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# COMBINING HGM AND EMAP PROCEDURES TO ASSESS WETLANDS AT THE WATERSHED SCALE — STATUS OF FLATS AND NON-TIDAL RIVERINE WETLANDS IN THE NANTICOKE RIVER WATERSHED, DELAWARE AND MARYLAND (USA)

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*Abstract:* The hydrogeomorphic (HGM) approach to wetland assessment was combined with the Environmental Monitoring and Assessment Program (EMAP) survey design procedures to evaluate the condition of non-tidal riverine and flats wetlands in the Nanticoke River watershed (Delaware and Maryland, USA). We found degradation of wetland functions below reference standard levels for the majority of wetlands in both classes. Wetland condition was also related to the level of disturbance in both wetland classes. In flats, the most common disturbances were associated with hydrologic and vegetation modifications. Flat wetlands with low HGM function scores for the Plant Community and Habitat functions had almost all been converted from hardwood forest to Loblolly pine plantations. Most modifications associated with riverine wetlands were associated with stream channelization. Results of this study demonstrate that a site-specific and reference-based approach to assessment (i.e., the HGM method) can successfully be applied at the scale of an entire watershed if it is combined with a sampling approach that allows sites to be selected without geographic bias. The approach can also be used to determine if wetland functions vary from one sub-basin to another, and results of this project can be used by managers to begin to develop strategies for restoration of wetland functions at the watershed scale.

*Key Words:* Chesapeake Bay, GIS, HGM, watershed, wetland assessment

## INTRODUCTION

Most methods that have been developed to assess the ecological condition and functions of wetlands emphasize individual wetlands (Bartoldus 1999, Fennessy et al. 2004), and many of them involve detailed, site-specific assessments (Brooks et al. 2004, Fennessy et al. 2004). Fewer methods have been developed to assess habitat integrity or wetland functions at the scale of an entire watershed (e.g., Zampella et al. 1994, Montgomery et al. 1995, Bedford 1996, Abbruzzese and Leibowitz 1997, Lemly 1997, Cormier et al. 2000, Detenbeck et al. 2000, Leibowitz et al. 2000, Tiner et al. 2000, Tiner 2004, 2005). Most watershed-scale assessment methods do not involve detailed, site-specific assessments; instead, they provide an overview of habitat integrity or assess potential wetland functions (e.g., Tiner et al. 2000, Tiner 2004, 2005), equivalent to a level-one or landscape assessment as described by Brooks et al. (2004) and Fennessy et al. (2004). Sutter et al. (1999) developed a method that uses spatial (e.g., GIS) data to assess the condition of individual wetlands in the context of a watershed or landscape, but we are not aware of any efforts to test or utilize the method. Lee et al. (2003) developed HGM models for all waters/wetlands in the Santa Margarita River watershed (California), but similarly we are unaware of any efforts to apply the models to determine wetland condition at the watershed or sub-basin scales in the Santa Margarita.

To make watershed-scale decisions about wetland resources, information is needed at all levels of assessment (Thomas and Lamb 2004, Tiner 2004), but ultimately, decisions that focus on restoration design require site-level information for individual wetlands or groups of wetlands. In other words, it would require site-level information using either rapid or intensive assessments (Brooks et al. 2004, Fennessy et al. 2004). In this paper, we describe an approach to watershed-scale assessment that combines site-level data produced by using the hydrogeomorphic (HGM) approach, with the U.S. Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP) procedures for selecting sampling sites.

The project focused on the Nanticoke River watershed in Maryland and Delaware (Figure 1). The Nanticoke River watershed is one of the most biologically important and wetland-rich watersheds in the mid-Atlantic region (The Nature Conservancy 1994); yet, many of its natural habitats have been degraded (Tiner et al. 2000, Tiner 2004, 2005). More than 40% of the watershed is covered by forest, but about the same amount is in agriculture, and agriculture and forest management have been supported by extensive drainage and channelization (Tiner 1985, 2004, 2005; Tiner and Burke 1995; Tiner et al. 2000).

The project had three goals. The first goal, the focus of this paper, was to assess the ecological condition of non-tidal riverine wetlands and flats, the two most widespread and abundant non-tidal classes of wetlands, at the watershed scale. The second goal, the focus of Weller et al. (2007), was to determine if analyses of spatially mapped data typically used for landscape assessments, could be used in combination with field-based HGM assessments to predict the condition of individual wetlands or groups of wetlands at the watershed scale. The third objective, Jordan et al. (2007), was to determine if the HGM models, referred to as HGM functions, that were developed for the project adequately characterized ecological processes in wetlands.

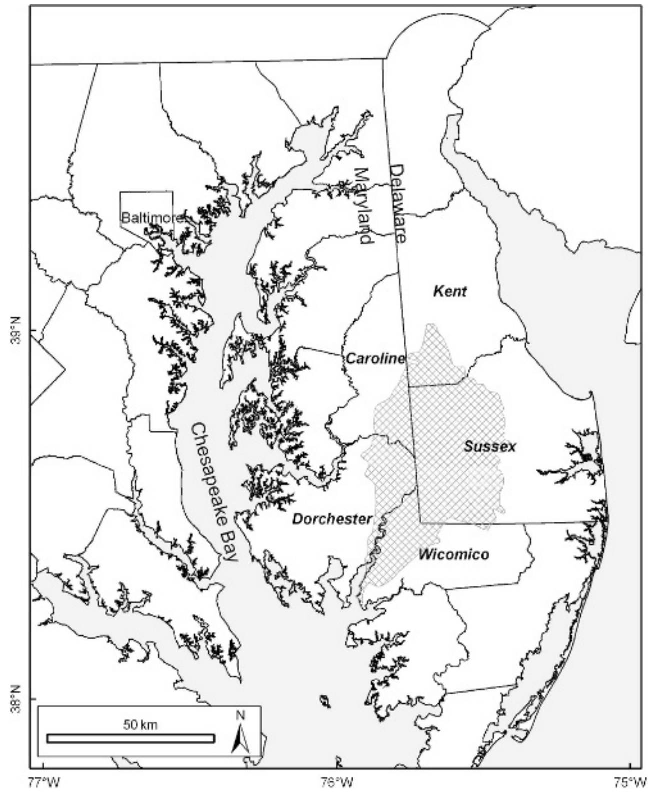


Figure 1. Map of the Nanticoke River watershed (hatched area) and its relationship to Chesapeake Bay.

## METHODS

Procedures used throughout the project followed U.S. Army Corps of Engineers guidelines for developing HGM models (http://www.wes.army.mil/el/wetlands/guidebooks.html). The HGM models were developed, calibrated, field tested, and applied by an interdisciplinary team in field and workshop formats. Collection of reference data, testing of assessment procedures, and assessment of sites selected by EMAP procedures were conducted by trained field teams of paid staff and volunteers.

In addition to details of the methods described here, information can also be found in Whigham et al. (2003). In year 1, we selected a preliminary list of

Table 1. Variables used in HGM models (Table 2) for flats and non-tidal riverine classes in the Nanticoke River watershed. Variable scores varied from 1.0–0.1, and there were two types (continuous and categorical). Continuous variables are shown as CO and categorical variables as CA.

| *Flats Class* | *Type* | *Descriptor* |
|---|---|---|
| $V_{DISTURB}$ | CA | Evidence of vegetation disturbance |
| $V_{DRAIN}$ | CO | Percent assessment area affected by drainage |
| $V_{FILL}$ | CA | Presence of anthropogenic derived sediment |
| $V_{HERB}$ | CA | Species of herbs present |
| $V_{MICRO}$ | CA | Presence of microtopographic features |
| $V_{RUBUS}$ | CA | Presence of *Rubus* sp. |
| $V_{SHRUB}$ | CO | Shrub density |
| $V_{SNAG}$ | CA | Density of standing dead trees |
| $V_{TBS}$ | CO | Basal area of trees |
| $V_{TDEN}$ | CO | Tree density |
| $V_{TREE}$ | CA | Tree species composition |
| *Riverine Class* | *Type* | *Descriptor* |
| $V_{FARBUFFER}$ | CA | Condition of buffer 20–100 m from wetland |
| $V_{FLOODPLAIN}$ | CA | Floodplain conditions |
| $V_{INVASIVE}$ | CO | Presence of invasive species |
| $V_{NEARBUFFER}$ | CO | Condition of buffer 0–20 m from wetland |
| $V_{SAPLING}$ | CA | Sapling species composition |
| $V_{SHRUB}$ | CO | Shrub density |
| $V_{STREAMIN}$ | CA | Stream condition inside assessment area |
| $V_{STREAMOUT}$ | CA | Stream condition outside assessment area |
| $V_{TBA}$ | CO | Basal area of trees |
| $V_{TDEN}$ | CO | Tree density |
| $V_{TREE}$ | CA | Tree species composition |
| $V_{DISTURB}$ | CA | Vegetation disturbance |

HGM variables, collected reference data for 23 non-tidal riverine (hereafter referred to as riverine) and 19 flats wetlands, selected the HGM variables (Table 1), scaled the variables based on data from reference sites, and finalized the HGM models (Table 2) used to conduct site assessments in year 2. In year 1, we also developed, field-tested, and finalized office and field protocols that followed procedures approved by EPA for the project (Whigham et al. 2000). Nomenclature for plant names follows Radford et al. (1968).

## Site Selection

Much of the first year was devoted to identifying and screening potential assessment sites. The first step was to evaluate existing digital wetland maps to develop a single sampling frame from which potential assessment sites could be selected. Three digital wetland maps were available. The National Wetland Inventory (NWI) created wetland maps for the entire watershed from 1981–82 aerial photography (http://www.nwi.fws.gov). Subsequent state mapping efforts updated the NWI classification by using more recent aerial photography, (1992 for Delaware (State of Delaware 1994) and 1988–89 for Maryland (http://dnrweb.dnr.state.md.us/gis/data/samples/doqqbase.html)), selecting more field-verification sites, and using smaller minimum mapping units to produce maps that included more wetlands, particularly smaller ones. We used 1996 Delaware state wetland maps prepared from 1992 aerial photography (D.S. Wallace, Delaware Department of Natural Resources and Environmental Control) for the 63% of the watershed in Delaware. The Maryland state wetland maps (http://dnrweb.dnr.state.md.us/gis/data/) were not complete when we prepared the sampling frame, but we used the Maryland state data that were available for another 19% of the watershed. For the remaining 18% of the

Table 2. HGM models used to calculate functional capacity index (FCI) scores for non-tidal riverine and flats wetland classes in the Nanticoke River watershed. Variables used in the models are listed and described in Table 1.

Flats Functions

Hydrology FCI = $0.25 * V_{FILL} + 0.75 * V_{DRAIN}$

Biogeochemistry FCI = $(V_{MICRO} + ((V_{SNAG} + V_{TBA} + V_{TDEN}) / 3)) / 2 *$ Hydrology FCI

Plant Community = $((V_{TREE} + V_{HERB}) / 2) * V_{RUBUS}$

Habitat = $(V_{DISTURB} + ((V_{TBA} + V_{TDEN}) / 2) + V_{SHRUB} + V_{SNAG}) / 4$

Riverine Functions

Hydrology FCI = SQRT $(((V_{STREAMIN} + (2 * V_{FLOODPLAIN})) / 3) * V_{STREAMOUT})$

Biogeochemistry FCI = $V_{TBA} *$ Hydrology FCI

Plant Community = $(0.75 * ((V_{TREE} + V_{SAPLING}) / 2)) + (0.25 * V_{INVASIVE})$

Habitat = $((((V_{TBA} + V_{TDEN}) / 2) + V_{SHRUB} + V_{DISTRUB}) / 3 + V_{STREAMIN}) / 2$

Landscape = $(0.5 * V_{NEARBUFFER}) + (0.25 * V_{FARBUFFER}) + (0.25 * V_{STREAMOUT})$

Nanticoke watershed that was in Maryland, we used the NWI wetland maps. The three data sources were merged into a single digital map layer using ESRI ArcINFO geographic information system software.

A sample of potential assessment sites was selected using the EMAP approach for drawing a sample. More information on the EMAP approach to sample design and how it was applied to wetlands can be found in Stevens and Hornsby (2007). In this case, a random tessellation stratified (RTS) sample (Dalenius et al. 1961, Overton and Stehman 1993, Stevens 1997) was drawn from the Nanticoke watershed sampling frame. An RTS sample is selected by randomly placing a regular grid over the target region and then drawing one point at random within each grid cell. Points that did not fall in a wetland polygon then were discarded. Much of the watershed is privately owned, and some difficulty in getting access permission to sample on private property was anticipated (Lesser 2001). To allow for lack of access, the initial draw consisted of 1,992 points, or approximately 10 times the target sample size. These points and their associated map coordinates were arranged in replicate groups of 25 points each, where each group in itself was a spatially balanced random sample of the wetland polygons. Hierarchical randomization (Stevens and Olsen 1999, 2000) was used to define the groups, and the groups were evaluated sequentially. For the sequential evaluation, an initial set of groups was selected, and the potential sampling sites were evaluated to ensure that the points were in the correct wetland class and that access permission could be obtained. If the initial set does not yield a sufficient sample size of the desired wetland classes, then the next group in sequence is evaluated, and so on, until a sufficient sample size is obtained. This procedure results in a spatially well-balanced probability sample of the accessible wetland population.

We evaluated 1,050 of 1,992 potential sites generated by RTS. Fifty-eight percent (604) of the 1,050 sites were eliminated from further consideration based on the following procedures: 1) sites were found to be in another wetland class or were not wetlands based on examination of digital orthophotographs, wetland maps, USGS topographic maps, and county soil surveys; 2) sites were eliminated because they were chosen for testing HGM models; and 3) a sizable number of flats were eliminated once the selection process resulted in a sufficient number of sites in that class, and we only needed additional riverine sites, which are comparatively less common, for the sample. We eventually selected 446 potential sites (211 riverine and 235 flats) for which we attempted to gain permission to access. First, we determined ownership and contact information for landowners. In Maryland, this information was available in digital form for all counties through the Maryland Property View CD-ROM disks (Maryland Property View, 2002 Edition, Provided by Maryland Department of Planning, Planning Services Division, Baltimore Maryland, Copyright Maryland Department of Planning). In Sussex and Kent County, Delaware, landowner contact information was obtained from hardcopy maps and associated tax records. Initial landowner contact occurred via letter. Written contact included a cover letter providing a brief introduction to project goals, scope, and anticipated benefits and a request for permission to access the wetland area of interest. A project brochure was included as an attachment. If phone numbers were available, letters were followed with a phone call to the landowners. If phone numbers were unavailable, access permission was based on positive returns of reply forms that were included with the cover letter.

We obtained access to all publicly owned sites (48). Of the privately owned sites (398) that we attempted to access, we were unable to contact landowners for 42% of the sites; however, when we did make contact with landowners, we had a success rate for obtaining access of 67%. Accessible sites were field-checked to verify that they were in fact wetlands (based on the presence of wetland plant species and soil or water indicators that clearly showed that wetland conditions were present) and to categorize them as either riverine or flats. Wetlands that were not in either class were deleted from the list of potential assessment sites. The screening process eventually resulted in assessment of 54 riverine and 89 flats (Figure 2) and took 145 person-days (1,160 hours).

As stated above, we encountered a sizable number of privately owned sites for which access permission was denied or was neither explicitly given nor denied (hereafter referred to as non-response sites). The fact that we were unable to sample these sites raised concerns about the representativeness of the achieved sample and the validity of extrapolating from the achieved sample to the entire watershed. The extension of results from the accessible sub-population to the entire watershed is possible only with the additional assumption that "the non-response is determined by a random selection mechanism unrelated to the response," (i.e., the responses are missing completely at random (MCAR)). However, we were more likely to get permission to access publicly owned sites than sites that were privately owned. As a result, the sample

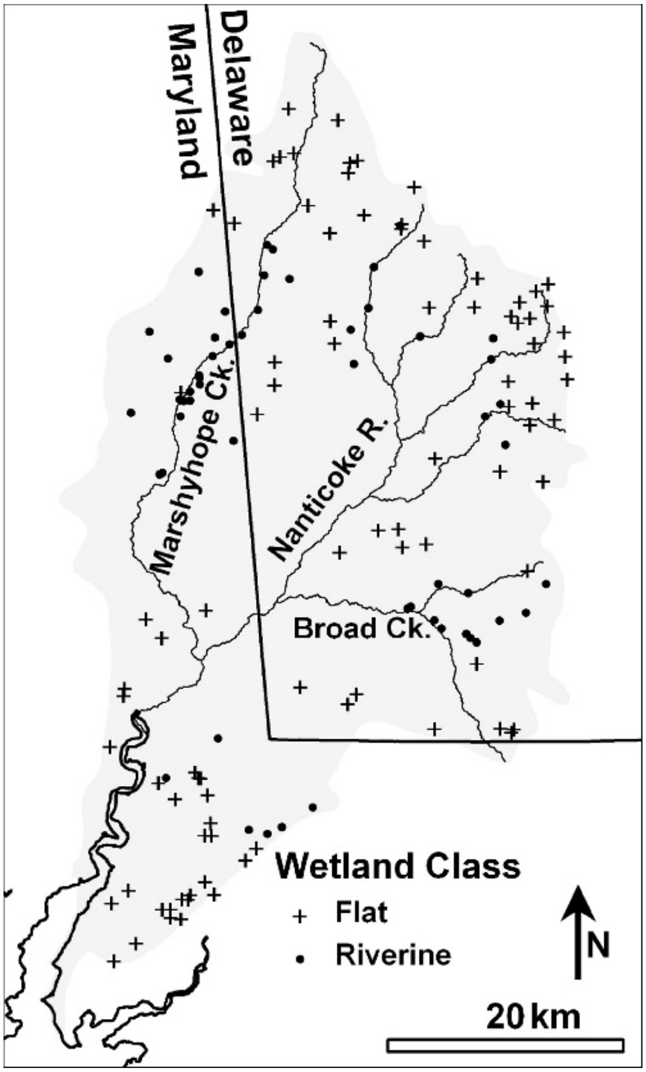


Figure 2. Distribution of wetland assessment sites in the non-tidal portion of the Nanticoke River watershed. The locations of the three major sub-basins within the watershed are also shown.

sites that were accessible had a disproportionate number of publicly owned sites (Pearson's $\chi^2 = 62.6$, $df = 1$, $p = 0.003$). These results raised the concern that the MCAR assumption was not tenable because differing management practices between publicly and privately owned wetlands could affect wetland condition and function. Therefore, we corrected for this sample bias by post-stratifying on ownership. Details of the post-stratification adjustment are in Stevens and Hornsby (2007).

## Field Procedures

Procedures used to collect data in the field are described here and in Whigham et al. (2000). Sampling points were located by using a geographic positioning system (GPS), in which the coordinates of each sample point had been entered. Once the sampling point was located, an assessment area (AA) was established by centering a 40-m-radius circle (0.5 ha) around the point. Information on alterations within the AA was recorded on a standard form, by category of alteration. Hydrologic condition was assessed by mapping the location of ditches, measuring their depth, and estimating how far each extended outside the AA up to a maximum of 300 m. Borings were made throughout the AA to determine the dominant soil series. A nested-plot design was used to characterize vegetation. Three randomly placed 7.98-m-radius circular plots (0.02-ha) were established. Within each of these plots, evidence of recent logging activities was recorded, the diameter at breast height of all trees $\geq$ 15 cm was measured, and downed logs, snags, and saplings were counted. A 2.25-m-radius plot was established in the center of each 0.02-ha plot, and the number of stems or clumps of each species of shrub and the number of tree seedlings were counted. Presence (i.e., one or more rooted plants) of blackberry species, (e.g., *Rubus allegheniensis* Porter) was recorded in the 2.25-m-radius plots. The presence or absence of *Rubus* was chosen as an indicator variable because blackberry species were common in all altered sites in the reference data set. Four 1-$m^2$ plots in each 0.02-ha plot (12 per site) were used to estimate cover of all non-vine herbaceous species, *Sphagnum* spp., *Mitchella repens* L., and unvegetated ground. The plots were placed at the end of each of two transects that perpendicularly bisected the tree plot and had their origin at the center of the plot. *Mitchella* was included as a field indicator in the herb plots and used to score the $V_{HERB}$ variable because analysis of reference data demonstrated that it was common in sites that had not been altered.

Riverine wetlands also were sampled by locating coordinates with a GPS unit and establishing an AA by centering a 1-ha area around the point. The area sampled was 100 m by 100 m, but in a few instances, adjustments were made when the distance between the stream channel and the upland was less than 100 m. When those circumstances occurred, the plots were 200 m by 50 m. Information on human alterations and qualitative assessment of floodplain condition within the AA was recorded on a standard form. Hydrology was assessed inside the AA by walking the area along the stream channel and noting alterations such as fill, channelization, and levees. The same information was recorded along a 500-m stretch of the channel upstream and downstream from the edge of the AA. Vegetation was characterized using the same nested-plot design

Table 3. Disturbance categories for each HGM wetland subclass (non-tidal riverine, flats). The Disturbance Index (DI) was calculated as the average number of disturbance categories that were present on a site as recorded on field data sheets.

| Disturbance Category | Riverine | Flats |
|---|---|---|
| Evidence of physical site disturbance, other than ditching and channelization | X | X |
| Evidence of vegetation disturbance (e.g., logging) | X | X |
| Ditches and levees present in assessment area | X | X |
| Evidence of fill, other than levees, in assessment area | X | X |
| Evidence of fill or channelization upstream of assessment area | X | |
| Evidence of fill or channelization downstream of assessment area | X | |

used for flats. The condition of the buffer associated with the floodplain was documented by recording the dominant land use in a 100-m by 100-m area that began at the toe slope of the floodplain on either side of the AA and extended into the upland. Each area was divided into a grid of 10 m × 10 m cells, and the dominant land use in each cell was recorded.

For all sites, a Disturbance Index (DI) was calculated from information recorded on the field data sheets. For all categories of entries on the data sheets, we determined which ones indicated some level of human alteration (e.g., presence of ditching in the AA, presence of fill in the AA, evidence of logging in the AA). We then calculated the DI for each site as a percentage of the maximum number of alteration categories. A listing of the alteration categories used to calculate the DI for each wetland class is provided in Table 3.

### Data Analysis

Variable Scores were entered into spreadsheets, and the equations for the HGM models (Table 2) were used to calculate Functional Capacity Index (FCI) scores. The distribution of FCI scores was examined by generating cumulative distribution (CDF) plots for the flats and riverine populations (Whittier et al. 2002). Besides showing the distribution of assessment scores over the sample population, CDF plots allow one to estimate what percent of the wetland area of the population is less than or equal to a particular FCI score. In this way, one can see how far the population departs from reference standard condition or some FCI score of interest.

The relationship of the sites to each other was also examined by applying a variety of non-parametric procedures, and it was determined that the relationships among sites and functions was best described by using the FCI scores in a Non-metric Multidimensional Scaling (NMS) ordination (McCune and Meffort 1999). Sorensen's similarity index was used as the distance measure in the ordinations, and based on preliminary exploration of the data, the analyses were run with two axes. For both classes, more than 95% of the variance was explained by the two axes. For the riverine class, a final solution to the ordination, based on procedures described in the manual (McCune and Meffort 1999), was reached after 26 iterations and the final stress was 5.1. For the flats class, two separate ordinations were run (the reasons are described in detail in the Results section). For flats that had not been altered in the past 50 years (determined at each site by the field assessment team based on professional judgment, coring trees to determine age, and information from landowners), the final solution of the ordination was reached after 37 iterations and the final stress was 9.7. A final solution was reached after 37 iterations, for flats altered in the past 50 years. The final stress for this group of sites was 7.2.

To examine spatial variation in wetland condition within the Nanticoke River watershed, we examined FCI scores in three major sub-basins of the watershed: Marshyhope Creek, Broad Creek, and main-stem Nanticoke River (Figure 2). We used state watershed boundaries (ftp://dnrftp.dnr.state.md.us/public/SpatialData/Watershed/WshedBndry/swshed12.htm, http://www.dnrec.state.de.us/dnreceis/downloads/zip/watersheds.zip) to identify assessment points within each sub-basin, then applied analysis of variance (Proc GLM, SAS 2004) to test for differences among the sub-basins in the FCI scores for both wetland classes. When we found significant sub-basin effects on an FCI score, we compared the mean score for the three sub-basins (REGWQ, SAS 2004) to identify which sub-basins were significantly different.

## RESULTS

### Condition of Non-Tidal Riverine and Flats Wetlands at the Watershed Scale

Variable scores and FCI scores for each site are provided in Appendix I for riverine sites and Appendix II for flats sites. We use several approaches to evaluate and describe the condition of wetlands in the two classes. First, the condition is

Table 4. Means and medians of the FCI scores for each function for non-tidal riverine and flats wetlands in the Nanticoke River watershed. 95% confidence intervals are in parentheses.

| | Flats | | Riverine | |
|---|---|---|---|---|
| Function | Mean | Median | Mean | Median |
| Hydrology | 0.76 (0.71, 0.81) | 0.92 (0.85, 0.94) | 0.53 (0.46, 0.59) | 0.60 (0.30, 0.65) |
| Biogeochemistry | 0.54 (0.49, 0.59) | 0.59 (0.38, 0.67) | 0.44 (0.38, 0.51) | 0.42 (0.23, 0.59) |
| Habitat | 0.63 (0.59, 0.67) | 0.64 (0.58, 0.70) | 0.64 (0.58, 0.71) | 0.74 (0.54, 0.83) |
| Plant Community | 0.50 (0.44, 0.56) | 0.56 (0.47, 0.63) | 0.84 (0.80, 0.88) | 0.89 (0.81, 0.91) |
| Landscape | | | 0.69 (0.65, 0.72) | 0.72 (0.68, 0.74) |

described relative to the mean FCI scores for each function (Table 4). Average FCI scores for the two wetland classes were $\geq 0.50$ for all functions except for Biogeochemistry for riverine wetlands. An average FCI score close to 0.50 indicates that the wetlands are performing, on average, at about 50% of the level of reference standard condition (a FCI score of 1.0). Mean scores of 0.84 for the Plant Community function of riverine wetlands and 0.76 for the Hydrology function of flats indicate that the wetlands are performing, on average, close to reference standard condition for those functions.

Second, examination of cumulative distribution function (CDF) plots provides additional insights into the condition of the population of wetlands in both classes. The CDF plots described in this section are representative of the two classes over the entire watershed because they incorporate the correction for sample bias due to site accessibility. The CDF plots for the Biogeochemistry and Plant Community functions for flats are close to linear, indicating that the FCI scores are evenly distributed over the population (Figure 3b, d). The plots for the Hydrology and Habitat functions for flats are not linear; both have distinct rises. In the case of the Hydrologic function, a sharp rise occurs as FCI scores approach 1.0, indicating that about 35% of the population is functioning at the level of reference standard condition (Figure 3a). Reflecting the sharp rise in the CDF plot, the median score for hydrology is 0.92 (Table 4), which is much higher than the mean of 0.76. This indicates that more than 50% of the population is functioning at $\geq 90\%$ of the level of reference standard. In the case of the Habitat function, a distinct inflection in the CDF plot occurs at a FCI score of about 0.43; therefore, about 80% of the population has a score above 0.43 (Figure 3c).

The CDF plots for riverine wetlands show a somewhat different pattern for the five functions. The Hydrology function shows that the assessment sites fall into two groups, with approximately 60% above the inflection point at an FCI score of about 0.6, which is also the median score (Table 4). In contrast, FCI scores are evenly distributed over the populations for the Biogeochemistry and Landscape functions (Figure 4b, e), and the median and mean are similar (Table 4). The relatively steep inflection points at FCI scores of approximately 0.7 and 0.8 for the Habitat and Plant Community functions (Figure 4c, d) indicate that the largest proportion of the population was functioning close to reference standard.

As described in the Data Analysis section, an ordination approach was used to compare conditions at the watershed scale further, as well as to evaluate the relationships among sites and functions (Figures 5–7). Ordination of FCI scores for the flats sites were most informative when we divided the data into two categories (Figures 5 and 6) based on logging history. The separation of flats into two groups was based on preliminary data analyses of the entire data set and our observations that most of the sites that had been harvested within the past

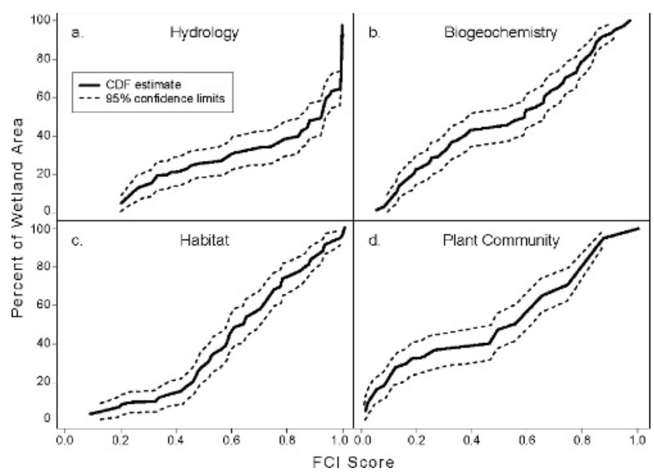


Figure 3. Cumulative distribution function (CDF) plots showing the estimated percent of wetland area with FCI scores less than or equal to any value on the x-axis for wetlands in the flats class in the Nanticoke River watershed. CDF plots (± 95% confidence intervals) are for the FCI scores for the a) Hydrology, b) Biogeochemistry, c) Habitat, and d) Plant Community functions relative to the total area of flats in the watershed.

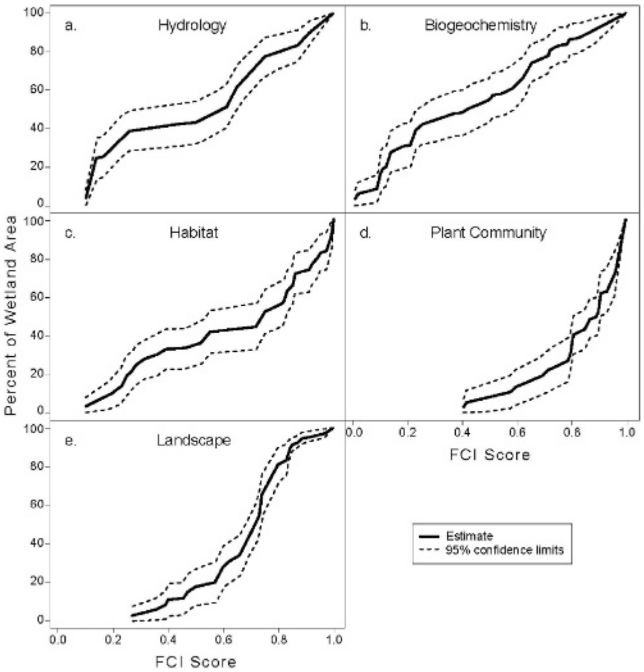


Figure 4. Cumulative distribution function (CDF) plots showing the estimated percent of wetland area with FCI scores less than or equal to any value on the x-axis for wetlands in the non-tidal riverine class in the Nanticoke River watershed. CDF plots (± 95% confidence intervals) are for the FCI scores for the a) Hydrology, b) Biogeochemistry, c) Habitat, d) Plant Community, and e) Landscape functions relative to the total area of riverine wetlands in the watershed.

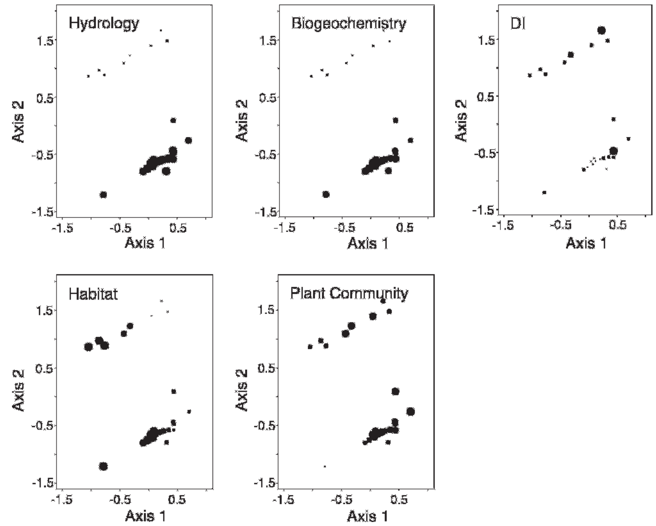


Figure 5. NMS ordination of FCI scores for the four HGM functions (Table 2) and the Disturbance Index (DI) for flats that had no evidence of disturbance during the past 50 years. In all diagrams, the size of the circle represents the relative magnitude of the FCI score (larger circles = higher FCI scores or DI values). The two axes account for 95.1% of the variance and the Hydrology (r = 0.526), Biogeochemistry (r = 0.366) and Plant Community (r = 0.449) are positively and the Habitat function (r = -0.633) negatively correlated with Axis 1. The strongest correlations on Axis 2 are with the Hydrology (r = -0.952) and Biogeochemistry (r = -0.965) functions. FCI scores are provided in Appendix II.

50 years had also been ditched and the surface soils were almost always mechanically altered (i.e., heavy equipment used to clear the site and form windrows of stumps and soil, etc.). Most of the sites that had not been altered within the past 50 years, based on the ages of trees on the site, had been previously logged but few had been physically altered, although a few of them had ditches within the assessment areas or within 1 km of the assessment area. Another difference between wetlands in the two categories is that sites that had been altered more recently are almost always dominated by Loblolly pine (*Pinus taeda* L.). While loblolly pine occurs naturally in non-tidal forested wetlands on the Eastern Shore (Tiner 1985, Tiner and Burke 1995), it is most abundant in pine plantations.

The sizes of the circles in the graphs of Figures 5–7 indicate the relative magnitude of the FCI and DI scores (e.g., larger circles indicate higher scores and smaller circles represent lower scores). The ordination of flats sites that had not been disturbed for the past 50 years results in two distinct groupings (Figure 5), and there was no clear pattern in the magnitude of the DI scores for sites in the two groups (Figure 5), demonstrating that alterations that occurred several decades ago continue to impact the assessment scores for the Hydrology and Biogeochemistry functions. In contrast, the Habitat and Plant Community functions differed little among the sites, most likely because those sites were dominated by facultative wetland species that are able to compete successfully under less wet conditions.

The ordination of sites that had been altered in the past 50 years resulted in a more complex pattern (Figure 6), with sites that had been altered in the past 15 years appearing in the lower portion of the plot of FCI scores for the Plant Community and, to a lesser degree, Habitat functions. The plot of DI values (Figure 6) showed only a general relationship with the FCI scores with sites to the right of the ordination corresponding with lower FCI scores for the Hydrology and Biogeochemistry functions.

The NMS ordination of FCI scores for the five HGM models for the riverine class resulted in a clear distribution of sites along the first two axes (Figure 7). The DI graph in Figure 7 shows that there was a negative relationship between FCI scores

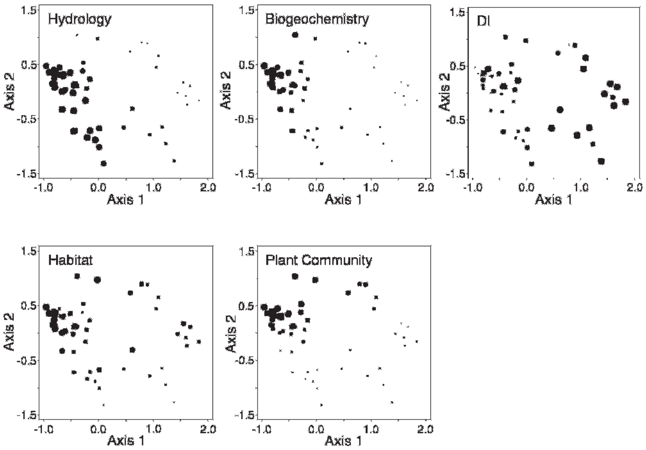


Figure 6. NMS ordination of FCI scores for the four HGM functions (Table 2) and the Disturbance Index (DI) for flats that had evidence of disturbance during the past 50 years. In all diagrams, the size of the circle represents the relative magnitude of the FCI score (larger circles = higher FCI scores or DI values). The two axes accounted for 96.0% of the variance, and 76.2% is explained by Axis 1, which is negatively correlated with the Hydrology (r = -0.882), Biogeochemistry (r = -0.927) and Habitat (r = -0.469) functions and positively (r = 0.616) with the Plant Community function. The Plant Community and Habitat functions are positively correlated with Axis 2 (r = 0.779 and 0.549, respectively). FCI scores are provided in Appendix II.

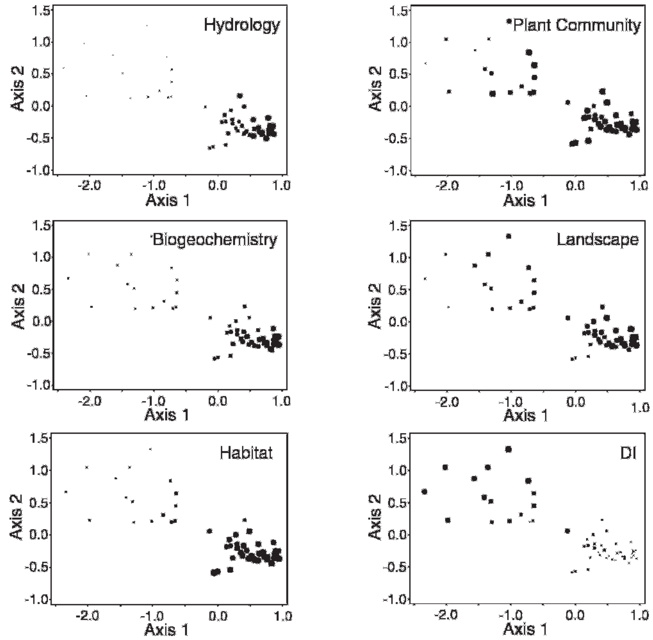


Figure 7. NMS ordination of FCI scores for the five HGM functions (Table 2) and the Disturbance Index (DI) for non-tidal riverine wetlands. In all diagrams, the size of the circle represents the relative magnitude of the FCI score (larger circles = higher FCI scores or DI values). Axis 1 accounted for 95.0% of the variance and it was highly and positively correlated with the Hydrology (r = 0.872), Biogeochemistry (r = 0.901), Habitat (r = 0.836), Plant Community (r = 0.732) and Landscape (r = 0.564) functions. Axis 2 accounted for little (4.0%) additional variance even though all of the functions except Landscape (r = 0.106) were highly correlated with it (Hydrology: r = 0.627, Biogeochemistry: r = -0.804, Habitat: r = 0.845, Plant Community: r = -0.610). DI was positively related to Axis 1 (r = 0.769) and Axis 2 (r = 0.755). FCI scores are provided in Appendix I.

and the magnitude of the DI. Most sites with high DI values had low FCI scores.

### Condition of Wetlands at the Sub-Basin Scale

There were no significant sub-basin differences in FCI scores for the flats subclass (Table 5), but there were significant differences for the riverine sites, with the Nanticoke River sub-basin having significantly lower FCI scores for four of the riverine functions.

## DISCUSSION

Wetlands in both classes had the full range of variable and function scores (Appendices I and II, Figures 3–7), indicating that wetland condition at the watershed scale is less than reference standard for many assessment sites. The methods that we have used to analyze the data allow us to determine how the HGM functions vary across the watershed, how they vary across the sites sampled, and how they vary in response to alterations. Our results clearly confirm predictions of Tiner et al. (2000) and Tiner (2004, 2005), based on GIS-based analyses of wetland functions and habitat integrity of the Nanticoke at the watershed scale, that there likely has been significant wetland degradation in the Nanticoke River basin. Tiner (2005) also reached similar conclusions in a comparison of historical changes in wetland area and potential losses of wetland functions in the Nanticoke watershed. Tiner (2004) also evaluated the Nanticoke watershed from the perspective of watershed integrity by using spatial data to evaluate features of the landscape that would be related to water and wetland quality. He found that the index of watershed integrity was low, indicating a 'stressed system' with 'significant human modification.'

While the objectives of our studies, as well as the approaches used by our group and by Tiner (2004) and Tiner et al. (2000), were different, we each came to similar conclusions, which is not surprising given the level of human-influenced alterations in the watershed (TNC 1994, Tiner 2004, 2005). These

Table 5. Results of ANOVA comparisons of mean FCI scores for three Nanticoke subwatersheds. Means that do not differ significantly share the same superscript at P ≤ 0.03 or better for the riverine sites and P ≥ 0.05 for the flats sites.

| Subwatershed | Hydrology | Biogeochemistry | Habitat | Plant Community | Landscape |
|---|---|---|---|---|---|
| *Riverine* | | | | | |
| Marshyhope Creek (N = 25) | $0.642^{a}$ | $0.543^{a}$ | $0.710^{a}$ | $0.823^{a}$ | $0.762^{a}$ |
| Nanticoke River (N = 11) | $0.265^{b}$ | $0.213^{b}$ | $0.401^{b}$ | $0.808^{a}$ | $0.602^{b}$ |
| Broad Creek (N = 12) | $0.729^{a}$ | $0.662^{a}$ | $0.869^{a}$ | $0.959^{b}$ | $0.789^{a}$ |
| *Flats* | | | | | |
| Marshyhope Creek (N = 16) | $0.715^{a}$ | $0.485^{a}$ | $0.679^{a}$ | $0.529^{a}$ | |
| Nanticoke River (N = 33) | $0.648^{a}$ | $0.551^{a}$ | $0.668^{a}$ | $0.576^{a}$ | |
| Broad Creek (N = 9) | $0.756^{a}$ | $0.490^{a}$ | $0.483^{a}$ | $0.574^{a}$ | |

alterations include a dense network of channelized streams and the conversion of a large number of wetlands into agricultural land uses (Tiner et al. 2000, Tiner 2004, 2005). Wang et al. (1997) also found that aquatic resources were degraded at the watershed scale following even relatively small levels of human-influenced activities (e.g., conversion of natural areas to agricultural and urban land uses). Houlahan and Findlay (2004) showed that wetland water quality also decreases in response to human activities near wetlands.

In contrast to similar findings at the watershed scale, results of our study and Tiner's (2004) study of watershed integrity differed at the sub-basin scale. Tiner found that eight of 11 indices of watershed integrity were lower in the Delaware portion of the Marshyhope Creek sub-basin (Table 8 in Tiner 2004). In our study, none of the wetland functions were significantly lower in the Marshyhope sub-basin for either wetland class, but four of five functions for riverine wetlands were significantly lower in the main-stem Nanticoke River sub-basin (Table 5). The differences between the two studies could result from differing methodologies. First, Tiner only evaluated the portion of the sub-basins that were in Delaware, while we also considered sites in both states for each sub-basin. Differences in wetland condition in the two states could lead to differing assessment results, but the experiences of our field teams suggest that this factor is not important. Differences between our results and Tiner's also point to results that might be expected when one works with assessment models for individual types of wetlands versus models that are not specific to wetland types. Tiner et al. (2000) predicted the potential (e.g., high and moderate) for different types of wetlands to perform 10 functions, but their assessment (Tiner et al. 2000, Tiner 2004) was not developed to assess function within individual wetland types (i.e., departure from "reference"). Our study, based on variables calibrated to reference data, indicates that wetland condition (and we assume wetland functions) is not the same for flats and riverine wetlands at either the watershed or sub-basin scales. Third, Tiner's study was based on an analysis and interpretation of GIS data, and there was no attempt to verify his findings either at the watershed or sub-basin scale and no consideration of wetland condition (R. Tiner, personal communication). Tiner recognized the limitation of the method in making spatial predictions about watershed integrity and suggested that the models could be improved by comparing predictions with field-based assessments using field indicators. Even though the methods differ, our results support Tiner's prediction a high level of wetland alteration in the Nanticoke watershed has occurred.

The approach that is used to assess wetlands at the watershed scale will determine how the results can be used. The landscape approach used in Tiner's studies provides an overview of wetland function or watershed integrity, and it can be used to infer wetland condition. Assessment of wetland condition, however, can only be accomplished by applying field-based assessment models that are calibrated to a range of wetland condition. This study and a companion study in the Juniata River watershed (Wardrop et al. 2007) are the only two of which we are aware of for which a field-based approach has been used to assess condition at the watershed and sub-basin scales. Because of the statistical method that was used to select our sites (Stevens and Olsen 1999, 2000), we assume that the results were representative of the sub-basins and watershed.

Our study also demonstrates that it is important to develop models for each type of wetland and to calibrate the models to reference data. We found that, to a large degree, the HGM models for the two wetland classes used different variables (Table 1), and we did not develop a landscape model for the flats subclass because, during the model development and testing phases, we could not identify any landscape metrics that were sensitive enough to quantify differences in condition between reference sites along a gradient of alteration. The comparison also suggests that there may be differences in condition of wetlands versus condition of the watershed. In other words, some individual wetlands may be in good condition despite significant alteration (e.g., degradation) elsewhere in the watershed. In a recent study of urbanized portions of New Jersey, Ehrenfeld (2005) found that relatively few wetlands had plant communities that were characteristic of reference standard conditions. She sampled wetlands in five HGM classes (non-tidal riverine, mineral flats, flats-riverine, depressions, and slopes) and found a high degree of similarity in vegetation because hydrologic alterations had resulted in an increase in the abundance of facultative wetland plant species, including invasives. As a result, Ehrenfeld was not able to separate plant communities on the basis of HGM classes, even though she found that a few sites in the riverine HGM class had plant communities that were similar to those at reference standard sites. Ehrenfeld's study supports our findings that hydrologic alterations at the watershed scale can have ubiquitous impacts as demonstrated by low FCI scores for many of the flats sites. Flats can be affected by landscape-scale hydrologic alterations such as those that have occurred in the Nanticoke watershed (i.e., rapid removal of surface water and shallow ground water through a vast network of interconnected ditches and canals).

The HGM approach that was used in this study also allows us to compare functions and identify which ones have been degraded. In riverine wetlands, for example, FCI scores were lower for the Hydrology and Biogeochemistry functions (Table 4), indicating that those functions have been degraded more than the others. Observations by Tiner (2004) that 79% of the streams were channelized in the Nanticoke watershed support this interpretation. Higher values for the Habitat, Plant Community, and Landscape functions for the riverine subclass (Table 4) also demonstrate that there can be a wide range of hydrologic changes before there are noticeable decreases in those functions. Once established, trees and shrubs in riverine wetlands may persist despite significant change in the hydrologic regime by channelization; the fine-textured soils may be able to retain sufficient moisture to support these species and thereby retain Habitat functions. In contrast, the FCI scores for the Hydrology function in the flats subclass (Table 4) were higher for many sites compared to the FCI scores for the other functions. These results suggest that the vegetation responds more dramatically to the variety of stresses (e.g., physical disturbance associated with logging activities, physical differences in soil properties resulting in variation in moisture retention capacity). There are also other possible interpretations for the relatively high FCI scores for the Hydrology function in the flats subclass. The model used in our study was adapted from the hydrology model for wet pine flats developed by Rheinhardt et al. (2002) for an area bounded by the Neuse River (North Carolina) to coastal northeast Florida and the Big Thicket area of southeastern Texas. The model developed by Rheinhardt et al. also was adapted for use in hardwood flats in the Coastal Plain of Virginia (Havens et al. 2001). We were unable to make direct hydrologic measurements to verify the applicability of the variables that Rheinhardt et al. used in their models for our more northern sites, but given the lower FCI scores for the Plant Community and Habitat functions, it seems likely that the model overestimated the Hydrology function of flats in the Nanticoke watershed. Further evaluation of the Hydrology function should be conducted with emphasis on the hydrologic alterations that are caused by ditches of varying sizes. Another possible explanation for our results is that extensive ditching within the watershed also has affected hydrologic conditions in reference standard sites against which all sites were calibrated. If this situation exists, calibration of the Hydrology model of Rheinhardt et al. with further data on the influences that ditches of varying sizes have on soil moisture and ground-water levels would be required to accurately compare assessment sites and reference standard sites.

In summary, we found that the HGM method can be applied to an entire watershed to evaluate wetland condition when it is used in combination with the EMAP approach for site selection. While time-consuming (e.g., the amount of time to develop the models, obtain access to sites, conduct the assessments), this approach has several benefits. First, it provides HGM models that are based on reference data, an important aspect of any assessment model (Brinson et al. 1995, Smith et al. 1995). The HGM models are available and can be used to assess individual sites as part of wetland assessments for permit applications. Second, the HGM models should be applicable in other parts of the Outer Coastal Plain where there are similar topographic conditions and similar vegetation. In this context, the flats models developed by Havens et al. (2001)

and Rheinhardt et al. (2002) are extended further north on the Atlantic Coastal Plain. Third, the approach that we have used in this study demonstrates that it is possible to identify portions of a watershed (i.e., subwatersheds) where wetland condition is either close to reference standard condition or where condition indicates that significant degradation has occurred. In instances where wetlands are close to reference standard condition, managers should focus on conservation. In areas where there is evidence of significant degradation, managers should focus on restoration. The results of this study can also be used to assist managers in restoration activities because the reference data can provide the basis for developing guidelines and criteria for restoration of specific sites, as well as data that can be used to track restoration success.

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Appendix I. Variable and FCI scores for sites in the Riverine subclass.

| SITE | $V_{FARBUFFER}$ | $V_{FLOODPLAIN}$ | $V_{INVASIVE}$ | $V_{NEARBUFFER}$ | $V_{SAPLING}$ | $V_{SHRUB}$ | $V_{STREAMIN}$ | $V_{STREAMOUT}$ | $V_{TBA}$ | $V_{TDEN}$ | $V_{TREE}$ | $V_{DISTURB}$ | Hydrology | Biogeochemistry | Habitat | Plant Community | Landscape |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | 0.50 | 0.75 | 0.75 | 0.97 | 1.00 | 0.10 | 1.00 | 0.50 | 1.00 | 0.70 | 1.00 | 1.00 | 0.65 | 0.65 | 0.83 | 0.94 | 0.74 |
| 30 | 0.56 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.75 | 1.00 | 0.84 | 1.00 | 1.00 | 0.87 | 0.87 | 0.99 | 1.00 | 0.83 |
| 34 | 0.89 | 0.25 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.45 | 0.84 | 1.00 | 1.00 | 0.71 | 0.32 | 0.94 | 1.00 | 0.97 |
| 36 | 0.56 | 0.75 | 0.94 | 0.93 | 0.75 | 1.00 | 1.00 | 1.00 | 0.85 | 0.60 | 1.00 | 1.00 | 0.91 | 0.78 | 0.95 | 0.89 | 0.86 |
| 73 | 1.00 | 0.25 | 1.00 | 0.99 | 0.90 | 1.00 | 1.00 | 1.00 | 1.00 | 0.91 | 0.90 | 1.00 | 0.71 | 0.71 | 0.99 | 0.93 | 1.00 |
| 123 | 0.56 | 1.00 | 1.00 | 0.92 | 0.75 | 1.00 | 0.10 | 0.10 | 0.81 | 1.00 | 0.75 | 1.00 | 0.26 | 0.21 | 0.53 | 0.81 | 0.63 |
| 135 | 0.13 | 0.75 | 1.00 | 1.00 | 0.75 | 1.00 | 0.75 | 0.75 | 0.80 | 0.74 | 0.75 | 0.50 | 0.75 | 0.60 | 0.75 | 0.81 | 0.72 |
| 165 | 0.88 | 0.10 | 1.00 | 0.98 | 1.00 | 0.10 | 0.10 | 0.10 | 1.00 | 1.00 | 1.00 | 0.75 | 0.10 | 0.10 | 0.36 | 1.00 | 0.74 |
| 186 | 0.31 | 0.25 | 1.00 | 0.54 | 0.90 | 1.00 | 1.00 | 0.50 | 0.79 | 1.00 | 0.90 | 1.00 | 0.50 | 0.40 | 0.98 | 0.93 | 0.47 |
| 197 | 0.52 | 0.75 | 1.00 | 1.00 | 0.75 | 1.00 | 0.10 | 0.10 | 0.79 | 0.84 | 0.50 | 1.00 | 0.23 | 0.18 | 0.52 | 0.72 | 0.66 |
| 211 | 1.00 | 1.00 | 1.00 | 1.00 | 0.90 | 1.00 | 1.00 | 0.75 | 1.00 | 1.00 | 0.75 | 1.00 | 0.87 | 0.87 | 1.00 | 0.87 | 0.94 |
| 237 | 0.94 | 0.75 | 1.00 | 0.95 | 1.00 | 1.00 | 0.75 | 0.50 | 0.84 | 1.00 | 0.90 | 1.00 | 0.61 | 0.51 | 0.86 | 0.96 | 0.84 |
| 241 | 1.00 | 0.75 | 0.92 | 1.00 | 0.75 | 0.10 | 0.10 | 0.10 | 1.00 | 0.84 | 0.90 | 1.00 | 0.23 | 0.23 | 0.39 | 0.85 | 0.78 |
| 261 | 0.56 | 0.75 | 1.00 | 0.78 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.91 | 0.91 | 1.00 | 1.00 | 0.78 |
| 264 | 0.53 | 0.75 | 1.00 | 0.93 | 0.75 | 1.00 | 0.10 | 0.10 | 1.00 | 0.91 | 0.90 | 1.00 | 0.23 | 0.23 | 0.54 | 0.87 | 0.62 |
| 277 | 0.81 | 0.25 | 0.89 | 0.91 | 0.75 | 1.00 | 0.50 | 0.50 | 0.91 | 1.00 | 0.75 | 1.00 | 0.41 | 0.37 | 0.74 | 0.79 | 0.78 |
| 301 | 0.13 | 1.00 | 1.00 | 0.81 | 0.75 | 1.00 | 1.00 | 1.00 | 0.72 | 0.63 | 0.90 | 1.00 | 1.00 | 0.72 | 0.95 | 0.87 | 0.69 |
| 309 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.88 | 0.98 | 1.00 | 1.00 | 1.00 | 0.88 | 0.99 | 1.00 | 1.00 |
| 334 | 0.56 | 1.00 | 1.00 | 1.00 | 1.00 | 0.10 | 1.00 | 1.00 | 1.00 | 0.67 | 1.00 | 1.00 | 1.00 | 1.00 | 0.82 | 1.00 | 0.89 |
| 355 | 0.48 | 0.75 | 1.00 | 0.97 | 1.00 | 0.61 | 1.00 | 0.50 | 1.00 | 1.00 | 1.00 | 1.00 | 0.65 | 0.65 | 0.94 | 1.00 | 0.73 |
| 391 | 0.50 | 0.25 | 0.66 | 0.50 | 0.25 | 0.44 | 0.10 | 0.10 | 0.16 | 0.28 | 0.90 | 0.10 | 0.14 | 0.02 | 0.18 | 0.60 | 0.40 |
| 409 | 0.56 | 1.00 | 1.00 | 0.92 | 1.00 | 1.00 | 1.00 | 0.50 | 1.00 | 1.00 | 1.00 | 1.00 | 0.71 | 0.71 | 1.00 | 1.00 | 0.73 |
| 416 | 0.67 | 0.25 | 0.98 | 1.00 | 1.00 | 1.00 | 0.25 | 0.10 | 0.76 | 0.74 | 1.00 | 0.25 | 0.16 | 0.12 | 0.46 | 1.00 | 0.69 |
| 423 | 0.50 | 0.25 | 0.94 | 0.87 | 0.50 | 0.36 | 0.10 | 0.10 | 0.90 | 0.63 | 0.90 | 0.25 | 0.14 | 0.13 | 0.28 | 0.76 | 0.59 |
| 436 | 1.00 | 1.00 | 1.00 | 1.00 | 0.75 | 1.00 | 1.00 | 1.00 | 1.00 | 0.95 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.91 | 1.00 |
| 440 | 0.88 | 0.75 | 1.00 | 0.86 | 1.00 | 0.86 | 1.00 | 0.75 | 1.00 | 0.98 | 1.00 | 1.00 | 0.79 | 0.79 | 0.98 | 1.00 | 0.84 |
| 506 | 0.69 | 0.75 | 1.00 | 0.69 | 0.75 | 1.00 | 0.75 | 0.75 | 1.00 | 1.00 | 1.00 | 0.50 | 0.75 | 0.75 | 0.79 | 0.91 | 0.71 |
| 551 | 0.56 | 1.00 | 1.00 | 0.96 | 0.75 | 0.34 | 1.00 | 1.00 | 1.00 | 0.77 | 0.75 | 1.00 | 1.00 | 1.00 | 0.87 | 0.81 | 0.87 |
| 570 | 0.13 | 0.25 | 0.88 | 0.42 | 0.50 | 0.38 | 0.10 | 0.10 | 0.95 | 0.39 | 0.75 | 0.25 | 0.14 | 0.13 | 0.27 | 0.69 | 0.27 |
| 572 | 0.44 | 1.00 | 1.00 | 0.85 | 1.00 | 0.36 | 0.50 | 1.00 | 0.47 | 0.35 | 1.00 | 1.00 | 0.91 | 0.43 | 0.55 | 1.00 | 0.79 |
| 576 | 1.00 | 1.00 | 0.95 | 1.00 | 0.75 | 0.10 | 1.00 | 1.00 | 0.82 | 0.70 | 0.75 | 1.00 | 1.00 | 0.82 | 0.81 | 0.80 | 1.00 |
| 595 | 0.56 | 0.25 | 0.92 | 1.00 | 0.25 | 0.15 | 0.10 | 0.10 | 0.68 | 0.70 | 0.50 | 0.25 | 0.14 | 0.10 | 0.23 | 0.51 | 0.67 |
| 596 | 0.56 | 0.75 | 1.00 | 0.85 | 1.00 | 0.50 | 0.75 | 0.50 | 0.81 | 0.42 | 1.00 | 1.00 | 0.61 | 0.50 | 0.73 | 1.00 | 0.69 |
| 646 | 0.44 | 0.75 | 1.00 | 0.73 | 0.75 | 0.40 | 0.10 | 0.10 | 0.49 | 0.56 | 1.00 | 1.00 | 0.23 | 0.11 | 0.37 | 0.91 | 0.50 |
| 697 | 0.94 | 0.75 | 1.00 | 0.87 | 0.90 | 0.69 | 1.00 | 1.00 | 0.59 | 0.84 | 1.00 | 1.00 | 0.91 | 0.54 | 0.90 | 0.96 | 0.92 |
| 734 | 0.50 | 1.00 | 1.00 | 1.00 | 0.75 | 1.00 | 1.00 | 1.00 | 1.00 | 0.67 | 1.00 | 1.00 | 1.00 | 1.00 | 0.97 | 0.91 | 0.88 |
| 739 | 0.94 | 0.10 | 1.00 | 0.94 | 0.75 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.75 | 0.10 | 0.10 | 0.01 | 0.10 | 0.81 | 0.73 |
| 747 | 1.00 | 0.75 | 1.00 | 1.00 | 0.50 | 1.00 | 0.75 | 0.50 | 0.82 | 0.91 | 0.75 | 0.75 | 0.61 | 0.50 | 0.81 | 0.72 | 0.88 |
| 752 | 0.13 | 0.25 | 0.91 | 0.66 | 0.25 | 0.10 | 0.10 | 0.10 | 0.69 | 0.53 | 0.25 | 0.25 | 0.14 | 0.10 | 0.21 | 0.42 | 0.39 |
| 784 | 0.92 | 1.00 | 1.00 | 0.88 | 1.00 | 1.00 | 1.00 | 0.50 | 1.00 | 1.00 | 1.00 | 1.00 | 0.71 | 0.71 | 1.00 | 1.00 | 0.80 |
| 786 | 0.58 | 1.00 | 1.00 | 0.97 | 1.00 | 0.21 | 1.00 | 1.00 | 1.00 | 0.84 | 1.00 | 1.00 | 1.00 | 1.00 | 0.86 | 1.00 | 0.88 |
| 797 | 1.00 | 0.25 | 0.83 | 0.95 | 0.25 | 0.10 | 0.10 | 0.10 | 0.61 | 0.53 | 0.75 | 0.10 | 0.14 | 0.09 | 0.18 | 0.58 | 0.75 |
| 811 | 1.00 | 1.00 | 1.00 | 1.00 | 0.90 | 0.10 | 1.00 | 1.00 | 1.00 | 0.63 | 1.00 | 1.00 | 1.00 | 1.00 | 0.82 | 0.96 | 1.00 |
| 821 | 0.75 | 0.25 | 0.87 | 0.75 | 0.50 | 0.13 | 0.10 | 0.10 | 0.96 | 0.63 | 0.75 | 0.25 | 0.14 | 0.14 | 0.25 | 0.69 | 0.59 |
| 823 | 0.19 | 0.75 | 1.00 | 0.60 | 1.00 | 1.00 | 1.00 | 0.50 | 0.39 | 0.70 | 1.00 | 1.00 | 0.65 | 0.25 | 0.92 | 1.00 | 0.47 |
| 827 | 1.00 | 0.75 | 0.95 | 0.95 | 0.75 | 0.10 | 1.00 | 0.50 | 1.00 | 1.00 | 0.75 | 1.00 | 0.65 | 0.65 | 0.85 | 0.80 | 0.85 |
| 830 | 0.53 | 0.25 | 0.97 | 0.84 | 0.75 | 0.31 | 1.00 | 0.75 | 0.94 | 0.60 | 1.00 | 0.25 | 0.61 | 0.58 | 0.72 | 0.90 | 0.74 |
| 838 | 0.34 | 0.25 | 1.00 | 0.47 | 0.75 | 0.61 | 1.00 | 0.50 | 1.00 | 0.70 | 1.00 | 1.00 | 0.50 | 0.50 | 0.91 | 0.91 | 0.45 |
| 848 | 0.53 | 1.00 | 1.00 | 0.83 | 0.75 | 0.36 | 0.10 | 0.10 | 0.88 | 0.56 | 0.75 | 0.50 | 0.26 | 0.23 | 0.31 | 0.81 | 0.57 |

Appendix I. Continued.

| SITE | $V_{FARBUFFER}$ | $V_{FLOODPLAIN}$ | $V_{INVASIVE}$ | $V_{NEARBUFFER}$ | $V_{SAPLING}$ | $V_{SHRUB}$ | $V_{STREAMIN}$ | $V_{STREAMOUT}$ | $V_{TBA}$ | $V_{TDEN}$ | $V_{TREE}$ | $V_{DISTURB}$ | Hydrology | Biogeochemistry | Habitat | Plant Community | Landscape |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 889 | 0.25 | 0.25 | 0.50 | 0.52 | 0.25 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.50 | 0.10 | 0.14 | 0.01 | 0.10 | 0.41 | 0.35 |
| 905 | 0.94 | 1.00 | 1.00 | 0.76 | 0.75 | 0.82 | 1.00 | 0.50 | 0.42 | 0.70 | 1.00 | 0.75 | 0.71 | 0.30 | 0.86 | 0.91 | 0.74 |
| 930 | 0.38 | 1.00 | 1.00 | 0.71 | 0.90 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.96 | 0.70 |
| 934 | 0.78 | 1.00 | 1.00 | 1.00 | 1.00 | 0.10 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.85 | 1.00 | 0.95 |
| 1045 | 0.13 | 1.00 | 1.00 | 0.89 | 0.75 | 0.10 | 1.00 | 0.50 | 0.88 | 0.84 | 0.75 | 1.00 | 0.71 | 0.62 | 0.83 | 0.81 | 0.60 |

Appendix II. Variable Scores and Functional Index Scores (FCI) for assessed sites in the Flats wetland class. Sites that were disturbed within the past 50 years are indicated in bold, and sites that were not disturbed within the past 50 years are indicated in italics. Variable scores appear in columns 2–12, and FCI scores in the last four columns. Descriptions of variables and equations used to calculate FCI scores are given in Tables 1 and 2, respectively.

| SITE | $V_{DISTURB}$ | $V_{DRAIN}$ | $V_{FILL}$ | $V_{HERB}$ | $V_{MICRO}$ | $V_{TREE}$ | $V_{RUBUS}$ | $V_{SHRUB}$ | $V_{SNAG}$ | $V_{TBA}$ | $V_{TDEN}$ | Hydrology | Biogeochemistry | Habitat | Plant Community |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **6** | 0.50 | 0.42 | 0.50 | 0.25 | 0.50 | 0.50 | 0.75 | 0.23 | 0.10 | 0.30 | 0.66 | 0.44 | 0.19 | 0.33 | 0.28 |
| *7* | 1.00 | 0.52 | 1.00 | 0.75 | 1.00 | 1.00 | 1.00 | 0.10 | 1.00 | 1.00 | 1.00 | 0.64 | 0.64 | 0.78 | 0.88 |
| *12* | 1.00 | 1.00 | 1.00 | 0.75 | 1.00 | 0.25 | 1.00 | 1.00 | 0.10 | 1.00 | 1.00 | 1.00 | 0.85 | 0.78 | 0.50 |
| *20* | 1.00 | 0.10 | 1.00 | 0.75 | 1.00 | 0.25 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.33 | 0.33 | 1.00 | 0.50 |
| **24** | 0.75 | 1.00 | 1.00 | 0.75 | 0.75 | 0.75 | 0.75 | 1.00 | 1.00 | 1.00 | 0.81 | 1.00 | 0.84 | 0.91 | 0.56 |
| **33** | 0.75 | 1.00 | 1.00 | 0.75 | 0.75 | 1.00 | 1.00 | 0.10 | 0.50 | 0.94 | 1.00 | 1.00 | 0.78 | 0.58 | 0.88 |
| **50** | 0.50 | 1.00 | 0.75 | 0.75 | 0.50 | 1.00 | 0.75 | 1.00 | 0.10 | 1.00 | 1.00 | 0.94 | 0.56 | 0.65 | 0.66 |
| **55** | 0.75 | 1.00 | 1.00 | 0.75 | 0.75 | 1.00 | 1.00 | 1.00 | 1.00 | 0.90 | 1.00 | 1.00 | 0.86 | 0.93 | 0.88 |
| *60* | 1.00 | 0.10 | 0.75 | 0.75 | 1.00 | 1.00 | 1.00 | 0.34 | 1.00 | 1.00 | 1.00 | 0.26 | 0.26 | 0.84 | 0.88 |
| **64** | 0.50 | 0.10 | 0.75 | 0.10 | 0.25 | 0.25 | 0.10 | 0.10 | 1.00 | 0.60 | 0.76 | 0.26 | 0.14 | 0.57 | 0.02 |
| *66* | 1.00 | 0.16 | 1.00 | 0.75 | 1.00 | 0.50 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.37 | 0.37 | 1.00 | 0.63 |
| **68** | 0.75 | 1.00 | 1.00 | 0.75 | 0.75 | 1.00 | 1.00 | 1.00 | 1.00 | 0.55 | 0.95 | 1.00 | 0.79 | 0.88 | 0.88 |
| **70** | 0.50 | 1.00 | 0.50 | 0.75 | 0.75 | 0.25 | 1.00 | 1.00 | 1.00 | 1.00 | 0.80 | 0.88 | 0.74 | 0.85 | 0.50 |
| **76** | 0.50 | 0.55 | 0.75 | 0.25 | 0.10 | 0.25 | 0.75 | 1.00 | 1.00 | 0.27 | 0.76 | 0.60 | 0.23 | 0.75 | 0.19 |
| *80* | 1.00 | 0.95 | 1.00 | 0.75 | 1.00 | 0.50 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.96 | 0.96 | 1.00 | 0.63 |
| **84** | 0.50 | 0.71 | 1.00 | 0.25 | 0.75 | 0.25 | 0.50 | 0.13 | 0.10 | 0.10 | 0.10 | 0.78 | 0.33 | 0.21 | 0.13 |
| **91** | 0.75 | 0.99 | 1.00 | 0.75 | 0.50 | 0.25 | 1.00 | 1.00 | 0.10 | 1.00 | 1.00 | 0.99 | 0.60 | 0.71 | 0.50 |
| **93** | 0.75 | 0.10 | 0.75 | 0.25 | 0.10 | 0.50 | 0.10 | 0.10 | 0.72 | 0.94 | 1.00 | 0.26 | 0.13 | 0.64 | 0.04 |
| **99** | 0.25 | 0.10 | 0.50 | 0.50 | 1.00 | 1.00 | 0.75 | 0.50 | 1.00 | 1.00 | 1.00 | 0.20 | 0.20 | 0.69 | 0.56 |
| **129** | 0.50 | 1.00 | 1.00 | 0.25 | 0.50 | 0.25 | 0.10 | 1.00 | 0.50 | 0.10 | 0.10 | 1.00 | 0.37 | 0.53 | 0.03 |
| **138** | 0.75 | 1.00 | 0.75 | 0.25 | 0.75 | 1.00 | 1.00 | 1.00 | 0.10 | 0.47 | 1.00 | 0.94 | 0.60 | 0.65 | 0.63 |
| **140** | 0.75 | 0.72 | 1.00 | 0.75 | 1.00 | 0.75 | 1.00 | 0.10 | 0.10 | 0.37 | 0.76 | 0.79 | 0.56 | 0.38 | 0.75 |
| *141* | 1.00 | 0.10 | 1.00 | 1.00 | 1.00 | 0.50 | 0.75 | 1.00 | 1.00 | 1.00 | 1.00 | 0.33 | 0.33 | 1.00 | 0.56 |
| *142* | 1.00 | 1.00 | 1.00 | 0.75 | 0.75 | 1.00 | 0.75 | 0.94 | 0.50 | 1.00 | 1.00 | 1.00 | 0.79 | 0.86 | 0.66 |
| **144** | 0.75 | 0.79 | 0.75 | 0.75 | 0.75 | 1.00 | 0.75 | 1.00 | 0.10 | 0.58 | 0.62 | 0.78 | 0.46 | 0.61 | 0.66 |
| *147* | 0.50 | 1.00 | 1.00 | 0.50 | 0.50 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 1.00 | 0.30 | 0.20 | 0.03 |
| *149* | 1.00 | 0.80 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.10 | 0.79 | 0.81 | 0.85 | 0.67 | 0.73 | 1.00 |
| *172* | 1.00 | 1.00 | 0.75 | 0.75 | 0.75 | 1.00 | 0.75 | 0.57 | 0.50 | 1.00 | 0.86 | 0.94 | 0.72 | 0.75 | 0.66 |
| **196** | 0.75 | 0.80 | 1.00 | 0.75 | 0.75 | 0.75 | 0.75 | 0.36 | 0.50 | 1.00 | 1.00 | 0.85 | 0.67 | 0.65 | 0.56 |
| **226** | 0.75 | 0.10 | 0.75 | 0.50 | 0.75 | 0.50 | 1.00 | 1.00 | 0.10 | 0.17 | 0.33 | 0.26 | 0.12 | 0.53 | 0.50 |
| **229** | 0.75 | 0.82 | 1.00 | 0.75 | 0.75 | 1.00 | 1.00 | 0.80 | 0.10 | 1.00 | 1.00 | 0.87 | 0.63 | 0.66 | 0.88 |
| **230** | 0.50 | 0.50 | 0.75 | 0.25 | 0.50 | 0.25 | 0.50 | 1.00 | 0.10 | 0.10 | 0.10 | 0.56 | 0.17 | 0.43 | 0.13 |
| **242** | 0.50 | 1.00 | 1.00 | 0.50 | 0.75 | 0.25 | 0.50 | 0.87 | 1.00 | 0.42 | 1.00 | 1.00 | 0.78 | 0.77 | 0.19 |
| **245** | 0.75 | 1.00 | 0.75 | 0.75 | 0.75 | 0.75 | 1.00 | 1.00 | 1.00 | 0.85 | 1.00 | 0.94 | 0.80 | 0.92 | 0.75 |
| **246** | 0.75 | 1.00 | 1.00 | 0.75 | 0.10 | 0.50 | 0.75 | 0.54 | 0.10 | 1.00 | 1.00 | 1.00 | 0.40 | 0.60 | 0.47 |
| *249* | 0.25 | 0.21 | 0.50 | 0.75 | 0.75 | 0.50 | 1.00 | 1.00 | 0.10 | 1.00 | 1.00 | 0.28 | 0.20 | 0.59 | 0.63 |
| *274* | 1.00 | 0.79 | 1.00 | 0.75 | 1.00 | 0.50 | 0.10 | 1.00 | 1.00 | 1.00 | 1.00 | 0.84 | 0.84 | 1.00 | 0.06 |
| **297** | 0.75 | 0.63 | 0.50 | 0.75 | 0.75 | 0.50 | 0.25 | 0.10 | 0.50 | 0.46 | 0.61 | 0.60 | 0.38 | 0.47 | 0.16 |
| **303** | 0.75 | 0.93 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.81 | 1.00 | 0.95 | 0.92 | 0.91 | 1.00 |
| **304** | 0.75 | 1.00 | 0.50 | 0.75 | 0.10 | 0.50 | 0.10 | 1.00 | 0.10 | 0.83 | 1.00 | 0.88 | 0.33 | 0.69 | 0.06 |
| **307** | 0.50 | 1.00 | 0.75 | 0.75 | 0.75 | 0.25 | 0.10 | 0.54 | 0.10 | 0.49 | 1.00 | 0.94 | 0.60 | 0.47 | 0.05 |
| *317* | 0.50 | 0.10 | 0.75 | 0.50 | 0.25 | 0.10 | 0.10 | 0.40 | 0.50 | 0.10 | 0.10 | 0.26 | 0.06 | 0.38 | 0.03 |
| **318** | 0.75 | 0.85 | 0.75 | 0.75 | 1.00 | 1.00 | 1.00 | 0.17 | 1.00 | 1.00 | 1.00 | 0.83 | 0.83 | 0.73 | 0.88 |
| **329** | 0.75 | 0.10 | 0.75 | 0.25 | 0.10 | 0.25 | 0.50 | 0.17 | 0.10 | 0.92 | 1.00 | 0.26 | 0.10 | 0.50 | 0.13 |
| **330** | 0.75 | 1.00 | 1.00 | 0.75 | 1.00 | 0.50 | 1.00 | 1.00 | 1.00 | 0.72 | 0.71 | 1.00 | 0.91 | 0.87 | 0.63 |
| **335** | 0.75 | 0.10 | 0.50 | 0.75 | 0.50 | 1.00 | 0.10 | 0.23 | 0.10 | 1.00 | 0.95 | 0.20 | 0.12 | 0.51 | 0.09 |

Appendix II. Continued.

| SITE | $V_{DISTURB}$ | $V_{DRAIN}$ | $V_{FILL}$ | $V_{HERB}$ | $V_{MICRO}$ | $V_{TREE}$ | $V_{RUBUS}$ | $V_{SHRUB}$ | $V_{SNAG}$ | $V_{TBA}$ | $V_{TDEN}$ | Hydrology | Biogeochemistry | Habitat | Plant Community |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **340** | 0.75 | 1.00 | 0.50 | 0.75 | 0.75 | 1.00 | 1.00 | 0.10 | 0.50 | 0.77 | 1.00 | 0.88 | 0.66 | 0.56 | 0.88 |
| **342** | 0.75 | 1.00 | 1.00 | 0.25 | 0.10 | 0.25 | 0.50 | 0.10 | 0.10 | 0.46 | 1.00 | 1.00 | 0.31 | 0.42 | 0.13 |
| **345** | 0.75 | 1.00 | 1.00 | 0.50 | 0.75 | 0.50 | 1.00 | 1.00 | 1.00 | 0.57 | 0.67 | 1.00 | 0.75 | 0.84 | 0.50 |
| *354* | 1.00 | 0.21 | 1.00 | 0.75 | 1.00 | 0.50 | 1.00 | 1.00 | 0.10 | 0.11 | 0.33 | 0.41 | 0.24 | 0.58 | 0.63 |
| *367* | 0.10 | 1.00 | 1.00 | 0.50 | 1.00 | 0.10 | 0.75 | 0.10 | 0.50 | 0.10 | 0.10 | 1.00 | 0.62 | 0.20 | 0.23 |
| *368* | 1.00 | 1.00 | 1.00 | 0.75 | 0.75 | 1.00 | 1.00 | 1.00 | 1.00 | 0.96 | 1.00 | 1.00 | 0.87 | 1.00 | 0.88 |
| *369* | 1.00 | 1.00 | 1.00 | 0.75 | 1.00 | 0.75 | 1.00 | 1.00 | 0.10 | 0.88 | 1.00 | 1.00 | 0.83 | 0.76 | 0.75 |
| *374* | 1.00 | 1.00 | 0.75 | 0.75 | 1.00 | 0.25 | 1.00 | 1.00 | 1.00 | 0.87 | 0.81 | 0.94 | 0.89 | 0.96 | 0.50 |
| **379** | 0.75 | 0.16 | 0.75 | 0.75 | 0.10 | 0.25 | 0.10 | 1.00 | 0.10 | 1.00 | 1.00 | 0.31 | 0.12 | 0.71 | 0.05 |
| *387* | 1.00 | 0.10 | 1.00 | 0.75 | 1.00 | 1.00 | 1.00 | 1.00 | 0.50 | 1.00 | 1.00 | 0.33 | 0.30 | 0.88 | 0.88 |
| *393* | 1.00 | 0.11 | 1.00 | 0.75 | 1.00 | 1.00 | 1.00 | 0.30 | 0.10 | 1.00 | 1.00 | 0.33 | 0.28 | 0.60 | 0.88 |
| *396* | 1.00 | 1.00 | 1.00 | 0.75 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.86 | 1.00 | 0.98 | 0.98 | 0.88 |
| *399* | 1.00 | 1.00 | 0.75 | 1.00 | 1.00 | 1.00 | 0.75 | 0.27 | 0.50 | 1.00 | 1.00 | 0.94 | 0.86 | 0.69 | 0.75 |
| **400** | 0.75 | 1.00 | 1.00 | 0.75 | 1.00 | 1.00 | 1.00 | 0.10 | 0.10 | 1.00 | 1.00 | 1.00 | 0.85 | 0.49 | 0.88 |
| **401** | 0.75 | 0.32 | 0.75 | 0.75 | 0.75 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.95 | 0.43 | 0.37 | 0.93 | 0.88 |
| **414** | 0.25 | 1.00 | 0.75 | 1.00 | 0.75 | 1.00 | 1.00 | 0.10 | 0.50 | 0.96 | 1.00 | 0.94 | 0.74 | 0.46 | 1.00 |
| **417** | 0.75 | 0.89 | 1.00 | 0.25 | 0.10 | 0.25 | 0.10 | 0.30 | 0.10 | 0.36 | 0.95 | 0.92 | 0.26 | 0.45 | 0.03 |
| **424** | 0.75 | 0.73 | 0.75 | 0.50 | 1.00 | 0.75 | 0.75 | 0.10 | 0.50 | 1.00 | 1.00 | 0.74 | 0.67 | 0.59 | 0.47 |
| **430** | 0.10 | 1.00 | 1.00 | 1.00 | 0.75 | 1.00 | 1.00 | 1.00 | 1.00 | 0.66 | 1.00 | 1.00 | 0.82 | 0.73 | 1.00 |
| **431** | 0.75 | 1.00 | 0.75 | 0.75 | 0.75 | 1.00 | 1.00 | 0.60 | 1.00 | 1.00 | 1.00 | 0.94 | 0.82 | 0.84 | 0.88 |
| **434** | 0.10 | 0.82 | 1.00 | 0.25 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.87 | 0.09 | 0.10 | 0.02 |
| **437** | 0.75 | 1.00 | 1.00 | 0.75 | 1.00 | 1.00 | 1.00 | 0.10 | 0.10 | 0.99 | 1.00 | 1.00 | 0.85 | 0.49 | 0.88 |
| *441* | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.75 | 1.00 | 1.00 | 0.50 | 1.00 | 1.00 | 1.00 | 0.92 | 0.88 | 0.88 |
| *442* | 0.50 | 0.52 | 0.75 | 0.25 | 0.75 | 0.10 | 0.10 | 0.27 | 0.10 | 0.10 | 0.10 | 0.58 | 0.25 | 0.24 | 0.02 |
| *449* | 1.00 | 1.00 | 1.00 | 0.75 | 1.00 | 1.00 | 1.00 | 1.00 | 0.72 | 1.00 | 1.00 | 1.00 | 0.95 | 0.93 | 0.88 |
| *455* | 1.00 | 1.00 | 1.00 | 0.75 | 0.75 | 0.75 | 1.00 | 1.00 | 0.10 | 0.80 | 1.00 | 1.00 | 0.69 | 0.75 | 0.75 |
| **461** | 0.50 | 0.30 | 1.00 | 0.25 | 0.10 | 0.25 | 0.50 | 0.10 | 0.10 | 0.34 | 1.00 | 0.48 | 0.14 | 0.34 | 0.13 |
| **462** | 0.75 | 0.10 | 0.50 | 0.75 | 1.00 | 0.50 | 1.00 | 0.27 | 0.10 | 0.96 | 1.00 | 0.20 | 0.17 | 0.53 | 0.63 |
| *464* | 0.10 | 0.10 | 0.75 | 0.25 | 0.50 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.26 | 0.08 | 0.10 | 0.02 |
| **469** | 0.25 | 0.10 | 0.50 | 0.25 | 1.00 | 0.25 | 0.75 | 1.00 | 0.10 | 0.66 | 0.81 | 0.20 | 0.15 | 0.52 | 0.19 |
| *474* | 0.10 | 1.00 | 1.00 | 0.25 | 0.25 | 0.10 | 0.50 | 0.10 | 0.10 | 0.10 | 0.10 | 1.00 | 0.18 | 0.10 | 0.09 |
| **492** | 0.75 | 1.00 | 1.00 | 0.50 | 1.00 | 0.25 | 0.75 | 1.00 | 1.00 | 0.26 | 0.48 | 1.00 | 0.79 | 0.78 | 0.28 |
| **494** | 0.75 | 1.00 | 1.00 | 0.75 | 1.00 | 1.00 | 1.00 | 1.00 | 0.10 | 0.39 | 0.76 | 1.00 | 0.71 | 0.61 | 0.88 |
| **504** | 0.50 | 1.00 | 1.00 | 0.25 | 0.75 | 0.50 | 0.10 | 0.30 | 1.00 | 0.10 | 0.19 | 1.00 | 0.59 | 0.49 | 0.04 |
| **505** | 0.50 | 1.00 | 1.00 | 0.25 | 0.10 | 0.25 | 0.50 | 0.37 | 0.10 | 1.00 | 1.00 | 1.00 | 0.40 | 0.49 | 0.13 |
| **507** | 0.50 | 1.00 | 1.00 | 0.50 | 0.75 | 0.50 | 0.50 | 0.27 | 1.00 | 0.28 | 0.52 | 1.00 | 0.68 | 0.54 | 0.25 |
| **511** | 0.75 | 0.10 | 1.00 | 0.25 | 0.75 | 1.00 | 1.00 | 1.00 | 0.10 | 0.97 | 0.95 | 0.33 | 0.23 | 0.70 | 0.63 |
| **513** | 0.50 | 0.35 | 0.75 | 0.25 | 0.50 | 0.25 | 0.50 | 0.10 | 0.10 | 0.10 | 0.10 | 0.45 | 0.14 | 0.20 | 0.13 |
| *519* | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.50 | 1.00 | 1.00 | 1.00 | 0.98 | 0.90 | 1.00 | 0.98 | 0.99 | 0.75 |
| **525** | 0.75 | 0.95 | 1.00 | 1.00 | 0.75 | 0.75 | 1.00 | 0.20 | 0.50 | 0.81 | 1.00 | 0.96 | 0.73 | 0.59 | 0.88 |
| **534** | 0.50 | 0.25 | 0.75 | 0.25 | 0.50 | 1.00 | 0.75 | 1.00 | 0.10 | 0.10 | 0.19 | 0.38 | 0.12 | 0.44 | 0.47 |
| **542** | 0.75 | 1.00 | 1.00 | 1.00 | 0.75 | 0.25 | 1.00 | 1.00 | 1.00 | 0.80 | 1.00 | 1.00 | 0.84 | 0.91 | 0.63 |
| **547** | 0.75 | 0.64 | 0.75 | 0.75 | 0.75 | 1.00 | 1.00 | 0.10 | 0.50 | 1.00 | 1.00 | 0.67 | 0.53 | 0.59 | 0.88 |