 99. Upland | n/a | n/a | 2.C.3. Temperate & Boreal Coastal Scrub & Herb Vegetation[contains dune swales]<br>3.A.1. Warm Semi-Desert<br>3.B.1. Cool Semi-Desert<br>6.B.2. Temperate and Boreal Cliff, Scree, & Other Rock Vegetation |

## IV.C. Hydrogeomorphic Classification (HGM)

Applications for a permit to discharge dredged or fill material in waters of the United States undergo a public review process that includes assessing the impacts of a proposed project on wetland functions. Results of the assessment are one of the factors considered in making the 404 permit decision. The hydrogeomorphic (HGM) classification developed by Brinson (1993) was developed in order to assist the Corp of Engineers with the evaluation of wetland impacts, and as such, overlaps with some of the purposes of ecological integrity assessments (Faber-Langendoen et al. 2006). HGM identifies groups of wetlands that function similarly, based on three fundamental factors that influence how wetlands function, including geomorphic setting, water source, and hydrodynamics (Smith et al. 1995):

> "Geomorphic setting refers to the landform of a wetland, its geologic evolution, and its topographic position in the landscape. For example, a wetland may occur in a depressional landform or a valley landform and may occur at the top, middle, or bottom of a watershed. Water source refers to the location of water just prior to entry into the wetland. All water on the land originates as precipitation, but in many cases the water will follow a circuitous path prior to entry into a wetland. For example, water may enter the wetland directly as precipitation, follow a less direct path over the surface of the ground as overland flow or overbank flow, follow a subsurface path as interflow, throughflow, or baseflow, or any combination of these (Figure 2). Hydrodynamics refers to the energy level of moving water, and the direction that surface and near-surface water moves in the wetland. For example, the level of energy of an isolated wetland is generally lower than a wetland on a river floodplain, and the movement of water in a riverine wetland is generally unidirectional and downstream. In the hydrogeomorphic classification, each of these factors is treated separately; however, considerable interaction is recognized given the multivariate nature of ecosystems."

At the highest level of hydrogeomorphic classification, wetlands are grouped into hydrogeomorphic wetland classes, including depression, lacustrine fringe, tidal fringe, slope, riverine, mineral flat, and organic flat (Table 8). Smith et al. (1995) and Brinson (1993) discuss these classes in greater detail.

Table 8. Hydrogeomorphic Classes of Wetlands showing dominant water sources, hydrodynamics, and examples of subclasses (from Smith et al. 1995).

| **Hydrogeomorphic Class (geomorphic setting)** | **Water Source (dominant)** | **Hydrodynamics (dominant)** | **Examples of Regional Subclass** | |
|---|---|---|---|---|
| | | | **Eastern USA** | **Western USA and Alaska** |
| Riverine | Overbank flow from channel | Unidirectional and horizontal | Bottomland hardwood forests | Riparian forested wetlands |
| Depressional | Return flow from groundwater and interflow | Vertical | Prairie pothole marshes | California vernal pools |
| Slope | Return flow from groundwater | Unidirectional, horizontal | Fens | Avalanche chutes |
| Mineral soil flats | Precipitation | Vertical | Wet pine flatwoods | Large playas |
| Organic soil flats | Precipitation | Vertical | Peat bogs; portions of Everglades | Peat bogs |
| Estuarine fringe | Overbank flow from estuary | Bidirectional, horizontal | Chesapeake Bay marshes | San Francisco Bay |
| Lacustrine fringe | Overbank flow from lake | Bidirectional, horizontal | Great Lakes marshes | Flathead Lake marshes |

At a continental scale, the variability encompassed by a single hydrogeomorphic wetland class is great. The level of variability can be reduced by applying the hydrogeomorphic classification at a regional scale and then developing regional subclasses. Regions are defined as geographic areas that are relatively homogenous with respect to climate, geology, and other large-scale factors that influence wetland function. A variety of eco-regional classifications have been developed for the United States based on climatic, geologic, physiographic, and ecological criteria and these may be used as the basis for defining the regions. The regional subclasses, like the hydrogeomorphic classes, are distinguished on the basis of geomorphic setting, water source, and hydrodynamics. There is considerable flexibility in defining wetland subclasses within a region. The number of regional wetland subclasses defined will depend on a variety of factors such as the diversity of wetlands in the region, assessment objectives, the ability to actually measure functional differences with the time and resources available, and the predilection towards lumping or splitting (Smith et al. 1995).

As can be seen from Appendix D, NVC formations have various relations to HGM classes. Because of a variety of compensating ecological factors, not just water-hydrology factors, the same HGM class can give rise to different formations. Conversely the same HGM class can span a wide variety of vegetation or ecosystem types. These would ultimately be refined by HGM using subclasses, etc., but currently no comprehensive framework for such a list of subclasses or regions has been developed. The NVC can provide that framework and the list of types.

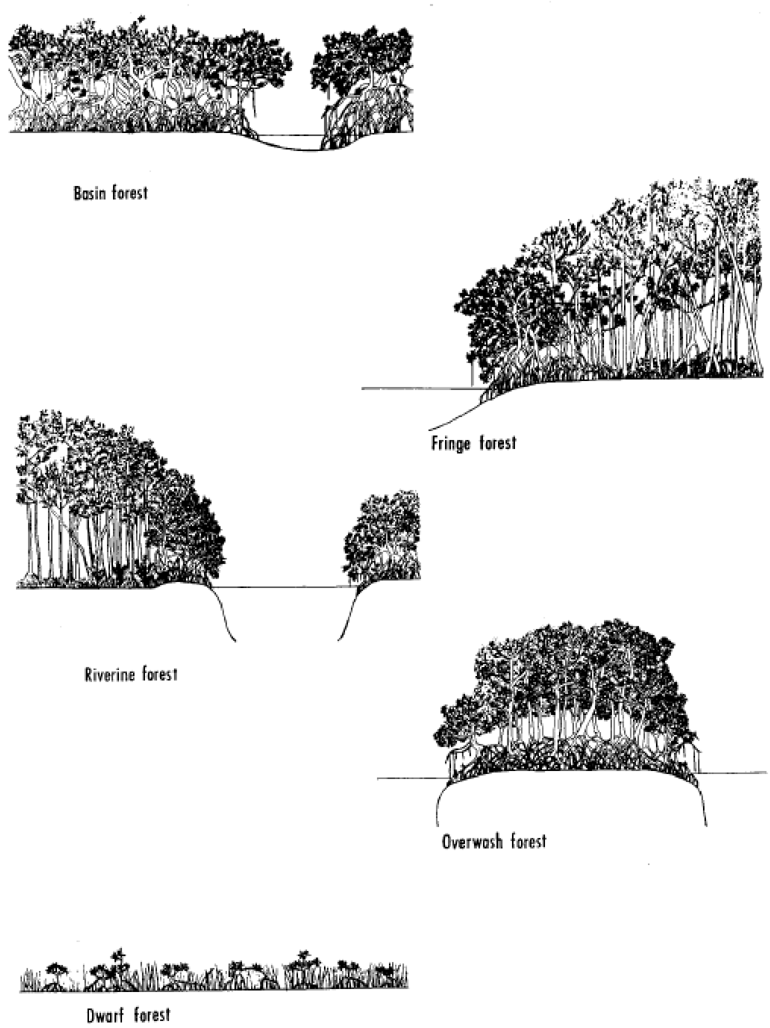
Given the widespread of HGM for helping set performance standards for wetland mitigation, we show how our ecological integrity assessments can be used both within the NVC classification (formation-level types in Table 6 above) and the HGM classification (class-level types in Table 8 above).

NVC formations have various relations to HGM classes. Because of a variety of compensating ecological factors, not just water-hydrology factors, the same HGM class can give rise to different formations (Fig 1 and 2). Conversely the same HGM class can span a wide variety of vegetation or ecosystem types. These would ultimately be refined by HGM using subclasses, etc., but currently no comprehensive framework for such a list of subclasses has been developed.

Table D.2.1. Relation of NVC Formations to HGM Classes (Brinson 1993).

| | NVC Class | HGM Class | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Wetland Category** | **FORMATION** | **Riverine** | **Depressional** | **Slope** | **Flats - Mineral** | **Flats - Organic** | **Estuarine Fringe** | **Lacustrine Fringe** |
| **Swamp** | **Mangrove** | X | X | | | | X | |
| | **Tropical Flooded & Swamp Forest** | X | X | | | (X) | | X |
| | **Temperate Flooded & Swamp Forest** | X | X | (X) | (X) | | | X |
| | **Boreal Flooded & Swamp Forest** | X | X | | | | | X |
| **Bog & Fen** | **Tropical Bog & Fen** | | X | X | | X | | |
| | **Temperate & Boreal Bog & Fen** | (X) | X | X | | X | | |
| **Marsh** | **Salt Marsh** | | X? | | | | X | |
| | **Tropical Freshwater Marsh** | X | X | (X) | X | | | X |
| | **Temperate & Boreal Freshwater Marsh** | X | X | X | X | | | X |
| | **Tundra Wet Meadow** | X | X | (X) | X | | | X |
| **Aquatic** | **Marine and Estuarine Aquatic Vegetation** | | | | | | X | |
| | **Freshwater Aquatic Vegetation** | X | X | | X | (X) | | X |

Figure 1. Mangrove formation and various hydrogeomorphic classes that it can occur in. (from Wharton et al. 1977; see also Brinson 1993). Basin = HGM Depressional; Fringe = Estuarine Fringe: Riverine = Riverine; Overwash = Estuarine Fringe; Dwarf Forest = ?




a. Five types proposed for mangroves in Florida by Lugo and Snedaker (1974) as illustrated in Wharton et al. (1977)

Figure 2. Example of various hydrogeomorphic classes found in flooded and swamp forests (from Golet et al. 1993).

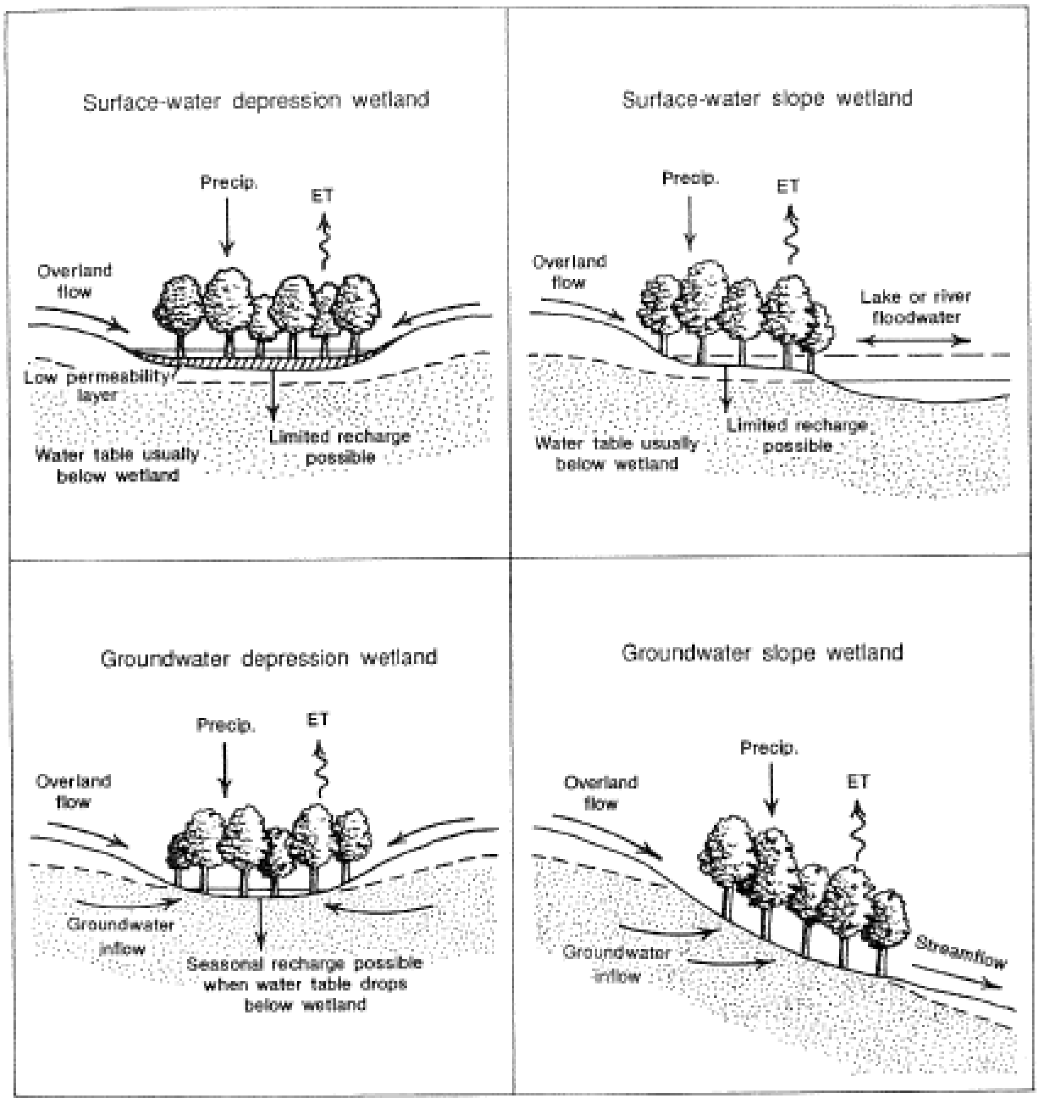



**Fig. 2.2.** Inland wetland hydrologic classes (based on Novitzki 1979a, 1982). The *shaded area* is the groundwater zone; its upper surface is the water table.

# IV.D. NVC and Ecological Systems Classifications

## U.S. National Vegetation Classification

The U.S. National Vegetation Classification is a conceptual/taxonomic hierarchy of vegetation, ranging from broad-scale formations to fine-scale alliances and associations. It is the primary classification used for our wetland assessments at the broadest level of wetland types – the formation (see Table 5). Our assessment is restricted to a consideration of those that are most common in the United States (see Table 6).

Table 6. Wetland formations (level 3) grouped by some common wetland categories (from FGDC Hierarchy Revisions Working Group 2007). Of the 13 formations, the 7 formations shown in bold are the primary focus of the assessments developed in this report.

| | **NVC FORMATION** |
|---|---|
| Swamp (wooded) | 1.A.4. Mangrove<br>1.A.3. Tropical Flooded & Swamp Forest<br>1.C.3. Temperate Flooded & Swamp Forest<br>1.D.2. Boreal Flooded & Swamp Forest |
| Bog & Fen (Peatland) | 2.A.4. Tropical Bog & Fen<br>2.C.4. Temperate & Boreal Bog & Fen |
| Marsh | 2.C.6. Salt Marsh<br>2.A.5. Tropical Freshwater Marsh<br>2.C.5. Temperate & Boreal Freshwater Marsh<br>4.C.2. Tundra Wet Meadow |
| Aquatic Vegetation | 5.A.1. Marine and Estuarine Aquatic Vegetation<br>5.B.1. Freshwater Aquatic Vegetation |

## Ecological Systems

A second classification approach, the Ecological Systems classification (Comer et al. 2003), can be used in conjunction with the NVC. Ecological systems provide a spatial-ecologic perspective on the relation of associations and alliances (fine-scale plant community types), much as soil associations help portray the spatial-ecologic relations among soil series in a soil taxonomic hierarchy. Systems types facilitate mapping at meso-scales (1:24,000 – 1:100,000). Currently there are about 600 ecological systems, of which about 250 are wetlands. Systems are somewhat comparable to the Group level of the revised NVC hierarchy, and can be linked to higher levels of the NVC hierarchy, including formations (See Table 7). A full set of Systems linked to higher levels of the Hierarchy is provided in Appendix E.

Table 7. The following table illustrates the placement of salt marshes within the NVC hierarchy, and an example of how Systems can be linked to the Hierarchy: The Acadian Coastal Salt Marsh system falls within the North American Atlantic Salt Marsh macrogroup, and probably even the North Atlantic Salt Marsh group, but the Spartina alterniflora alliance occurs in a variety of Atlantic Coast marshes.

| **NVC Hierarchy** | **Pilot CNVC Types** | |
|---|---|---|
| Formation | Salt Marsh | |
| Division | Temperate Atlantic Rim Salt Marsh | |
| Macrogroup | North American Atlantic Salt Marsh | |
| Group | North Atlantic Salt Marsh | ***Acadian Coastal Salt Marsh*** *System* |
| Alliance | Spartina alterniflora Tidal Herbaceous | |

Both the NVC Formations and Systems share with the HGM approach (see below) the use of hydrogeomorphic criteria, but both also use biotic, soils, climate and other criteria to define types. Full details of the NVC Formations and their link to Ecological Systems are provided in a separate report (Faber-Langendoen et al. 2007). A key to the formations is provided in Appendix F.

# Appendix V: Key to NVC Wetland Formations

| Key to Wetland Formations (adapted from National Wetlands Working Group 1997) | Type |
|---|---|
| 1. Terrain not affected by high water table or excess surface water, or if affected, only for short periods such that hydrophytic vegetation or aquatic processes do not exist. | *Upland (non-wetland)* |
| 1. Terrain affected by water table at, near or above the land surface and which is saturated for sufficient time to promote hydrophytic wetland vegetation or aquatic processes | *Wetlands – 2* |
| 2. Wetland ecosystem characterized by an accumulation of peat. | *Peatlands – 3* |
| 3. Peatland dominated by bryophytes (especially Sphagnum and brown* mosses) and graminoids, with variable cover of (especially ericaceous) dwarf-shrubs (<0.5 m); trees, if present, often sparse and stunted, rarely dense (except on raised bogs). Hydrology typically saturated, occasionally flooded. | *Bogs and fens – 4* |
| 4. Peatland contains needleleaf conifer or broadleaf deciduous trees and shrubs (rarely tall evergreen shrubs, as in pocosins); found in temperate or boreal regions. | **Temperate & Boreal Bog & Fen** |
| 4. Peatland contains broadleaf evergreen trees and shrubs, needleleaf conifers absent; found in tropical regions (in U.S., only found in Hawaii.). | **Tropical Bog & Fen** |
| 3. Peatland dominated by trees, shrubs and forbs; waters are rich in dissolved minerals, sometimes flooded. Hydrology variable. | *Floodplain and swamp forests - 7* |
| 2. Wetland ecosystem characterized by minimal or no peat accumulation, although thin layers of muck and a mix of mineral and organic muck may be present | *Mineral or aquatic wetlands – 5* |
| 5. Wetland with free surface water persisting above the ground surface for variable periods or not at all. If surface water persists through the summer, water depths are sufficiently shallow to permit survival of emergent woody or herbaceous vegetation which cover more than 25% of the surface area of the wetland. | *Emergent herbaceous and woody mineral wetlands - 6* |
| 6. Vegetation dominated by woody plants, typically more than 2 m high, with periodically standing surface water and gently moving, nutrient-rich groundwater, or tidal salt water. | *Floodplain and swamp forests or mangroves - 7* |
| 7. Wetland dominated by needleleaf or broadleaf deciduous (rarely evergreen) trees and tall deciduous (rarely evergreen) shrubs; found in temperate or boreal regions. | *Temperate and boreal floodplain and swamp forests – 8* |
| 8. Wetland contains needleleaf conifer or broadleaf deciduous (rarely evergreen) hardwood trees, and deciduous (rarely evergreen) tall shrubs; strata vary from simple to complex. | **Temperate Flooded & Swamp Forest** |
| 8. Wetland contains primarily needleleaf conifer (typically conical species such as spruce or fir) or broadleaf deciduous hardwood trees and tall shrubs; strata simple; found in boreal regions (in U.S., only found in Alaska and border states from Minnesota to Maine, and parts of New England). | **Boreal Flooded & Swamp Forest** |
| 7. Wetland dominated by broadleaf evergreen trees and shrubs, found in tropical regions (in U.S., only found in Florida, Hawaii, and U.S. territories). | *Tropical floodplain and swamp forests - 9* |
| 9. Wetland dominated by a diversity of broadleaf evergreen trees, and 9shrubs, typically with multiple strata; water is freshwater, typically non-tidal. | **Tropical Flooded & Swamp Forest** |
| 9. Wetland dominated by a simple set of broadleaf evergreen trees, and shrubs, varying in size from dwarf shrubs to tall trees; pneumatophores may be present; strata are typically simple; water is saline, hydrology is tidal; often associated with mudflats. (in U.S., only found in Florida, U.S. territories and Hawaii, where it is introduced). | **Mangrove** |
| 6. Vegetation is dominated by graminoids, such as rushes, reeds, grasses and sedges, with some low (< 2 m) shrubs) and broad-leaved forbs (occasionally dominant). Periodic or persistent standing water or slow moving surface water, which is circumneutral to alkaline and generally nutrient-rich. | *Marshes (including wet meadows) - 10* |
| 10. Vegetation typically dominated by graminoids. Also present may be floating-leaved and submergent species, and non-vascular plants such as brown mosses, liverworts, and (rarely) macroscopic algae. Water is shallow, and has levels that usually fluctuate due to flooding, evapotranspiration, groundwater recharge, or seepage losses; rarely tidal | *Freshwater marshes, (including wet meadows) – 11* |
| 11. Vegetation dominated by low sedge and moss (typically <0.25 m height). Hydrology varies from drier sites to saturated soils and standing water (50-60 cm deep), soils frozen for most of the year [?]. | **Tundra Wet Meadow** |

| | |
|---|---|
| 11. Not as above. Vegetation dominated by tall graminoids and forbs, mosses sparse. | *Temperate and tropical freshwater marshes* |
| 12. Vegetation dominated by seasonal green graminoids, forbs, and low shrubs. [other differences?]<br>12. Vegetation dominated by evergreen graminoids, forbs, and low shrubs. [other differences?] | **Temperate & Boreal Freshwater Marsh**<br>**Tropical Freshwater Marsh** |
| 10. Vegetation typically dominated by graminoids, as well as halophytic succulents and low shrubs, and broad-leaved forbs. Also found are macroscopic algae. Vegetation often arranged in distinct zones of parallel patterns in response to gradients of tidal flooding frequency and duration, water chemistry or disturbance, sometimes described simply as "high marsh" (limits of high tide) and "low marsh" (intertidal marsh). Daily drawdowns may expose mudflats which contain a sparse mix of pioneering herb and grass species. (found only in coastal environments – exclude inland salt marsh?). Tropical, Temperate, Boreal and Arctic salt marshes are physiognomically and ecologically similar enough that they are treated under this one formation | **Salt Marsh (mainly temperate and boreal, but some polar and tropical)** |
| 5. Submerged or floating aquatic plants usually dominate the vegetation, with less than 25% of the surface water area occluded by standing emergent or woody plants. Free surface water up to 2 m deep, present for all or most of the year. | *Aquatic (floating and submergent) vegetation - 14* |
| 14. Submerged or floating seasonal green aquatic plants usually dominate the vegetation. Macroalga rare. Free surface water rarely exceeds 2 m deep, present for all or most of the year. Water is fresh or, rarely, brackish.<br>14. Submerged or floating evergreen aquatic plants usually dominate the vegetation, Macroalga may be common. Open surface water at a range of depths is present for all or most of the year. Water is saline. (found only in marine and estuarine coastal environments).(exclude inland salt aquatic?] | **Freshwater Aquatic Vegetation**<br>**Marine & Estuarine Aquatic Vegetation** |

* brown mosses include, among others, species from the genera *Aulacomnium*, *Campylium*, *Drepanocladus*, *Scorpidium*, and *Tomenthypnum*.

*Example Field Form*

# VI.1 Biotic Composition – Vegetation Form

Table A.1 Field Information needed to evaluate Vegetation Structure and Vegetation Composition

| Layer | Total Cover (%) | Exotic Cover (%) | Height* (m) | Most abundant species, and % cover of each (e.g., Acer rubrum (60%), etc.). In each layer, list all species or surfaces greater than 5**%,** including unknowns ***If tree layer, list ALL species.*** | Live Stem: # ≥ 30(?) cm dbh | | | Snags: # ≥ 30 (?) cm dbh | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 30 | 40 | ≥50 | 30 | 40 | ≥50 |
| Tree – Overstory | | | | | | | | | | |
| Tree – Regeneration | | | | | | | | | | |
| Shrub Layer | | | | | Notes: | | | | | |
| Herb/Field Layer | | | | | | | | | | |
| Non-vascular Layer (Moss, Lichen, Alga) | | | | | | | | | | |
| Floating/Submerged Layer | | | | | | | | | | |
| Unvegetated Surface | | | | | | | | | | |
| Coarse Woody Debris | - | | - | List # of large fallen stems by size classes in column to the right. Note # large stems > 30 cm in advanced** stages of decay:_______ | | | | | | |

*Height is the predominant height of the main canopy, not of the tallest emergent.

**Advanced decay = At least a decay class of IV on the Pyle and Brown (1998) scale. I.e.: Bark generally absent, log shape and integrity is oval or flattend, no longer a solid piece, though some hard chunks remain, and wood condition is very spongy wood, responds to finger pressure and may exude moisture – and powder wood – flows through fingers like coarse sawdust.

## VI.2. Vegetation Field Sampling

Although plot-based or area-based measurements are preferred, depending on time and financial constraints, this metric can also be measured using plot-less techniques. The two methods are described as follows: (1) Site Survey (semi-quantitative): walk the entire occurrence of the community type at the site and make notes on vegetation strata, their cover, and exotic species. (2) Quantitative Plot Data: Use a fixed area method. A variety of techniques are available, including line transects, transects with 20 or more small 0.25 – 1 $m^2$ quadrants laid along them, or fixed-area plot methods of 100 to 1000 $m^2$. Studies by Yorks and Dabydeen (1998) and Rocchio (2006) found that the transect method did not pick up most non-dominant species and therefore was biased toward dominant species and resulted in biased proportions for some guilds (graminoids, forbs, low levels of exotics, etc.). This can result in metrics which are less sensitive to changes resulting from human disturbances. Thus, the plot (or reléve) method is preferred.

The plot method may either be a "rapid plot" or a more intensive plot, following the 0.1 ha modular approach of Peet et al. (1998). The rapid plot incorporates some aspects of the intensive plot. For the rapid plot 1 or more 10 x 10 or 20 x 20 m plots may be systemically or randomly placed within the assessment area.

The plot method described by Peet et al. (1998) is a recommended approach for collecting quantitative vegetation data. This method uses a 20 x 50 m plot which is typically established in a 2 x 5 arrangement of 10 x 10 m modules, and provides a standard 0.1 ha sample area, a widely used standard for assessing species richness. However, the array of modules can be rearranged or reduced to meet site conditions (e.g. 1 x 5 for linear areas or 2 x 2 for small, circular sites). Species presence and cover is recorded in each of four modules. If time permits, the reset of the 50 x 20 m area can be surveyed for additional species to obtain a 0.1 ha sample. The method is suitable for most types of vegetation, provides information on species composition across spatial scales, is flexible in intensity and effort, and compatible with data from other sampling methods (Peet et al. 1998, Mack 2004).

# *Appendix VII: NVC Wetland Types and NatureServe Ecological Systems*

A Pilot Set of NVC Wetland Types (Formation to Macrogroup) and links to NatureServe Ecological System Types. See Appendix IV.D for details on the relationship between the NVC and Ecological Systems. NVC types are under review through the peer review process specified in the FGDC 2008 standard.

[Table begins on next page.]

| U.S. NATIONAL VEGETATION CLASSIFICATION | | | | | NATURESERVE | |
|---|---|---|---|---|---|---|
| L1. Form. Class | L2. Form. Sub-class | L3. Formation Name | L4. Division | L5. Macrogroup | ECOLOGICAL SYSTEM | CODE |
| 1. | 1.A. | **1.A.3. Tropical Flooded & Swamp Forest** | Neotropical Flooded & Swamp Forest (or Caribbean-Central American?) | Caribbean Flooded & Swamp Forest | South Florida Bayhead Swamp | CES411.366 |
| | | | | | South Florida Cypress Dome | CES411.365 |
| | | | | | South Florida Dwarf Cypress Savanna | CES411.290 |
| | | | | | South Florida Hydric Hammock | CES411.273 |
| | | | | | South Florida Pond-apple/Popash Slough | CES411.486 |
| | | | Tropical Pacific Islands Flooded & Swamp Forest | Polynesian Riparian Forest | Hawaiian Riparian Forest and Shrubland | CES412.220 |
| | | | | Polynesian Sloping Wetland Forest [needs work] | Hawaiian Uluhe Fern Woodland | CES412.219 |
| | | | | | Hawaiian Wet Cliff and Ridge Crest Dwarf Forest and Shrubland | CES412.218 |
| | | 1.A.4. Mangrove | Atlantic-Caribbean-East Pacific Mangrove | Western Atlantic/Caribbean Mangrove | South Florida Mangrove Swamp | CES411.289 |
| | | | | | Southwest Florida Perched Barriers Tidal Swamp and Lagoon | CES203.540 |
| | 1.C. | 1.C.3. Temperate Flooded & Swamp Forest | Eastern North America Flooded & Swamp Forest | Central Hardwoods Swamp Forest | Central Interior Highlands and Appalachian Sinkhole and Depression Pond | CES202.018 |
| | | | | | Cumberland Seepage Forest | CES202.361 |
| | | | | | Interior Highlands Forested Acid Seep | CES202.321 |
| | | | | | North-Central Interior Wet Flatwoods | CES202.700 |
| | | | | | Red River Large Floodplain Forest | CES203.065 |

| U.S. NATIONAL VEGETATION CLASSIFICATION | | | | | NATURESERVE | |
|---|---|---|---|---|---|---|
| | | | | Northern and Central Floodplain Forest | Central Appalachian River Floodplain | CES202.608 |
| | | | | | Central Appalachian Stream and Riparian | CES202.609 |
| | | | | | Laurentian-Acadian Floodplain Forest | CES201.587 |
| | | | | | North-Central Interior Floodplain | CES202.694 |
| | | | | | Ozark-Ouachita Riparian | CES202.703 |
| | | | | | South-Central Interior Large Floodplain | CES202.705 |
| | | | | | South-Central Interior Small Stream and Riparian | CES202.706 |
| | | | | Northern Hardwoods Swamp Forest | Acadian-Appalachian Conifer Seepage Forest | CES201.576 |
| | | | | | Laurentian-Acadian Alkaline Conifer-Hardwood Swamp | CES201.575 |
| | | | | | Laurentian-Acadian Conifer-Hardwood Acid Swamp | CES201.574 |
| | | | | | North-Central Appalachian Acidic Swamp | CES202.604 |
| | | | | | North-Central Interior and Appalachian Rich Swamp | CES202.605 |
| | | | | Southern Bottomland Flooded & Swamp Forest | Atlantic Coastal Plain Blackwater Stream Floodplain Forest | CES203.247 |
| | | | | | Atlantic Coastal Plain Brownwater Stream Floodplain Forest | CES203.248 |
| | | | | | Atlantic Coastal Plain Large River Floodplain Forest | CES203.066 |
| | | | | | Atlantic Coastal Plain Small Blackwater River Floodplain Forest | CES203.249 |
| | | | | | Atlantic Coastal Plain Small Brownwater River Floodplain Forest | CES203.250 |
| | | | | | Atlantic Coastal Plain Streamhead Seepage Swamp, Pocosin, and Baygall | CES203.252 |
| | | | | | East Gulf Coastal Plain Large River Floodplain Forest | CES203.489 |
| | | | | | East Gulf Coastal Plain Northern Seepage Swamp | CES203.554 |
| | | | | | East Gulf Coastal Plain Small Stream and River Floodplain Forest | CES203.559 |
| | | | | | East Gulf Coastal Plain Tidal Wooded Swamp | CES203.299 |

| U.S. NATIONAL VEGETATION CLASSIFICATION | | | | | NATURESERVE | |
|---|---|---|---|---|---|---|
| | | | | | Mississippi River Bottomland Depression | CES203.490 |
| | | | | | Mississippi River High Floodplain (Bottomland) Forest | CES203.196 |
| | | | | | Mississippi River Low Floodplain (Bottomland) Forest | CES203.195 |
| | | | | | Mississippi River Riparian Forest | CES203.190 |
| | | | | | Northern Atlantic Coastal Plain Stream and River | CES203.070 |
| | | | | | Northern Atlantic Coastal Plain Tidal Swamp | CES203.282 |
| | | | | | South-Central Interior / Upper Coastal Plain Wet Flatwoods | CES203.480 |
| | | | | | Southern Atlantic Coastal Plain Tidal Wooded Swamp | CES203.240 |
| | | | | | Southern Coastal Plain Blackwater River Floodplain Forest | CES203.493 |
| | | | | | Southern Piedmont Large Floodplain Forest | CES202.324 |
| | | | | | Southern Piedmont Small Floodplain and Riparian Forest | CES202.323 |
| | | | | | West Gulf Coastal Plain Large River Floodplain Forest | CES203.488 |
| | | | | | West Gulf Coastal Plain Near-Coast Large River Swamp | CES203.459 |
| | | | | | West Gulf Coastal Plain Seepage Swamp and Baygall | CES203.372 |
| | | | | | West Gulf Coastal Plain Small Stream and River Forest | CES203.487 |
| | | | | Southern Coastal Plain Broadleaf Evergreen and Conifer Swamp | Southern Coastal Plain Hydric Hammock | CES203.501 |
| | | | | | Southern Coastal Plain Seepage Swamp and Baygall | CES203.505 |
| | | | | Southern Non-riverine Flats and Basin Swamps | Atlantic Coastal Plain Clay-Based Carolina Bay Wetland | CES203.245 |
| | | | | | Central Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest | CES203.304 |
| | | | | | East Gulf Coastal Plain Southern Loblolly-Hardwood Flatwoods | CES203.557 |
| | | | | | Northern Atlantic Coastal Plain Basin Peat Swamp | CES203.522 |
| | | | | | Northern Atlantic Coastal Plain Basin Swamp and Wet Hardwood Forest | CES203.520 |
| | | | | | Northern Atlantic Coastal Plain Pitch Pine Lowland | CES203.374 |
| | | | | | Piedmont Seepage Wetland | CES202.298 |
| | | | | | Piedmont Upland Depression Swamp | CES202.336 |

| U.S. NATIONAL VEGETATION CLASSIFICATION | | | | | NATURESERVE | |
|---|---|---|---|---|---|---|
| | | | | | Southern Atlantic White-cedar Peatland Forest [Provisional] | CES203.068 |
| | | | | | Southern Coastal Plain Nonriverine Basin Swamp | CES203.384 |
| | | | | | Southern Coastal Plain Nonriverine Cypress Dome | CES203.251 |
| | | | | | West Gulf Coastal Plain Nonriverine Wet Hardwood Flatwoods | CES203.548 |
| | | | | | West Gulf Coastal Plain Pine-Hardwood Flatwoods | CES203.278 |
| | | | | Western Great Plains Flooded & Swamp Forest | Northwestern Great Plains Riparian | CES303.677 |
| | | | | | Western Great Plains Floodplain | CES303.678 |
| | | | | | Western Great Plains Riparian Woodland and Shrubland | CES303.956 |
| | | | | | Western Great Plains Wooded Draw and Ravine | CES303.680 |
| | | | | Great Plains Flooded & Swamp Forest | Edwards Plateau Floodplain Terrace [Provisional] | CES303.651 |
| | | | | | Edwards Plateau Riparian [Provisional] | CES303.652 |
| | | | | | Northwestern Great Plains Floodplain | CES303.676 |
| | | | Warm Temperate Flooded & Swamp Forest | Warm Desert Riparian, Flooded & Swamp Forest | North American Warm Desert Lower Montane Riparian Woodland and Shrubland | CES302.748 |
| | | | | | North American Warm Desert Riparian Woodland and Shrubland | CES302.753 |
| | | | | | Sonoran Fan Palm Oasis | CES302.759 |
| | | | | | Tamaulipan Floodplain | CES301.990 |
| | | | | | Tamaulipan Palm Grove Riparian Forest | CES301.991 |
| | | | Western North America Flooded & Swamp Forest | Rocky Mtn and Great Basin Flooded & Swamp Forest | Columbia Basin Foothill Riparian Woodland and Shrubland | CES304.768 |
| | | | | | Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland | CES304.045 |

| U.S. NATIONAL VEGETATION CLASSIFICATION | | | | | NATURESERVE | |
|---|---|---|---|---|---|---|
| | | | | | Northern Rocky Mountain Conifer Swamp | CES306.803 |
| | | | | | Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland | CES306.804 |
| | | | | | Northern Rocky Mountain Wooded Vernal Pool | CES304.060 |
| | | | | | Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland | CES306.821 |
| | | | | | Rocky Mountain Subalpine-Montane Riparian Shrubland | CES306.832 |
| | | | | | Rocky Mountain Subalpine-Montane Riparian Woodland | CES306.833 |
| | | | | Vancouverian Flooded & Swamp Forest | California Central Valley Riparian Woodland and Shrubland | CES206.946 |
| | | | | | Mediterranean California Foothill and Lower Montane Riparian Woodland | CES206.944 |
| | | | | | Mediterranean California Serpentine Foothill and Lower Montane Riparian Woodland and Seep | CES206.945 |
| | | | | | North Pacific Glacial Outwash Forest and Shrubland | CES204.868 |
| | | | | | North Pacific Hardwood-Conifer Swamp | CES204.090 |
| | | | | | North Pacific Lowland Riparian Forest and Shrubland | CES204.869 |
| | | | | | North Pacific Montane Riparian Woodland and Shrubland | CES204.866 |
| | | | | | North Pacific Shrub Swamp | CES204.865 |
| | 1.D. | 1.D.2. Boreal Flooded and Swamp Forest | North America Boreal Flooded & Swamp Forest | North American Boreal Conifer Swamp Forest | Boreal Depressional Bog | CES103.871 |
| | | | | | Boreal-Laurentian Conifer Acid Swamp | CES103.724 |
| | | | | | Eastern Boreal Floodplain | CES103.588 |
| 2. | 2.A. | 2.A.4. Tropical Scrub & Herb Peatland | Tropical Pacific Islands Peatland | Polynesian Peatland | Hawaiian Montane Bog | CES412.216 |
| | | 2.A.5. Tropical Freshwater Marsh | Neotropical Freshwater Marsh | Caribbean - Central American Freshwater Marsh | South Florida Depression Pondshore | CES411.054 |
| | | | | | South Florida Everglades Sawgrass Marsh | CES411.286 |

| U.S. NATIONAL VEGETATION CLASSIFICATION | | | | | NATURESERVE | |
|---|---|---|---|---|---|---|
| | | | | | South Florida Slough, Gator Hole, and Willow Head | CES411.485 |
| | | | | | South Florida Wet Marl Prairie | CES411.370 |
| | | | Tropical Pacific Islands Freshwater Marsh | Polynesian Freshwater Marsh | Hawaiian Freshwater Marsh | CES412.222 |
| | 2.C. | 2.C.3. Temperate & Boreal Coastal Scrub & Herb Vegetation | Atlantic North America Coastal Grassland & Shrubland | Southeast Coastal Plain Dune Grassland & Shrubland | Central and Upper Texas Coast Dune and Coastal Grassland | CES203.465 |
| | | | | | East Gulf Coastal Plain Dune and Coastal Grassland | CES203.500 |
| | | | | | Northern Atlantic Coastal Plain Dune and Maritime Grassland | CES203.264 |
| | | | | | South Texas Dune and Coastal Grassland | CES301.460 |
| | | | | | Southern Atlantic Coastal Plain Dune and Maritime Grassland | CES203.273 |
| | | | Temperate & Boreal Atlantic Rim Strand and Riverwash Vegetation | Eastern Coastal Beach Strand | Louisiana Beach | CES203.469 |
| | | | | | Southern Atlantic Coastal Plain Beach | CES203.535 |
| | | | | | Texas Coastal Bend Beach | CES203.463 |
| | | | | | Upper Texas Coast Beach | CES203.544 |
| | | | Pacific Coast Xeric Scrub & Herb Vegetation | Warm Pacific Coastal Beach, Dune & Bluff Vegetation | Mediterranean California Northern Coastal Dune | CES206.907 |
| | | | | | Mediterranean California Southern Coastal Dune | CES206.908 |
| | | | | | Mediterranean California Coastal Bluff | CES206.906 |
| | | | | | Baja-Sonoran Coastal Dune | CES302.003 |
| | | | | Cool Pacific Coastal Beach, Dune & Bluff Vegetation | North Pacific Active Inland Dune | CES204.861 |
| | | | | | North Pacific Maritime Coastal Sand Dune | CES200.881 |

| U.S. NATIONAL VEGETATION CLASSIFICATION | | | | | NATURESERVE | |
|---|---|---|---|---|---|---|
| | | 2.C.4. Temperate & Boreal Bog & Fen | North American Bog & Fen | Appalachian & Interior Plateau Bog & Fen | Interior Low Plateau Seepage Fen | CES202.346 |
| | | | | | North-Central Appalachian Seepage Fen | CES202.607 |
| | | | | | North-Central Interior and Appalachian Acid Peatland | CES202.606 |
| | | | | | North-Central Interior Shrub-Graminoid Alkaline Fen | CES202.702 |
| | | | | | Ozark-Ouachita Fen | CES202.052 |
| | | | | | Southern and Central Appalachian Bog and Fen | CES202.300 |
| | | | | | Southern Appalachian Seepage Wetland | CES202.317 |
| | | | | North Pacific Bog and Fen | Mediterranean California Serpentine Fen | CES206.953 |
| | | | | | Mediterranean California Subalpine-Montane Fen | CES206.952 |
| | | | | | North Pacific Bog and Fen | CES204.063 |
| | | | | Rocky Mountain Subalpine-Montane Fen | Rocky Mountain Subalpine-Montane Fen | CES306.831 |
| | | | | Southeast Coastal Plain Bog & Fen | Atlantic Coastal Plain Peatland Pocosin and Canebrake | CES203.267 |
| | | | | | Atlantic Coastal Plain Sandhill Seep | CES203.253 |
| | | | | | East Gulf Coastal Plain Interior Shrub Bog | CES203.385 |
| | | | | | Southern Coastal Plain Herbaceous Seep and Bog | CES203.078 |
| | | | | | West Gulf Coastal Plain Herbaceous Seepage Bog | CES203.194 |
| | | | | North American Boreal Bog & Fen | Acadian Maritime Bog | CES201.580 |
| | | | | | Atlantic Coastal Plain Northern Bog | CES203.893 |
| | | | | | Boreal Fen | CES103.872 |
| | | | | | Boreal-Laurentian Bog | CES103.581 |
| | | | | | Boreal-Laurentian-Acadian Acidic Basin Fen | CES201.583 |
| | | | | | Laurentian-Acadian Alkaline Fen | CES201.585 |
| | | 2.C.5. Temperate & Boreal Freshwater Marsh | (Eastern) North America Freshwater Marsh | Atlantic and Gulf Coastal Plain Freshwater Tidal Marsh | Atlantic Coastal Plain Embayed Region Tidal Freshwater Marsh | CES203.259 |
| | | | | | Central and Upper Texas Coast Fresh and Oligohaline Tidal Marsh | CES203.472 |

| U.S. NATIONAL VEGETATION CLASSIFICATION | | | | | NATURESERVE | |
|---|---|---|---|---|---|---|
| | | | | | Central Atlantic Coastal Plain Fresh and Oligohaline Tidal Marsh | CES203.376 |
| | | | | | Florida Big Bend Fresh and Oligohaline Tidal Marsh | CES203.507 |
| | | | | | Gulf Coast Chenier Plain Fresh and Oligohaline Tidal Marsh | CES203.467 |
| | | | | | Mississippi Delta Fresh and Oligohaline Tidal Marsh | CES203.470 |
| | | | | | Mississippi Sound Fresh and Oligohaline Tidal Marsh | CES203.067 |
| | | | | | Northern Atlantic Coastal Plain Fresh and Oligohaline Tidal Marsh | CES203.516 |
| | | | | Atlantic and Gulf Coastal Plain Pondshore and Wet Prairie | Central Florida Herbaceous Pondshore | CES203.890 |
| | | | | | Central Florida Wet Prairie and Herbaceous Seep | CES203.491 |
| | | | | | East Gulf Coastal Plain Depression Pondshore | CES203.558 |
| | | | | | East Gulf Coastal Plain Sandhill Lakeshore Depression | CES203.292 |
| | | | | | Northern Atlantic Coastal Plain Pondshore | CES203.518 |
| | | | | | Southeastern Coastal Plain Interdunal Wetland | CES203.258 |
| | | | | | Southeastern Coastal Plain Natural Lakeshore | CES203.044 |
| | | | | | Southern Atlantic Coastal Plain Depression Pondshore | CES203.262 |
| | | | | | Texas-Louisiana Coastal Prairie | CES203.550 |
| | | | | | Texas-Louisiana Coastal Prairie Pondshore | CES203.541 |
| | | | | | Texas-Louisiana Coastal Prairie Slough | CES203.542 |
| | | | | | West Gulf Coastal Plain Flatwoods Pond | CES203.547 |
| | | | | Eastern North America Freshwater Marsh | Florida River Floodplain Marsh | CES203.055 |
| | | | | | Floridian Highlands Freshwater Marsh | CES203.077 |
| | | | | | Great Lakes Freshwater Estuary and Delta | CES202.033 |
| | | | | | Laurentian-Acadian Freshwater Marsh | CES201.594 |
| | | | | | Laurentian-Acadian Wet Meadow-Shrub Swamp | CES201.582 |
| | | | | | North-Central Interior Freshwater Marsh | CES202.899 |
| | | | | | Northern Great Lakes Coastal Marsh | CES201.722 |

| U.S. NATIONAL VEGETATION CLASSIFICATION | | | | | **NATURESERVE** | |
|---|---|---|---|---|---|---|
| | | | | Eastern North America Wet Meadow and Prairie | Boreal Ice-Scour Rivershore | CES103.589 |
| | | | | | Cumberland Riverscour | CES202.036 |
| | | | | | East Gulf Coastal Plain Savanna and Wet Prairie | CES203.192 |
| | | | | | Eastern Great Plains Wet Meadow, Prairie, and Marsh | CES205.687 |
| | | | | | Great Lakes Wet-Mesic Lakeplain Prairie | CES202.027 |
| | | | | | North-Central Interior Wet Meadow-Shrub Swamp | CES202.701 |
| | | | | | Northern Great Lakes Interdunal Wetland | CES201.034 |
| | | | | | West Gulf Coastal Plain Saline Glade | CES203.291 |
| | | | Great Plains Marsh | Great Plains Brackish Marsh & Saline Wet Meadow | Western Great Plains Saline Depression Wetland | CES303.669 |
| | | | | Great Plains Freshwater Marsh | Edwards Plateau Upland Depression [Provisional] | CES303.654 |
| | | | | | Great Plains Prairie Pothole | CES303.661 |
| | | | | | Western Great Plains Closed Depression Wetland | CES303.666 |
| | | | | | Western Great Plains Open Freshwater Depression Wetland | CES303.675 |
| | | | Western North American Warm Temperate Freshwater Marsh | Warm Desert Freshwater Shrubland, Meadow & Marsh | Chihuahuan-Sonoran Desert Bottomland and Swale Grassland | CES302.746 |
| | | | | | North American Arid West Emergent Marsh | CES300.729 |
| | | | | | North American Warm Desert Cienega | CES302.747 |
| | | | | | North American Warm Desert Interdunal Swale Wetland | CES302.039 |
| | | | | | North American Warm Desert Riparian Mesquite Bosque | CES302.752 |
| | | | (Western) North America Freshwater Marsh | Boreal Wet Meadow | Boreal Wet Meadow | CES103.873 |

| U.S. NATIONAL VEGETATION CLASSIFICATION | | | | | **NATURESERVE** | |
|---|---|---|---|---|---|---|
| | | | | Western North America Freshwater Marsh | Mediterranean California Coastal Interdunal Wetland | CES206.951 |
| | | | | | North Pacific Coastal Interdunal Wetland | CES204.062 |
| | | | | | North Pacific Intertidal Freshwater Wetland | CES204.875 |
| | | | | | Northern Columbia Plateau Basalt Pothole Ponds | CES304.058 |
| | | | | | Temperate Pacific Freshwater Emergent Marsh | CES200.877 |
| | | | | Western North America Vernal Pool | Columbia Plateau Vernal Pool | CES304.057 |
| | | | | | Modoc Basalt Flow Vernal Pool | CES204.996 |
| | | | | | North Pacific Hardpan Vernal Pool | CES204.859 |
| | | | | | Northern California Claypan Vernal Pool | CES206.948 |
| | | | | | Northern California Volcanic Vernal Pool | CES206.949 |
| | | | | | South Coastal California Vernal Pool | CES206.950 |
| | | | | Western North America Wet Meadow & Low shrub carr | Rocky Mountain Alpine-Montane Wet Meadow | CES306.812 |
| | | | | | Temperate Pacific Subalpine-Montane Wet Meadow | CES200.998 |
| | | | | | Willamette Valley Wet Prairie | CES204.874 |
| | | 2.C.6. Salt Marsh | Temperate & Boreal Atlantic Rim Salt Marsh | Arctic salt marsh macrogroup | (blank) | (blank) |
| | | | | Eastern North American Atlantic Salt Marsh | Acadian Coastal Salt Marsh | CES201.578 |
| | | | | | Acadian Estuary Marsh | CES201.579 |
| | | | | | Atlantic Coastal Plain Embayed Region Tidal Salt and Brackish Marsh | CES203.260 |
| | | | | | Atlantic Coastal Plain Northern Salt Pond Marsh | CES203.892 |
| | | | | | Central and Upper Texas Coast Salt and Brackish Tidal Marsh | CES203.473 |
| | | | | | Central Atlantic Coastal Plain Salt and Brackish Tidal Marsh | CES203.270 |

| U.S. NATIONAL VEGETATION CLASSIFICATION | | | | | NATURESERVE | |
|---|---|---|---|---|---|---|
| | | | | | Florida Big Bend Salt and Brackish Tidal Marsh | CES203.508 |
| | | | | | Gulf Coast Chenier Plain Salt and Brackish Tidal Marsh | CES203.468 |
| | | | | | Mississippi Delta Salt and Brackish Tidal Marsh | CES203.471 |
| | | | | | Mississippi Sound Salt and Brackish Tidal Marsh | CES203.303 |
| | | | | | Northern Atlantic Coastal Plain Brackish Tidal Marsh | CES203.894 |
| | | | | | Northern Atlantic Coastal Plain Tidal Salt Marsh | CES203.519 |
| | | | | | South Texas Salt and Brackish Tidal Flat | CES301.461 |
| | | | | | Texas-Louisiana Saline Coastal Prairie | CES203.543 |
| | | | Temperate and Boreal Pacific Rim Salt Marsh | North American Inland Salt Marsh | North American Warm Desert Playa | CES302.751 |
| | | | | North American Pacific Salt Marsh | Baja-Sonoran Coastal Tidal Flat and Marsh | CES302.005 |
| | | | | | California Central Valley Alkali Sink | CES206.954 |
| | | | | | Mediterranean California Alkali Marsh | CES206.947 |
| | | | | | Temperate Pacific Tidal Salt and Brackish Marsh | CES200.091 |
| | | | Tropical Atlantic Salt Marsh | Caribbean - Central American Salt Marsh? | Atlantic Coastal Plain Indian River Lagoon Tidal Marsh | CES203.257 |
| | | | | | Caribbean Salt Flat and Pond | CES411.460 |
| | | | Tropical Pacific Islands Salt Marsh | Polynesian Salt Marsh | Northern Polynesia Tidal Salt Marsh | CES412.224 |
| 5. | 5.A. | 5.A.1. Marine and Estuarine Saltwater Aquatic Vegetation (and inland saltwater?) | Neotropical Saltwater Aquatic Vegetation | Caribbean Intertidal Shore | (blank) | (blank) |
| | | | | Caribbean Seagrass Bed | Florida Keys Seagrass Bed | CES411.285 |
| | | | Temperate Atlantic Saltwater Aquatic Vegetation | Temperate Atlantic Intertidal Shore | North Atlantic Intertidal Mudflat | CES201.050 |
| | | | | | North Atlantic Rocky Intertidal | CES201.048 |
| | | | | | North Atlantic Tidal Sand Flat | CES201.049 |

| U.S. NATIONAL VEGETATION CLASSIFICATION | | | | | NATURESERVE | |
|---|---|---|---|---|---|---|
| | | | | Temperate Atlantic Seagrass Bed | Atlantic Coastal Plain Embayed Region Seagrass Bed | CES203.243 |
| | | | | | Atlantic Coastal Plain Indian River Lagoon Seagrass Bed | CES203.256 |
| | | | | | East Gulf Coastal Plain Florida Big Bend Seagrass Bed | CES203.244 |
| | | | | | Northern Atlantic Coastal Plain Seagrass Bed | CES203.246 |
| | | | | | Northern Atlantic Coastal Plain Subtidal Aquatic Bed | CES203.521 |
| | | | | | Northern Gulf of Mexico Seagrass Bed | CES203.263 |
| | | | | | Southwest Florida Seagrass Bed | CES203.274 |
| | | | | | Texas Coastal Bend Seagrass Bed | CES203.474 |
| | | | | | Upper Texas Coast Seagrass Bed | CES203.545 |
| | | | Temperate Pacific Saltwater Aquatic Vegetation | Temperate Pacific Eelgrass Bed | Mediterranean California Eelgrass Bed | CES206.999 |
| | | | | | North Pacific Maritime Eelgrass Bed | CES200.882 |
| | | | (blank) | (blank) | (blank) | (blank) |
| | 5.B. | 5.B.1. Freshwater Aquatic Vegetation | North American Freshwater Aquatic Vegetation | Eastern North America Freshwater Aquatic Vegetation | Southern Coastal Plain Spring-run Stream Aquatic Vegetation | CES203.275 |
| | | | | | Texas-Louisiana Fresh-Oligohaline Subtidal Aquatic Vegetation | CES203.511 |
| | | | | Western North American Freshwater Aquatic Vegetation | Temperate Pacific Freshwater Aquatic Bed | CES200.876 |

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