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A Draft Regional Guidebook for Applying the Hydrogeomorphic Approach to Wet Hardwood Flats on Mineral Soils in the Coastal Plain of Virginia

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Chapter 1. Introduction

The hydrogeomorphic (HGM) approach applies functional indices to the assessment of functions by comparing functions across a suite of reference sites that range from severely altered to unaltered. This Draft Regional Guidebook is the result of applying the HGM approach to Hardwood Mineral Flats in the coastal plain of Virginia.

In developing the Draft Regional Guidebook, various models from Kentucky, Pennsylvania, and North Carolina, as well as, input from a workshop held in Wakefield, Virginia on May 13-14, 1998 were used to provide a template for model development. The workshop was attended by hydrologists, biogeochemists, soil scientists, wildlife biologists, and botanists from the public, private and academic sectors who have extensive knowledge of Hardwood Mineral Flats (Table 1). This Draft Regional Guidebook incorporates material from the "Regional Guidebook for Applying the Hydrogeomorphic Approach to Wet Pine Flats on Mineral Soils in the Atlantic and Gulf Coastal Plains" by Richard Rheinhardt, Martha Rheinhardt, and Mark Brinson (1999). Excerpted material includes the overview of the HGM approach and the hydrology section (since the approach utilized for pine flats is also appropriate for hardwood flats). Additional input was gained from the "Draft Functional Assessment for Deciduous Mineral Flat Wetlands, Version 5 - 1999" by the Natural Resources Conservation Service staff.

Valuable suggestions from end-users of other HGM guidebooks regarding the pros and cons of various sampling methods were considered and incorporated into this draft guidebook where possible.

An attempt was made to incorporate data that is routinely collected as part of wetlands delineations to reduce duplication of field data and expedite the assessment procedure. The field sampling time for this assessment will depend on the size of the site, and the skill level and number of personnel. The sampling assessment protocol can be conducted by one person (though sampling of microtopography will require the use of a measured stake that can be installed temporarily in the ground). Two people can collect field data on a three- plot site in three to four hours.

Table 1. List of Workshop Participants.

Ms. Rebecca Arenson- Virginia Institute of Marine Science
Dr. Sam Austin - Virginia Department of Forestry
Mr. Thomas Barnard - Wetlands Program, Virginia Institute of Marine Science
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Chapter 2. Overview of the Hydrogeomorphic Approach (excerpted and modified slightly from Rheinhardt et al. 1999)

The HGM approach consists of four major components that include hydrogeomorphic classification, reference wetlands, assessment models and functional indices, and application procedures. The first three components of the HGM approach are addressed during a Development Phase by an interdisciplinary team of experts, or "Assessment Team." The Development Phase begins with the assessment team classifying the wetlands within a region into regional subclasses using the principles and criteria of the Hydrogeomorphic Classification. Next, focusing on a specific regional wetland subclass, the team develops an ecological characterization or profile of the subclass. The team then identifies the important wetland functions, defines the factors that influence each function, and conceptualizes an assessment model for each function. Next, the team identifies and collects field data from a group of reference wetlands that represent the range of variability exhibited by the regional subclass. Field data from reference wetlands is then used to calibrate, verify, and validate the initially conceptualized assessment models. Finally, the assessment team develops a set of procedures for applying the functional indices to the assessment of wetland functions. The product resulting from the Development Phase is a Regional Guidebook for assessing the functions of a regional wetland subclass. During the Application Phase of the HGM approach, the application procedures outlined in the Regional Guidebook are applied to specific projects requiring the assessment of wetland functions by regulators, managers, consultants, and other end users.

Hydrogeomorphic classification, reference wetlands, assessment models and functional indices, and application procedures are discussed briefly below. More extensive discussions can be found in Brinson (1993), Brinson (1995), Smith et al. (1995), Brinson and Rheinhardt (1996, 1997), Rheinhardt, Brinson, and Farley (1997), Brinson et al. (1999), and Rheinhardt et al. (1999).

Hydrogeomorphic Classification

Wetlands ecosystems share a number of features including relatively long hydroperiods, hydrophytic vegetation, and hydric soils. However, despite these common features, wetlands exist under a wide range of climatic, geologic, and physiographic situations and exhibit a wide variety of physical, chemical, and biological characteristics. The variability exhibited by wetlands coupled with the short time frames for conducting assessments present a challenge to developing accurate and practical methods for assessing wetland functions. More "generic" methods, designed to assess multiple types of wetlands, lack the level of detail necessary to detect significant changes in function. In order to assess wetland functions at the appropriate level of resolution and within a short time frame, the the amount of natural variability exhibited by the wetlands under consideration must be considered in assessment (Smith et al. 1995). This is done by first separating (classifying) wetlands by regional sub-class. Then a wetland's potential to function is determined relative to reference data obtained from relatively unaltered sites within the regional wetland subclass to which the assessed wetland belongs.

The HGM Classification (Brinson 1993) was developed specifically to accomplish this task. Its objective is to identify groups of wetlands that function similarly using three criteria that fundamentally influence how wetlands function: geomorphic setting; water source; and hydrodynamics. Geomorphic setting refers to the landform in which the wetland occurs, its geologic evolution, and its topographic position in the landscape. Water source refers to the origination of water just prior to entering the wetland. The three primary water sources are precipitation, overbank surface flow (in riverine systems), and ground water discharge. Hydrodynamics refers to the level of energy and the direction that water moves in a wetland.

Based on these three classification criteria any number of "functional" wetland groups can be identified at different spatial or temporal scales. For example, at a broad continental scale Brinson (1993) identified five hydrogeomorphic wetland classes. These were later expanded (Smith et al. 1995) to the seven classes described in Table 2. In most cases, the level of variability encompassed by each of these broad hydrogeomorphic classes is too great to allow development of assessment models that can be rapidly applied while being sensitive enough to detect significant change in function.

In order to reduce the amount of variability that must be considered in assessment to a tractable level, it is necessary to first identify the regional wetland subclass of a wetland by applying the classification criteria at a spatial scale that reduces both inter-regional and intra-regional variability. In many parts of the country wetland classifications exist to serve as a starting point for developing a regional hydrogeomorphic classification (Stewart and Kantrud 1971, Rheinhardt, Brinson, and Farley (1997), and Rheinhardt and Rheinhardt 2000). Regional wetland subclasses, like the wetland classes, are distinguished on the basis of geomorphic setting, water source, and hydrodynamics. In addition, certain ecosystem or landscape characteristics may also be useful for distinguishing regional subclasses in certain regions. For example, regional depression subclasses might be based on water source (i.e., groundwater versus surface water), or the degree of connection between the wetland and other surface waters (i.e., the flow of surface water in or out of the depression through defined channels. In the estuarine fringe class, subclasses could be based on salinity gradients. Regional slope subclasses might be based on the degree of slope, landscape position, the source of water (i.e., overland flow versus groundwater discharge), or other factors. Regional riverine subclasses could be based on water source, position in the watershed, stream order, watershed size, channel gradient, or floodplain width. Examples of potential regional subclasses are shown in Table 3 and provided by Smith et al. (1995) Rheinhardt, Brinson, and Farley (1997), Ainslie (1999), and Rheinhardt and Rheinhardt (2000). Regional Guidebooks include a thorough characterization of the regional wetland subclass in terms of its geomorphic setting, water sources, hydrodynamics, vegetation, soil, and other features that were taken into consideration during the classification process.

Reference Wetlands

Reference wetlands are wetland sites that represent the range of variability that occurs in a regional wetland subclass as a result of natural processes (e.g., succession, channel migration, fire, erosion and sedimentation) as well as anthropogenic alterations. The HGM approach uses reference wetlands to accomplish several objectives. First, they provide a concrete physical representation of wetlands from the regional subclass whose characteristics can observed and measured. Second, they establish the range of variability that exists in the regional subclass within the Reference Domain (the geographic area from which reference wetlands are selected). Finally, they provide data for calibration of assessment model variables and functional indices (see Chapter 9).

Reference standard wetlands are the subset of reference wetlands that achieve a level of functioning that is both characteristic for the subclass and sustainable across the suite of functions inherent to the subclass. Generally, they are the least altered wetland sites in the least altered landscapes. By definition, the functional index for all functions in reference standard wetlands is 1 .O. Reference standards are the range of conditions exhibited by assessment model variables in reference standard wetlands. By definition, the variable subindex for assessment model variables in reference standard wetlands is 1 .O (Smith et al. 1995). The Glossary presents reference wetland terms and definitions used in the HGM approach.

Assessment Models and Functional Indices

In the HGM approach, assessment models are simple representations of functions performed by wetland ecosystems that are constructed and calibrated by the assessment team during the development phase. Assessment models define the relationship between one or more characteristic or process of the wetland ecosystem or surrounding landscape, and the functional capacity of a wetland ecosystem. Functional capacity is simply the ability of a wetland to perform a function. Assessment model variables represent the characteristics of a wetland ecosystem of a given subclass and the condition of its surrounding landscape, which both influence its functional capacity. The condition of model variables vary depending on the range of conditions exhibited by reference wetlands of a wetland subclass in a given Reference Domain. For example, plant species richness can be more or less rich, overbank flow can be more or less frequent, and soils can be more or less permeable than the least altered wetlands of the regional wetland subclass. Model variables are assigned a subindex ranging from 0.0-1 .O based on the degree to which its condition varies relative to its condition in the least altered wetlands of the regional subclass (reference standard wetlands). When the condition of a variable is similar to the reference standard (defined by reference standard wetlands), it is assigned an index of 1 .O. The condition of variables that deviate from the range of conditions exhibited by reference standard wetlands are assigned lower values; the more a variable deviates from the reference standard, the lower will be its variable subindex. Lower subindices are reflected in lower functional capacities.

In addition to defining the relationship between each variable and functional capacity, the assessment model defines the relationship among variables. Variables are combined to produce a functional capacity index (FCI) using an aggregation equation. The FCI, ranging from O.O- 1 .O, is a measure of the functional capacity of a wetland to perform a function relative to the level characteristic of the regional subclass to which it belongs. Thus, wetlands with a functional capacity index of 1 .O exhibit conditions similar to reference standard wetlands (i.e., within the range of natural variability for the functional capacity of the subclass). The FCI decreases as conditions deviate from reference standards.

Application Procedures

Once the Development Phase is completed the application procedures outlined in the Regional Guidebook can be used to assess wetland functions in the context of regulatory, planning, or management programs (Smith et al. 1995). The Application Phase includes a characterization, assessment and analysis, and application component. Characterization involves describing the wetland ecosystem and the surrounding landscape, describing the proposed project and its potential impacts, and identifying the wetland areas to be assessed. Assessment and analysis involves collecting the field data necessary to run the assessment models and calculating functional indices for the wetland assessment areas under existing (i.e. pre-project conditions), and if necessary, post-project conditions. Application involves applying the results of the assessment to alternatives analysis, assessing potential impacts, determining compensatory mitigation, designing restoration projects, monitoring success of mitigation compliance, comparing wetland management alternatives or their results, determining restoration potential, or identifying sites for acquisition (Smith et al. 1995).

Prior to Field Data Collection

Describe the project area using available soils, vegetation, land use, land cover and any additional information on existing site conditions.

Chapter 3. Determing the Wetland Assessment Area (WAA).
(Rheinhardt et al. 1999).

Before a functional assessment is performed, one must determine whether the WAA needs to be partitioned into two or more partial WAA's. In determining whether a given WAA should be divided into partial WAAs, first determine whether or not: 1) vegetation has been altered by conversion, mowing, etc., 2) soils have been altered by bedding, rutting from vehicles, compaction, tilling, etc., and 3) there have been alterations to the hydrologic regime (dams, fill, ditches, etc.). The extent (boundaries) of hydrologic alterations are often the least obvious because there are often several alterations in close proximity to one another (e.g. a dam, ditches, and fill material).

For any area defined as a partial WAA, a complete assessment should be conducted in each area, i.e., all pertinent field indicators should be measured in each area. However, depending on the cover-type and/or hydrologic alteration used to define the WAA, some field indicators may not have to be measured. The following discussion explains how various hydrologic alterations interact in a wet mineral flat.

A dam impedes the surface flow of water in a wet flat if constructed across the gradient of the flat, either perpendicular (Fig. 3a) or at an angle (Fig. 3b). A dam across a flat creates a reservoir on the up-gradient side of the dam and a reservoir shadow on the down-gradient side (Fig 3, 5a, 5d). In this case, a separate WAA should be identified for both the up-gradient and down-gradient sides of the dam. However, if culverts at ground level are present, they would allow water to flow under the potential impediment and prevent water from being detained up-gradient (Fig. 5b). In this case, the footprint of the dam should be identified as a partial WAA. (Note however, if culverts are above ground level, then there is an impediment to flow and the height of the dam is the lowest point of the culvert).

Most (perhaps all) dams are roads and most roads have a ditch or ditches running parallel to them. Sometimes these ditches are simply elongated barrow pits from which fill was excavated to raise the road surface above the usual flooding elevation (Fig. 5c). Usually, however, adjacent ditches are also designed to transport water away from a site. If ditches adjacent to the road (or other impediment) transport water from the WAA, care must be taken to determine the general direction of flow through the wet flat, the alignment and effectiveness of ditches, and the presence of culverts under the dam.

If a ditch or ditches designed to drain a site are located adjacent to a road (potential dam), then the road would be ineffective in impeding the flow of water because the ditch(es) would remove water from the site before it could accumulate up-gradient (Fig. 5e). In this case, at least two WAAs must be demarcated: one for the area drained by ditches (determined by the lateral drainage distance) and one for the area covered by the road adjacent to the ditches.

If ditches adjacent to a road do not transport water from the WAA, then the road impedes water flow and the road and ditch(es) act as a fill and excavation, respectively (Fig. 5d). In this case, at least three separate partial WAAs must be defined: one for the area constituting the reservoir of the dam, one for the reservoir shadow, and one for the combined are of the road (fill material) and ditches (excavation). However, if the road has culverts that allow water to flow under it, then no damming effect is created; in this case, a separate partial WAA should be demarcated only for the combined area over which the road and ditches occur.

If there is no road or other impediment to flow, but there is a ditch running through the WAA, then one must determine whether the ditch has been maintained sufficiently so that it does indeed drain. If the ditch is capable of draining the area, then a partial WAA must be defined that encompasses the lateral drainage distance of the ditch (Fig. 4).

It is possible that a given WAA may be subjected to water imported from elsewhere. In such a circumstance, at least two partial WAAs will have to be determined: one for the area above the point of water import and one below.

Variations in alterations to soils and microtopography are also sufficient for establishing two or more partial WAAs. Alterations occur following land-clearing activities, industrial and silvicultural activities, creation and maintenance of utility right-of-ways, and traffic from off-road vehicles.

Chapter 4. Collecting Field Data

Before assessing a Wetland Assessment Area (WAA), obtain the necessary field gear, topographic maps, county soil surveys, and recent aerial photographs of the site.
The following is a list of gear that may be necessary for collection of field data.

- Data sheets
- Pencils
- Sharpshooter shovel
- Binoculars
- Hand lens
- Plant identification guides
- Compass
- Hand-level and stadia rod
- Two 20 meter tapes
- Tree caliper or dbh tape or pre-formed calipers
- High resolution aerial photographs
- Transparent dot grid overlay
- USDA/NRCS Field book for describing and sampling soils
- USDA county soil surveys
- USGS topographic maps
- Calculator
- Flagging
- Cruise angle BAF 10
- Meter stick

To begin collecting plot data, randomly locate the first sampling point near the middle of the WAA. A number of methods can be used to randomly select the first sampling plot. A simple method is to walk a predetermined number of paces toward the center of the WAA. Once the sample plot has been located, dig a soil pit (approximately 20cm x 40cm) using a sharpshooter shovel. Examine the shovel slice for the presence of an O horizon and an A horizon. Examine a 10cm x 10cm area of the soil sample and characterize the root/pore area as none, few, common, or many. Examine the soil sample and measure the vertical pore continuity and characterize the sample as none, low, moderate, or high. Examine the sample and record the presence (or absence) or redoximorphic features. If unfamiliar with examining soils refer to Figures 1 and 2 and to the "Field book for describing and sampling soils" by Schoeneberger, P.J., D.A. Wysocki, E.C. Benham, and W.D. Broderson, 1998.

After completion of the soil data collection, lay out two 20 meter tapes that cross each other perpendicularly at the 10 meter point. The 10 meter points should be center on the soil pit. This establishes the 10 meter radius plot. Visually survey the plot and record all herbaceous species that occur. Using a angle gauge or simple prism of a Basal Area Factor (BAF) of 10, record the number of species of all counted trees. Next record the number of species of all saplings <7.5 cm diameter at breast height (dbh) and $\geq$ 1 m high, all mid-story trees $\geq$ 7.5 cm & < 15 cm dbh and all shrubs within the 10 meter radius plot. Record all species of exotic plants and the strata in which they occur (refer to Appendix A for exotic plant species list). Count all dead standing trees within the 10 meter radius plot that are over 2 meters in height and 15cm dbh. Count all tree cavities with openings greater than 2.5 cm in diameter within 2 meters of the ground surface on trees within the 10 meter radius plot.

Next count all downed woody debris greater than 2.5cm in diameter that intersect the two 20 meter tapes that define the 10 meter radius plot and divide by two to get an average count per plot. Use a hand level and stadia rod to obtain the highest and lowest elevation point along the two 20 meter transect tapes and divide by two to get the average elevation difference per plot. Repeat the above procedure for at least two more randomly selected points within the WAA.

The landscape variable $V_{LANDSCAPE}$ is based on the interpretation of maps and on-site investigation. A recent aerial photograph, National Wetlands Inventory map, Landuse/Landcover map or USGS topographic map will be necessary for this variable.

Chapter 5. Function 1: Maintain Characteristic Water Level Regime (FCI_{HYDRO}) (Excerpted and slightly modified from Rheinhardt et al. 1999)

Definition

This function models alterations to conditions in a wet flat that affect fluctuations in water level, including variations in depth, duration, frequency, and season of flooding or ponding.

Rationale for Selecting the Function

Hydrologic regime is one of the main factors controlling ecosystem functions in wetlands, including those of Hardwood Mineral Flats. The timing, duration, and depth of fluctuations in water level affect biogeochemical processes and plant and animal (especially amphibians) distribution patterns. Flats differ from other wetland types in that fluctuations in water level are primarily vertical, driven by a balance between precipitation and evapotranspiration. Alterations to the input, export, or storage of water all change spatial and temporal variations in hydrologic regime, which in turn affect biogeochemical and habitat functions. These alterations include impounding water, subsurface drainage (ditching), fill or excavation of soil, transport of water into a site from another catchment, and changes in potential evapotranspiration, microtopography, and soil porosity.

Characteristics and Processes that Influence the Function

Precipitation is by far the major source of water into Hardwood Mineral Flats; groundwater discharge to these systems is minimal. ET is the major export pathway, but the slow export of water down-gradient (via surface and subsurface flow) is another pathway. Because Hardwood Mineral Flats are low gradient and thus not hydrodynamically energetic, most alterations to hydrologic regime (with the exception of artificial drainage) are very localized in their effect on biogeochemical processes and site-quality. For example, a dam (even a low one such as a road fill) can back water up over a large area, thus inundating the area upgradient from the dam for a longer-than-normal period. Input of excess water from off-site can likewise increase the duration and depth of water levels. Fill and excavations of soil alter flooding depth and duration in the footprint of the fill or excavation. A decrease in Leaf Area Index (LAI) (due to mechanical clearing) alters the rate that water is lost to the atmosphere via ET. Alterations to water balance thus change the duration and timing of flooding. In contrast, artificial drainage also affects conditions off-site in that ditches transport water, nutrients, and dissolved organic matter to streams at a higher rate of flow than would occur in the absence of drainage, thus altering the hydrologic regime of streams down-gradient and contributing additional nutrients to them.

Water level fluctuations can be quantified with data obtained from monitoring wells over time. However, the collection of monitoring well data is time-consuming and expensive, and so is not practical for rapidly assessing functions. Therefore, the approach taken here was to model alterations to hydrologic regime and to evaluate the effects of hydrologic alterations (where possible) on other field indicators. However, to calibrate a model variable designed to indicate degree of alteration, it is necessary to isolate the effect that a single alteration has on the function. Unfortunately, it was difficult, and for some variables not possible, to locate reference sites wherein only one selected hydrologic parameter had been altered. Fortunately, water table behavior can be calibrated from hydrodynamic principles derived from research on the effects of alterations in a variety of soil-types. Hydrologic monitoring should be undertaken to better calibrate the indirect indicators (model variables) used here to model alterations to water level regime and all reference sites have automatic water level recorders installed. Data is being collected to provide a 5 year record for future model adjustment.

Description of Model Variables

Indicators of hydrologic alterations are used both to determine the FCI of the hydrologic model and to divide a WAA into partial WAAs. In most cases, once a WAA has been defined by a given type of hydrologic alteration, only the hydrologic field indicator specific to that alteration is relevant to the function, i.e., all other field indicators are usually not applicable. Thus, hydrologic field indicators both model hydrologic functions and determine boundaries of WAAs (see Chapter 3 on defining WAAs).

Impediment to Flow (Vdam)

This variable represents the alteration to water storage capacity due to an impediment (usually a road) obstructing the flow of surface water. An obstruction placed perpendicular to the gradient of a wet flat will alter the water level regime of a Hardwood Mineral Flat by impeding the flow of surface water through it. An impediment to flow (dam) causes water to flood more deeply, more frequently, and for a longer period on the upgradient side of the dam than it would had a dam not been in place. In contrast, a water deficit (relative to the undammed condition) occurs on the down-gradient side of a dam, i.e., water generally floods less deeply, less frequently, and for a shorter duration. Therefore, a dam increases surface water storage upgradient and decreases surface water storage down-gradient. Dams in wet flats are not likely to be very high (0.5 m or less), but because gradients are so low in flats, even a low dam can create a relatively large reservoir upgradient and a reservoir shadow down-gradient. For example, if a given wet flat has a slope of 0.2% and a dam crossing it is 0.5 m high at its lowest point, the area impacted by the dam will extend 250 m in both the upgradient and down-gradient directions (distance determined by dividing dam height by slope of flat). Because water levels in Wet Flats are primarily controlled by a balance between precipitation and evapotranspiration (ET), a reservoir may only fill with water completely when precipitation exceeds ET for extended periods or when a major precipitation event occurs.

Roads are the most common (and perhaps only) type of impediment constructed across Hardwood Mineral Flats. Most road beds are constructed using material excavated along one or both sides of a road's route, thus creating adjacent ditches or by the importation of fill material. Usually, enough material is excavated to assure that the road will be above the normal flooding height. However, roadside ditches are sometimes designed so that they will also drain water away from the road and the Hardwood Mineral Flat through which it traverses. For situations in which a ditch adjacent to a dam drains a Hardwood Mineral Flat, the effect of the ditch supersedes the effect of the dam (see Chapter 3 on defining WAAs and V_{DRAIN} below).

In order to determine the area over which a given dam alters hydrologic regime, one must know the height of the dam and the gradient (slope) of the flat over which the dam crosses. Gradients are extremely low in Hardwood Mineral Flats. In reference sites, mean gradient was 0.0019, similar to that determined by Rheinhardt et al. (1999) in Wet Pine Flats (0.0018) and so a laser level or surveying equipment would be required to obtain accurate measurements of gradients. Since access to a laser level or surveying equipment may not always possible, two methods for determining area altered by a dam are provided: one method requires a laser level or surveying station; the other requires a hand-level, a stadia rod, and information from reference data.

Method 1: Determine the lowest point on the dam (overflow point). The lowest point could be located on the upper surface of the dam (if no culvert is present) or at the base of lowest culvert under the dam. If culverts are present and their base elevation (overflow points) are at ground level, then there is no obstruction of surface flow. However, if the overflow point is above ground level, use a laser level or surveying station to locate a point or points upgradient from the dam that are at the same elevation as the overflow elevation.

All points upgradient from the dam that are at the same elevation as the overflow point are used to map the reservoir boundary (the perimeter of the area altered on the upgradient side of the dam). If the obstruction lies perpendicular or nearly perpendicular to the gradient and the gradient is uniform across the entire flat, the reservoir boundary will circumscribe a 180" arc centered on the overflow point (Fig. 3a). However, if the obstruction is not perpendicular to the direction of flow, the area upslope is determined by circumscribing a boundary of elevation equal to that of the outlet point. Its precise shape is unknown, but may be in the shape of ellipsoid with the focus at the overflow point (Fig. 3b). The reservoir shadow is assumed to be the same size as the reservoir. In both cases, the area altered on the down-gradient side of the dam (reservoir shadow) is assumed to be a mirror image of the area altered on the upgradient side.

Method 2: This method assumes a gradient of 0.2% (0.002), which was derived from the mean gradient of reference sites. To determine dam height, place a hand-level at a selected height (on a pole or tripod) above the overflow point and sight a level line toward a plumb stadia rod directly upgradient from dam. The stadia rod should be placed as closely as possible to the dam, but on unaltered topography (i.e., not in an adjacent ditch if one is present or atop a hummock). Subtract the elevation of the hand-level (pole or tripod height) from the elevation read on the stadia rod; this difference is the height of the dam. If the dam is perpendicular to the gradient, calculate the radius of the 180" arc that defines the upgradient (reservoir) and down-gradient (reservoir shadow) by dividing dam height by 0.002. For example, a 0.5 m high dam would be expected to alter a circular area with a radius of 250 m (0.5 m/0.002), half of which is located upgradient and half downgradient from the dam. Partition the WAA into at least two partial WAAs, one encompassing the reservoir and the other, the reservoir shadow. The total area of alteration (both partial WAAs combined) would be πr^2 = 19.63 ha (48.7 acres).
To calculate the subindex for V_{DAM}, assume that the entire area within a dam's reservoir and reservoir shadow is completely altered hydrologically by the dam (i.e., $V_{DAM} = 0.0$). All area outside the reservoir and reservoir shadow are completely unaltered the dam (i.e., V_{dam} = 1 .O).

Lateral Drainage Effect (V drain)

This variable represents the removal of water by a conveyance structure such as a ditch or tile drain. Drainage conveyances alter water level regime in wet flats by more rapidly exporting subsurface water located in the vicinity of a drainage feature. Soil in a Hardwood Mineral Flat adjacent to a drainage feature is saturated for a shorter duration and less frequently than it would have been had the drainage feature not been present. The lateral distance over which alters hydrologic regime is related to the depth of the drainage feature, the saturated hydraulic conductivity of the soil through which water is being drained, and the drainable porosity of the soil. Fine-textured, clayey soils impede groundwater flow and drainage more than more porous, loamy or sandy soils; thus, fine-textured soils naturally drain more slowly than coarse-textured soils. Likewise, deep drainage features drain over a greater lateral distances than shallow drainage features. The lateral affect of drainage features can be determined by matching soil series with the effective depth of the drainage feature (see Chapter 3 on bounding the WAA). The lateral distance over which a given drainage feature will drain a given soil-type was derived using the van Schilfgaarde equation (www.sedlab.olemiss.edu/java/schilfgaarde_java.html). This algorithm was developed to determine the optimum depth and spacing of ditches for draining agricultural fields. The equation uses physical the depth of a drainage feature, information on soil permeability and porosity, and integrates these data over time to estimate the distance over which a given drainage conveyance will remove water (it's lateral drainage distance). The lateral drainage distance shows a negative curvilinear relationship (Fig. 4).

Match the soil series drainage category with the depth of drainage to calculate the lateral drainage distance (Table 2). It is assumed that the hydrologic regime of any area that falls within the effective lateral distance of drainage is completely altered (i.e., the subindex for $V_{DRAIN} = 0.0$). Thus, any WAA within the lateral drainage distance should be treated as a partial WAA (see Chapter 3 on defining WAAs). Any part of the WAA outside (beyond) the area of lateral drainage effect is therefore unaltered by drainage (i.e., V_{DRAIN} = 1 .O) and should be treated as another partial WAA. Care should be taken to determine if a ditch or other drainage feature is effective in draining a portion of the WAA. To be effective in draining, a conveyance structure must be capable of transporting water away from the WAA (note, sometimes a ditch is created to provide fill material for an adjacent road, but does not export water from a site). If the drainage feature does not drain any portion of a WAA, the V_{DRAIN} variable is not applicable (i.e., the subindex for V_{DRAIN} =1 .O). However, a roadside ditch that does not drain water away from a site should be treated as an excavation (i.e., $V_{volume} = 0.0$). Sometimes, a ditch transports water to a wet flat from elsewhere, thus increasing the flow of water into or through the flat. In such a case, the WAA is altered by excess water and it should be partitioned into a partial WAA, wherein the subindex for $V_{win}= 0.0$.

The variable V_{drain} was calibrated using a data base on soil drainage characteristics of soil-types identified in reference sites and other soils in which Hardwood Mineral Flats are likely to be associated; it was not calibrated with on-site hydrologic data (Table 2). Further calibration and refinement of this variable should be derived from studies with monitoring wells in Hardwood Mineral Flats.

Addition or Excavation of Material (V_{volume})

This variable represents material placed on or excavated from a Hardwood Mineral Flat. Removal or addition of material alters water storage capacity, which in turn alters water level regime at the location of the fill material or excavation. Placing material (soil, debris, etc.) on a Hardwood Mineral Flat alters water level regime by reducing the capacity of the flat to store surface water, while excavating material reduces the capacity to store water in subsurface pore spaces. Roads are the main type of fill material placed in Hardwood Mineral Flats, while ditches are the most common excavation. Usually, ditches on one or both sides of a road are excavations from which the road is constructed. If the ditch or ditches are not designed to drain water from a WAA and culverts allow water to flow unimpeded under the road, then both the road and ditch or ditches are together used to demarcate a partial WAA (Fig. 5) wherein the subindex for V_{volume} = 0.0.

Table 2. Determination of lateral drainage. Match soil series with soil drainage category. If soil series is not on list, determine appropriate soil category from NRCS National Soil Sediment Laboratory or calculate a soil moisture characteristic curve to determine hydraulic conductivity (K) nad drainable porosity (f). For category 1 (K<1 cm/hr and f< 0.02), category 2 (K > 1 and < 3.3 cm/hr and f< 0.1), and category 3 (K > 3.3 cm/hr or K > 1 cm/hr and f >0.1).

Soils	Category	Soils	Category
Acredale	2	Nimmo	3
Backbay	2	Othello	2
Chickahominy	1	Pocomoke	3
Elkton	2	Polawana	3
Fallingston	2	Roanoke	1
Featherstone	2	Tomotley	2
Meggett	1		

	Lateral Drainage Distance (m)		
Depth of Drainage Feature	Category 1 Soils	Category 2 Soils	Category 3 Soils
0.4	27	50	73
0.5	34	61	90
0.6	39	70	103
0.7	43	78	114
0.8	47	84	123
0.9	50	90	132
1.0	53	95	139
1.1	56	100	146
1.2	58	104	152
1.3	60	108	158
1.4	62	112	163
1.5	64	115	168
1.6	66	118	172
1.7	67	121	176
1.8	69	123	179
1.9	70	125	183
2.0	71	127	185
2.1	72	129	191
2.2	73	131	190
2.3	74	132	192
2.4	74	133	194
2.5	75	134	196
2.6	75	135	197
2.7	76	135	198
2.8	76	136	198
2.9	76	136	199
3.0	76	136	199

However, sometimes a road (or other addition of material) across a Hardwood Mineral Flat also impedes (dams) surface water flow (i.e., there are no culverts under the road). In this case, at least three partial WAAs would have to be determined: one for the road (and ditches if present) wherein the subindex for $V_{volume} = 0.0$, one for the reservoir wherein the subindex for $V_{dam} = 0.0$, and one for the reservoir shadow wherein the subindex for $V_{dam} = 0.0$ (Fig. 5).

Usually, ditches alongside roads are also designed to drain water. In such cases, at least two partial WAAs would have to be demarcated: one for the area where the road and ditch or ditches occur, wherein the subindex for $V_{VOLUME} = 0.0$ and one for the area drained by the ditch or ditches, wherein the subindex for $V_{VOLUME} = 0.0$ (Fig. 5).

Reference sites were not used to calibrate this variable. It was assumed that adding or removing material displaces surface area available for storage in the area displaced by the till material or excavation. This assumption was made because flooding is usually shallow in wet flats (10-20 cm) and the addition of material is designed to bring the land surface above the usual depth of flooding, i.e., the height of fill material is always greater than the maximum flooding depth. Therefore, alteration of surface storage capacity can be directly determined by area covered by fill material.

Likewise, a change in subsurface storage capacity is affected by an excavation (e.g., borrow pit), which reduces subsurface water storage. (A ditch with no outlet is treated as an excavation.) Therefore, alteration of subsurface storage capacity can be directly determined by area of excavation.

Since Hardwood Mineral Flats are not completely flat (mean slope = 0.2%), it is not necessary to determine the proportion of the entire wet flat that has been covered or excavated to estimate an alteration in hydrologic regime (as would be necessary in a depressional system). That is, the effect of fill material or excavation is restricted to the footprint of the alteration in a flat. However, one must determine whether fill material is placed across the gradient of the wet flat, thus creating an impediment to surface water flow (see V_{DAM}).

One can use a tape measure and compass or surveying equipment to estimate the area covered by fill material or removed by excavation. Alternatively, one could determine the area covered by fill material or area excavated from high resolution aerial photos and then digitizing the area or using a dot grid overlay.

Evapotranspiration Potential (V_{ET})

This variable represents the potential loss of water to the atmosphere via evaporation and plant transpiration. Groundwater input is negligible in Hardwood Mineral Flats and any input from groundwater is probably balanced by the export of water down-gradient. Therefore, water level fluctuations are primarily controlled by the balance between precipitation and evapotranspiration (ET) under the influence of local climatic conditions. Local climatic conditions are not under anthropogenic control, but both evaporation and transpiration rates can be anthropogenically altered by removing vegetation. The balance between evaporation and transpiration is controlled by seasonal climatic influences and vegetation cover. In naturally vegetated, seasonally wet ecosystems, water usually ponds during periods when photosynthetic production (and hence, transpiration) is lowest. Removing vegetation reduces transpiration rates during periods when transpiration would normally be high, thus allowing the water table level to rise. Ponding and evaporation occur when the water table rises above ground.

Water is rapidly lost during the growing season in Hardwood Mineral Flats via evaporation from standing (ponded) water and transpiration by vegetation from soil water. When there is no vegetation to transpire water to the atmosphere, the water table remains near the surface for longer than it would have naturally, had vegetation been left intact. Therefore, alterations in Hardwood Mineral Flats that affect vegetation cover, a primary determinant of evapotranspiration rates, affect the timing, duration, and depth of flooding and soil saturation.

To calculate V_{ET} obtain site history from recent (< 2 y old) high resolution aerial photography or from information provided by land managers or local people familiar with the site history. First determine whether vegetation has been permanently removed from the WAA (i.e., converted to an impervious surface). If so, V_{volume} would be a more appropriate measure, since V_{volume} would equal 0.0 and thus supersede V_{et}. Otherwise, determine (1) if vegetation has been removed (cleared), but allowed to undergo succession, or (2) if vegetation has been removed and succession has been inhibited (e.g., it is being maintained as a utility right-of-way) or periodically mowed. Subindex scores are as follows for the two possible scenarios.

(1) If vegetation has recently (<1 year) been removed from the WAA, assign 0.2 to V_{ET}. (Note: permanent removal of vegetation (e.g., conversion to a road or impervious surface) is best assessed using V_{VOLUME}). If vegetation has been undergoing succession for 1-10 years ago, V_{ET}, = 0.4. If vegetation has been undergoing succession for between 10 and 20 years, assign 0.60 to V_{ET}. If vegetation has been undergoing succession for between 20 and 40 years, assign 0.80 to V_{ET}. If vegetation has been undergoing succession for more than 40 years, assign 1.0 to V_{ET}.

(2) If the WAA is being maintained as a utility right-of-way (power line, gas line, etc.) or is periodically mowed, assign 0.40 to V_{ET}.

Importation of Water from Elsewhere (V_{WIN})

This variable represents the proportional increase in water table elevation caused by water transported into a WAA from other drainage basins. Water, transported into a Hardwood Mineral Flat can increase the volume of water the flat must transport down-gradient, thus increasing the depth, duration, and timing of hydrologic fluctuations down-gradient from the point at which water is imported. Some ditches along major roads or highways may bring water into Hardwood Mineral Flats from adjacent drainage basins. Also, development near urbanizing areas can shunt surface run-off to wet flats if appropriate grading and storm run-off controls are not applied.

To estimate the amount of excess water entering a WAA, one must know the size of the drainage basin from which the water is being transported relative to the size of the natural drainage basin of the WAA. If part of the WAA is located up-gradient from the point of water importation, the WAA must be partitioned into at least two separate WAAs: one above the water input point (where V_{WIN} = 1 .O) and one below the input point. Use aerial photographs and county drainage maps (where available) in conjunction with USGS topographic maps to establish the boundaries of the drainage basins. Air photos and drainage maps can be used to determine the source of ditches or other artificial water transport structures; USGS maps are used to determine drainage basin boundaries (topographic boundaries). Estimate (1) the size of the drainage basin from which excess water is being imported and (2) the size of the natural drainage basin of the wet flat upgradient from the water input point. Either digitize the drainage basin areas or use a dot grid overlay to determine areas.

Another possible way to measure the extent of alterations by water importation may be to determine marked changes in vegetation caused by excessive flooding. If an effect can be seen, delineate a partial WAA along boundary where excess water has altered vegetation.

In calibrating V_{WIN} it was assumed that the importation of water has an additive negative effect on water level regime such that a doubling of water volume completely alters water level regime (i.e., $V_{WIN} = 0.0$) and that less than twice the water input alters hydrology, but not completely. Further research is needed to determine the effect importation of water has on water level regime in a Hardwood Mineral Flat and how far down gradient from the water input point hydrologic effects should be expected to occur.

In order to determine the subindex for V_{WIN} divide the size of the drainage basin from which water is imported by the size of the natural drainage basin to which excess water is being imported, then subtract this ratio from 1 .O. For example, if the size of the drainage basin from which water is being imported is 100 ha and the size of the WAA's natural drainage basin is 1,000 ha, then the subindex for V_{WIN} = (1 .O - (100 ha/1,000 ha) = 0.9. If the drainage basin area from which water is imported is as large or larger than the WAA, then assign 0.0 to V_{WIN}).

Microtopographic Features (V_{MICRO})

This variable represents the degree to which natural microtopographic features have been altered. These small-scale features slow the flow of surface water, thus increasing surface storage capacity. Altering microtopography will alter the duration and depth of flooding in a Hardwood Mineral Flat. Duration (and timing) of ponding on Hardwood Mineral Flats is an important habitat component, particularly for amphibians. To measure V_{MICRO} use a hand level and stadia rod to obtain the highest and lowest elevation point along the two 20 meter transect tapes. Calculate the mean elevation difference for the WAA. To calculate the subindex compare the mean elevation difference value with Table 3 below.

Table 3. Subindex scores for V_{MICRO}.

V_{MICRO} - Elevation Difference (cm)	Subindex
0	0.0
0.1 - 5.0	0.25
5.1 - 10.0	0.50
10.1 - 15.0	0.75
15.1 - 30.0	1.0

30.1 - 50.0	0.75
50.1 - 75.0	0.50
75.1 - 100.0	0.25
>100.1	0.0

Soil Porosity (Vporosity)

Mineral flats as described by Smith et al. 1995 are precipitation driven wetland systems and are therefore surficially ombrotrophic with additional aquatards (usually clay layers) in lower horizons that may have off-site sources. The primary functions of soil in mineral flat wetlands are mineral sequestration,and slow release of water by transpiration, evaporation, percolation, or lateral flow. These functions are primary and prerequisite to maintenance of site-quality hydrology and biogeochemical processes. Dig a soil sample with a sharpshooter shovel (shovel "slice") and extract an undisturbed block of about 20 cm x 40cm. Observe the presence or absence of the O horizon and the A horizon and the quantity of roots and pores as described below.

The following submodels are used to calculate the variable $V_{POROSITY}$.

$\mathbf{V_O}$ is the presence or absence of the O horizon measured as the uppermost horizon that consists of at least partially decomposed leaves, needles, twigs, moss, and lichens (fresh needle fall that has not undergone observable decomposition should be excluded) (Soil Survey Staff, 1993). The lower boundary is the A horizon or mineral flat soil surface. Soils with O horizons will reduce runoff during storm events and provide recycling of nutrients in the forest community. An O horizon will allow water to enter due to its porosity. The subindex should be assigned as follows: O horizon present = 1.0, absent = 0.0.

$\mathbf{V_A}$ is the presence or absence of an A horizon (mineral soil stained by the breakdown of organics on the soil surface). The A horizon is a mineral horizon formed at the surface or below an O horizon. The emphasized feature is an accumulation of humified organic matter resulting in organic staining or streaks. Organic staining of the upper regions of the soil profile requires infiltration of water and demonstrates that the soil is functioning by accepting water from the surface. The subindex should be assigned as follows: A horizon present = 1.0, absent = 0.0.

$\mathbf{V_{ROOTS/PORES}}$. Pore space (voids in the soil) and the number of roots are measures of the infiltration capacity of the soil and the level of alteration when soil is compacted or tilled. To measure $V_{ROOTS/PORES}$ count the medium to coarse roots and pores (greater than 3.5 mm, see Figures 1 and 2 for size class diagram) in three separate 10 cm^2 areas of the soil material and divide by three to get an average. Assign the subindex according to the following Table 4.

Table 4. Subindex for $V_{ROOTS/PORES}$.

Number of pores (> 0.5 mm) per 10 cm^2	Subindex
None	0.0

Few (< 1)	0.3
Common (1 - 5)	0.6
Many (> 5)	1.0

$V_{PORE\ CONTINUITY}$ is another measure of the capacity of soils to store subsurface water and involves assessment of the average vertical distance through which the minimum pore diameter exceeds 3.5 mm when the soil layer is moderately moist or wetter. Pore continuity has extreme importance in assessing the capacity of the soil layer to transmit free water vertically (Schoeneberger et al. 1998). To measure $V_{PORE\ CONTINUITY}$ observe the soil sample and measure the average vertical distance through which the minimum pore diameter exceeds 3.5 mm when the soil is moderately moist or wetter. Assign the subindex using the following Table 5.

Table 5. Subindex scores for $V_{PORE\ CONTINUITY}$.

Average vertical distance traveled by pores > 0.5 mm in diameter.	Subindex
None	0.0
Low (less than 1 cm)	0.3
Moderate (between 1 - 10 cm)	0.6
High (greater than 10 cm)	1.0

$$V_{POROSITY} = \frac{V_O + V_A + V_{ROOTS/PORES} + V_{PORE\text{-}CONTINUITY}}{4}$$

Functional Capacity Index

Most of the parameters used to model the function Maintain Characteristic Water Level Regime are processes controlled by physical conditions.This means that the impact of many of the hydrologic alterations supersede impacts caused by other types of hydrologic alterations. For example, a road crossing a Hardwood Mineral Flat increases the duration and depth of flooding on the upgradient side of a road, but an adjacent ditch that drains water from the site would negate any effect that the road would have otherwise had on its hydrologic regime. Given the nature hydrologic interactions, the model for the hydrologic function was constructed using five sub-models, with the caveat that the lowest scoring submodel defines the Functional Capacity Index for the function (FCI_{HYDRO}). The five independent submodels are:

1. V_{dam}
2. V_{drain}
3. V_{volume}
4. V_{win}
5. (Vet X ((Vmicro + Vporosity)/2)) ½

Each submodel can stand alone to provide an FCI for the function. However, because submodels 1-4 are also used to define partial WAAs, the other submodels are irrelevant when a partial WAA is defined by one these parameters (see Chapter 3 on defining WAAs). For example, if a WAA has been partitioned into two partial WAA (one within the area of lateral drainage distance and one beyond the drainage distance), V_{DRAIN} is the only submodel pertinent to the hydrologic function within the area defined by the lateral drainage distance. All other variables are irrelevant there because $V_{DRAIN} = 0.0$ within the partial WAA. Thus, if a WAA has to be subdivided into partial WAAs due to any of the hydrologic alterations 1-4 above, the subindex for that alteration is 0.0 and the other field variables need not be measured.

Submodel # 5 above requires that three field variables be measured (V_{et}, V_{micro} and $V_{POROSITY}$) and is used if submodels 1-4 are not relevant (i.e., there are no dams, ditches, fill, excavations, or input of water from other drainage basins in the WAA). Microtopography (V_{MICRO}) affects surface water storage (ponding), which in turn affects surface area available for evaporation. Alterations to soil porosity ($V_{POROSITY}$) affects subsurface water storage, which in turn affects the volume of water available for transpiration. Thus, V_{ET}, is related to both V_{micro} and $V_{POROSITY}$. In addition, whenever V_{micro} or $V_{POROSITY}$ is altered, the other variable ($V_{POROSITY}$ or V_{micro},respectively) is usually altered as well.

The FCI submodel averages $V_{POROSITY}$ and V_{micro} (which together model water storage capacity), multiplies the average by V_{ET}, and determines the geometric mean. The main driving process in the submodel is ET, which is altered directly by alteration of LAI or indirectly by altering water storage capacity ($V_{POROSITY}$ and V_{micro}).

Water table monitoring (with wells) over long time periods is required to independently measure this function. Hydrographs of hydrologically altered sites should be compared with hydrographs of reference standard sites relative to variations in soil drainage characteristics. Automatic wells have been installed on all reference sites to collect 5 year water level records.

Chapter 6. Function 2: Maintain Site-Quality for Characteristic Plant Communities (FCI_{PLANTS})

Definition

The ability of a WAA to maintain on-site habitat conditions suitable for maintaining plant communities characteristic of natural, Hardwood Mineral Flats. Herbaceous indicator species, canopy trees, saplings, seedlings, shrubs, and exotic species are used to indicate habitat quality for the plant community.

Rationale for Selecting the Function

Due to the immobility of plants, plant community site quality is determined by habitat conditions that occur within the site. Site quality for plant communities characteristic of unaltered Hardwood Mineral Flats is determined primarily by hydrologic regime.

Model Variables

There are 5 model variables that are combined to produce the FCI associated with this function.

Herbaceous Indicator Score (V_{herb})

This variable generally represents the short-term hydrologic regime of the site and is expressed by the presence or absence of a select group of herbaceous species indicative of site-quality. The selected group of 27 indicator plants (Appendix B) was chosen to indicate degree of disturbance to site-quality. Indicator plants were selected based on the following criteria: 1) they were identified by workshop participants as being sensitive to alterations to site-quality, and 2) they occur throughout the Reference Domain.

Sampling of the reference domain revealed wide variability in percent coverage among the herbaceous species (nine square meter plots per site x seventy-two sites). Due to the variability in percent cover data a presence/absence method is used to measure V_{HERB}. To measure V_{HERB} survey the area within the 10m radius plot (see Chapter 3 on defining WAA's and laying out sampling plots). Record each indicator plant present within the plot. Repeat for each plot accessed within the WAA (sample at least three per WAA) and divide by the number of plots. Next add up the number of different indicator species identified in the plots. Determine the modifier score (I) from Table 6. Use the equation below to assign the subindex score. For example if an indicator species occurs in all three plots and has 7 of the indicator species, the calculation would be as follows :V_{herb} = 3/3 (0.66) = 0.66. If an indicator species occurs in two of the plots and has 7 of the indicator species, the calculation would be as follows: V_{herb} = 2/3 (0.66) = 0.44.

$$V_{herb} = N_i / N \, (I)$$

N_i = number of plots with indicator species
N = total number of plots
I = score from Table 6

Table 6. Modifier Score (I) for number of herbaceous indicator species found on WAA.

Number of species	Score
0	0.0
1 - 4	0.33
5 - 8	0.66
≥ 9	1.0

Canopy Trees V_{TREE} and V_{BASAL}

This variable represents the long-term hydrologic regime of the site as expressed by the population of mature trees. Sampling of the Reference Domain revealed broad patterns in species dominance. Reference Standard sites have higher percentages of oak (*quercus* spp.) though most sites are dominated by red maple (*Acer rubrum*) and sweetgum (*Liquidambar styraciflua*) which is similar to sites sampled by Rheinhardt and Rheinhardt (2000).

To measure V_{TREE} utilize a point sample (plotless method) using a angle gauge or simple prism of BAF 10. In eastern United States a BAF of 10 is commonly used for second-growth saw timber or dense pole timber stands (Avery and Burkhardt 1983).

From the plot center (see Chapter 2 for laying out plots) record the number and species of trees within the sample area. Assess at least three plots per WAA. Determine the relative dominance of species within the WAA. Assign subindex scores using Table 7 (See Appendix C for a list of hardwood species).

Table 7.Subindex score for canopy tree dominance.

V_{TREE} - relative dominance	Subindex
No canopy trees	0.0
>50% Pine	0.0
>50% Hardwoods, >25% Pine, <1% Oak	0.2
>50% Hardwoods, <25% Pine, <1% Oak	0.3
>50% Hardwoods, >25% Pine, 1-10% Oak	0.5
>50% Hardwoods, <25% Pine, 1-10% Oak	0.7
>50% Hardwoods, >25% Pine, >10% Oak	0.8
>50% Hardwoods, <25% Pine, >10% Oak	1.0

Calculate the basal area (m^2) per hectare using the following formula:

$$\text{Basal area per hectare} = \frac{(\text{Total number of trees tallied})\,(\text{BAF } 10)\,(2.47)\,(0.093)}{\text{Number of plots}}$$

Assign a subindex score for V_{BASAL} using Table 8.

Table 8. Subindex score for basal area per hectare.

Basal area per hectare (m^2)	Subindex
> 80	0.50
55 - 80	0.75
30 - 55	1.0
20 - 29	0.75
10 - 19	0.50
1 - 9	0.25
< 1	0.0

Saplings $V_{SAPLING}$

This variable represents recent recruitment and survival of tree species as related to hydrologic regime. To measure $V_{SAPLING}$ count and identify all trees <7.5 cm dbh and $\geq$ 1 m high within the 10 m radius plot. A 7.5 cm caliper can be used to quickly assess whether to count the plant as a sapling or mid-story tree (rather than using a dbh tape to measure all trees). Assess at least three plots per WAA. Determine the relative dominance of the sapling species within the WAA. Assign the subindex according to Table 9 (See Appendix C for a list of hardwood species).

Table 9. Subindex score sapling dominance.

$V_{SAPLING}$ - relative dominance 10m radius plot	Subindex
No saplings	0.0
>50% Pine	0.0
>50% Hardwoods, 25%-50% Pine, <1% Oak	0.25
>50% Hardwoods, 25%-50% Pine, >1% Oak	0.5
>50% Hardwoods, <25% Pine, <1% Oak	0.75
>50% Hardwoods, <25% Pine, >1% Oak	1.0

Midstory Trees $V_{MIDSTORY}$

This variable represents the subcanopy component of the forested system. To measure $V_{MIDSTORY}$ count and identify all trees $\geq$ 7.5 cm & < 15 cm dbh within the 10 m radius plot. Assess at least three plots per WAA. Determine relative dominance of the midstory species within the WAA. Assign indicator scores as follows: Assign the subindex according to Table 10 (see Appendix C for a list of hardwood species).

Table 10. Subindex score midstory tree dominance.

$V_{MIDSTORY}$ - relative dominance 10m radius plot	Subindex
No midstory trees	0.0
>50% Pine	0.0
>50% Hardwoods, >25% Pine, <1% Oak	0.2
>50% Hardwoods, <25% Pine, <1% Oak	0.3
>50% Hardwoods, >25% Pine, 1-10% Oak	0.5
>50% Hardwoods, <25% Pine, 1-10% Oak	0.7
>50% Hardwoods, >25% Pine, >10% Oak	0.8
>50% Hardwoods, <25% Pine, >10% Oak	1.0

Shrubs V_{SHRUB}

This variable represents the shrub component of the forested system and has been separated from the tree midstory variable since shrubs represent a different life form from trees. To measure V_{SHRUB} count and identify all shrubs within the 10 m radius plot. Match species with the reference shrub list. Assess at least three plots within the WAA. Calculate the average shrub density per hectare by multiplying the average density by 31.8 for those species matching the reference list. Assign the subindex according to Table11 (see Appendix D for the reference shrub list).

Table 11. Subindex score shrub density.

V_{SHRUB} - mean density per hectare	Subindex
< 50	0.0
50 - 199	0.33
200 - 399	0.66
≥ 400	1.0

V_{EXOTIC}

This variable represents the presence of exotic species which may be indicative of disturbance. To measure V_{EXOTIC} list any exotic species that occurs within each stratum measured and score each species for invasiveness (high = 0.2, medium = 0.6, low = 0.8) using the Department of Conservation and Historic Resouces, Division of Natural Heritage list of Invasive Alien Plant Species of Virginia (Appendix A or http://www.dcr.state.va.us/dnh/index.html). Add the scores and divide by the number of species.

$$V_{EXOTIC} = \frac{S_1 + S_N}{N}$$

Where S_1 = Exotic species high, medium or low score
N = number of species

Modify the subindex of the stratum in which the exotic species occurs by multiplying by the resulting V_{EXOTIC} score. If no exotic species occurs within the stratum, no multiplier is used.

The formula for calculating the FCI for Maintaining Site-Quality Characteristics for Plant Communities (FCI_{PLANTS})is as follows:

$$\frac{V_{HERB}(V_{EXOTIC}) + V_{TREE}(V_{BASAL})(V_{EXOTIC}) + V_{MIDSTORY}(V_{EXOTIC}) + V_{SAPLING}(V_{EXOTIC}) + V_{SHRUB}(V_{EXOTIC})}{5}$$

If the V_{TREE}, $V_{MIDSTORY}$, or $V_{SAPLING}$, strata subindex equals zero as a result of a greater than 50% component of pine (*Pinus* spp.) consider evaluating the site utilizing the Wet Pines Flat guidebook (Rheinhardt et al. 1999).

Chapter 7. Function 3: Maintain site-quality of characteristic animal communities ($FCI_{HABITAT}$)

Definition

The ability of a WAA and its surrounding landscape to together provide the resources required for maintaining the suite of animals characteristic of unaltered Hardwood Mineral Flats. The amount of coarse woody debris, fragmentation of the landscape, physical structure, food sources, microtopography, tree cavities, plant communities, and standing dead trees are used to indicate habitat quality for animal communities.

Rationale for selecting the function

Animals are an important part of the biota of Hardwood Mineral Flats. Physical structure, surrounding landuse and plant communities together provide attributes important to maintaining quality for animals.

There are 8 variables selected for this function: V_{PLANTS}, $V_{STRUCTURE}$, V_{FOOD}, V_{CWD}, V_{SD}, $V_{CAVITIES}$, V_{MICRO}, and $V_{LANDSCAPE}$..

V_{PLANTS}

This variable represents site quality for the plant community. Herbaceous indicator species, canopy trees, saplings, seedlings, shrubs, and exotic species are used to indicate habitat quality for the plant community and is calculated in Function 2.

$V_{STRUCTURE}$

This variable represents the multi-strata component within Hardwood Mineral Flat systems. Unaltered Hardwood Mineral Flats have all five strata represented. To measure $V_{STRUCTURE}$ use the data from Function 2 (Maintain Site-Quality for Characteristic Plant Communities) and determine whether each of the following strata herbaceous, shrub, sapling, midstory trees, canopy trees are present in each plot for the WAA. Add the number of strata present in each plot, divide by the number of plots and multiply by 0.2 to get the subindex. $V_{STRUCTURE} = \sum S_N/N(0.2)$ where S_N= number of strata per plot and N= number of plots. For example if a WAA has all five strata present in three plots the calculation would be as follows:

$V_{STRUCTURE} = 5+5+5/3(0.2)= 15/3(0.2)= 1.0$

V_{FOOD}

This variable represents the importance of food producing plants to the habitat quality of Hardwood Mineral Flats. Different plant species have various wildlife forage potential depending on the type of fruit and the season that is produced (Martin et al. 1961). Both hard seed producing plants (i.e. *Quercus* spp.) and soft fleshy fruit producing plants (i.e. *Asimina triloba*) have value to foraging wildlife. To measure V_{FOOD} use the data from Function 2 (Maintain Site-Quality for Characteristic Plant Communities) and the list on Appendix E to determine how many different types of high value fruit producers are recorded in the WAA. To calculate the subindex for the WAA, compare the plant site list to Table 12 below and use the Winter Food Modifier if appropriate.

Table 12. Subindex score for number of food species.

Number of different high value plant types	Subindex
0	0.0
1 - 4	0.25
5 - 9	0.50
10 - 14	0.75
> 15	1.0

Winter food modifier. If one or two of the families in the WAA produce fruits or seeds over much of the winter, modify the subindex V_{FOOD} by dividing by 0.6. If three or more of the families in the WAA produce fruits or seeds over much of the winter, modify the subindex V_{FOOD} by dividing by 0.4. If the resulting value is greater than 1.0, assign 1.0 to V_{FOOD}. Winter producing plants include *Smilax* spp., *Celtis* spp., *Ilex* spp., *Lonicera japonica*, *Diospyros virginiana*, *Pinus* spp., *Toxicodendron radicans*, and *Rhus* spp. Winter can be a time of hardship for most wildlife and is a critical period for food supply. The availability of insect and plant food decreases significantly after the first frost. Plants that provide seeds and fruits during this time become highly valued sources of food.

V_{CWD}

This variable represents the total mass of organic matter contained in woody debris on or near the surface of the ground. To measure V_{CWD} count all downed woody debris greater than 2.5cm in diameter that intersect the two 20 meter tapes that define the 10 meter radius plot. To calculate the subindex refer to the Table 13 below.

Table 13. Subindex score for coarse woody debris count.

V_{CWD} - Mean count per site	Subindex
0	0.0
0.1 - 1.0	0.2
1.1 - 2.0	0.4
2.1 - 4.0	0.6
4.1 - 6.0	0.8
6.1 - 8.0	1.0
8.1 - 10.0	0.8
10.1 - 12.0	0.6
12.1 -14.0	0.4

14.1 - 16.0	0.2
>16.1	0.1

V_{SD}

This variable measures dead standing trees greater than 2 meters in height with a diameter at breast height (dbh) greater than 15cm. Standing dead trees are important for habitat quality and provide foraging and nesting sites for various birds. To measure V_{SD} count all dead standing trees within the 10 meter radius plot that are over 2 meters in height and 15cm dbh. To calculate the subindex divide the mean number of standing dead trees by the mean number of canopy trees used to determine V_{TREE} and multiply by 100 to get percent standing dead. Use Table 14 below to assign the appropriate subindex.

Table 14. Subindex score for dead standing trees.

V_{SD} - Percent Standing Dead Trees >15cm dbh & >2 m high	Subindex I
0	0.0
.1 - 1.0	0.25
1.1 - 3.0	0.50
3.1 - 5.0	0.75
5.1 - 10.0	1.0
10.1 - 15.0	0.75
15.1 - 20.0	0.50
20.1 - 25.0	0.25
>25.0	0.0

$V_{CAVITIES}$

This variable measures presence and abundance of tree cavities. Tree cavities are important habitat components to forested systems providing both cover and nesting sites (Carey 1983; Davis 1983). To measure $V_{CAVITIES}$ count all cavities $\geq$ 2.5 cm in diameter within 2 meters of the ground surface on trees within the 10 meter radius plot. To calculate the subindex compare the mean number of cavities within the WAA with Table 15 below.

Table 15. Subindex score for tree cavities.

$V_{CAVITIES}$ - Mean number of cavities	Subindex
0	0.0

.1 - 1.0	0.33
1.1 - 2.0	0.66
> 2.0	1.0

V_{MICRO}

This variable represents the degree to which natural microtopographic features have been altered. Altering microtopography will alter the duration and depth of flooding in a Hardwood Mineral Flat. Duration (and timing) of ponding on Hardwood Mineral Flats is an important habitat component, particularly for amphibians. To measure V_{MICRO} use a hand level and stadia rod to obtain the highest and lowest elevation point along the two 20 meter transect tapes. Calculate the mean elevation difference for the WAA. To calculate the subindex compare the mean elevation difference value with Table 16 below.

Table 16. Subindex score for elevation change (cm).

V_{MICRO} - Elevation Difference (cm)	Subindex
0	0.0
0.1 - 5.0	0.25
5.1 - 10.0	0.50
10.1 - 15.0	0.75
15.1 - 30.0	1.0
30.1 - 50.0	0.75
50.1 - 75.0	0.50
75.1 - 100.0	0.25
>100.1	0.0

$V_{LANDSCAPE}$

This variable measures the degree of alteration within the surrounding landscape as well as specific impacts due to the reduction of buffers around the WAA. Two subindices, V_{BUFFER} and $V_{LANDUSE}$ are used to calculate the variable $V_{LANDSCAPE}$.

V_{BUFFER}

This variable represents the degree to which the land adjacent to the WAA has been fragmented by various land use types and the subsequent exposure of interior forest bird species to edge predation, competition, and parasitism (Temple and Cary 1988). Continuous forested, wetland or scrub/shrub communities with a width greater than 200 m (Paton 1994; Keyser et al. 1998) are considered the highest value land use type to maintain characteristic wildlife habitat for Hardwood Mineral Flats. Various land use types are assigned different indicator scores according to their probability of disturbance. The indicator score is modified by the number of polygons (i.e. land use blocks) of the specific type of land use. To measure V_{BUFFER} overlay a dot matrix grid on a topographic map or recent aerial photograph. Delineate a 200 m buffer around the WAA (Geographic Information System programs can be substituted if available). Determine the percentage of land use types that encroach into the 200 m buffer and count the number of separate encroachments by land use type. To calculate the subindex, use Table 17 below and the following formula. See Figure 6 for an example.

$V_{BUFFER} = \sum L_T (L_S) / N$

Where L_T = Percent Land use type
L_S = Land use type score
N = Number of polygons

$V_{LANDUSE}$

Fragmentation, the breaking up of continuous habitats, can have significant impacts on animal communities. Such impacts include: reduced habitat area, reduced interior area, increased isolation of patches, increased edge and decreased patch size (Rosenberg et al. 1997; Davidson 1998; Fagan et al. 1999). Surrounding landuse can indicate a potential for continued encroachment and impact to the WAA. To measure $V_{LANDUSE}$ overlay a dot matrix grid on a topographic map, landuse map or recent aerial photograph. Delineate a 1000 m buffer (Brooks et al. 1997) around the WAA (Geographic Information System programs can be substituted if available). Determine the percentage of land use types that encroach into the 1000 m buffer and count the number of separate encroachments by land use type (see Figure 6 for an example). To calculate the subindex, use Table 17 below and the following formula.

$V_{LANDUSE} = \sum L_T (L_S) / N$

Where L_T = Percent Land use type
L_S = Land use type score
N = Number of polygons

Table 17. Subindex score for landuse types.

Land use type	Subindex
Industrial	0.1
Urban - high developed	0.25
Rural - low developed	0.50
Agricultural	0.75
Forested, Wetland, or Scrub / Shrub, Open Water	1.0

To calculate the variable $V_{LANDSCAPE}$ use the following formula:

$$V_{LANDSCAPE} = \frac{V_{BUFFER} + V_{LANDUSE}}{2}$$

To calculate the Functional Capacity Index for Function 3 "Maintain Site-Quality of Characteristic Animal Communities" use the following formula:

$$FCI_{HABITAT} = \frac{V_{PLANTS} + V_{STRUCTURE} + V_{FOOD} + V_{CWD} + V_{SD} + V_{CAVITIES} + V_{MICRO} + V_{LANDSCAPE}}{8}$$

Chapter 8. Function 4: Maintain Characteristic Biogeochemical Processes (FCI_{SOILS})

Definition

The ability of a WAA to maintain processes such as nutrient and elemental cycling and biogeochemical transformations at the rate, magnitude and timing characteristic for unaltered Hardwood Mineral Flats.

Rationale for Selecting Function

Biogeochemical processes are basic to wetland function and provide value in maintaining water quality. The combination of microbial interaction with a fluctuating water table and a carbon source provides anaerobic and aerobic processing characteristic of Hardwood Mineral Flats.

There are 4 variables associated with this function: V_{REDOX}, $V_{ORGANICS}$, V_{PLANTS}, $V_{POROSITY}$.

V_{REDOX}

V_{REDOX} is used to describe the presence or absence of redoximorphic features which are formed by the processes of reduction, translocation, and oxidation of Fe and Mn oxides. The presence of redoximorphic features is evidence of a fluctuating water table indicative of Hardwood Mineral Flats. See Table 18 for a list of redoximorphic features. Assign subindex as follows: present = 1.0, absent = 0.0.

$V_{ORGANICS}$

$V_{ORGANICS}$ is used to describe the amount of carbon (and subsequent microbial action and nutrient cycling) available to the system. Assign the subindex using the following formula.

$$V_{ORGANICS} = \frac{V_{SD} + V_{CWD}}{2}$$

Table 18. List of redoximorphic features[1].

Redox concentrations (nodules and concretions, masses, pore linings)
Redox depletions (iron depletions, clay depletions)
Reduced matrices

[1]For more detailed information on redoximorphic features see Vepraskas, M.J. 1994. Redoximorphic features for identifying aquic conditions. Tech. Bulletin 301. North Carolina Ag. Research Service, North Carolina State Univ., Raleigh, North Carolina.

$$FCI\ (V_{SOILS}) = \frac{V_{REDOX} + V_{PLANTS}\text{ (from Function 2)} + V_{ORGANICS} + V_{POROSITY}\text{ (from Function 1)}}{4}$$

Chapter 9. Model Development and Collection and Analysis of Reference Data

Workshop

A workshop was convened to discuss existing relevant models, identify field indicators, and recommend methods for the collection of field data. The workshop was conducted at the Airfield Conference Center in Wakefield, Virginia on May 13-14, 1998 and included an interdisciplinary group of scientists (including hydrologists, botanists, soil scientists, wildlife biologists, and biogeochemists) and regulatory personnel with expertise in hardwood mineral flats (Table 1).

Reference Site Data

Data were collected at 24 reference sites throughout the Reference Domain (coastal plain of Virginia). Sites were selected to represent a wide range of variation from anthropogenic alterations to natural responses to moisture gradients. Model development targeted Hardwood Mineral Flats (those sites where canopy coverage is dominated by hardwood species) but some sites were selected that were dominated by pine for comparison (Appendix F).

Sites were chosen that appeared to have a dominance of hardwood species and mineral flats hydrogeomorphology. Sites were chosen that represented a range of alteration from little (Reference Standard) to severe (highly disturbed by fill and construction).

Reference sites were at least 1 ha in size and three randomly selected plots were sampled within each. All sampling points were marked with a hand-held GPS (geographic positioning system) instrument. All sites were outfitted with a Remote Data Systems WL40 continuous water level recorder. Wells were installed in 1998 - 1999 and will be maintained as long as possible with a target of 5 years. Two sites in the Dismal Swamp were abandoned due to constant bear damage to the automatic wells. One well on the Middle Pennisula was lost due to vandalism.

A number of sampling methods were used to determine the most efficient and useful for sampling Hardwood Mineral Flats. For sampling of vegetation, methods such as 30 meter strip transect, 27 square meter plots per site, 10 meter radius plots, point sampling with cruise angles and gauges (plotless method), and point-quarter method were tested. The square meter sampling for the herbaceous layer was too variable to be useful in determining vegetation patterns due to the shading effect (patchiness) of the forested area. The point-quarter method proved too cumbersome for use in a majority of sites particularly the dismal swamp sites with high *Arundinaria gigantea* and *Smilax* spp. components. The strip-transect method (Mueller-Dombois and Ellenberg 1974) also proved cumbersome and resulted in sample sizes two small for adequate analysis. To measure microtopography, a 30 meter tape was laid out and, using a hand level and stadia rod, elevation measurements were taken on 1 meter increments. We also recorded the highest and lowest elevations within the 10 meter radius plot which we found to be as reliable in determining alterations to microtopography (mostly the result of fill or past tilling activities).

The most efficient and effective sample method proved to be the 10 meter radius plot for herbaceous, shrub, sapling, and midstory vegetation and the point sampling (plotless) method (Avery and Burkhardt 1983) for canopy trees. The 10 meter radius plot resulted in a sampling area of 314 square meters and also proved effective for coarse woody debris (fallen and dead standing), cavities, and microtopography.

To begin sampling a site, we first established a plot center by digging a soil pit. Soil profiles were established for all sites to a depth of approximately 140 cm. Data on the depth of the O horizon and the A horizon, pores, pore continuity, structure grade, structure size, structure shape, roots, rupture resistance, texture and redoximorphic features were collected (Schoeneberger et al. 1998). Samples at the 5cm and 20cm depths were collected and returned to the laboratory for analysis of percent clay, silt, sand, and gravel, bulk density, organic matter, and pH. Slight differences ($p = 0.03$) in mean pH were observed at the 5cm depth between pine dominated sites and reference standard sites of 4.2 and 3.9, respectively. Soil compaction data was taken at each site with a Soil Compaction Meter - Investigator Model (Spectrum Technologies, Inc.) and differences ($p < 0.05$) in mean kPA were observed between reference standard sites and the more disturbed sites at 5 and 20 cm depths.

Using the soil pit as the center of the plot, two twenty meter tapes were laid down perpendicular to each other with the 10 meter mark centered on the soil pit. This delineated the 10 meter radius plot. One of the tapes was extended to 30 meters to test the thirty meter strip sampling method. In this sampling, all canopy trees, mid-story trees, saplings, shrubs, and dead standing trees within 1 meter on either side of the tape were counted and measured (dbh). This 30 meter tape was also used to measure micotopography at one meter increments. In addition, nine square meter plots were randomly selected along the 30 meter transect to measure percent cover of herbaceous plants. Standing at the center of the plot we used both a 5 and 10 BAF (Basal Area Factor) gauge to determine relative dominance of the canopy trees. Next all midstory trees (dbh $\geq$ 7.5 cm & < 15 cm), saplings (dbh < 7.5 cm and > 1 meter high), and all shrubs (> 1 meter high) were counted and identified within the 10 meter radius plot. Voucher specimens of all plants were collected according to Hellquist (1993). Next all dead standing trees (dbh > 15 cm and > 2 meters high) and all tree cavities with openings with diameters greater than 2.5 cm were counted. Finally, all downed woody debris greater than 2.5 cm in diameter intersected by the two twenty meter tapes were counted. We also measured the volume (dbh x estimated height) of all dead standing trees within the 10 meter radius plot. This was somewhat cumbersome and time- consuming and a comparison of CWD volume with a simple count of dead standing trees (dbh > 15 cm & > 2 meters high) showed a strong correlation (Pearson $c = 0.856$, $p < 0.001$).

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Invasive Alien Plant Species of Virginia

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June 1999

This list was developed in a cooperative project between the Virginia Department of Conservation and Recreation's Division of Natural Heritage and the Virginia Native Plant Society

Key

A = High, B = Medium, C = Low
M = Mountains, P = Piedmont, C = Coastal
F = Full sun, P = Partial sun, S = Shade
H = Hydric, M = Mesic, X = Xeric

COMMON NAME	SCIENTIFIC NAME	INVASIVENESS			REGION			LIGHT			MOISTURE		
		A	B	C	M	P	C	F	P	S	H	M	X
TREES													
Black pine	*Pinus thunbergii*			•			•	•	•			•	
China-berry	*Melia azedarach*		•			•	•	•	•			•	
Mimosa	*Albizia julibrissin*			•	•	•	•	•	•			•	
Norway maple	*Acer platanoides*		•		•	•	•	•	•			•	
Sawtooth oak	*Quercus acutissima*			•	•			•				•	
Siberian elm	*Ulmus pumila*			•		•		•	•			•	
Tree-of-heaven	*Ailanthus altissima*	•			•	•	•	•	•			•	
White mulberry	*Morus alba*			•	•	•	•	•	•			•	
White poplar	*Populus alba*		•		•	•	•	•	•			•	
VINES													
Balloon vine	*Cardiospermum halicababum*		•				•	•				•	
Chinese wisteria	*Wisteria sinensis*		•			•	•		•	•		•	
English ivy	*Hedera helix*		•			•	•	•	•	•		•	
Fiveleaf akebia	*Akebia quinata*		•			•	•	•	•	•		•	
Japanese honeysuckle	*Lonicera japonica*	•			•	•	•	•	•	•		•	
Japanese hops	*Humulus japonicus*		•		•	•	•	•	•	•	•	•	
Japanese wisteria	*Wisteria floribunda*			•			•		•	•		•	
Kudzu vine	*Pueraria lobata* (*P. montana*)	•			•	•	•	•	•	•		•	
Oriental bittersweet	*Celastrus orbiculatus*	•			•	•	•		•	•		•	
Periwinkle	*Vinca minor* & *V. major*			•	•	•	•	•	•	•		•	
Porcelain-berry	*Ampelopsis brevipedunculata*	•				•		•	•	•		•	

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COMMON NAME	SCIENTIFIC NAME	INVASIVENESS			REGION			LIGHT			MOISTURE		
		A	B	C	M	P	C	F	P	S	H	M	X
SHRUBS													
Amur honeysuckle	*Lonicera maackii*		•		•	•			•			•	
Autumn olive	*Elaeagnus umbellata*	•			•	•	•	•	•			•	
Bell's honeysuckle	*Lonicera x bella*			•	•	•	•	•	•			•	
Blunt-leaved privet	*Ligustrum obtusifolium*		•			•	•			•		•	
Chinese privet	*Ligustrum sinense*	•			•	•	•		•	•		•	
Japanese barberry	*Berberis thunbergii*		•		•	•	•	•	•	•		•	
Japanese spirea	*Spiraea japonica*		•		•	•			•	•	•	•	
Linden viburnum	*Viburnum dilatatum*			•		•		•	•			•	
Morrow's honeysuckle	*Lonicera morrowii*	•			•	•		•	•	•		•	
Multiflora rose	*Rosa multiflora*	•			•	•	•	•	•			•	
Russian olive	*Elaeagnus angustifolia*			•	•	•	•	•	•			•	
Standish's honeysuckle	*Lonicera standishii*	•			•	•			•	•		•	
Sweet breath of spring	*Lonicera fragrantissima*			•		•		•	•			•	
Tartarian honeysuckle	*Lonicera tatarica*		•		•	•		•	•			•	
Thorny elaeagnus	*Elaeagnus pungens*			•		•	•		•			•	
Wineberry	*Rubus phoenicolasius*	•			•	•	•		•	•		•	
Winged burning bush	*Euonymus alatus*	•				•			•	•		•	
Wintercreeper	*Euonymus fortunei*		•				•		•	•	•	•	

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http://www.vnps.org

June 1999

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Key

A = High
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P = Partial sun
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COMMON NAME	SCIENTIFIC NAME	INVASIVENESS			REGION			LIGHT			MOISTURE		
		A	B	C	M	P	C	F	P	S	H	M	X
HERBACEOUS PLANTS													
Alligator weed	*Alternanthera philoxeroides*	•					•	•	•		•		
Aneilima	*Murdannia keisak*	•				•	•	•	•		•		
Asiatic sand sedge	*Carex kobomugi*	•					•	•	•				•
Beefsteak plant	*Perilla frutescens*			•	•	•	•		•	•		•	
Bermuda grass	*Cynodon dactylon*		•		•	•	•	•				•	
Birdsfoot trefoil	*Lotus corniculatus*			•	•	•	•	•	•			•	•
Brazilian water-weed	*Egeria densa*		•		•	•	•	•	•		•		
Bristled knotweed	*Polygonum cespitosum*		•		•	•	•	•	•	•	•	•	
Brown knapweed	*Centaurea jacea*		•		•	•		•	•			•	•
Bugleweed	*Ajuga reptans*			•	•	•	•	•	•			•	•
Bull-thistle	*Cirsium vulgare*		•		•	•	•	•				•	
Canada bluegrass	*Poa compressa*		•		•	•	•	•	•	•		•	•
Canada thistle	*Cirsium arvense*	•			•	•	•	•				•	
Chinese lespedeza	*Lespedeza cuneata*	•			•	•		•				•	
Chinese yam	*Dioscorea batatas*	•			•	•	•		•	•		•	
Cogon grass	*Imperata cylindrica*	•					•		•	•		•	
Common chickweed	*Stellaria media*		•		•	•	•	•	•	•		•	
Common cocklebur	*Xanthium strumarium*		•		•	•	•	•	•			•	•
Common dayflower	*Commelina communis*			•	•	•	•	•	•			•	
Common morning-glory	*Ipomoea purpurea*		•		•	•	•	•				•	
Common reed	*Phragmites australis*	•				•	•	•	•		•	•	
Common teasel	*Dipsacus sylvestris*		•		•	•	•	•			•	•	
Crown-vetch	*Coronilla varia*		•		•	•	•	•				•	•
Curled dock	*Rumex crispus*		•		•	•		•				•	•
Cut-leaf teasel	*Dipsacus laciniatus*		•		•			•				•	
European water-milfoil	*Myriophyllum spicatum*	•			•	•	•	•			•		
Fennel	*Foeniculum vulgare*		•			•	•	•			•	•	•
Field-bindweed	*Convovulus arvensis*		•		•	•	•	•	•			•	
Garlic mustard	*Alliaria petiolata*	•			•	•		•	•	•		•	

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COMMON NAME	SCIENTIFIC NAME	INVASIVENESS			REGION			LIGHT			MOISTURE		
		A	B	C	M	P	C	F	P	S	H	M	X
Giant foxtail	*Setaria faberi*		•			•	•	•	•			•	
Giant reed	*Arundo donax*		•			•	•	•	•		•	•	
Gill-over-the-ground	*Glechoma hederacea*		•		•	•	•		•	•		•	
Golden bamboo	*Phyllostachys aurea*		•			•	•	•	•			•	
Hydrilla	*Hydrilla verticillata*	•					•	•	•		•		
Ivy-leaved morning-glory	*Ipomoea hederacea*		•		•	•	•	•	•		•	•	
Ivy-leaved speedwell	*Veronica herderaefolia*		•		•	•	•	•	•	•		•	
Japanese knotweed	*Polygonum cuspidatum*	•			•	•	•	•	•			•	
Japanese stilt grass	*Microstegium vimineum*	•			•	•	•	•	•	•	•	•	
Johnson-grass	*Sorghum halapense*	•			•	•	•	•	•			•	
Jointed charlock	*Raphanus raphanistrum*		•		•	•	•	•				•	
Jointed grass	*Arthraxon hispidus*		•		•	•	•	•	•	•	•	•	
Leafy spurge	*Euphorbia esula*			•	•	•			•	•		•	
Lesser celandine	*Ranunculus ficaria*	•					•		•	•		•	
Mile-a-minute	*Polygonum perfoliatum*	•				•		•	•	•		•	
Moneywort	*Lysimachia nummularia*		•		•	•	•	•	•	•	•	•	
Mugwort	*Artemisia vulgaris*		•		•	•	•	•	•			•	•
Musk thistle	*Carduus nutans*		•		•	•	•	•				•	
Nipplewort	*Lapsana communis*			•	•			•	•			•	
Oatgrass	*Arrhenatherum elatius*			•	•	•	•	•	•			•	
Orchard grass	*Dactylis glomerata*			•	•	•	•	•	•			•	
Parrot's feather	*Myriophyllum aquaticum*	•			•	•	•	•			•		
Poison hemlock	*Conium maculatum*			•	•	•	•	•	•			•	
Purple loosestrife	*Lythrum salicaria* & *L. virgatum*	•			•	•	•	•			•	•	
Quack grass	*Agropyron repans*		•		•	•	•	•	•			•	
Red morning-glory	*Ipomoea coccinea*			•	•	•	•	•				•	
Red sorrel	*Rumex acetosella*		•		•	•	•	•	•			•	
Redtop	*Agrostis gigantea*		•		•	•	•	•	•			•	
Rhode Island bent-grass	*Agrostis tenuis*		•		•	•		•	•			•	
Rough bluegrass	*Poa trivialis*		•		•	•	•	•	•	•	•	•	
Short-fringed knapweed	*Centaurea dubia*	•			•			•	•			•	•

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COMMON NAME	SCIENTIFIC NAME	INVASIVENESS			REGION			LIGHT			MOISTURE		
		A	B	C	M	P	C	F	P	S	H	M	X
Shrubby bushclover	*Lespedeza bicolor*		•		•	•	•	•	•			•	
Sickle pod	*Cassia obtusifolia*		•			•	•	•	•			•	•
Silvergrass	*Miscanthus sinense*			•	•	•	•	•	•			•	
Spotted knapweed	*Centaurea maculosa*	•			•	•	•	•	•				•
Tall fescue	*Festuca elatior (F. pratensis)*		•		•	•	•	•	•			•	
Timothy	*Phleum pratense*			•	•	•	•	•	•			•	
Velvet-grass	*Holcus lanatus*		•		•	•	•	•	•		•	•	
Water chestnut	*Trapa natans*			•			•	•			•	•	
Weeping lovegrass	*Eragrostis curvula*		•		•	•	•	•				•	•
White sweet clover	*Melilotus alba*		•		•	•	•	•	•			•	
Wild onion	*Allium vineale*		•		•	•	•	•	•			•	
Wild parsnip	*Pastinaca sativa*			•	•	•	•	•	•			•	
Yellow flag	*Iris pseudacorus*		•		•	•	•	•	•		•		
Yellow sweet clover	*Melilotus officinalis*		•		•	•	•	•	•			•	

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COMMON NAME	SCIENTIFIC NAME	INVASIVENESS			REGION			LIGHT			MOISTURE		
		A	B	C	M	P	C	F	P	S	H	M	X

About the List
This is an advisory list published by Virginia Department of Conservation and Recreation (VDCR) to inform land managers of potential risks associated with certain plant species known to exhibit invasive behavior in some situations. It should be noted the list is not regulatory in nature, and thus does not prohibit the use of the listed plant species.
DCR Natural Heritage and Virginia Native Plant Society use detailed criteria to assess the invasiveness of a plant. Factors used to rank each species include: culmulative impacts on natural areas; potential to disperse and invade natural landscapes; distribution and abundance; difficulty to manage; and impacts on other species. The list is periodically reviewed and updated by land managers, nurserymen, landscape architects, horticulturalists, botanists, wildlife biologists, and other conservation parterners.

Invasiveness Ranking
Each species on the list is assessed according to its cumulative effects on natural areas and native plant habitats where it typically occurs.

The A-ranked species exhibit the most invasive tendancies in natural areas and native plant habitats. they may disrupt ecosystem processes and cause ma

The B-ranked species exhibit moderate invasiveness in natural areas. They may have minor influence on ecosystem processes, alter plant community com
threatening all species found in the community. These species usually require a minor disturbance to become established.

The C-ranked species generally do not affect ecosystem processes but may alter plant community composition by outcompeting one or more native plant species. They often establish in severely disturbed areas. The disturbance may be natural or human origin, such as icestorm damage, windthrow, or road construction. These species spread slowly or not at all from disturbed sites.

Regions
For purposes of this list, the state has been divided into three regions. Coastal Plain and Piedmont follow conventional boundaries. Blue Ridge, Ridge and Valley, and Cumberland Plateau and grouped together into one region called Mountain.

Habitat Requirements
The categories for light and soil requirements are very broad and are meant only to give general indication of habitat adaptations for these plants.

Appendix B.

Herbaceous Species Indicator List

Acer rubrum
Arisaema triphyllum
Arundinaria gigantea
Asimina triloba
Bignonia capreolata
Carex spp.
Carpinus caroliniana
Clethra alnifolia
Euonymus americana
Fraxinus pennsylvanica
Ilex opaca
Itea virginica
Leucothoe axillaris
Liquidambar styraciflua
Liriodendron tulipera
Mitchella repens
Nyssa sylvatica
Onoclea sensibilis
Parthenocissus quinquefolia
Quercus sp
Smilax rotundifolia
Toxicodendron radicans
Vaccinium corymbosum
Vitis labrusca
Vitis rotundifolia
Woodwardia areolata
Woodwardia virginica

Appendix C.

Hardwood Species List

Acer spp.---------------------------------Maple
Aesculus spp.----------------------------Buckeye
Ailanthus altissima---------------------Ailanthus
Alnus spp.-------------------------------Alder
Arbutus menziesii----------------------Madrone
Betula spp.------------------------------Birch
Carpinus caroliniana------------------Hornbeam
Carya spp.------------------------------Hickory
Celtis spp.-------------------------------Hackberry
Cercis canadensis----------------------Redbud
Cornus-----------------------------------Dogwood
Diospyros-------------------------------Persimmon
Fagus------------------------------------Beech
Fraxinus---------------------------------Ash
Gleditsia---------------------------------Honeylocust
Halesia----------------------------------Silverbell
Ilex--------------------------------------Holly
Juglans---------------------------------Walnut
Liquidambar---------------------------Sweetgum
Liriodendron-------------------------Yellow-popular
Maclura--------------------------------Osage-orange
Magnolia------------------------------Magnolia
Morus----------------------------------Mulberry
Nyssa----------------------------------Tupelo
Ostrya---------------------------------Hophornbeam
Oxydendrum-------------------------Sourwood
Paulownia----------------------------Paulownia
Persea---------------------------------Redbay
Platanus------------------------------ Sycamore
Populus-------------------------------Aspen, Cottonwood, Poplar
Prunus--------------------------------Cherry
Quercus------------------------------Oak
Robinia-------------------------------Locust
Salix----------------------------------Willow
Sassafras-----------------------------Sassafras
Tilia-----------------------------------Basswood
Ulmus--------------------------------Elm

Appendix D. Shrub list.

Clethra alnifolia
Euonymus americana
Ilex spp.
Leucothoe axillaris
Leucothoe racemosa
Lindera benzoin
Myrica cerifera
Rhododendron spp.
Symplocos tinctoria
Vaccinium corymbosum

Appendix E.

Wildlife Value Plants

Acer negundo
Acer rubrum
Amelanchier obovalis
Aralia spinosa
Asimina triloba
Carex
Carpinus caroliniana
Carya
Celtis
Clethra alnifolia
Cornus florida
Coruns amomum
Diospyros virginiana
Euonymus
Fagus
Fraxinus
Hypericum
Ilex
Itea virginica
Juglans
Juniperus
Leucothoe
Lindera
Liquidambar
Liriodendron
Lonicera japonica
Magnolia
Myrica
Nyssa
Oxydendron arboreum
Panicum
Parthenocissus quinquefolia
Persea barbonia
Pinus
Prunus serotina
Quercus
Rhododendron
Rhus
Rubus
Sambucus canadensis
Sassafras albidum
Smilax
Symplocos tinctoria
Toxicodendron radicans
Ulmus americana
Vaccinium corymbosum
Viburnum prunifolium

Appendix F Reference domain data set.

SITE	Canopy Trees %Hwood	Canopy Trees %Oak	Canopy Trees %Pine	Basal Area(m2)	Mid-story Trees %Hwood	Mid-story Trees %Oak	Mid-story Trees %Pine	Saplings %Hwood	Saplings %Oak	Saplings %Pine	ShrubDen per ha	Mean Elev differ.(cm)	MeanCav	MeanCwd	%StDead	# of food plants	# of Winter food plant	# of Exotic species	Number of Strata
BT	11	2	89	85	100	0	0	100	0	0	137	29.7	1.3	5.7	1.8	11	3	0	5
CP	47	10	53	44.4	100	0	0	100	15	0	118	17	2.3	3	0	17	3	0	5
CS1	83	33	17	36.8	86	10	14	96	8	4	245	20.3	2	4.3	0	16	4	1	5
CS2	48	7	52	42.9	100	0	0	100	6	0	64	16.6	0	7.7	0	22	4	0	5
DS1	100	20	0	36.8	100	0	0	100	3	0	1994	29.6	3	7.3	16.6	14	3	2	5
DS2	98	28	2	45.9	100	0	0	100	0	0	731	26.6	2.7	4.3	8.3	13	3	0	5
DS3	87	2	13	47.5	100	4	0	100	0	0	350	16.8	0.7	3.7	4.8	16	5	1	5
DS6	100	0	0	39.8	100	0	0	100	3	0	731	22.5	2.3	3.3	1.9	12	2	0	3
DS7	0	0	100	0.8	0	0	0	100	0	0	0	7.3	0	0.3	0	4	4	1	1
DS8	0	0	100	5.4	0	0	0	100	0	0	0	8.8	0	0.3	0	6	6	3	1
DS9	0	0	0	0	0	0	0	0	0	0	0	10.7	0	0	0	4	4	4	5
ELM	100	4	0	35.2	100	0	0	100	0	0	3743	7.6	3	12	17.4	24	4	3	5
LAN	100	0	0	27.6	100	0	0	100	5	0	1358	18.8	0.3	3.3	5.6	22	4	2	4
NC	42	4	58	65.1	100	0	0	100	0	0	159	16.8	1.7	5.3	0	14	3	0	5
NWR	71	16	29	42.9	100	21	0	100	8	0	254	18.2	3.7	3.7	3.6	15	2	0	5
POC	80	20	20	45.2	100	10	0	100	2	0	1208	16.3	2.3	7.3	7.7	14	3	0	5
SB1	96	54	4	53.6	100	0	0	97	27	3	1972	18.3	4	4.7	1.4	12	3	0	5
SB2	94	24	6	47.5	100	6	0	100	0	0	890	27.5	2	7	0	17	4	0	5
SF1	76	46	24	41.3	100	21	0	100	2	0	477	26.1	1.3	4.7	3.7	19	4	0	5
SF2	94	55	6	23.7	100	16	0	100	1	0	277	22.3	1.7	7.7	0	20	5	1	5
SHM	72	3	28	52.8	100	23	0	100	21	0	223	18.5	2	4	0	15	4	0	5
STL	95	70	5	48.2	100	0	0	100	1	0	286	8.3	5.7	4.7	0	18	4	0	5
TN1	93	74	7	35.2	0	0	100	100	33	0	0	4.5	0.3	1.3	0	7	4	1	3
TN2	93	44	7	32.9	100	0	0	100	3	0	9763	15.5	2.3	6.7	9.3	18	3	0	5

SITE	BDg/50cc 5cm/20cm	%OM 5cm/20cm	pH 5cm/20cm	%Clay 5cm/20cm	%Silt 5cm/20cm	%Sand 5cm/20cm	%Gravel 5cm/20cm	Texture at 20 cm
BT	52.1/94.6	7.0/1.0	3.5/3.7	6.0/16.0	28.0/14.0	66.0/70.0	0	Loamy Sand
CP	41.2/66.3	9.0/3.0	4.1/4.5	10.0/18.0	26.0/11.0	64.0/71.0	0	Clay Loam
CS1	48.5/65.2	6.0/4.0	3.7/3.6	19.0/31.0	27.0/27.0	52.0/41	1.0/1.0	Silty Clay Loam
CS2	76.9/51.8	3.0/8.0	4.3/3.8	14.0/7.0	9.0/15.0	75.0/76.0	2.0/2.0	Sandy Loam
DS1	37.4/50.5	21.0/12.0	3.7/3.8	10.0/11.0	29.0/36.0	61.0/53.0	0	Sandy Loam
DS2	43.8/53.6	14.0/7.0	3.7/4.3	5.0/11.0	30.0/27.0	66.0/62.0	0	Silty Clay Loam
DS3	38.9/65.8	10.0/4.0	3.7/4.0	21.0/24.0	38.0/27.0	41.0/48.0	1.0/0.0	Sandy Loam
DS6	29.0/50.7	19.0/7.0	4.2/4.1	18.0/16.0	29.0/23.0	52.0/61.0	0	Clay Loam
DS7	82.4/82.7	3.0/3.0	5.0/4.3	16.0/30.0	36.0/28.0	48.0/42.0	0	Silty Clay Loam
DS8	72.5/87.0	4.0/2.0	4.9/4.2	18.0/26.0	40.0/28.0	43.0/46.0	0	Silty Clay Loam
DS9	75.4/88.6	3.0/3.0	5.0/4.8	18.0/23.0	33.0/32.0	49.0/45.0	0	Silty Clay Loam
ELM	51.2/79.1	10.0/4.0	4.9/5.3	13.0/23.0	19.0/17.0	67.0/60.0	0	Silty Clay Loam
LAN	92.4/95.1	5.0/6.0	5.0/5.0	4.0/6.0	6.0/5.0	62.0/66.0	28.0/24.0	Sandy Loam
NC	54.2/82.9	6.0/1.0	3.6/3.9	10.0/16.0	31.0/21.0	59.0/63.0	0	Loam
NWR	40.8/76.1	14.0/3.0	4.0/4.1	17.0/33.0	52.0/45.0	31.0/22.0	0	Silty Clay Loam
POC	67.5/69.2	4.0/2.0	3.6/3.7	21.0/33.0	62.0/52.0	18.0/15.0	0	Silty Clay Loam
SB1	34.6/74.0	14.0/4.0	3.5/3.9	10.0/21.0	34.0/12.0	55.0/60.0	1.0/8.0	Clay Loam
SB2	37.2/65.9	18.0/6.0	4.0/4.0	18.0/32.0	43.0/32.0	35.0/35.0	4.0/2.0	Sandy Loam
SF1	49.6/71.3	9.0/2.0	4.1/4.0	4.0/7.0	17.0/17.0	79.0/74.0	0/1.0	Silty Clay Loam
SF2	53.6/81.7	9.0/4.0	3.9/4.5	6.0/9.0	18.0/11.0	76.0/79.0	0/1.0	Silty Clay Loam
SHM	54.3/72.6	9.0/5.0	3.7/3.9	20.0/37.0	70.0/55.0	10.0/8.0	0	Silty Clay Loam
STL	52.3/72.1	6.0/3.0	4.2/4.2	22.0/30.0	64.0/57.0	14.0/13.0	0	Sandy Loam
TN1	66.5/56.3	6.0/6.0	4.1/4.1	10.0/8.0	17.0/19.0	73.0/72.0	0/1.0	Loamy Sand
TN2	53.2/75.1	9.0/4.0	3.6/4.0	11.0/13.0	22.0/17.0	68.0/70.0	0	Loamy Sand

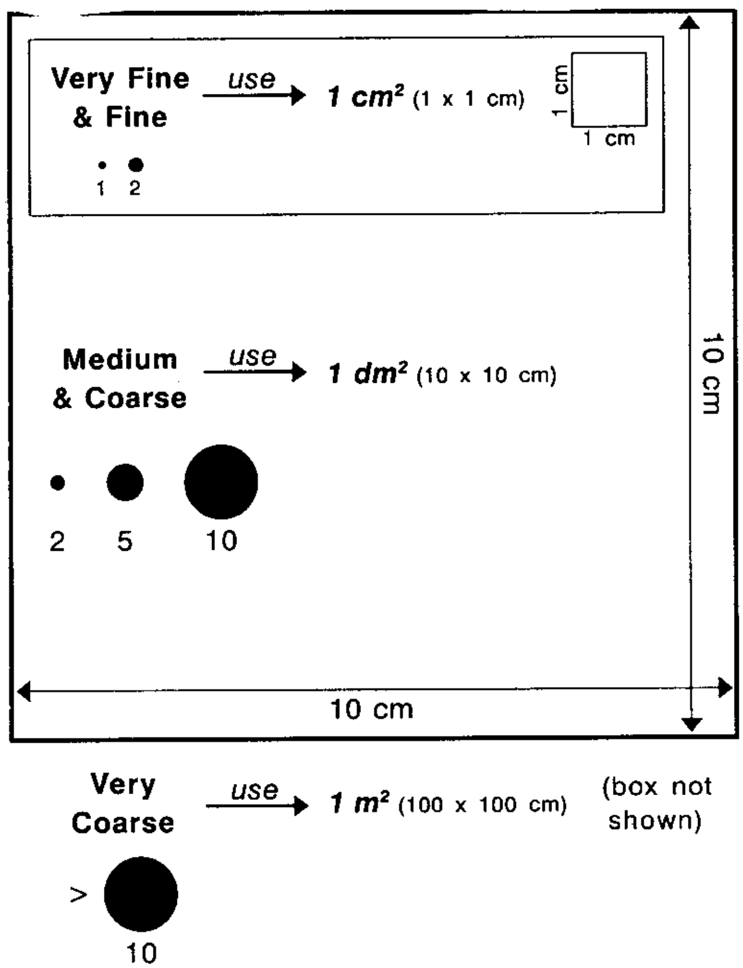
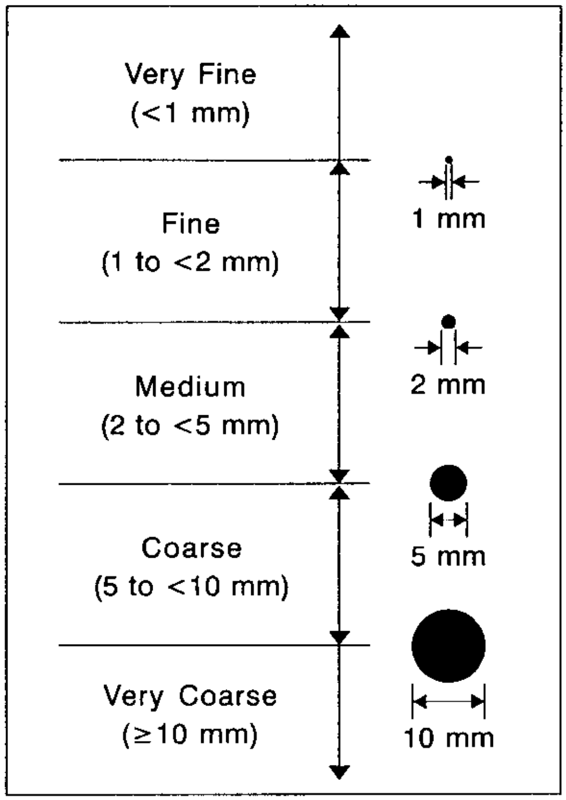


Figure 1. Roots - Quantity (Roots & Pores) - soil to be assessed (from Schoeneberger et al. 1998).

Root and Pore Size Classes



ROOTS - LOCATION (Roots) -

Location	Code
Between Peds	P
In Cracks	C
Throughout	T
In Mat at Top of Horizon [1]	M
Matted Around Rock Fragments	R

[1] Describing a root mat at the top of a horizon rather than at the bottom or within the horizon, flags the horizon that restricts root growth.

Figure 2. Roots & Pore Size Classes (from Schoeneberger et al. 1998).

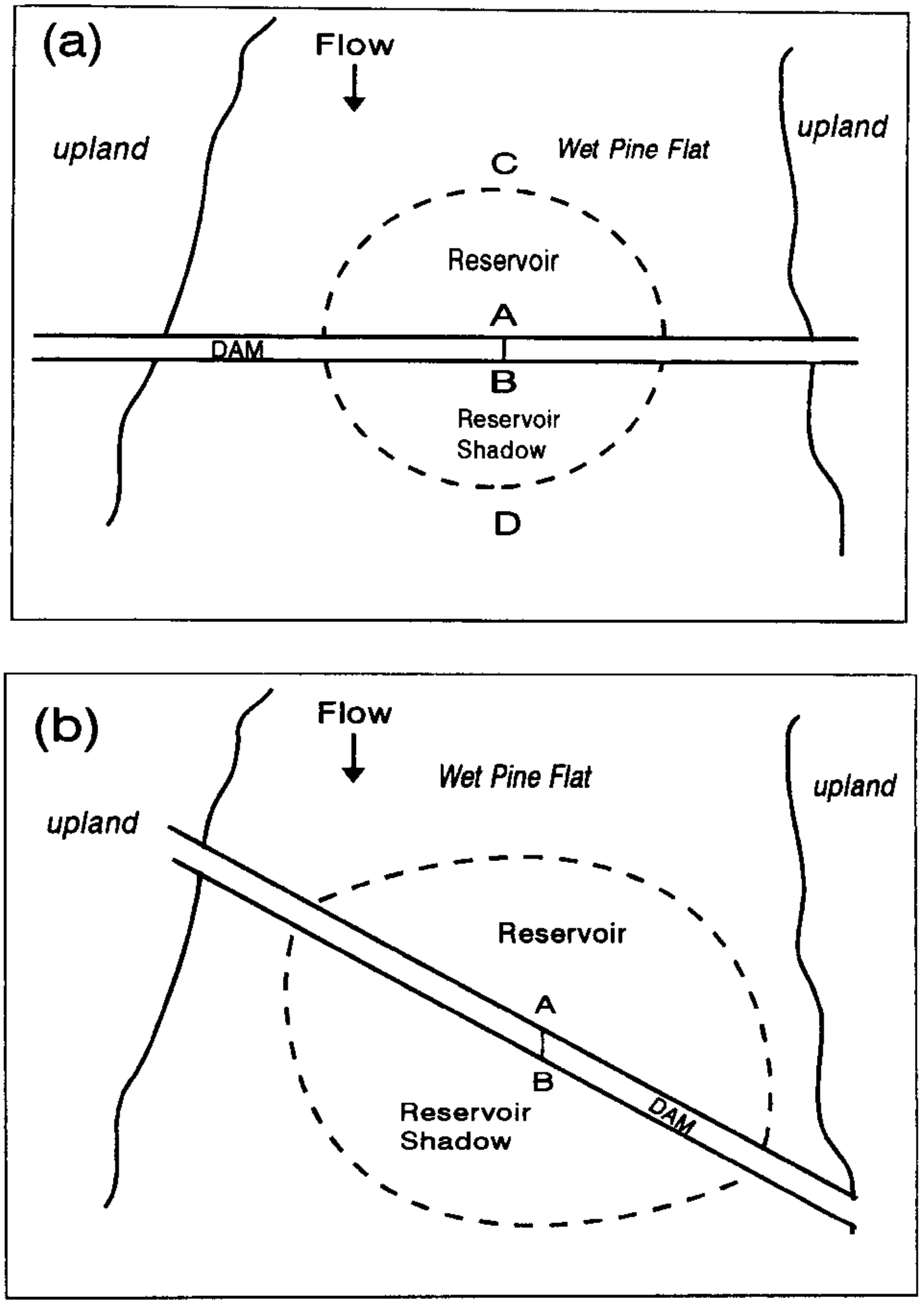
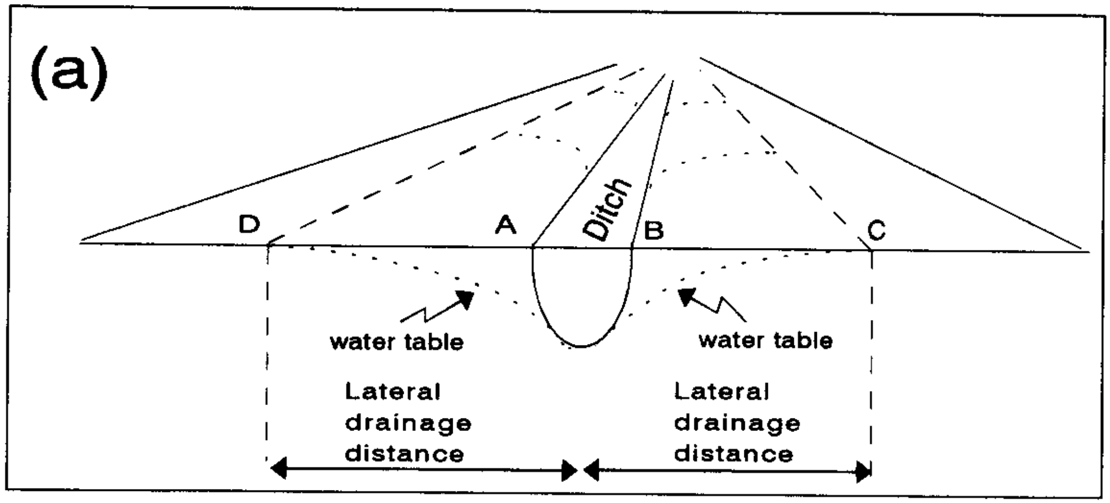


Figure 3. Alteration to hydrologic regime caused by an impediment to flow (V_{DAM}). **(a)** For dams that cross a flat perpendicular to the direction of flow, the elevation of the overflow point (A) is the same as that of the reservoir boundary (area within dotted line below C). The distance from A to C equals the distance from the outlet point (B) to the boundary of the reservoir shadow (area within dotted line above D). If the gradient of the wet flat is 0.002 (0.2%) and the overflow point on the dam is 0.5 m high, then the distance from A to C and B to D is 250 m (0.5/0.002). Note: footprint of dam is treated as a fill (see V_{VOLUME}). **(b)** Dam crossing a wet flat at angle that is not perpendicular to flow. The area upslope is determined by circumscribing a boundary of elevation equal to that of the outlet point, but its precise shape is unknown. The reservoir shadow is assumed to be the same size as the reservoir.



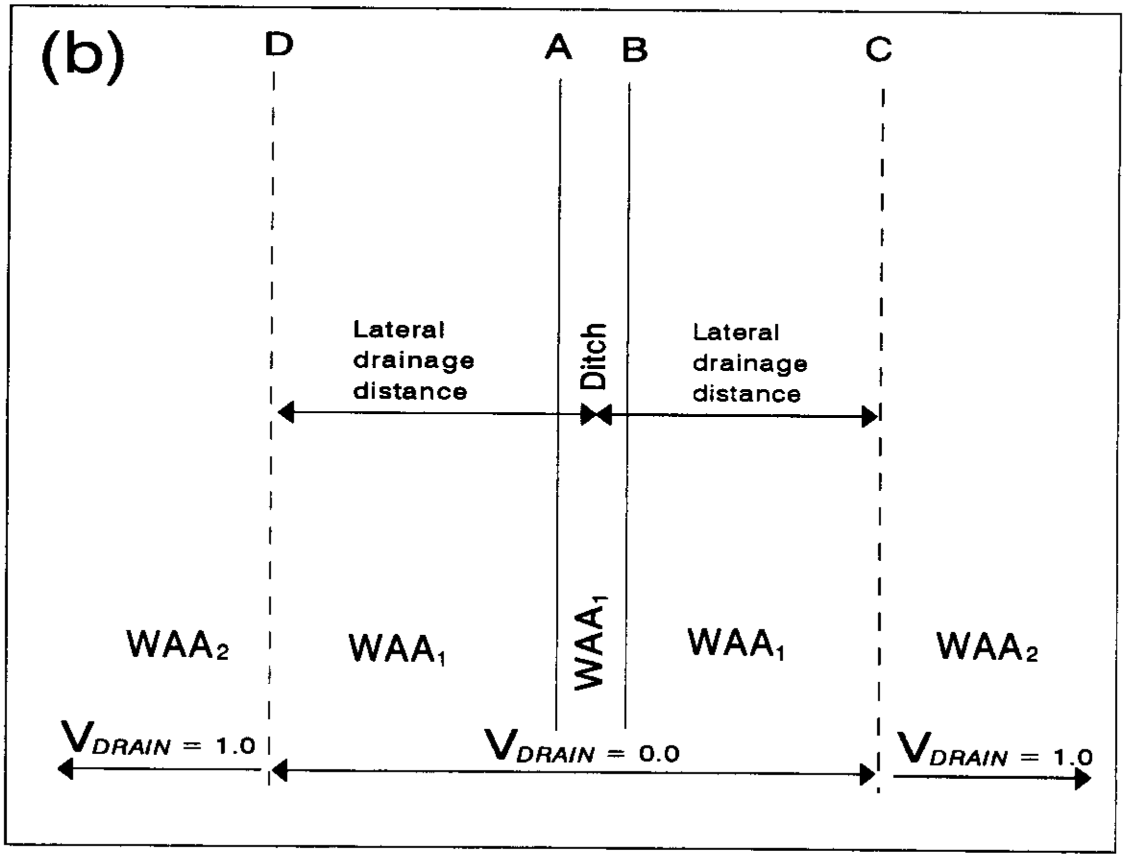


Figure 4. Alteration in water table caused by a drainage ditch on subsurface water storage (lateral drainage distance). (a) Cross sectional view. Dashed line shows horizonal extent of altered water table on both sides of ditch (from A to B and from B to C), while dotted line shows vertical effect of reduced water table. (b) Plane view. Assessment area should be split into al least two partial WAAs (WAA1 and WAA2) based on lateral drainage distance.

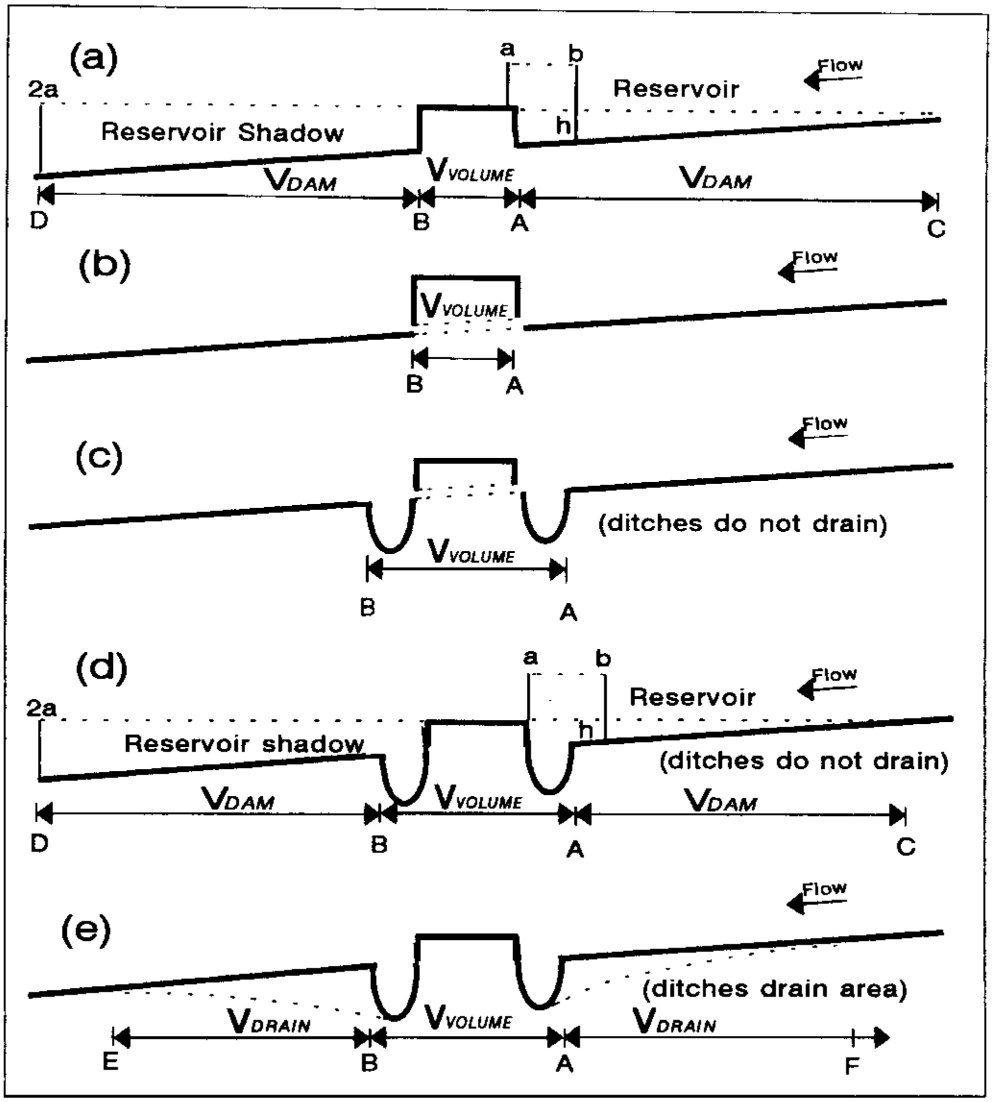


Figure 5. Interactive effects of several types of alterations to hydrologic associated with a dam and ditch. See Fig. 3 for plan view. **(a)** Site with a dam (road), but no ditch. Height of dam (h) = b minus a, where b = distance from ground to hand level and a = top of dam to hand level. Hydrologic alteration by V_{DAM} occurs from A to C (reservoir) and from B to D (reservoir shadow). Hydrologic alteration of fill (V_{VOLUME}) is determined by footprint of dam (from A to B). **(b)** Site with a road culverts under road, no ditches. Only V_{VOLUME} is applicable between A and B. **(c)** Site with a road, ditches alongside road, and culverts under road, but ditches do not drain site. Hydrologic alteration restricted to footprint of road and ditch (V_{VOLUME}) from A to B. **(d)** Site with a road, ditches that do not drain site and no culverts under road. Hydrologic alteration occurs in reservoir and reservoir shadow (V_{DAM}) from A to C and from B to D; alteration due to footprint of road and ditches (V_{VOLUME}) occurs from A to B. **(e)** Site with a road and ditches that drain the site. Hydrologic alteration is due to drainage effect of ditches (V_{DRAIN}) occurs from B to E and from A to F; alteration due to footprint of road (V_{VOLUME}) occurs from A to B.

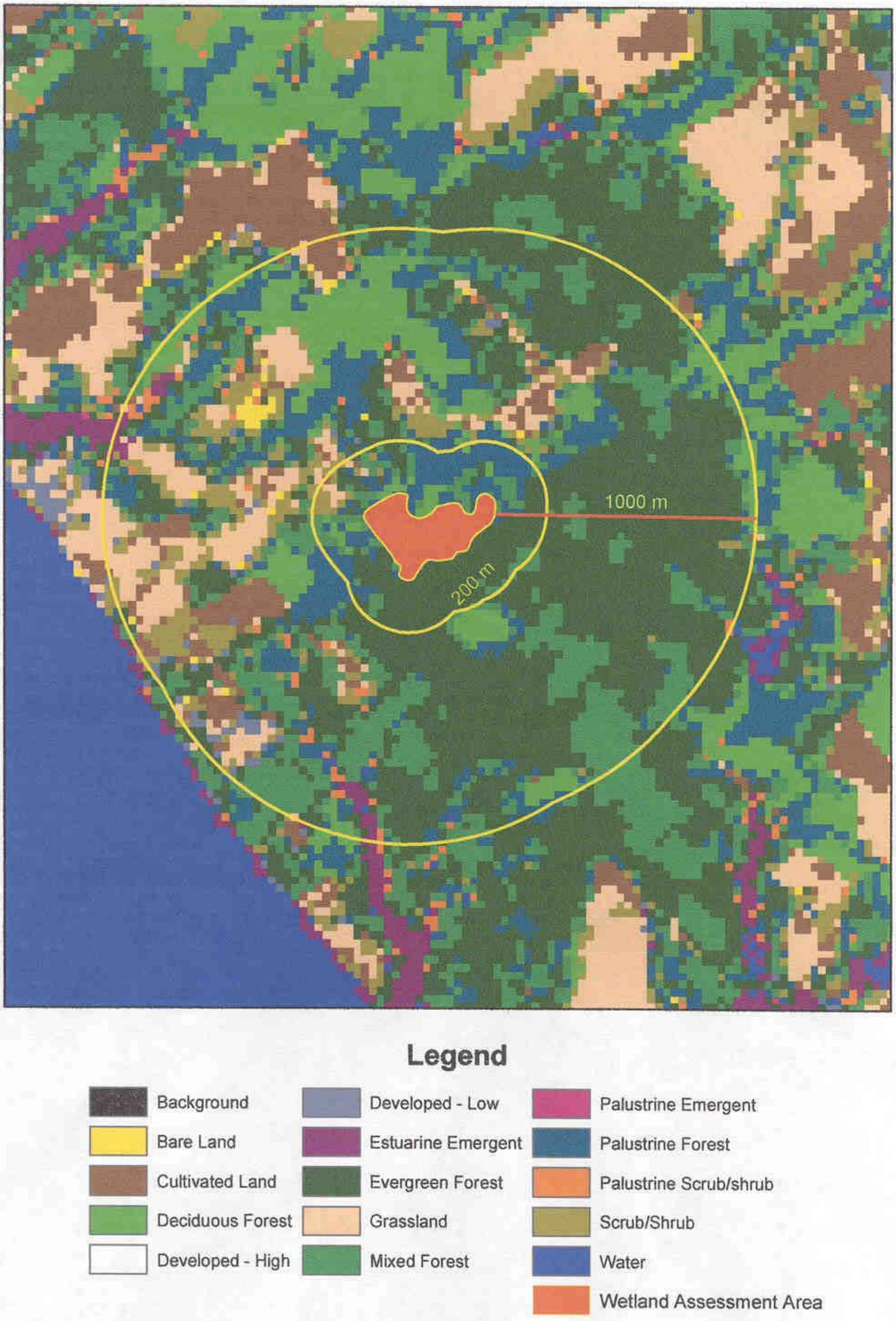


Figure 6. Landuse buffer determination.

Field Collection Data Sheets

Field Investigator (s) ____________________

Site____________________ Date ________

Plot____________________

Canopy Trees - Variable plot method

Basal Area Factor________

Species	Tally	Rel. Dom.
1. ________	________	____
2. ________	________	____
3. ________	________	____
4. ________	________	____
5. ________	________	____
6. ________	________	____
7. ________	________	____
8. ________	________	____
9. ________	________	____
10________	________	____

Mid Story Trees ≥ 7.5 cm & < 15 cm DBH, 10 meter radius plot.

1________	________	____
2________	________	____
3________	________	____
4________	________	____
5________	________	____
6________	________	____
7________	________	____
8________	________	____

Field Collection Data Sheets

Field Investigator (s) ______________________________

Site ______________________ Date __________

Plot ______________________

Saplings < 7.5 cm & ≥ 1 m high, 10 meter radius plot.

Species	Tally	Rel. Dom.
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10		

Shrubs ≥ 1 m high, 10 meter radius plot.

1		
2		
3		
4		
5		
6		
7		
8		

Field Collection Data Sheets

Field Investigator (s) ______________________________

Site______________________ Date __________

Plot______________________

Herbaceous species woody plants < 1 m high and all non-woody species, 10 meter radius plot.

Species

____

____

____

____

____

____

____

____

____

Exotic species - as defined by the list of Invasive Alien Plant Species of Virginia

Species	Invasiveness Rating	Strata
____________________	__________	____________________
____________________	__________	____________________
____________________	__________	____________________
____________________	__________	____________________
____________________	__________	____________________
____________________	__________	____________________

Field Collection Data Sheets

Field Investigator (s) ____

Site____________________________ Date ________

Plot____________________________

Standing Dead > 2 m high & > 15 cm DBH, 10 meter radius plot.

Tally

Coarse Woody Debris > 2.5 cm diameter intercepted by 20 m transect tapes.

	Tally
20 meter transect A	
20 meter transect B	
	____ / 2 = (Average)

Ground level cavities, ≥ 2.5 cm in diameter within 2 m of ground surface, 10 m radius plot.

Tally

Microtopography, relative elevations of high and low points along 20 meter transect tapes.

	High	Low	Elevation Difference
20 meter transect A			
20 meter transect B			
			______ / 2 = (Average)

Soils Data Collection Sheet

O horizon __________ Present __________ Absent
1.0 0.0

A horizon __________ Present __________Absent
1.0 0.0

Roots/Pores ________ None _______ Few _______Common _______Many
0.0 0.3 0.6 1.0

Pore Continuity _______None _______ Low _______Moderate _______High
0.0 0.3 0.6 1.0

Redoximorphic Features ________ Present _______Absent
1.0 0.0

Landscape Fragmentation Data Collection Sheet

Landscape Fragmentation - 1000m and 200 meter buffer around WAA

200m buffer.

Landuse Type	Tally	Percent
____________________	_____________	________________
____________________	_____________	________________
____________________	_____________	________________
____________________	_____________	________________
____________________	_____________	________________

1000m buffer

Landuse Type	Tally	Percent
____________________	_____________	________________
____________________	_____________	________________
____________________	_____________	________________
____________________	_____________	________________
____________________	_____________	________________

Worksheet for Determining Functional Capacity Indices.

$\mathbf{FCI_{HYRDO}} = V_{DRAIN}$ or V_{DAM} or V_{WIN} or V_{VOLUME} or (Vet X ((Vmicro + Vporosity)/2)) ½ whichever is lowest.

$$\mathbf{FCI_{PLANTS}} = \frac{V_{HERB}(V_{EXOTIC}) + V_{TREE}(V_{BASAL})(V_{EXOTIC}) + V_{MIDSTORY}(V_{EXOTIC}) + V_{SAPLING}(V_{EXOTIC}) + V_{SHRUB}(V_{EXOTIC})}{5}$$

$$\mathbf{FCI_{HABITAT}} = \frac{V_{PLANTS} + V_{STRUCTURE} + V_{FOOD} + V_{CWD} + V_{SD} + V_{CAVITIES} + V_{MICRO} + V_{LANDSCAPE}}{8}$$

$$\mathbf{FCI\ (V_{SOILS})} = \frac{V_{REDOX} + V_{PLANTS}\text{ (from Function 2)} + V_{ORGANICS} + V_{POROSITY}\text{ (from Function 1)}}{4}$$