ERDC/EL TR-02-4

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# A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Selected Regional Wetland Subclasses, Yazoo Basin, Lower Mississippi River Alluvial Valley

R. Daniel Smith and Charles V. Klimas

April 2002

Environmental Laboratory

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**Wetlands Research Program**

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# A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Selected Regional Wetland Subclasses, Yazoo Basin, Lower Mississippi River Alluvial Valley

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Final report

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Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

# Assessing Wetland Functions

***A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Selected Regional Wetland Subclasses, Yazoo Basin, Lower Mississippi River Alluvial Valley (ERDC/EL TR-02-4)***

**ISSUE:** Section 404 of the Clean Water Act directs the U.S. Army Corps of Engineers to administer a regulatory program for permitting the discharge of dredged or fill material in "waters of the United States." As part of the permit review process, the impact of discharging dredged or fill material on wetland functions must be assessed. On 16 August 1996, a National Action Plan to Implement the Hydrogeomorphic Approach (NAP) for developing Regional Guidebooks to assess wetland functions was published. This report is one of a series of Regional Guidebooks that will be published in accordance with the National Action Plan.

**RESEARCH OBJECTIVE:** The objective of this research was to develop a Regional Guidebook for assessing the functions of selected regional wetland subclasses in the Yazoo Basin, Lower Mississippi River Alluvial Valley, in the context of the 404 Regulatory Program.

**SUMMARY:** The Hydrogeomorphic (HGM) Approach is a collection of concepts and methods for developing functional indices and subsequently using them to assess the capacity of a wetland to perform functions relative to similar wetlands in a region. The Approach was initially designed to be used in the context of the Clean Water Act Section 404 Regulatory Program permit review sequence to consider alternatives, minimize impacts, assess unavoidable project impacts, determine mitigation requirements, and monitor the success of the mitigation projects. However, a variety of other potential applications for the Approach have been identified, including; determining minimal effects under the Food Security Act, designing mitigation projects, and managing wetlands.

This report uses the HGM Approach to develop a Regional Guidebook for assessing the functions of selected regional wetland subclasses in the Yazoo Basin, Lower Mississippi River Alluvial Valley.

**AVAILABILITY OF REPORT:** The report is available at the following Web site: http://www.wes.army.mil/el/wetlands/wlpubs.html. The report is also available on Interlibrary Loan Service from the U.S. Army Engineer Research and Development Center (ERDC) Research Library, telephone (601) 634-2355, or the following Web site: http://libweb.wes.army.mil/index.htm. Individuals should arrange for Interlibrary Loan Service either through the library of their business concerns or through the interlibrary loan services of their local libraries. To purchase a copy, call the National Technical Information Service (NTIS) at 1-800-553-6847 or (703) 605-6000, or visit the following Web site: http://www.ntis.gov/. For help in identifying a title for sale call 1-800-553-6847. NTIS report numbers may also be requested from the ERDC librarians.

About the authors: Mr. R. Daniel Smith is a research ecologist at the U.S. Army Engineer Research and Development Center Environmental Laboratory, Vicksburg, MS. Dr. Charles V. Klimas is an ecologist and principal at CVK & Associates, Seattle, WA.

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# Preface

This Regional Guidebook was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Characterization and Restoration of Wetlands Research Program (CRWRP). It is published as an Operational Draft for field testing for a 2-year period. Comments should be submitted via the Internet at the following address: http://www.wes.army.mil/el/wetlands/hgmhp.html. Written comments should be addressed to: Department of the Army, Research and Development Center, CEERD-EE-W, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199.

The work was performed under Work Unit 32985, "Technical Development of HGM," for which Dr. Ellis J. Clairain, Jr., Environmental Laboratory (EL), Vicksburg, MS, U.S. Army Engineer Research and Development Center (ERDC), was the Principal Investigator.

Mr. Dave Mathis, CERD-C, was the CRWRP Coordinator at the Directorate of Research and Development, HQUSACE; Ms. Colleen Charles, CECW-OR, served as the CRWRP Technical Monitor's Representative; Dr. Russell F. Theriot, EL, was the CRWRP Program Manager; and Dr. Clairain was the Task Area Manager.

This report was prepared by Messrs. R. Daniel Smith, Wetlands and Coastal Ecology Branch (WCEB), EL, and Charles V. Klimas, CVK & Associates, Seattle, WA. The authors wish to acknowledge the efforts of the following people for assistance with developing the classification, characterizing the regional subclasses, conducting field sampling, and reviewing drafts of the Regional Guidebook: Messrs. Russell Pringle, National Resource Conservation Service (NRCS); Bill Ainslie, Environmental Protection Agency (EPA), Atlanta, GA; John Campbell, EL; Bruce Pruitt, EPA, Athens, GA; Delaney Johnson, NRCS, Jackson, MS; and Paul Rodrigue, Mississippi State University, Starkville, MS, and Ms. Ramona Warren, Vicksburg District, USACE. Mmes. Carolyn Schneider and Monica Craft assisted with the manipulation and analysis of reference wetland data and reviewed the draft Regional Guidebook. The "Regional Guidebook for Assessing the Functions of Low-Gradient Riverine Wetlands in Western Kentucky" served as a template for the development of this regional guidebook. The wildlife section authored by Dr. Thomas H. Roberts, Tennessee Technological University, Cookville, TN, was particularly helpful, and portions of this section of the document are included verbatim.

This work took place under the general supervision of Dr. Morris Mauney, Jr., Chief, WCEB; Dr. David J. Tazik, Chief, Ecosystem Evaluation and Engineering Division, EL; and Dr. Edwin A. Theriot, Director, EL.

At the time of publication of this report, Dr. James R. Houston was Director of ERDC, and COL John W. Morris III, EN, was Commander and Executive Director.

This report should be cited as follows:

> Smith, R. D., and Klimas, C. V. (2002). "A regional guidebook for applying the hydrogeomorphic approach to assessing wetland functions of selected regional wetland subclasses, Yazoo Basin, Lower Mississippi River Alluvial Valley," ERDC/EL TR-02-4, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

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# 1 Introduction

The Hydrogeomorphic (HGM) Approach is a method for developing functional indices and the protocols used to apply these indices to the assessment of wetland functions at a site-specific scale. The HGM Approach was initially designed to be used in the context of the Clean Water Act Section 404 Regulatory Program permit review to analyze project alternatives, minimize impacts, assess unavoidable impacts, determine mitigation requirements, and monitor the success of compensatory mitigation. However, a variety of other potential uses have been identified, including the determination of minimal effects under the Food Security Act, design of wetland restoration projects, and management of wetlands.

In the HGM Approach, the functional indices and assessment protocols used to assess a specific type of wetland in a specific geographic region are published in a document referred to as a Regional Guidebook. Guidelines for developing Regional Guidebooks were published in the National Action Plan (National Interagency Implementation Team 1996) developed cooperatively by the U.S. Army Corps of Engineers (USACE), U.S. Environmental Protection Agency (USEPA), Natural Resources Conservation Service (NRCS), Federal Highways Administration (FHWA), and U.S. Fish and Wildlife Service (USFWS). The Action Plan, available online at http://www.epa.gov/OWOW/wetlands/science/hgm.html, outlines a strategy for developing Regional Guidebooks throughout the United States, provides guidelines and an explicit set of tasks required to develop a Regional Guidebook under the HGM Approach, and solicits the cooperation and participation of Federal, State, and local agencies, academia, and the private sector.

This document represents a Regional Guidebook developed for assessing several types of wetlands that occur in the Yazoo Basin of the Lower Mississippi River Alluvial Valley in the United States. Normally, a Regional Guidebook focuses on a single regional wetland subclass (the term for wetland types in HGM Approach terminology), however, a different strategy is employed in this Regional Guidebook in that multiple regional wetland subclasses are considered. The rationale for this approach is that the lower Mississippi River and its tributaries have created a complex landscape that supports a variety of interspersed wetland types in the Yazoo Basin specifically and in the Lower Mississippi River Alluvial Valley generally. Subtle differences in terrain and water movement result in distinctly different functions being performed by wetlands that are in close proximity to or are contiguous with one another.

Further, massive flood control works that have been instituted in this century have dramatically affected nearly all of the wetlands in the Lower Mississippi River Alluvial Valley. Because the origins of these systems are closely related, and they have been universally influenced by flood protection efforts, it is most sensible to deal with their classification and assessment in a single integrated Regional Guidebook. This does not mean that wetlands of different HGM classes and regional wetland subclasses are lumped for assessment purposes, but that the factors influencing their functions and the indicators employed in their evaluation are best developed and presented in a unified manner. Therefore, this Regional Guidebook, as well as others planned for the Lower Mississippi River Alluvial Valley, was developed for multiple regional wetlands subclasses that commonly occur together in a sub-basin. It is expected that the classification of regional wetland subclasses, assessment variables, and assessment models developed for the Yazoo Basin will have general applicability in other sub-basins of the Lower Mississippi River Alluvial Valley. However, development of Regional Guidebooks for other sub-basins will require collection of additional reference data that reflect regional variation in wetland characteristics within a particular sub-basin.

The objectives of this Regional Guidebook are to:

*a.* Characterize selected regional wetland subclasses in the Yazoo Basin of the Lower Mississippi River Alluvial Valley.

*b.* Present the rationale used to select functions to be assessed in these regional subclasses.

*c.* Present the rationale used to select assessment variables and metrics.

*d.* Present the rationale used to develop assessment models.

*e.* Provide data from reference wetlands and document their use in calibrating assessment variables and assessment models.

*f.* Describe the protocols for applying the functional indices to the assessment of wetland functions.

This document is organized in the following manner. Chapter 1 provides the background, objectives, and organization of the document. Chapter 2 provides a brief overview of the major components of the HGM, including the procedures recommended for development and application of Regional Guidebooks. Chapter 3 characterizes the regional wetland subclasses in the Yazoo Basin included in this guidebook. Chapter 4 discusses the wetland functions, assessment variables, and functional indices used in the guidebook from a generic perspective. This discussion includes:

*a.* A definition for each function.

*b.* A description of a quantitative, independent measure of each function for the purposes of validation.

*c.* Descriptions of ecosystem and landscape characteristics and processes that influence assessed functions.

*d.* Definitions and descriptions of assessment variables used to represent the aforementioned characteristics and processes.

*e.* A discussion of the assessment model on which the functional index is based.

*f.* An explanation of the rationale used to calibrate assessment variables and the functional index with reference wetland data.

In Chapter 5, the assessment models are applied to specific regional wetland subclasses, and the relationships of assessment variables to reference data are defined. Chapter 6 outlines the assessment protocol for conducting a functional assessment of regional wetland subclasses in the Yazoo Basin. Appendix A is a glossary of terms, Appendix B provides spreadsheets for analyzing the data collected during the assessment, and Appendix C provides the information necessary to access the reference wetland data and spatial information collected during the project.

While it is possible to assess the functions of selected regional wetland subclasses in the Yazoo Basin using only the information contained in Chapter 6 and the Appendices, it is strongly suggested that, prior to conducting an assessment, users familiarize themselves with the information and documentation provided in Chapters 2-5.

# 2 Overview of the Hydrogeomorphic Approach

## Development and Application Phases

The HGM Approach consists of four components including: (a) the HGM Classification, (b) reference wetlands, (c) assessment variables and assessment models from which functional indices are derived, and (d) assessment protocols. The HGM Approach is conducted in two phases. The Development Phase of the HGM Approach is completed by an interdisciplinary team of experts known as the "Assessment Team" or "A-Team." The task of the A-Team is to develop and integrate the classification, reference wetland, assessment variables, models, and protocol components of the HGM Approach into a Regional Guidebook (Figure 1).

In developing a Regional Guidebook, the team completes the tasks outlined in the National Action Plan (National Interagency Implementation Team 1996). These tasks include:

Task 1: Organize the A-Team

A. Identify team members

B. Train team in the HGM Approach

Task 2: Select and Characterize Regional Wetland Subclass

A. Identify/prioritize regional wetland subclasses

B. Select regional wetland subclass and define reference domain

C. Initiate literature review

D. Develop preliminary characterization of regional wetland subclass

E. Identify and define wetland functions

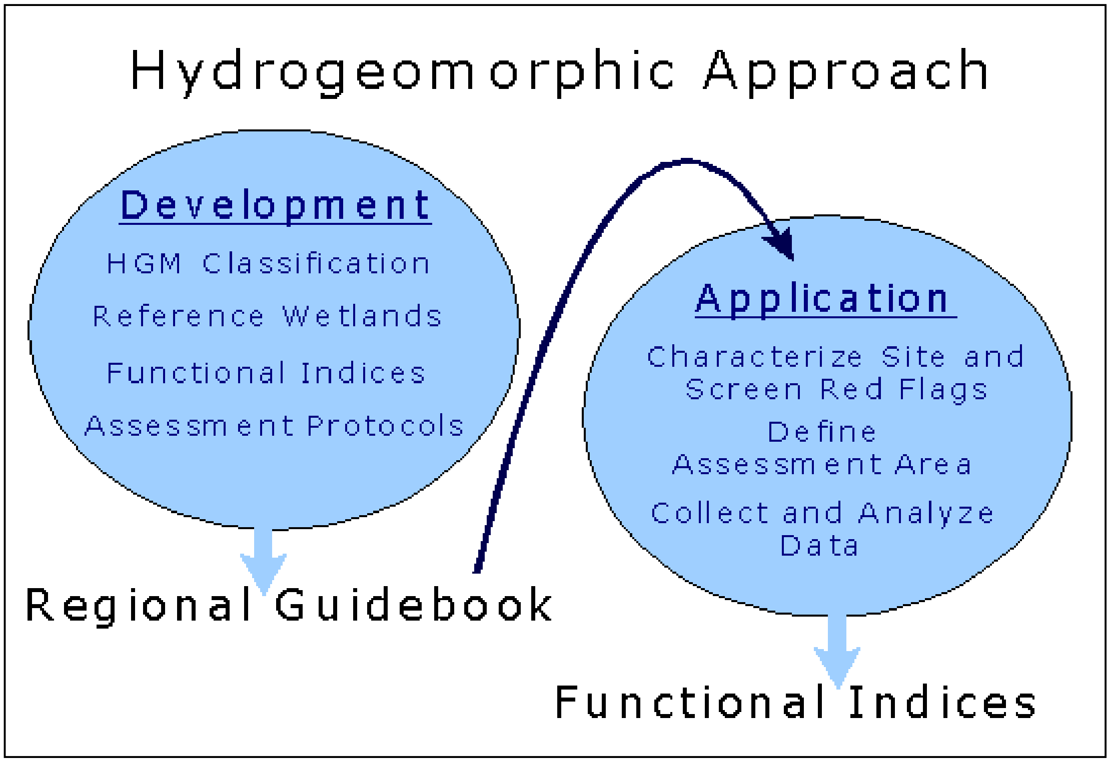


Figure 1. Schematic of development and application phases of the HGM approach

Task 3: Select Assessment Variables and Metrics and Construct Conceptual Assessment Models

A. Review existing assessment models

B. Identify assessment variables and metrics

C. Define initial relationship between assessment variables and functional capacity

D. Construct conceptual assessment models for deriving functional capacity indices (FCI)

E. Complete Precalibrated Draft Regional Guidebook (PDRG)

Task 4: Conduct Peer Review of Precalibrated Draft Regional Guidebook

A. Distribute PDRG to peer reviewers

B. Conduct interdisciplinary, interagency workshop of PDRG

C. Revise PDRG to reflect peer review recommendations

D. Distribute revised PDRG to peer reviewers for comment

E. Incorporate final comments from peer reviewers on revisions into the PDRG

Task 5: Identify and Collect Data From Reference Wetlands

A. Identify reference wetland field sites

B. Collect data from reference wetland field sites

C. Analyze reference wetland data

Task 6: Calibrate and Field Test Assessment Models

A. Calibrate assessment variables using reference wetland data

B. Verify and validate (optional) assessment models

C. Field test assessment models for repeatability and accuracy

D. Revise PDRG based on calibration, verification, validation (optional), and
field testing results into a Calibrated Draft Regional Guidebook (CDRG)

Task 7: Conduct Peer Review and Field Test of Calibrated Draft Regional Guidebook

A. Distribute CDRG to peer reviewers

B. Field test CDRG

C. Revise CDRG to reflect peer review and field test recommendations

D. Distribute CDRG to peer reviewers for final comment on revisions

E. Incorporate peer reviewers' final comments on revisions

F. Publish Operational Draft Regional Guidebook (ODRG)

Task 8: Technology Transfer

A. Train end users in the use of the ODRG

B. Provide continuing technical assistance to end users of the ODRG

After organization and training, the first task of the team is to classify the wetlands within the region of interest into regional wetland subclasses using the principles and criteria of the Hydrogeomorphic Classification (Brinson 1993a; Smith et al. 1995). Next, focusing on the specific regional wetland subclass selected, the team develops an ecological characterization or functional profile of the subclass. The A-Team then identifies the important wetland functions, conceptualizes assessment models, identifies assessment variables to represent the characteristics and processes that influence each function, and defines metrics for quantifying assessment variables. Next, reference wetlands are identified to represent the range of variability exhibited by the regional subclass, and field data are collected and used to calibrate assessment variables and indices resulting from assessment models. Finally, the team develops the assessment protocols necessary for regulators, managers, consultants, and other end users to apply the indices to the assessment of wetland functions in the context of 404 Permit review. The following list provides the detailed steps involved in the general sequence described above.

During the Application Phase of the HGM Approach, the assessment variables, models, and protocols are used to assess wetland functions. This involves two steps. The first is to apply the assessment protocols outlined in the Regional Guidebook to complete the following tasks.

*a.* Define assessment objectives.

*b.* Characterize the project site.

*c.* Screen for red flags.

*d.* Define the Wetland Assessment Area.

*e.* Collect field data.

*f.* Analyze field data.

The second step involves applying the results of the assessment at various decision-making points in the permit review sequence, such as alternatives analysis, minimization, assessment of unavoidable impacts, determination of compensatory mitigation, design and monitoring of mitigation, comparison of wetland management alternatives or results, determination of restoration potential, or identification of acquisition or mitigation sites.

Each of the components of the HGM Approach that are developed and integrated into the Regional Guidebook is discussed briefly in the following paragraphs. More extensive treatment of these components can be found in Brinson (1993a,b; 1995a,b), Brinson et al. (1995, 1996, 1998), Smith et al. (1995), Hauer and Smith (1998), Smith (2001), Smith and Wakeley (2001), and Wakeley and Smith (2001).

## Hydrogeomorphic Classification

Wetland ecosystems share a number of common attributes including relatively long periods of inundation or saturation by water, hydrophytic vegetation, and hydric soils. In spite of these common attributes, wetlands occur under a wide range of climatic, geologic, and physiographic situations and exhibit a wide range of physical, chemical, and biological characteristics and processes (Ferren, Fiedler, and Leidy (1996); Ferren et al. 1996a,b; Mitch and Gosselink 1993; Semeniuk 1987; Cowardin et al. 1979). The variability of wetlands makes it challenging to develop assessment methods that are both accurate (i.e., sensitive to significant changes in function) and practical (i.e., can be completed in the relatively short time frame normally available for conducting assessments). "Generic" wetland assessment methods have been developed to assess multiple wetland types throughout the United States. In general, these methods can be applied relatively rapidly, but lack the resolution necessary to detect significant changes in function. One way to achieve an appropriate level of resolution within a rapid time frame (i.e., one day or less) is to employ an approach that focuses on a subset of the wetland universe, thereby reducing the level of variability that must be considered (Smith et al. 1995).

The HGM Classification was developed specifically to accomplish this task (Brinson 1993a). It identifies groups of wetlands that function similarly using three criteria that fundamentally influence how wetlands function. These criteria are geomorphic setting, water source, and hydrodynamics. Geomorphic setting refers to the landform and position of the wetland in the landscape. Water source refers to the primary source of water in the wetland, such as precipitation, overbank floodwater, or groundwater. Hydrodynamics refers to the level of energy and the direction that water moves in the wetland.

Based on these three criteria, any number of "functional" wetland groups can be identified at different spatial or temporal scales. For example, at a continental scale, Brinson (1993a,b) identified five HGM wetland classes. These were later expanded to the seven classes described in Table 1 (Smith et al. 1995). In some cases, the level of variability encompassed by wetlands at the continental scale of HGM class is still too great to allow for developing assessment indices that can be applied rapidly while retaining the level of sensitivity necessary to detect changes in function at a level of resolution appropriate to the 404 Permit review. For example, at a continental geographic scale, the depression class includes wetlands as diverse as California vernal pools (Zedler 1987), prairie potholes in North and South Dakota (Kantrud, Krapu, and Swanson 1989; Hubbard 1988), playa lakes in the high plains of Texas (Bolen, Smith, and Schramm 1989), kettles in New England, and cypress domes in Florida (Kurz and Wagner 1953, Ewel and Odum 1984).

In order to reduce both inter- and intraregional variability, the three classification criteria must be applied at a smaller, regional geographic scale to identify regional wetland subclasses. In many parts of the country, existing wetland classifications can serve as a starting point for identifying these regional subclasses (Stewart and Kantrud 1971; Golet and Larson 1974; Wharton et al. 1982; Ferren, Fiedler, and Leidy 1996; Ferren et al. 1996a,b). Regional subclasses, like the continental scale wetland classes, are distinguished on the basis of geomorphic setting, water source, and hydrodynamics. Examples of potential regional subclasses are shown in Table 2 (Smith et al. 1995; Rheinhardt, Brinson, and Farley 1997). In addition, certain ecosystem or landscape characteristics may also be useful for distinguishing regional subclasses in certain regions. For example, depression subclasses might be based on water source (i.e.,

**Table 1**
**Hydrogeomorphic Wetland Classes**

| HGM Wetland Class | Definition |
|---|---|
| Depression | Depression wetlands occur in topographic depressions (i.e., closed elevation contours) that allow the accumulation of surface water. Depression wetlands may have any combination of inlets and outlets or lack them completely. Potential water sources are precipitation, overland flow, streams, or groundwater/ interflow from adjacent uplands. The predominant direction of flow is from the higher elevations toward the center of the depression. The predominant hydrodynamics are vertical fluctuations that range from diurnal to seasonal. Depression wetlands may lose water through evapotranspiration, intermittent or perennial outlets, or recharge to groundwater. Prairie potholes, playa lakes, and cypress domes are common examples of depression wetlands. |
| Tidal Fringe | Tidal fringe wetlands occur along coasts and estuaries and are under the influence of sea level. They intergrade landward with riverine wetlands where tidal current diminishes and river flow becomes the dominant water source. Additional water sources may be groundwater discharge and precipitation. The interface between the tidal fringe and riverine classes is where bidirectional flows from tides dominate over unidirectional ones controlled by floodplain slope of riverine wetlands. Because tidal fringe wetlands are frequently flooded and water table elevations are controlled mainly by sea surface elevation, tidal fringe wetlands seldom dry for significant periods. Tidal fringe wetlands lose water by tidal exchange, by overland flow to tidal creek channels, and by evapotranspiration. Organic matter normally accumulates in higher elevation marsh areas where flooding is less frequent and the wetlands are isolated from shoreline wave erosion by intervening areas of low marsh. Spartina alterniflora salt marshes are a common example of tidal fringe wetlands. |
| Lacustrine Fringe | Lacustrine fringe wetlands are adjacent to lakes where the water elevation of the lake maintains the water table in the wetland. In some cases, these wetlands consist of a floating mat attached to land. Additional sources of water are precipitation and groundwater discharge, the latter dominating where lacustrine fringe wetlands intergrade with uplands or slope wetlands. Surface water flow is bidirectional, usually controlled by water level fluctuations resulting from wind or seiche. Lacustrine wetlands lose water by flow returning to the lake after flooding and evapotranspiration. Organic matter may accumulate in areas sufficiently protected from shoreline wave erosion. Unimpounded marshes bordering the Great Lakes are an example of lacustrine fringe wetlands. |
| Slope | Slope wetlands are found in association with the discharge of groundwater to the land surface or sites with saturated overland flow with no channel formation. They normally occur on sloping land ranging from slight to steep. The predominant source of water is groundwater or interflow discharging at the land surface. Precipitation is often a secondary contributing source of water. Hydrodynamics are dominated by downslope unidirectional water flow. Slope wetlands can occur in nearly flat landscapes if groundwater discharge is a dominant source to the wetland surface. Slope wetlands lose water primarily by saturated subsurface flows, surface flows, and evapotranspiration. Slope wetlands may develop channels, but the channels serve only to convey water away from the slope wetland. Slope wetlands are distinguished from depression wetlands by the lack of a closed topographic depression and the predominance of the groundwater/interflow water source. Fens are a common example of slope wetlands |
| Mineral Soil Flats | Mineral soil flats are most common on interfluves, extensive relic lake bottoms, or large alluvial terraces where the main source of water is precipitation. They receive virtually no groundwater discharge, which distinguishes them from depressions and slopes. Dominant hydrodynamics are vertical fluctuations. Mineral soil flats lose water by evapotranspiration, overland flow, and seepage to underlying groundwater. They are distinguished from flat non-wetland areas by their poor vertical drainage due to impermeable layers (e.g., hardpans), slow lateral drainage, and low hydraulic gradients. Mineral soil flats that accumulate peat can eventually become organic soil flats. They typically occur in relatively humid climates. Pine flatwoods with hydric soils are an example of mineral soil flat wetlands. |
| Organic Soil Flats | Organic soil flats, or extensive peatlands, differ from mineral soil flats in part because their elevation and topography are controlled by vertical accretion of organic matter. They occur commonly on flat interfluves, but may also be located where depressions have become filled with peat to form a relatively large flat surface. Water source is dominated by precipitation, while water loss is by overland flow and seepage to underlying groundwater. They occur in relatively humid climates. Raised bogs share many of these characteristics but may be considered a separate class because of their convex upward form and distinct edaphic conditions for plants. Portions of the Everglades and northern Minnesota peatlands are examples of organic soil flat wetlands. |
| Riverine | Riverine wetlands occur in floodplains and riparian corridors in association with stream channels. Dominant water sources are overbank flow or backwater from the channel or subsurface hydraulic connections between the stream channel and wetlands. Additional sources may be interflow, overland flow from adjacent uplands, tributary inflow, and precipitation. When overbank flow occurs, surface flows down the floodplain may dominate hydrodynamics. In headwaters, riverine wetlands often intergrade with slope, depressional, poorly drained flat wetlands, or uplands as the channel (bed) and bank disappear. Perennial flow is not required. Riverine wetlands lose surface water via the return of floodwater to the channel after flooding and through surface flow to the channel during rainfall events. They lose subsurface water by discharge to the channel, movement to deeper groundwater (for losing streams), and evapotranspiration. Peat may accumulate in off-channel depressions (oxbows) that have become isolated from riverine processes and subjected to long periods of saturation from groundwater sources. Bottomland hardwoods on floodplains are an example of riverine wetlands. |

**Table 2**
**Potential Regional Wetland Subclasses in Relation to Classification Criteria**

| Classification Criteria | | | Potential Regional Wetland Subclasses | |
|---|---|---|---|---|
| **Geomorphic Setting** | **Dominant Water Source** | **Dominant Hydrodynamics** | **Eastern United States** | **Western United States/Alaska** |
| Depression | Groundwater or interflow | Vertical | Prairie pothole marshes, Carolina bays | California vernal pools |
| Fringe (tidal) | Ocean | Bidirectional, horizontal | Chesapeake Bay and Gulf of Mexico tidal marshes | San Francisco Bay marshes |
| Fringe (lacustrine) | Lake | Bidirectional, horizontal | Great Lakes marshes | Flathead Lake marshes |
| Slope | Groundwater | Unidirectional, horizontal | Fens | Avalanche chutes |
| Flat (mineral soil) | Precipitation | Vertical | Wet pine flatwoods | Large playas |
| Flat (organic soil) | Precipitation | Vertical | Peat bogs; portions of Everglades | Peatlands over permafrost |
| Riverine | Overbank flow from channels | Unidirectional, horizontal | Bottomland hardwood forests | Riparian wetlands |

groundwater versus surface water) or the degree of connection between the wetland and other surface waters (i.e., the flow of surface water into or out of the depression through defined channels). Tidal fringe subclasses might be based on salinity gradients (Shafer and Yozzo 1998). Slope subclasses might be based on the degree of slope, landscape position, source of water (i.e., throughflow versus groundwater), or other factors. Riverine subclasses may be based on water source, position in the watershed, stream order, watershed size, channel gradient, or floodplain width. 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 the wetland sites selected to represent the range of variability that occurs in a regional wetland subclass as a result of natural processes and disturbance (e.g., succession, channel migration, fire, erosion, and sedimentation) as well as cultural alteration. The reference domain is the geographic area occupied by the reference wetlands (Smith et al. 1995). Ideally, the geographic extent of the reference domain will mirror the geographic area encompassed by the regional wetland subclass; however, this is not always possible due to time and resource constraints.

Reference wetlands serve several purposes. First, they establish a basis for defining what constitutes a characteristic and sustainable level of function across the suite of functions selected for a regional wetland subclass. Second, reference wetlands establish the range and variability of conditions exhibited by assessment variables and provide the data necessary for calibrating assessment variables and models. Finally, they provide a concrete physical representation of wetland ecosystems that can be observed and measured repeatedly.

Reference standard wetlands are the subset of reference wetlands that perform the suite of functions selected for the regional subclass at a level that is characteristic of the least altered wetland sites in the least altered landscapes. Table 3 outlines the terms used by the HGM Approach in the context of reference wetlands.

**Table 3**
**Reference Wetland Terms and Definitions**

| Term | Definition |
|---|---|
| Reference Domain | The geographic area from which reference wetlands representing the regional wetland subclass are selected (Smith et al. 1995). |
| Reference Wetlands | A group of wetlands that encompass the known range of variability in the regional wetland subclass resulting from natural processes and human alteration. |
| Reference Standard Wetlands | The subset of reference wetlands that perform a representative suite of functions at a level that is both sustainable and characteristic of the least human altered wetland sites in the least human altered landscapes. By definition, the functional capacity index for all functions in a reference standard wetland is 1.0. |
| Reference Standard Wetland Variable Condition | The range of conditions exhibited by assessment variables in reference standard wetlands. By definition, reference standard conditions receive a variable subindex score of 1.0. |
| Site Potential (mitigation project context) | The highest level of function possible given local constraints of disturbance history, land use, or other factors. Site potential may be less than or equal to the levels of function in reference standard wetlands of the regional wetland subclass. |
| Project Target (mitigation project context) | The level of function identified or negotiated for a restoration or creation project. |
| Project Standards (mitigation project context) | Performance criteria and/or specifications used to guide the restoration or creation activities toward the project target. Project standards should specify reasonable contingency measures if the project target is not being achieved. |

## Assessment Models and Functional Indices

In the HGM Approach, an assessment model is a simple representation of a function performed by a wetland ecosystem. The assessment model defines the relationship between the characteristics and processes of the wetland ecosystem and the surrounding landscape that influences the functional capacity of a wetland ecosystem. Characteristics and processes are represented in the assessment model by assessment variables. Functional capacity is the ability of a wetland to perform a specific function relative to the ability of reference standard wetlands to perform the same function. Assessment models result in a Functional Capacity Index (FCI) ranging from 0.0 - 1.0. The FCI is a measure of the functional capacity of a wetland relative to reference standard wetlands in the reference domain. Wetlands with an FCI of 1.0 perform the assessed function at a level that is characteristic of reference standard wetlands. A lower FCI indicates that the wetland is performing a function at a level below the level that is characteristic of reference standard wetlands.

For example, Equation 1 shows an assessment model that could be used to assess the capacity of a wetland to detain floodwater.

$$FCI = V_{FREQ} \times \left[ \frac{\left( V_{LOG} + V_{GVC} + V_{SSD} + V_{TDEN} \right)}{4} \right] \quad (1)$$

The assessment model has five assessment variables including: frequency of flooding ($V_{FREQ}$), which represents the frequency at which a wetland is inundated by overbank flooding, and the assessment variables of log density ($V_{LOG}$), ground vegetation cover ($V_{GVC}$), shrub and sapling density ($V_{SSD}$), and tree stem density ($V_{TDENS}$), which together represent resistance (i.e., roughness) to overbank floodwater within the wetland.

Assessment variables are ecological quantities that consist of five components (Schneider 1994). These include: (a) a name, (b) a symbol, (c) a metric and a procedure for measurement, (d) metric value (i.e., the numbers, categories, or numerical estimates that are generated by applying the procedural statement (Leibowitz and Hyman 1997)), and (e) units on the appropriate measurement scale. Table 4 provides several examples.

**Table 4**
**Components of an Assessment Variable**

| Name | Symbol | Metric and Procedure | Metric Value | Units (Scale) |
|---|---|---|---|---|
| Redoxomorphic features | $V_{REDO}$ | Metric: Status of redoxomorphic features<br>Procedure: Visual inspection of soil profile for redoxomorphic features | Present<br>Absent | Unitless (nominal scale) |
| Floodplain roughness | $V_{ROUGH}$ | Metric: Manning's Roughness Coefficient (n) Procedure: Observe wetland characteristics to determine adjustment values for roughness component to add to base value | 0.01<br>0.1<br>0.21 | Unitless (interval scale) |
| Tree biomass | $V_{TBA}$ | Metric: Tree basal area<br>Procedure: Measure diameter of trees in sample plots (cm), convert to area (m2), and extrapolate to per hectare basis | 5<br>12.8<br>36 | m2/ha<br>(ratio scale) |

Assessment variables occur in a variety of states or conditions. The state or condition of an assessment variable is denoted by the value of the metric used to assess a variable. For example, tree basal area, the metric used to assess tree biomass in a wetland, can be large or small, or recurrence interval, the metric used to assess frequency of overbank flooding, can be frequent or infrequent.

Based on the metric value, an assessment variable is assigned a variable subindex. When the metric value of an assessment variable is within the range of conditions exhibited by reference standard wetlands, a variable subindex of 1.0 is assigned. As the metric value deflects in either direction from the reference standard condition, the variable subindex decreases based on a defined relationship between metric values and functional capacity. Thus, as the metric value deviates from the conditions exhibited in reference standard wetlands, it receives a progressively lower subindex reflecting the decreased functional capacity of the wetland. Figure 2 illustrates the relationship between metric values of return interval ($V_{FREQ}$) and the variable subindex. As shown in the graph, when return interval is 2 years or less, a variable subindex of 1.0 is

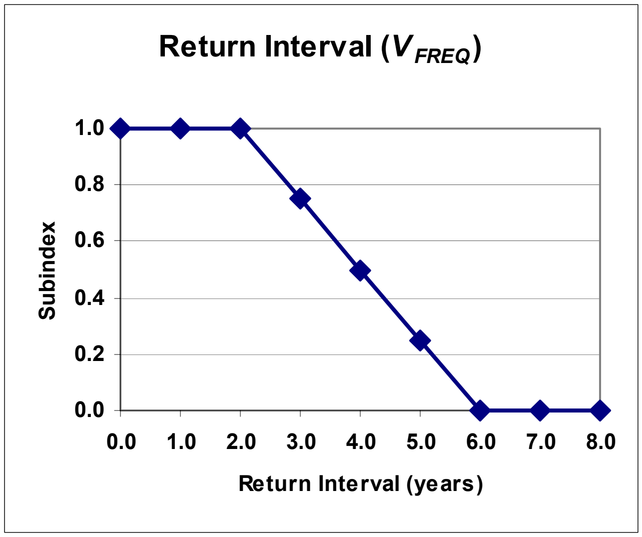


Figure 2. Subindex graph for the Return Interval ($V_{FREQ}$) assessment variable

assigned. This relationship is based on samples of reference standard wetlands where the condition of return interval was found to be 2 years or less.

In some cases, the variable subindex drops to 0. For example, when no trees are present, the subindex for tree basal area is 0. In other cases, the subindex for a variable does not drop to 0 because the metric value does not drop to 0. For example, regardless of the condition of a site, Manning's Roughness Coefficient ($n$), by definition, will always be greater than 0.

## Assessment Protocol

The final component of the HGM Approach is the assessment protocol. The assessment protocol is a defined set of tasks, along with specific instructions, that allows the end user to assess the functions of a particular wetland area using the assessment variables, assessment models, and functional indices in the Regional Guidebook. The first task is characterization of the wetland ecosystem and the surrounding landscape, describing the proposed project and its potential impacts, and identifying the wetland areas to be assessed. The second task is collecting the field data for assessment variables. The final task is an analysis that involves calculation of functional indices.

# 3 Characterization of Regional Wetland Subclasses in the Yazoo Basin

This chapter begins with a description of the Yazoo Basin reference domain, and then provides an overview of physical and biological characteristics of the reference domain. It concludes with descriptions of the HGM wetland classes and regional wetland subclasses that occur in the reference domain and guidelines for recognizing them in the field.

## Reference Domain

The reference domain for this guidebook is the portion of the Yazoo River Basin that occurs between Memphis, TN, and Vicksburg, MS, bounded on the east by the valley wall and on the west by the Mississippi River mainline levee system that controls Mississippi River flooding. (Figure 3). The reference domain does not include the non-alluvial portions of the Yazoo River Basin that lie east of the valley wall of the alluvial plain of the Lower Mississippi River Valley. In addition, the reference domain does not include the batture, the relatively narrow strip of land that occurs between the Mississippi River channel and the mainline levee system. The batture is subject to significantly different hydrologic regimes than the areas protected by the mainline levee system and is therefore excluded from the reference domain.

## Environment and Resources of the Yazoo Basin

All of the wetlands within the Yazoo Basin are on landforms created by the action of the Mississippi River or its tributaries. Cultural alteration within the Yazoo Basin has drastically affected both the hydrology of the basin and certain physical features that influence wetland conditions. Therefore, it is important to understand the geology and geomorphology of both the Lower Mississippi Valley as a whole and the Yazoo Basin, as well as the history and effects of human alterations to that landscape. Only in that context can the characteristics

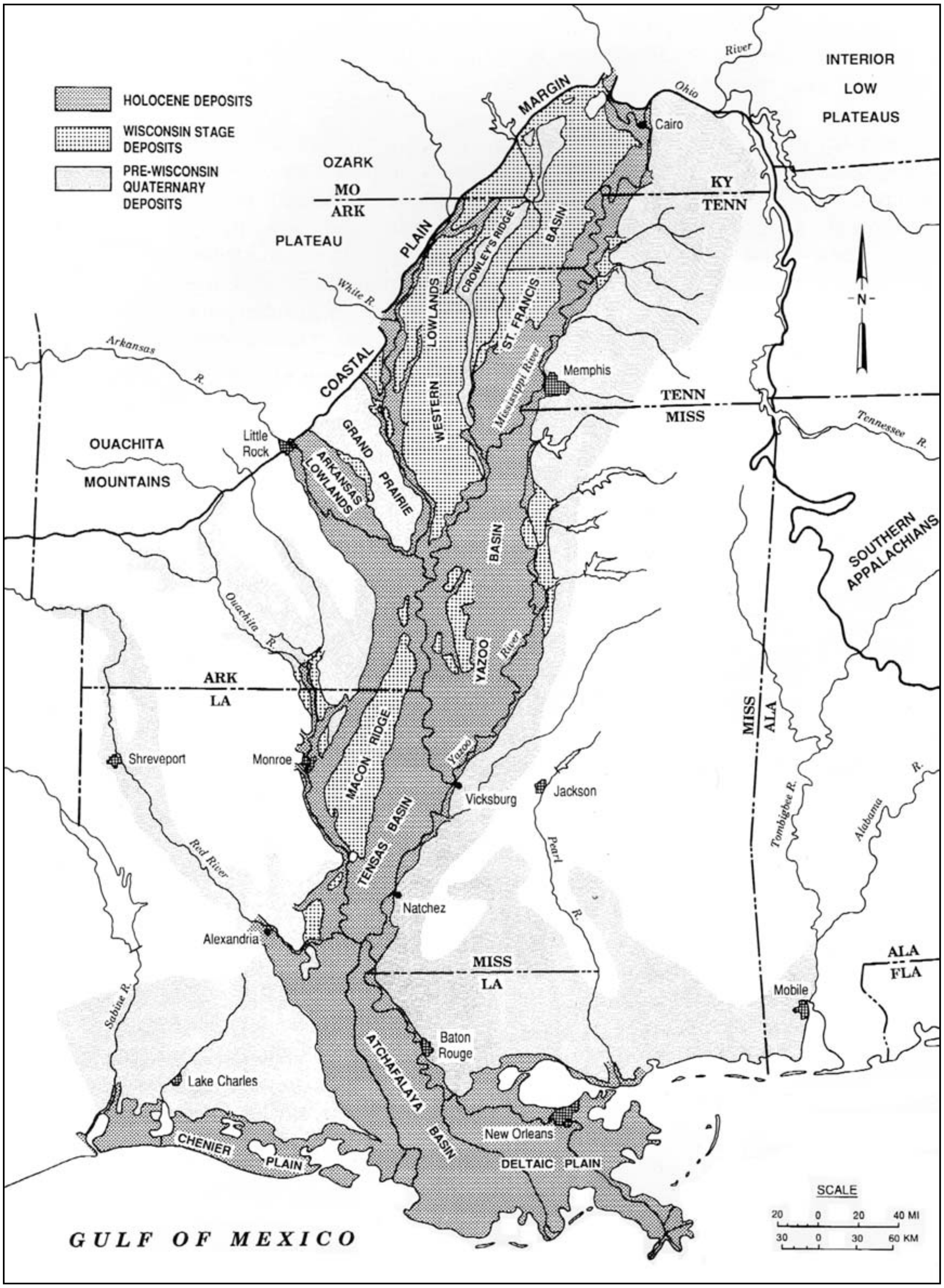


Figure 3. Mississippi Alluvial Valley (from Saucier 1994)

and functions of the wetlands within the basin be described in a manner consistent with the HGM Approach. The following subsections review major concepts that have bearing on the classification and functions of wetlands in the modern landscape of the Yazoo Basin.

## Physiography and Climate

The Yazoo Basin occurs within the Mississippi River Alluvial Plain Section of the Coastal Plain Physiographic Province. The Yazoo Basin is the largest of six major sub-basins within the Mississippi Alluvial Valley, occupying an area of approximately 20,000 $km^2$. The basin is approximately 800 km long and 80 to 160 km wide, with an average southward slope of about 11.3 cm/km (0.6 ft/mile) (Hunt 1967, Saucier 1994). Surface topography within the alluvial valley is defined by the characteristics of a deep alluvial fill that overlies Coastal Plain geologic formations and deeper Paleozoic and older rocks. The Mississippi Alluvial Valley is bounded on the east and west primarily by exposures of the Coastal Plain sediments.

Climate within the Yazoo Basin is humid subtropical, with temperate winters and long hot summers. Prevailing southerly winds carry moisture from the Gulf Coast, creating high humidity levels and a high incidence of thunderstorms. Tornadoes and ice storms occur commonly in the area (National Weather Service 1998). Monthly mean temperatures in the northern part of the basin range from a low in January of 5.5 °C (42 °F) to highs of 27.2 °C (81 °F) in July and August, with an overall annual average of 16.7 °C (62 °F). In the southern part of the area, average summer temperatures are one or two degrees warmer than the overall basin average, but January temperatures are about -13.8 °C (7 °F). Daily average maximum temperatures are 32.2 °C (90 °F) during June, July, and August throughout most of the area, and freezing temperatures reach the entire area for short periods in most years (Brown et al. 1971, Southern Regional Climate Center 1998).

Long-term average total precipitation does not vary greatly within the Yazoo Basin, ranging from about 127 to 132 cm (50-52 in.) per year, depending on location. Precipitation is highest from December to April with an average of more than 12 cm (4.7 in.) per month. August, September, and October are the lowest precipitation months, averaging less than 8 cm (3.1 in.) per month (National Weather Service 1998). Snow or sleet falls in the area in most years, but does not persist. The distribution of precipitation is such that excess moisture is present in the winter and spring months, and frequent soil moisture deficits occur through the months of May to October (Brown et al. 1971).

## Drainage System and Hydrology

The dominant drainage feature of the Mississippi Alluvial Valley is the Mississippi River, which formed the topography of the basin and thereby largely determined the configuration and locations of most of the existing wetlands and stream systems (see the following section, Geology and Geomorphology). Prior to construction of modern flood protection works, the Mississippi River also dominated the hydrology of the valley during major floods, and it continues to exert a major influence during high river stages by causing backwater flooding.

The drainage area of the Mississippi River basin is approximately 3,227,000 $km^2$, which is about 41 percent of the land area of the continental United States (USACE 1973). Major floods on the lower Mississippi River usually originate in the Ohio basin and can crest in any month from January to May. High flows that originate in the upper Mississippi River system generally occur in late spring and early summer (Tuttle and Pinner 1982).

Average flow of the Mississippi River at Vicksburg is 16,225 $m^3$/sec (573,000 $ft^3$/sec) , and 250 million tons of sediment are transported past that point annually (Bolton and Metzger 1998). Discharges during floods often have been 3 to 4 times the average flow; the 1927 flood peak discharge at Vicksburg was approximately 64,506 $m^3$/s (2,278,000 $ft^3$/s) (Tuttle and Pinner 1982). Seventeen major floods have occurred on the Lower Mississippi River since 1879. This is an average of one major flood every 7 years, but the actual interval between major events has ranged from 1 to 23 years (USACE-MVD 1998).

Prior to construction of modern levees, major Mississippi River floods would have inundated most or all of the Yazoo Basin (Moore 1972). However, modern mainstem levees that prevent Mississippi River overbank flooding do not completely eliminate the influence of the river on hydrology of the Yazoo Basin. High stages on the Mississippi River cause impeded drainage of tributary streams, which results in backwater flooding. An analysis of the major flood of 1973 (USACE 1973) indicated that the event would have inundated the entire Yazoo Basin had flood protection works not been in place; however, even though no Federal levees failed in the Lower Mississippi Valley, approximately 40 percent of the Yazoo Basin was flooded anyway, mostly due to backwater effects.

Except during major floods, surface water entering the Yazoo Basin arrives as precipitation or as runoff from the hills along the eastern flank of the basin. The only surface outlet is through the Yazoo River, which enters the Mississippi River at the southern end of the basin near Vicksburg (Figure 3). Most surface water discharge in the Yazoo River originates in the uplands along the eastern flank of the basin and is carried to the Yazoo via the Coldwater, Yocona, Tallahatchie, and Yalobusha Rivers as well as several smaller streams. Interior drainage is provided by numerous small streams that discharge to Deer Creek, the Big Sunflower River, Steele Bayou, or Bogue Phalia, which flow to the lower Yazoo River. The pattern of drainage within the basin is generally southward, but can be quite convoluted, reflecting the influence of a complex topography dominated by abandoned meander belts of the Mississippi River (Saucier 1994).

Groundwater also is a significant component of the hydrology of the Yazoo Basin. The geologic units that flank and underlie the alluvial valley include significant non-alluvial aquifers. In places, these are contiguous with the alluvial aquifer within the Mississippi Alluvial Valley, which occupies coarse-grained deposits that originated as glacial outwash and from more recent alluvial activity. Generally, the surface of the alluvial aquifer is within 10 m of the land surface and is approximately 38 m thick. It is essentially continuous throughout the Mississippi Alluvial Valley and constitutes one of the largest and most heavily used freshwater sources in the United States. Where the topstratum is made up of coarse sediments, the alluvial aquifer is recharged by surface waters and the aquifer subsequently contributes to stream baseflow during low-flow periods (Saucier 1994, O'Hara 1996).

All of the major elements of the drainage system and hydrology of the Yazoo Basin have been modified to varying degrees in historic times. At the time of European settlement, much of the Yazoo Basin was subject to: prolonged, extensive ponding following the winter wet season in virtually all years; localized short-term ponding following rains at any time of year; and extensive inundation within tributary flood basins due to rainfall in headwater areas in most years. During major flood events, large-scale backwater flooding influenced numerous tributary systems, and complete inundation of most, or all, of the basin occurred when Mississippi River stages were high enough to cause overbank flows. The engineering projects and agricultural activities which have incrementally altered, and continue to alter, these various sources of wetland hydrology are described in the Alterations to Environmental Conditions section of this chapter.

## Geology and Geomorphology

### Development of the Mississippi Alluvial Valley

The first comprehensive discussion of the geology and geomorphology of the Mississippi Alluvial Valley was presented by Fisk (1944). The only major reassessments since that work have been an overview by Autin et al. (1991) and a major synthesis by Saucier (1994). Unless otherwise attributed, the discussion below is derived primarily from the latter source.

The Mississippi Alluvial Valley had its origins in the continental rifting, warping, and uplifting that shaped the Mississippi Embayment, a massive syncline where Paleozoic rocks downwarp as much as 3,000 m. Areas of narrowing and changes in the orientation of the Lower Mississippi Valley reflect areas of uplift in west-central and southern Mississippi and in northeastern Louisiana and southeastern Arkansas. Faulting has occurred at various locations, but the effects are not particularly evident in most instances. However, faulting and uplift have occurred in recent times (Holocene) in the northern portion of the Lower Mississippi Valley in the area known as the New Madrid Earthquake Zone. Some of the more dramatic effects of this activity have occurred in historic times in the Reelfoot Lake area of western Tennessee, but there are no significant surface expressions of tectonic activity within the Yazoo Basin (Saucier 1994).

The modern valley is, for the most part, bounded by Tertiary and Mesozoic sediments of the Gulf Coastal Plain (Autin et al. 1991), although older rocks are present at the surface on Crowley's Ridge in Arkansas and parts of the western valley margin (Saucier 1994). Formations exposed in the bluffs flanking the eastern edge of the Yazoo Basin reflect environments of deposition ranging from marine (lowest) through estuarine, fluvial, and eolian (highest). As a result, streams draining the uplands and entering the Yazoo Basin are eroding a wide variety of materials, including limestone, marl, and thick clays deposited in marine and estuarine settings, as well as gravels and sands transported by flowing water from the Appalachians or the continental interior in the late Tertiary. They also carry wind-blown fine silts (loess) that originated in the glacial outwash carried down the Mississippi Valley during waning Wisconsin glacial cycles. In historic times, erosion rates have increased by orders of magnitude due to forest clearing and agriculture, particularly in the highly erodible loess deposits (Barnhardt 1988, Saucier 1994).

The modern Yazoo Basin is one of six major sub-basins within the Lower Mississippi Valley, and it must be understood in that context. Although the Lower Mississippi Valley developed as a result of the downwarping of Paleozoic rocks and confinement by uplifted surfaces, the characteristics of the existing landscape were shaped largely by erosion and deposition processes. By the end of the Tertiary, the downwarped surface had been largely filled by sediments transported from the north and upland flanks to the east and west. The ancestral Mississippi River was established in a valley smaller than the present, the source area (drainage area) was smaller than it is now, and the river had lower discharge. Pleistocene glaciation enlarged the river's drainage area by diverting formerly north-flowing rivers into the Mississippi system. Over an estimated 2.8 million years, periods of waxing and waning glaciation and associated changes in flows, sediment loads, and base level gradually produced a wider valley filled with thick alluvium, with the Mississippi and Ohio Rivers flowing on opposite sides of Crowley's Ridge and converging somewhere south of present-day Helena, Arkansas. This general configuration was maintained until late in the Wisconsin stage, when the Mississippi shifted east of the Ridge and the Ohio became confluent farther north. The alluvial landforms within the valley that resulted from glacial outwash during the Pleistocene epoch usually exhibit surface features characteristics of braided-stream deposition, such as relict braid bars and gathering channels. They dominate the alluvial valley north of the latitude of Memphis.

Glacial outwash deposition ceased within the Lower Mississippi Alluvial Valley at the beginning of the Holocene epoch, about 10,000 years ago. Sea level variation continued to influence depositional processes in the southernmost parts of the valley, but, in the central and northern portions of the Valley, all Holocene alluvial surfaces have been primarily the result of meandering stream processes, which have reworked much of the earlier braided-stream deposits and produced distinctly different landscape features. During Holocene times, the Mississippi and Arkansas Rivers, and various smaller streams, have reworked portions of the glacially deposited material within broad meander belts, and the larger streams have relocated and established new meander belts at various times. Within its meander belts, the Mississippi River has removed the pre-Holocene glacial outwash to an average depth of about 30 m (the average depth of the river channel) and replaced it with a complex of depositional features that include abandoned stream channels, abandoned stream courses, point bar deposits, and natural levees. Within the Yazoo Basin, the existence of six distinct Mississippi River meander belts is indicated. Each meander belt is 5 or more kilometers wide, but their characteristics vary, evidently reflecting differing levels of discharge in response to climatic variation or because they carried only part of the total discharge of the river, the remainder being carried by a separate channel. The current meander belt has been occupied and carrying the full flow of the Mississippi River for about 2,000 years. Because sedimentation rates are highest along the active stream channel, meander belts tend to develop into an alluvial ridge, where elevations are higher than the adjacent floodplain. The result is that local drainage is directed away from the major stream channel, and the areas between meander belts become basins that collect runoff, pool floodwaters, and accumulate fine sediments.

### Geomorphic features of the Yazoo Basin

The combination of Pleistocene alluvial terraces and modern (Holocene) floodplain features and depositional patterns has resulted in distinctive landforms that have been mapped in considerable detail throughout the valley (Figure 4). Within the Yazoo Basin, these landforms are categorized as valley trains, backswamps, point bars, abandoned channels, abandoned courses, and natural levees (Kolb et al. 1968, Saucier 1994). Each of these landforms is discussed and illustrated in the following paragraphs (Figure 5).

a. *Valley trains.* Valley trains are Pleistocene glacial outwash deposits from the Mississippi and Ohio Rivers, with surface features that reflect braided-stream depositional regimes. Although they make up about 54 percent of the Mississippi Alluvial Valley as a whole, they are of limited extent in the Yazoo Basin, where they have been largely eroded away by lateral channel migration or buried by deep sediments during recent (Holocene) times. The remnant valley train landscapes that occur in the northeastern and west-central part of the basin are evidently late Wisconsin in age, meaning they are at least 11,000 years old, but their precise age is not known. The topstratum of valley train deposits is a 1.5- to 3-m-thick layer of predominantly fine-grained material that forms a continuous blanket across the relict braided channels and interfluves but does not obscure their presence.

   The topstratum may include materials laid down during waning stages of glacial outwash deposition, loess, and slackwater overbank deposits from later Mississippi River meander belts. The buried channel systems on valley trains differ from abandoned channels within the Mississippi River meander belts in that the valley train channels tend to be filled with coarse sediments (massive sands) below the surface veneer of fine-grained material, whereas more recent channels are typically filled with fine-grained material throughout.

b. *Backswamps.* Backswamps are flat, poorly drained areas bounded by uplands and/or other features such as natural levees. In the Yazoo Basin, they are commonly found between the various past and present meander

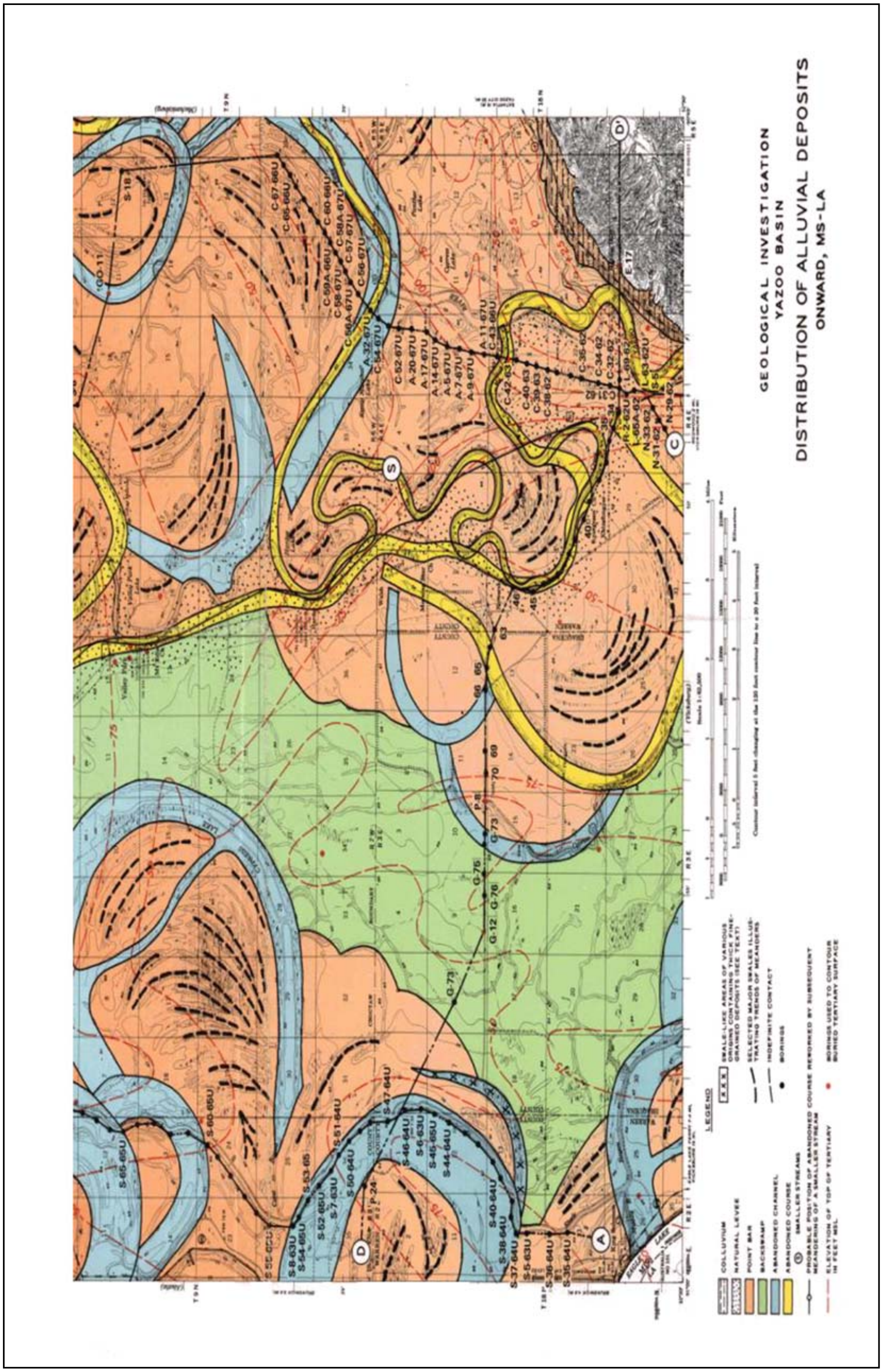


Figure 4. Principal geomorphic features of the Yazoo Basin (from Saucier 1994)

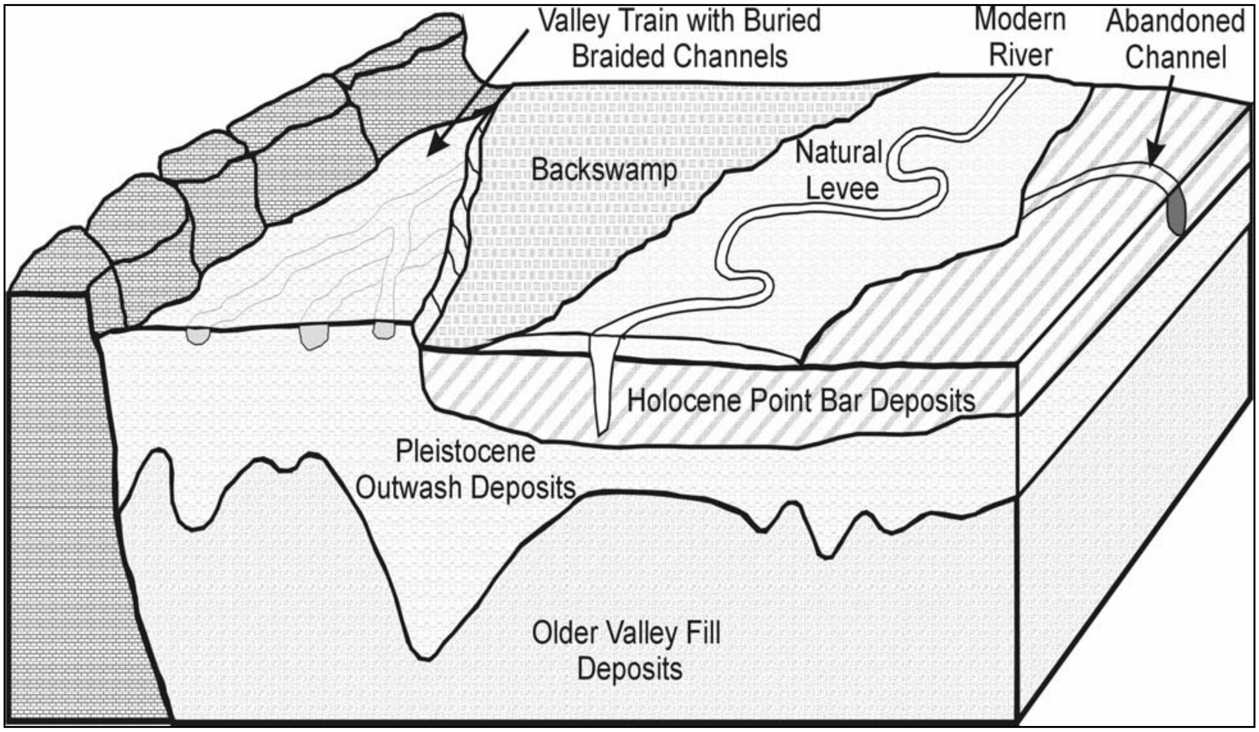


Figure 5. Block schematic of geomorphic features of the Yazoo Basin (from Saucier 1994)

belts of the Mississippi River or adjacent to the valley wall. Backswamp environments are underlain by coarse glacial outwash, but surface deposits are fine-grained sediments that were slowly deposited in slack-water conditions. Thus, under unmodified conditions, backswamps characteristically have substrates of massive clays and are incompletely drained by small, sometimes anastomosing, streams. They may include large areas that do not fully drain through channel systems but remain ponded well into the growing season. In much of the Mississippi Alluvial Valley, backswamp deposits are 12 m thick or more, although they tend to be somewhat thinner in the south-central portion of the Yazoo Basin.

Note that sites mapped as valley train and backswamp have essentially the same sequence of deep, coarse glacial outwash overlain by fine-grained slackwater deposits. The basis for separating them as map units is the thickness of the fine-grained deposits; they are mapped as backswamp where the surface deposits are sufficiently thick to obscure the braided channel pattern on the valley train surface. On valley trains, surface deposits (other than those from historic erosion) are typically older and thinner and occupy better-drained landscape positions than similar fine-grained deposits of backswamps.

c. *Point bars.* Point bar deposits predominate within the Yazoo Basin. They generally consist of relatively coarse-grained materials (silts and sands) laid down on the inside (convex) bend of a migrating stream channel. The rate at which point bar deposition occurs and the height and width of individual deposits vary with sediment supply, flood stage, and other factors. The result is a characteristic topography of low arcuate ridges separated by swales. Point bar swales range from narrow and shallow to broad and deep and usually are closed at each end to form depressions. The scale and depth of point bar swales depend on the depositional environment that formed the adjacent ridges and the degree of sedimentation within the swale since it formed.

d. *Abandoned channels.* These features are the result of cutoffs, where a stream abandons a channel segment either because flood flows have scoured out a point bar swale and created a new main channel (chute cutoff) or because migrating bendways intersect and channel flow moves through the neck (neck cutoff). Chute cutoffs tend to be relatively small and to fill rapidly with sediment. They do not typically form lakes, but may persist as large depressions. The typical sequence of events following a neck cutoff (which is much more common than a chute cutoff) is that the upper and lower ends of the abandoned channel segment quickly fill with coarse sediments, creating an open oxbow lake. Usually, small connecting channels (batture channels) maintain a connection between the river and the lake, at least at high river stages; so river-borne fine-grained sediments gradually fill the abandoned channel segment. If this process is not interrupted, the lake eventually fills completely, the result being an arcuate swath of cohesive, impermeable clays within a better-drained point bar deposit. Often, however, the river migrates away from the channel segment and the hydraulic connection is lost, or the connection is interrupted by later deposition of point bar or natural levee deposits. In either case, the filling process is dramatically slowed, and abandoned channel segments may persist as open lakes or depressions of various depths and dimensions.

e. *Abandoned courses.* An abandoned course is a stream channel segment left behind when a stream diverts flow to a new meander belt. Abandoned course segments can be hundreds of miles long, or only short segments may remain where the original course has been largely obliterated by subsequent stream activity. There are a variety of possible fates for abandoned courses. In some cases, they are captured by smaller streams, which meander within the former channel and develop their own point bars and other features. Within the Yazoo Basin, much of the Tallahatchie and Yazoo Rivers, and portions of many smaller streams, flow within abandoned courses of the Mississippi River. Where the stream course is abandoned gradually, the remnant stream may fill the former channel with point bar deposits even as its flow declines. Thus, while abandoned channels often become depressions with heavy soils, abandoned courses are more likely to be fairly continuous with the point bar deposits of the original stream or to become part of the meander belt of a smaller stream.

f. *Natural levees.* A natural levee forms where overbank flows result in deposition of relatively coarse sediments (sand and silt) adjacent to the stream channel. The material is deposited as a continuous sheet that thins with distance from the stream, resulting in a relatively high ridge along the bankline and a gradual backslope that becomes progressively more fine-grained with distance from the channel. Along the modern Mississippi River, natural levees rise about 4.5 m above the elevation of the adjacent floodplain and may extend for several kilometers or more from the channel. Natural levees formed by smaller streams or over short periods of time tend to be proportionately smaller, but the dimensions and composition of natural levee deposits are the product of various factors, including sediment sources and the specific mode of deposition. Natural levees may be deposited in association with sheetflow or as a series of crevasse splays, which are deltaic deposits formed by small channels that breach the existing natural levee during high flows.

A different type of crevasse splay occurs where man-made levees have been breached during major floods. These splays have an irregular, hummocky surface, and are composed of very coarse sediments, may be very extensive. They are the result of very high-velocity flows, because the initial levee break releases water that has a surface much higher than the adjacent land surface. Often, the point at which the levee failed is marked by a deep scour pool, commonly called a "blue hole."

## Soils

Parent materials of soils in the Yazoo Basin are fluvial sediments. The periodic influx of glacial outwash and subsequent development of multiple Mississippi River meander belts produced complex but characteristic landforms where sediments are sorted to varying degrees based on their mode and environment of deposition. The sorting process has produced textural and topographic gradients that are fairly consistent on a gross level and result in distinctive soils. Generally, within a meander belt, surface substrates grade from relatively coarse-textured, well-drained, higher elevation soils on natural levees directly adjacent to river channels through progressively finer-textured and less well-drained materials on levee backslopes and point bar deposits to very heavy clays in closed basins within large swales and abandoned channels. Backswamp deposits between meander belts are also heavy clays. Valley train deposits typically have a topstratum (upper 1.5-3 m) of fine-grained material (clays and silts) that blankets the underlying network of braided channels and bars (Brown et al. 1971, Saucier 1994).

The gradient of increasingly fine soil textures from high-energy to low-energy environments of deposition (natural levees and point bars to abandoned channels and backswamps) implies increasing soil organic matter content, increasing cation exchange capacity, and decreasing permeability. However, all of these patterns are generalizations, and quite different conditions occur regularly. The nature of alluvial deposition varies between and within flood events, and laminated or localized deposits of varying textures are common within a single general landform. Thus, natural levees dominated by coarse-textured sediments may contain strata with high clay content, and valley train surfaces that are usually fine-grained may have some soil units with high sand content. Point bar deposits, which typically have less organic matter incorporated into the surface soils than backswamps or abandoned channels, may actually contain more total organic matter on a volume basis due to the presence of large numbers of buried logs and other stream-transported organic material (Saucier 1994).

Climate also has had significant influence on soil development, particularly with respect to organic matter accumulation and weathering processes. In general, the A horizons of soils in the Yazoo Basin are lighter than those in more northerly portions of the Mississippi Alluvial Valley where colder temperatures and lower rainfall inhibit the oxidation of organic material. Similarly, soils to the south of the Yazoo Basin also have dark A horizons due to a longer growing season and more evenly distributed precipitation, which promote high plant productivity and maintain equilibrium between organic matter gains and losses (Brown et al. 1971).

Soils of older meander belts are likely to show greater A soil horizon development than soils in equivalent positions within younger meander belts (Autin et al. 1991). Similarly, older soils are likely to be more acid and deeper, show less depositional stratification and more horizonation, and have other characteristics of more advanced soil development than soils of younger meander belts. The classification of soils in the region reflects the importance of soil age and related development at the highest classification level (Soil Order). Alfisols are the oldest and most developed soils; Entisols are the most recent deposits with the least development; and Inceptisols are of intermediate age and development. At the suborder level, degree of wetness is a major classification factor, and, at lower levels of classification, the characteristics of specific soil horizons are among the principal discriminating factors. A brief overview of the principal soil associations within the Yazoo Basin is presented in Table 5.

Table 6 contrasts selected characteristics of soils on surfaces of increasing age (meander belt 1 is youngest, 5 is oldest) for relatively coarse-textured (Commerce-Mhoon-Dundee) and clayey (Sharkey-Alligator) deposits. Note that “pedogenic succession” is more pronounced in the coarser materials (Autin et al. 1991). The distribution of the major associations in the Yazoo Basin is illustrated in Figure 6. It should be noted that the classification of soils within the Yazoo Basin has been undergoing considerable modification recently. However, the existing soil surveys and maps do not reflect these changes; therefore, the classification and terminology used in this discussion remain consistent with the existing published resources.

## Vegetation

The Yazoo Basin is in the east-central portion of the Mississippi Alluvial Plain Ecoregion (Omernik 1987, USEPA 1998). It is included in the Mississippi Alluvial Plain Section of the Southeastern Evergreen Forest Region of Braun (1950) and is classified as the Southern Floodplain Forest Type of Kuchler

**Table 5**
**Classification of the Principal Soil Associations of the Yazoo Basin (after U.S. Department of Agriculture-SCS-MAFES 1974 and U.S. Department of Agriculture-NRCS 1998b)**

| | |
|---|---|
| **Order Alfisols: Soils that are medium to high in bases and have gray to brown A horizons and B horizons of clay accumulation.** | |
| **Suborder Aqualfs: Seasonally wet Alfisols that have mottles, iron-manganese concretions, or gray colors.** | |
| **Great Group Ochraqualf (now called Endoaqualfs): Dominantly wet soils with a gradual change in texture from the A horizon to the B horizon of clay accumulation.** | |
| A-2 | Dundee-Dubbs association<br>Nearly level or gently sloping and somewhat poorly drained; and well-drained silty soils on natural levees. |
| A-3 | Dundee-Forestdale-Dubbs association<br>Nearly level or gently sloping and somewhat poorly drained silty soils; poorly drained soils with silty A horizons and clayey B-horizons; and well-drained silty soils on natural levees. |
| A-4 | Forestdale-Alligator association<br>Nearly level, poorly drained soils with silty A horizons and clayey B-horizons on natural levees; and poorly drained, clayey soils on floodplains. |
| **Suborder Udalfs: Alfisols that are usually moist but, during the warm season of the year, may be intermittently dry in some horizons for short periods.** | |
| **Great Group Hapludalfs: Dominantly soils with light colored A horizons and brownish or reddish moderately thick B horizons of clay accumulation.** | |
| A-10 | Dubbs-Dundee association<br>Nearly level and gently sloping, well-drained and somewhat poorly drained silty soils on natural levees. |
| **Order Entisols: Soils that have no little or evidence of development of pedogenic horizons.** | |
| **Suborder Aquents: Entisols that are wet for long periods and have gray colors.** | |
| **Great Group Fluvaquents: Dominantly wet soils of floodplains with a content of organic matter that decreases irregularly with depth.** | |
| E-3 | Commerce-Robinsonville-Crevasse association<br>Nearly level, somewhat poorly drained, silty soils; well-drained, loamy soils; and excessively drained, sandy soils. |
| E-5 | Commerce-Tunica-Bowdre association<br>Nearly level, somewhat poorly drained, silty soils; and poorly drained and somewhat poorly drained, clayey over loamy soils. |
| E-6 | Falaya-Collins-Waverly association<br>Nearly level, somewhat poorly drained, moderately well-drained, and poorly drained, acid, silty soils. |
| **Suborder Fluvents: Dominantly soils that are brownish colored, are rarely wet, and have a content of organic matter that decreases irregularly with depth.** | |
| **Great Group Udifluvents: Dominantly soils of floodplains that are usually moist.** | |
| E-11 | Morganfield-Adler association<br>Nearly level, well-drained and moderately well-drained, nonacid, silty soils. |
| **Order Inceptisols: Soils that have weakly differentiated horizons; materials in the soil have been altered or removed but have not accumulated.** | |
| **Suborder Aquepts: Inceptisols that are seasonally wet and have gray colors** | |
| **Great Group Haplaquepts: Dominantly wet soils with a light colored or a thin dark A horizon.** | |
| I-1 | Alligator association<br>Nearly level, poorly drained, acid, clayey soils in backswamp areas of the floodplain. |
| I-2 | Alligator-Forestdale association<br>Nearly level, poorly drained, clayey soils on floodplains; and poorly drained soils with thin silty A horizons and clayey B horizons on natural levees. |
| I-4 | Sharkey association<br>Nearly level, poorly drained, nonacid, clayey soils on floodplains. |
| I-5 | Sharkey-Alligator association<br>Nearly level, poorly drained, nonacid and acid, clayey soils on floodplains. |
| I-6 | Sharkey-Commerce association, frequently flooded<br>Nearly level, poorly drained, nonacid, clayey soils; and somewhat poorly drained, nonacid, silty soils. |
| I-7 | Sharkey-Tunica association<br>Nearly level, poorly drained, nonacid, clayey soils; and somewhat poorly drained, nonacid, clayey over loamy soils on floodplains. |

**Table 6**
**Comparisons of Typical Landscape Settings and Soil Development for Selected Soil Series in the Yazoo Basin. (Adapted from Autin et al. 1991, with supplemental information from Brown et al. 1971 and U.S. Department of Agriculture-NRCS 1998a)**

| Characteristics | Mississippi River Meander Belts[1] | | | | |
|---|---|---|---|---|---|
| | 1,2 | 1,2 | 3,4,5 | 1,2,3 | 3,4,5 |
| Soil Series | Commerce | Mhoon | Dundee | Sharkey | Alligator |
| Classification | Aeric Fluvaquent | Typic Fluvaquent | Aeric Ochraqualf | Vertic Haplaquept | Vertic Haplaquept |
| Geomorphic setting | levee crest and backslope | levee backslope | levee, low terraces | levee backslope. backswamp | backswamp, low terraces, (valley train) |
| Solum thickness, cm | 50-100 | 50-125 | 60-150 | 90-150 | 100-150 |
| Typical horizon sequence | A-B-C | A-Bg-Cg | A-Btg-Bg-Cg | A-Bg-Cg | A-Bg-Cg |

[1] Of the meander belts included here, meander belt 1 is the active meander belt of the Mississippi River and meander belt 5 is the oldest.

(1969). Forests of the basin are referred to as bottomland hardwoods, a term which incorporates a wide range of species and community types, all of which can tolerate inundation or soil saturation for at least some portion of the growing season (Wharton et al. 1982). Bottomland hardwood forests are among the most productive and diverse ecosystems in North America. Under presettlement conditions, they were essentially continuous throughout the Lower Mississippi Valley, and they interacted with the entire watershed, via floodwaters, to import, store, cycle, and export nutrients (Brinson et al. 1980, Wharton et al. 1982). Although these conditions have changed dramatically in modern times (see the following section, Alterations to Environmental Conditions), the remaining forests still exist as a complex mosaic of community types that reflect variations in alluvial and hydrologic environments. Within-stand diversity varies from dominance by one or a few species to forests with a dozen or more overstory species and diverse assemblages of understory, ground cover, and vine species (Putnam 1951, Wharton et al. 1982, Wiseman 1982, Klimas 1988). These forests support a detritus-based trophic network that includes numerous resident and migratory wildlife species that are adapted to the highly dynamic and diverse environment (Fredrickson 1978, Wharton et al. 1982).

Most major overviews of bottomland hardwood forest ecology emphasize the relationship between plant community distribution and inundation, usually assuming that floodplain surfaces that occupy different elevations in relation to a river channel reflect different flood frequency, depth, and duration (e.g., Wharton and Brinson 1978, Brinson et al. 1981, Larson et al. 1981, Wharton et al. 1982). This leads to classification of forests in terms of hydrologic "zones," each zone having characteristic plant communities. In most cases, the authors employing zonal classification systems acknowledge that parallel bands of vegetation rarely exist and that most floodplains are geomorphically complex and support mosaics of communities. Nevertheless, zonal characterization systems generally reference most sites to a presumed stream entrenchment process that leaves a sequence of terraces, and they often regard features such as natural levees as relatively minor components of the landscape (e.g., Larson et al. 1981). A certain degree of such sequential zonation occurs in some major stream drainages within the Mississippi

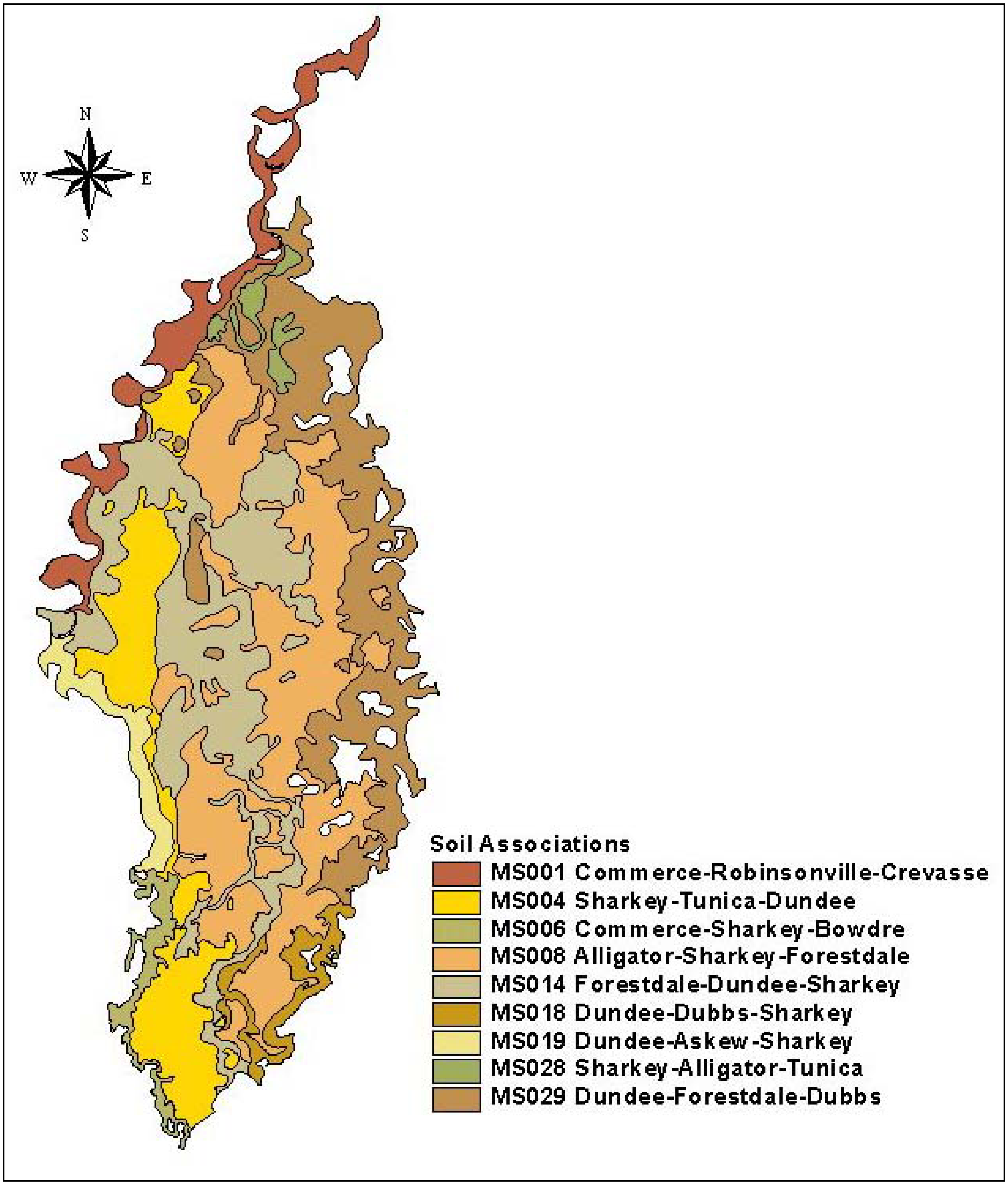


Figure 6. Major soil associations of the Yazoo Basin

Alluvial Valley, such as the Cache River in Arkansas (Smith 1996). However, zonal concepts have limited utility in the Yazoo Basin, where multiple meander belts of the Mississippi River dominate the landscape. All major stream systems that internally drain the basin are either captured by these meander belts or are constrained between them and have not formed a series of abandoned floodplain "terraces." In the Yazoo Basin, the term "terrace" generally refers to glacial outwash valley train deposits rather than abandoned floodplains of extant tributary streams. Features such as natural levees and abandoned channels, which may be rather minor components of some southeastern floodplains, are major deposits that occupy thousands of square kilometers in the Yazoo Basin. In much the same way, the general zonal models imply that the principal hydrologic controls on community composition are flood frequency, depth, and duration, as indicated by elevation relative to a stream channel. As described previously, overbank flooding is just one of many important sources of water in the wetlands of the Yazoo Basin, and factors such as ponding of precipitation may be more important than flooding effects in many landscape settings.

Despite the complexity of the landscape and the limited applicability of zonal models of plant community distribution, plant communities do occur on recognizable combinations of site hydrology and geomorphology within the Yazoo Basin. The synthesis documents of Putnam (1951) and Putnam, Furnival, and McKnight (1960) adopt a perspective that recognizes the unique terrain of the Mississippi Alluvial Valley and summarize the principal combinations of landscape setting, drainage characteristics, and flood environment as they influence plant community composition. Table 7 is based on that approach. Table 8 equates Putnam's (1951) community types with corresponding community designations in the most commonly referenced forest classification system, the Society of American Forester's (SAF) cover types (Eyre 1980).

Under natural conditions, forest stands within the Yazoo Basin undergo change at various temporal and spatial scales. Primary succession occurs on recently deposited substrates, which include abandoned stream channels, point bars, crevasse splays, and abandoned beaver ponds. One familiar example is the colonization of new bars adjacent to river channels by black willow (*Salix nigra*), which is replaced over time by other species such as sugarberry (*Celtis laevigata*) and green ash (*Fraxinus pennsylvanica*) and eventually by long-lived, heavy-seeded species such as oaks (*Quercus* sp.) and hickories (*Carya* sp.) (Putnam, Furnival, and McKnight 1960, Meadows and Nowacki 1996). Although this sequential replacement does occur, it is actually a complex process that includes changes in the elevation and composition of the substrate as colonizing plants and flood flows interact to induce sedimentation and, on a longer-term scale, as soils mature and river channels migrate away from the site and cease delivering large volumes of new sediments. In the Yazoo Basin, creation and colonization of new point bars is limited, because many of the internal streams are deeply entrenched within old Mississippi River channels or have been channelized and do not migrate significantly. Creation of other new substrates due to Mississippi River channel migration and overbank flows has been curtailed in the Yazoo Basin by levee construction and bank stabilization projects (Klimas 1991).

**Table 7**
**Composition and Site Affinities of Common Forest Communities in the Yazoo Basin (after Putnam 1951)**

| Forest Cover Type | Characteristic Species | Site Characteristics |
|---|---|---|
| Sweetgum - water oaks | *Liquidambar styraciflua*<br>*Quercus nigra*<br>*Quercus nuttallii*<br>*Quercus phellos*<br>*Ulmus americana*<br>*Celtis laevigata*<br>*Fraxinus pennsylvanica* | In first bottoms except for deep sloughs, swamps, fronts, and poorest flats. Also on terrace flats. |
| White oaks - red oaks - other hardwoods | *Quercus michauxii*<br>*Quercus stellata* var. *paludosa*<br>*Quercus falcata* var. *pagodifolia*<br>*Quercus shumardii*<br>*Quercus falcata* var. *falcata*<br>*Fraxinus americana*<br>*Carya* spp.<br>*Nyssa sylvatica*<br>*Ulmus alata* | Fine, sandy loam and other well-drained soils on first bottom and terrace ridges. |
| Hackberry - elm - ash | *Celtis laevigata*<br>*Ulmus americana*<br>*Fraxinus pennsylvanica*<br>*Carya aquatica*<br>*Quercus phellos* | Low ridges, flats, and sloughs in first bottoms, terrace flats, and sloughs. Occasionally on new lands or fronts. |
| Overcup oak - water hickory | *Quercus lyrata*<br>*Carya aquatica* | Poorly drained flats, low ridges, sloughs, and backwater basins with tight soils. |
| Cottonwood | *Populus deltoides*<br>*Carya illinoensis*<br>*Platanus occidentalis*<br>*Celtis laevigata* | Front land ridges and well-drained flats. |
| Willow | *Salix nigra* | Front land sloughs and low flats. |
| Riverfront hardwoods | *Platanus occidentalis*<br>*Carya illinoensis*<br>*Fraxinus pennsylvanica*<br>*Ulmus americana*<br>*Celtis laevigata*<br>*Acer saccharinum* | All front lands except deep sloughs and swamps. |
| Cypress - tupelo | *Taxodium distichum*<br>*Nyssa aquatica*<br>*Nyssa sylvatica* var. *biflora* | Low, poorly drained flats, deep sloughs, and swamps in first bottoms and terraces. |

**Table 8**
**Correspondence Between Putnam's Community Forest Cover Types in the Yazoo Basin and Standard Society of American Foresters (SAF) Forest Cover Type Designations**

| SAF Forest Cover Types [1] | Type # | Putnam's Cover Type[2] |
|---|---|---|
| Cottonwood | 63 | Cottonwood |
| Willow Oak - water oak - diamondleaf (Laurel) oak | 88 | Sweetgum - water oaks |
| Swamp chestnut oak- cherrybark oak | 91 | White oaks - red oaks - other hardwoods |
| Sweetgum - willow oak | 92 | Sweetgum - water oaks |
| Sugarberry - American elm - green ash | 93 | Hackberry - elm - ash |
| Sycamore - sweetgum - American elm | 94 | Riverfront hardwoods |
| Black willow | 95 | Willow |
| Overcup oak - water hickory | 96 | Overcup oak - bitter pecan |
| Baldcypress | 101 | Cypress - tupelo |
| Baldcypress - tupelo | 102 | Cypress - tupelo |
| Water tupelo - swamp tupelo | 103 | Cypress - tupelo |

[1] SAF forest cover type naming conventions.
[2] Putnam (1951).

Typically, natural regeneration processes in established forest stands are initiated within small forest openings that occur due to windthrow, disease, lightning strikes, and similar influences that kill individual trees or small groups of trees (Dickson 1991) or in larger openings caused by fire, prolonged flooding (especially due to beaver), tornados, hurricanes, or ice storms. The resulting openings are rapidly colonized, but the composition of the colonizing trees may vary widely depending on factors such as existing advanced reproduction, seed rain from adjacent mature trees, and importation of seed by animals or floodwaters. Often, this pattern results in small, even-aged groves of trees, sometimes of a single species (Putnam, Furnival, and McKnight 1960).

Under presettlement conditions, fire may have been a significant factor in stand structure, but the evidence regarding the extent of this influence is unclear. Putnam (1951) stated that southern bottomland forests experience a “serious fire season” every 5-8 years and that fires typically destroy much of the understory and cause damage to some larger trees that eventually provides points of entry for insects and disease. Similarly, it is difficult to estimate the influence of beaver in the presettlement landscape, because they were largely removed very early in the settlement process. However, it is likely that widespread beaver activity resulted in extensive areas of dead timber, open water, marsh, moist soil, and shrub swamp at any given time.

## Alterations to Environmental Conditions

The physical and biological environment of the Yazoo Basin has been extensively altered by human activity. Isolation and stabilization of the Mississippi River have effectively halted the large-scale channel migration and overbank sediment deposition processes that have continually modified the Yazoo Basin over the past 10,000 years (Smith and Winkley 1996). At the same time, sediment input to depressions and sub-basins within the area has increased manyfold in historic times due to erosion of uplands and agricultural fields (Barnhardt 1988, Smith and Patrick 1991, Saucier 1994). The Mississippi River no longer overwhelms the landscape with floods that course through the basin, but it continues to influence large areas through backwater effects. Patterns of land use and resource exploitation have had differential effects on the distribution and quality of remaining forest communities. Assessment of wetland functions in this highly modified landscape requires an understanding of the scope of some of the more ubiquitous changes that have taken place.

### Land use and management

Natural levees, which commonly are the highest elevations in the landscape of the Yazoo Basin and often are in direct proximity to water, have been the focus of human settlement during both prehistoric and historic times (Saucier 1994). At the time of European settlement, natural levees were extensively used for maize agriculture by Native Americans. By the time detailed surveys of the Mississippi River were made in the 1880s, there were extensive agricultural fields on the natural levees adjacent to the Mississippi River through the entire reach bordering the Yazoo Basin (Mississippi River Commission 1881-1897). Lower terrain had not been similarly developed, however, and in 1879 less than 10 percent of the Yazoo Basin had been cleared. With improved flood control and farming equipment, conversion of forested land to agriculture progressed to other sites. From an estimated original area of 9 to 10 million hectares, Mississippi Alluvial Valley forests were reduced by about 50 percent by 1937, and, currently, less than 25 percent of the original area remains forested (Smith, Hamel, and Ford 1993). Much of the remaining forest is highly fragmented, with the greatest degree of fragmentation occurring on drier sites (such as natural levees) and the largest remaining tracts being in the wettest areas (Rudis 1995). The differential conversion of higher, drier sites to agriculture may be a major contributing factor in the near disappearance of the extensive stands of cane (*Arundinaria gigantea*), which many early travelers remarked upon as common features of the natural levees (Remsen 1986, Dickson 1991). Within the Yazoo Basin, approximately 10 percent of the original forest area remains.

Nearly all of the remaining forests within the basin have been harvested at least once, and many are in a degraded condition due to past high-grading practices (Putnam 1951, Rudis and Birdsey 1986). However, large intact tracts remained in the interior lowlands until at least the mid 1930s. Conarro (undated) described his efforts to purchase forested land in the Yazoo Basin on behalf of the U.S. Forest Service in 1935 (the origins of the Delta National Forest). He mentioned the purchase of "14,000 acres of virgin timber" (for $55 per acre), much of which he immediately marked for a timber sale. He also mentioned another "large block of virgin hardwood" that was currently being cut by a lumber company, and he noted his interest in purchasing another tract of "about 46,000 acres of land from which the redgum and other high-grade species had been removed."

Limited old-growth areas are protected within the Research Natural Area system on Delta National Forest, but most of the remaining forests are in various stages of recovery from past harvests, and many of the current stands of mature forest date from a period of intensive harvest activity in the 1930s and 1940s. Clearly, many of these stands originated from high-graded stands, and many have been subjected to additional selective harvests, some with the objective of timber stand improvement. Not all of the current forests are in a "managed" condition by any means, and very few are in any condition that reflects the "natural" development of forested stands over many generations.

Forest management has shifted to an emphasis on wildlife habitat in recent decades on many of the remaining large tracts. Much of this has come about as an attempt to mitigate some of the impacts of flood control and navigation projects within the Yazoo Basin and elsewhere in the region. Parts of the Delta National Forest were converted to green-tree reservoirs in the 1980s in an attempt to provide habitat for wintering waterfowl. Management of these areas requires pumping water into shallow, forested impoundments during late fall (Bolton and Metzger 1998). Water management systems have also been constructed within existing national wildlife refuge lands (Young 1998), and large forest tracts have been converted to wildlife management areas. Approximately 5,600 ha of former bottomland forest and wetlands that had been converted to agriculture have been replanted, and more than 7,000 ha are scheduled for acquisition and reforestation in the future (Young 1998). In addition to these Federal mitigation efforts, considerable reforestation is underway on private lands, primarily under the auspices of the Wetland Reserve Program (WRP) administered by the Natural Resources Conservation Service of the U.S. Department of Agriculture.

### Hydrology

The hydrology of the Yazoo Basin has been modified extensively and purposefully. Federal projects have largely protected the basin from the effects of major floods, allowing extensive land clearing and agricultural development. The water that enters or underlies the modern basin is rerouted, stored, and exported from the system in complex patterns that can result in more or less water available to remaining wetlands. For example, the uneven annual distribution of rainfall makes both supplemental irrigation and drainage common agricultural practices (Brown et al. 1971). Drainage may involve land leveling as well as ditching and can have various effects on wetlands, which may serve as sumps to which adjacent fields drain, and/or they may themselves be drained to streams or larger ditches. During periods of backwater flooding, these same artificial drainage networks may function in reverse and deliver water to low areas far from the source stream channels. Groundwater withdrawals, particularly for agricultural purposes, have caused depletion of the aquifer in some areas. In 1994, more than 2,000 Mgal/day was withdrawn from wells in this aquifer (O'Hara 1996). However, the overwhelming influence on hydrology in the basin has been the Mississippi River and Tributaries Project (MR&T), which is the largest flood control project in the world (USACE, MVD 1998). In order to understand the extent to which hydrology has been modified in the Yazoo Basin and the way the remaining wetlands receive and move water, it is essential to understand the development and current status of the MR&T.

Efforts to control flooding on the lower Mississippi River began with the construction of small private levees in the early 19$^{th}$ century (Mississippi River Commission 1970). Levee construction in the Yazoo Basin portion of the Delta advanced quickly, and more than 500 km of levee were in place by 1858. Corps of Engineers activities through most of the 1800s focused principally on survey and engineering efforts relating to navigation improvement. In 1879, Congress authorized the creation of the Mississippi River Commission to oversee a coordinated Federal effort, carried out by the Corps of Engineers, to provide reliable navigation throughout the entire Mississippi River (Moore 1972). Over the next 5 decades, the authority of the Commission was expanded to include flood control, and its jurisdiction gradually enveloped various tributary stream systems. Funding was appropriated to support basic studies and projects, including channel dredging and the construction of an extensive levee system (Moore 1972). During the first decades of this century, local drainage districts were formed throughout the region to improve interior drainage (Barham 1964, Sartain undated). By 1927, levee construction and related works were believed to be providing effective protection from Mississippi River floods, as well as effective drainage for communities and farmlands throughout the entire lower valley.

A devastating flood in 1927 showed that the flood protection works were inadequate, and the Flood Control Act of 1928 authorized the Corps of Engineers to implement a new and comprehensive plan for preventing flooding in the Lower Mississippi Valley. The approach included construction of larger and stronger levees as well as various channel improvements, bank protection works, and other features. The multiple elements of this plan and its subsequent modifications are collectively referred to as the Mississippi River and Tributaries Project (MR&T) (Moore 1972).

Congress directed changes to the MR&T plan in the 1930s and 1940s that included the addition of cutoffs, tributary reservoirs, and an emphasis on maintenance of a stable, deep Mississippi River channel as a levee-protection measure and to provide navigation benefits. In the 1950s, 60s, and 70s, the project was expanded to include numerous tributary improvements, pump stations, harbor improvement projects, and lock and dam projects, as well as channel and levee projects, throughout the system. During this latter period, fish and wildlife considerations also became authorized project purposes. Meeting fish and wildlife objectives generally involved constructing water control structures within floodways and sump areas to allow habitat management for waterfowl (Moore 1972).

With the advent of the National Environmental Policy Act (NEPA) in 1969 and other environmental legislation, proposed modifications to the MR&T have been subject to more complex planning and coordination requirements than previously existed. Actions likely to adversely affect fish, wildlife, wetland ecosystems, and other natural resources have been re-evaluated to identify ways to avoid or minimize environmental impacts (Moore 1972, Bolton and Metzger 1998). Compensation for impacts deemed unavoidable has included acquisition and restoration of many thousands of acres of forest within the project area, as well as construction of additional water management facilities to benefit wildlife, particularly waterfowl (Young 1998). Maintenance of existing project features continues, and additional authorized features are under construction or in planning stages. The Yazoo Basin portion of the MR&T Project area has been the focus of a large proportion of the work to date, and additional flood control work is in the planning stages (Bolton and Metzger 1998).

## MR&T features in the Yazoo Basin

The original 1928 Flood Control Act required that flood control plans for certain tributary streams be developed in addition to the general plan for flood abatement along the mainstem Mississippi River. A 1931 report on the Yazoo Basin portion of the project area identified three major sources of flooding: overflow from the Mississippi River, backwater due to high stages on the Mississippi River, and direct overflow of the Yazoo River and its tributaries. The mainstem levee solved the first of these problems, but the remaining flooding

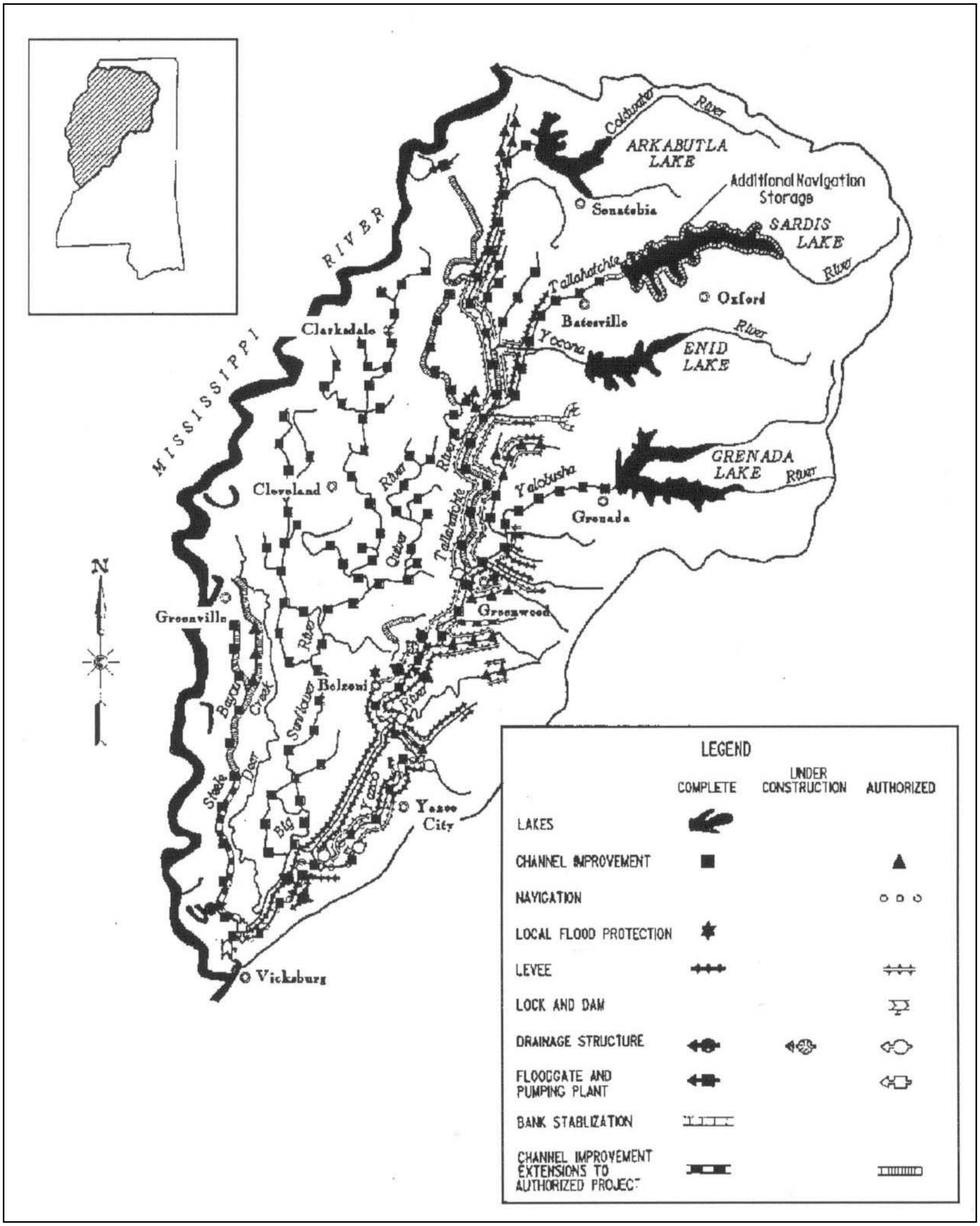


Figure 7. Major features of the MR&T Project in the Yazoo Basin

sources have been addressed by a complex series of projects that were incrementally developed, authorized, and constructed over the past six decades.

The planned work has not been completed to date, and in recent years the Corps has undertaken reformulation studies of the uncompleted work to develop alternatives that address changing objectives and concerns. Most of the major elements of the existing Yazoo Basin Project were carried out as three distinct components under separate authorizations. These are described in the following paragraphs and illustrated in Figure 7.

*a.* *Yazoo Headwater Area.* The Yazoo Headwater Area includes about 6,000 $km^2$ of the Mississippi Alluvial Valley and 17,000 $km^2$ of hilly uplands upstream of Yazoo City. The principal project features are four detention reservoirs on headwater streams and a system of levees and channel works throughout the project area. Sardis Reservoir, on the Little Tallahatchie River, was completed in 1940; Arkabutla, on the Coldwater River, was completed in 1943; Enid, on the Yocona River, was completed in 1952; and Grenada, on the Yalobusha River, was completed in 1954. Together, these reservoirs reduced peak flows immediately downstream by more than two-thirds (Bolton and Metzger 1998). Channel enlargements, clearing, and cutoff construction began in 1939 and within 5 years work was underway on the Yalobusha, Yazoo, Tallahatchie, Little Tallahatchie, and Coldwater Rivers, as well as the Panola-Quitman Floodway and the Cassidy and Bobo Bayous. In the late 1940s and 1950s, channel excavation and clearing proceeded on the Arkabutla Canal, the Yocona River, the David and Burrell Bayous, and the Hillside Floodway. In the 1960s, the Lower Auxiliary Channel (Will M. Whittington Auxiliary Channel) was completed, which greatly reduced flooding on the lower Yazoo River (Bolton and Metzger 1998). Channel improvements and pumping facilities on McKinney Bayou were also built in that decade. Levee construction was an integral component of many of these actions, and by 1972 about 400 km of levees were in place within the headwater project area.

*b.* *Big Sunflower Area.* The Big Sunflower Area includes approximately 10,600 $km^2$ in northwest Mississippi. Work began in 1946 and consisted of channel clearing, enlargement, realignment, cutoffs, and other projects on the Big Sunflower, Little Sunflower, Huspuckena, and Quiver Rivers and their tributaries and on Hull Brake-Mill Creek Canal, Bogue Phalia, Ditchlow Bayou, Deer Creek, and Steele Bayou. In the 1960s, additional work was authorized on Steele Bayou as well as Gin and Muddy Bayous. By 1972, 1,000 km of channel improvements had been completed under these authorizations.

*c.* *Yazoo Backwater Area*. The Yazoo Backwater Area occupies the southern portion of the Yazoo Basin between the Mississippi River levee on the west and the valley wall to the south and east. It extends approximately 100 km to the north, to about the latitude of Belzoni. Flooding within the Yazoo Backwater Area can occur from various sources. Under the original flood control plan for the entire Lower Mississippi Valley, backwater areas (including the Yazoo Backwater) are protected by levees designed to be overtopped to relieve pressure on mainstem levees during extreme floods on the Mississippi River.

Further, such areas are designed to carry floodwater entering through gaps in the backwater (tributary) levee during high stages on the Mississippi River. Therefore, the Yazoo Backwater Area is a flood-storage component of the overall MR&T Project. However, because the backwater levee system also impounds internal drainage and extends flood durations and depths within parts of the backwater area, the project authorizations have included provisions to protect certain areas from backwater flooding and to evacuate impounded floodwaters as quickly as possible.

The Yazoo Backwater Area project is subdivided into five parts. The first part, know as the Yazoo Area, comprises about 82 percent of the backwater area west of the Will M. Whittington Auxiliary Channel. The Big Sunflower River, Little Sunflower River, Deer Creek, and Steele Bayou flow through the area, and the Deer Creek natural levee forms a divide between the Steele Bayou and Sunflower River drainage basins. A levee along the west bank of the Yazoo River connects the Mississippi River mainstem levee with the Will Whittington Auxiliary Channel levee, and it incorporates drainage structures at the mouth of the Little Sunflower and at the mouth of Steele Bayou. The other major project components are channels, from the Big Sunflower to the Little Sunflower Rivers and then to Steel Bayou, which connect the sumps and levee-impounded areas interior to the levee system. These features were all completed between 1969 and 1978. The final planned element of the project was a pumping plant at Steele Bayou to allow evacuation of water ponded within the levee system during periods when high water on the Mississippi and Yazoo Rivers preclude opening of the drainage structures at the Little Sunflower and Steele Bayou. The pump station has not been completed (see the following section, Yazoo Basin Reformulation Study)

In the 1970s, the Yazoo Backwater Project was modified to include installation of a water control structure to improve water quality and facilitate fish management. Another modification to the Project was the construction of green-tree reservoirs and slough impoundments within Delta National Forest as mitigation for fish and wildlife impacts resulting from constructed flood control works in the backwater area.

The second part of the Yazoo Backwater Area, known as the Carter Area, occupies about 400 $km^2$ that lie east of the Auxiliary Channel and west of the Yazoo River. It is not protected from Yazoo River flooding in the reach from Yazoo City to the Auxiliary Channel east levee. The authorized project calls for completion of a levee on the west bank of the river and construction of an interior channel and drainage structure to evacuate interior flooding. No work has been initiated on these project features, and, in recent years, large sections of the Carter Area have been converted to environmental purposes. For example, the majority of the Panther Swamp National Wildlife Refuge and part of the Lake George Wildlife Wetland Restoration Project are within the Carter Area.

The third part, known as the Rocky Bayou Area, is located east of the Yazoo River and west of the hills, between Yazoo City and Satartia. A locally constructed levee system provides partial protection to an area of about 57 $km^2$. Interior drainage is provided through a floodgate near the southern junction of the levee and the hills. The authorized project would bring the levee system up to project standards and replace the floodgate, but no work has been completed other than a short levee segment upgraded in conjunction with a highway construction project.

The fourth part of the project area, known as the Satartia Area consists of about 115 $km^2$ that includes the town of Satartia and lands to the south of town, between the Yazoo River and the hills. In 1976, a loop levee was completed around this area, tying into the hills, and with internal drainage provided by a floodgate.

The fifth part, known as the Satartia Extension Area, is a 13-$km^2$ area south of the Satartia Area. Flood protection measures similar to those employed in the Satartia Area have been authorized, but no construction has been initiated.

*d.* *Yazoo Basin Reformulation Study.* In 1989, the Yazoo Basin Reformulation Study was initiated to consider the remaining unconstructed features of the Yazoo Basin Project. Alternatives under consideration fall into three general categories: (a) no further action, (b) implementation of nonstructural solutions to flooding problems (such as purchasing flood easements), and (c) implementation of structural solutions. Structural alternatives are likely to be of significantly reduced scope relative to the authorized projects and to incorporate various measures to minimize or offset environmental impacts. However, structural alternatives under consideration include extensive channel enlargement in the Yazoo-Tallahatchie-Coldwater Rivers, installation of the Steele Bayou pumping plant, and similar actions that would effect considerable changes in the hydrology of portions of the Yazoo Basin. Similarly, mitigation measures that would accompany implementation of such structural solutions would involve extensive reforestation, other habitat restoration, and water management specifically to benefit fish and wildlife (USACE 1997).

## Description of Regional Wetland Subclasses

Reconnaissance studies during 1997 and 1998 indicated that four of the seven HGM wetland classes identified by Smith et al. (1995) were relatively common within the Yazoo Basin. These included the Flats, Riverine, Depression, and Fringe classes. These four wetland classes were subdivided into seven regional wetland subclasses including Flats, Riverine Overbank, Riverine Backwater, Isolated Depression, Connected Depression, Isolated Fringe, and Connected Fringe. A general description of each of these regional wetland subclasses is provided in the following paragraphs. Figure 8 illustrates typical

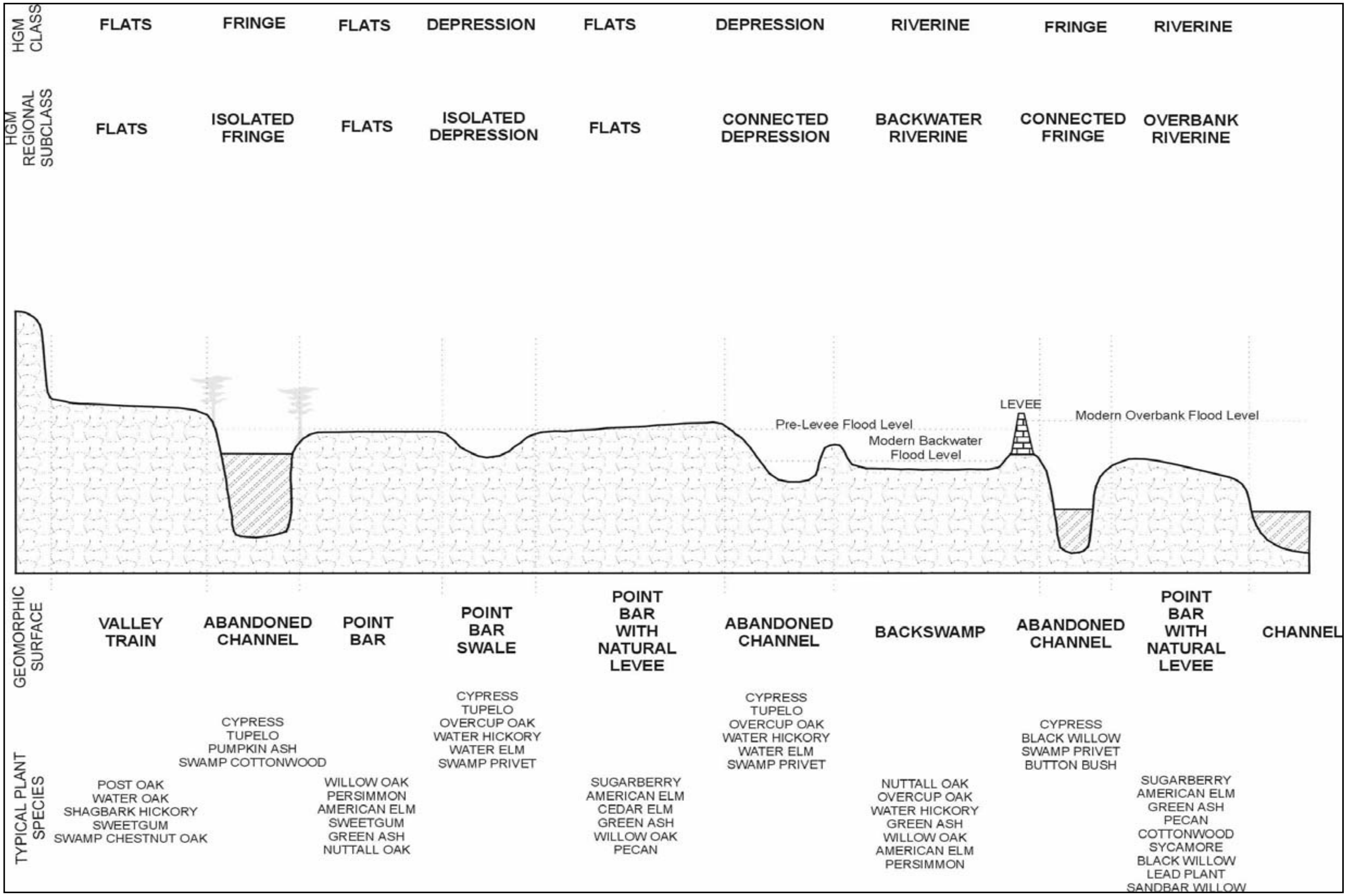


Figure 8. Typical hydrologic conditions, geomorphic settings, and plant communities associated with regional wetland subclasses of the Yazoo Basin

hydrologic conditions, geomorphic settings, and plant communities associated with each of the regional wetland classes and subclasses.

### Flats

The Flats Subclass may occur on a variety of depositional surfaces, but is most characteristic of point bar deposits. It includes the driest communities in the study area, with species such as shagbark hickory (*Carya ovata*) and water oak (*Quercus nigra*) being characteristic. There is also a wet phase of the flats community, found in large, shallow depressions that do not meet the criteria for the Depression Subclass. These vernal pool sites typically support species such as overcup oak (*Quercus lyrata*) and water hickory (*Carya aquatica*).

### Riverine Backwater

The Riverine Backwater Subclass includes those wetlands subject to backwater flooding from streams at frequencies of 5 years or less. Backwater flooding is defined here as inundation resulting from impeded drainage, usually due to high water in downstream systems. A typical backwater flooding scenario is that a large stream in flood stage will prevent the tributary network from draining efficiently, and the low-lying areas associated with those tributaries will fill with relatively still water. In the Yazoo Basin, there is an additional type of backwater flooding that is related to the operation of structures within the flood-control project. However, in both cases, the principal criteria that establish areas as Riverine Backwater are:

*a.* There is a direct connection to a channel system during flood stages (at least 5-year frequency).

*b.* The channel connection is principally through backwater rather than overbank flows (at least 5-year frequency).

*c.* Floodwaters largely drain from the site back to the channel as flood stages fall (rather than being retained on-site in large depressions).

The Riverine Backwater Subclass is similar to the Flats Subclass in that it occurs on various substrates and supports a broad range of community types. However, in its most common form it occupies backswamp deposits, and characteristic species include green ash (*Fraxinus pennsylvanica*) and Nuttall oak (*Quercus nuttallii*). Like the Flats Subclass, Riverine Backwater sites may have included vernal pools supporting species such as overcup oak (*Quercus lyrata*) and water hickory (*Carya aquatica*).

### Riverine Overbank

The Riverine Overbank Subclass includes those wetlands subject to direct overbank flooding at return intervals of 5 years or less. Overbank flooding differs from backwater flooding in that flows move parallel to the stream channel and maintain moderate-to-high velocities. Not many sites meet this criterion within the Yazoo Basin because channel incision and levees have disconnected most streams from their adjacent historic floodplains. Riverine Overbank wetlands occur primarily along banks and on small bars within the incised channels of streams and on the limited floodplain surfaces adjacent to some channels. Sites subject to overbank flow are commonly on point bar or backswamp deposits, usually with a natural levee veneer. Off-channel areas subject to overbank flows may be similar to Flats in composition, though usually with a larger component of species with broad tolerance to sedimentation, such as box elder (*Acer negundo*) and sugarberry (*Celtis laevigata*). Certain communities and species are very characteristic of the riverfront area, such as black willow (*Salix nigra*), cottonwood (*Populus deltoides*), and sycamore (*Platanus occidentalis*). Included depressional areas may occur in high-flow channels and swales and typically support species such as swamp privet (*Forestiera accuminata*).

### Isolated Depression

Depressions (both isolated and connected) are distinguished from included depressional phases of the Flats and Riverine Subclasses in several ways. Depressions tend to occur in abandoned channels, abandoned courses, and large point bar swales, while included depressions in Flats and Riverine wetlands occur in minor swales or in areas bounded by natural levee deposits. Depressions hold water for extended periods due to their size, depth, and ability to collect surface and subsurface flows from an area much larger than the depression itself. They tend to fill during the winter and spring and dry very slowly. Prolonged rains may fill them periodically during the growing season, after which they again dry very slowly. Included depressions (vernal pools) in Flats and Riverine settings, in contrast, fill primarily due to direct precipitation inputs and dry out within days or weeks. Depression Subclass wetlands usually exhibit two or more of the following characteristics:

*a.* Hydric soil indicators F2 (Loamy Gleyed Matrix) or A4 (Hydrogen Sulfide) (U.S. Department of Agriculture, NRCS 1998a).

*b.* A topographic depression with Dowling or Tunica soils (flooded phase). Dowling soils are not recognized in the current classification of soils in the Yazoo Basin, but they appear on the existing soil surveys and have proven to be useful in HGM classification.

*c.* Vegetation includes a significant component of one or more of the following species: baldcypress (*Taxodium distichum*), swamp tupelo (*Nyssa aquatica*), swamp privet (*Forestiera accuminata*), water elm (*Planera aquatica*),and buttonbush (*Cephalanthus occidentalis*).

Depressions may be dominated or fringed by species such as overcup oak (*Quercus lyrata*) and water hickory (*Carya aquatica*), but will otherwise meet the criteria above. The Isolated Depression Subclass is not affected by overbank or backwater flooding during floods occurring at 5-year or more frequent return intervals.

### Connected Depression

The characteristics of Isolated Depressions described above apply equally to Connected Depressions. However, Connected Depressions have an additional water source due to periodic inundation by floodwaters.

### Isolated Fringe

Fringe wetlands occur along the perimeter of water bodies that maintain an open water zone at least 2 m deep in most years. The fringe wetland is in the fluctuation zone of the water body. Typical examples within the Delta include the baldcypress (*Taxodium distichum*) fringe common on oxbow lakes or the black willow (*Salix nigra*) fringe often associated with borrow pits. Isolated Fringe wetlands are disconnected from river flooding (5-year event), although they may have small inlet and outlet streams, at least during periods of high rainfall.

### Connected Fringe

Connected Fringe wetlands are similar in most respects to Isolated Fringe systems, but in addition have a direct connection to major stream systems during flood events.

## Identifying HGM Wetland Classes and Regional Subclasses

Identifying the regional wetland subclass for occurs at a particular site can be difficult at times because of the complexity of the landscape and hydrology within the Yazoo Basin. In order to facilitate this process, we developed classification criteria and keys for identifying the wetland class and regional subclasses to which a particular site belongs. The classification criteria are based on existing map data such as flood frequency, soils, and geomorphology. However, in some cases, the classification process will require field evaluation of additional factors to correctly ascertain the most appropriate designation for a particular site.

One of the primary criteria used to identify regional wetland subclasses in the Yazoo Basin is flood return interval. A 5-year or less flood return interval is regarded as sufficient to support major functions that involve periodic connection to stream systems. Sites with a flood return interval of 5 years or less are placed in the Riverine, Connected Depression, or Connected Fringe subclasses, while sites with a flood return interval greater than 5 years are placed in the Flats, Isolated Depression, or Isolated Fringe subclasses. The 5-year threshold was selected for practical reasons, namely that the hydrologic models used to develop flood return interval maps in the Yazoo Basin have been verified using photography taken during specific 5-year flood events (Figure 9). Adopting this criterion necessarily implies that the baseline hydrologic condition in the basin includes the changes that have occurred as a result of the MR&T flood control project as it existed at the time the data were assembled for this document in 1997.

The Fringe and Depression Classes are distinguished from the Flat and Riverine Classes by the fact that they occur in topographic depressions. The Fringe Class is distinguished from the Depression Class based on the depth of permanent water, and the Flat Class is distinguished from the Riverine Class based on the presence or absence of overbank flooding and backwater areas.

At the regional wetland subclass level, the classification recognizes that certain sites that function primarily as Fringe or Depression wetlands are periodically affected by stream flooding, and therefore have a Riverine functional component. This is incorporated in the classification system by establishing "river-connected" subclasses within the Fringe and Depression Classes. Sites that function primarily as Riverine or Flats wetlands often incorporate small, shallow depressions sometimes characterized as vernal pools and micro-depressions, which are regarded as normal components of the Riverine and Flats ecosystems, and are not separated into the Depression Class unless they meet specific criteria. Connected Fringe and Depression Classes are distinguished from the Isolated Fringe and Depression Classes based on whether or not a site is within the 5-year floodplain. The Riverine Overbank and Riverine Backwater Classes are distinguished based on whether or not floodwater moves at a relatively high velocity in a direction parallel to the channel or has little flow and enters a site by moving laterally or backing up from the channel.

Figures 10 and 11 provide dichotomous keys that incorporate the foregoing criteria to identify the appropriate wetland class or regional wetland subclass for a particular site in the Yazoo Basin of the of the Lower Mississippi River Alluvial Valley. To use either key, begin at Number 1 and follow the leads to the appropriate wetland class or regional wetland subclass.

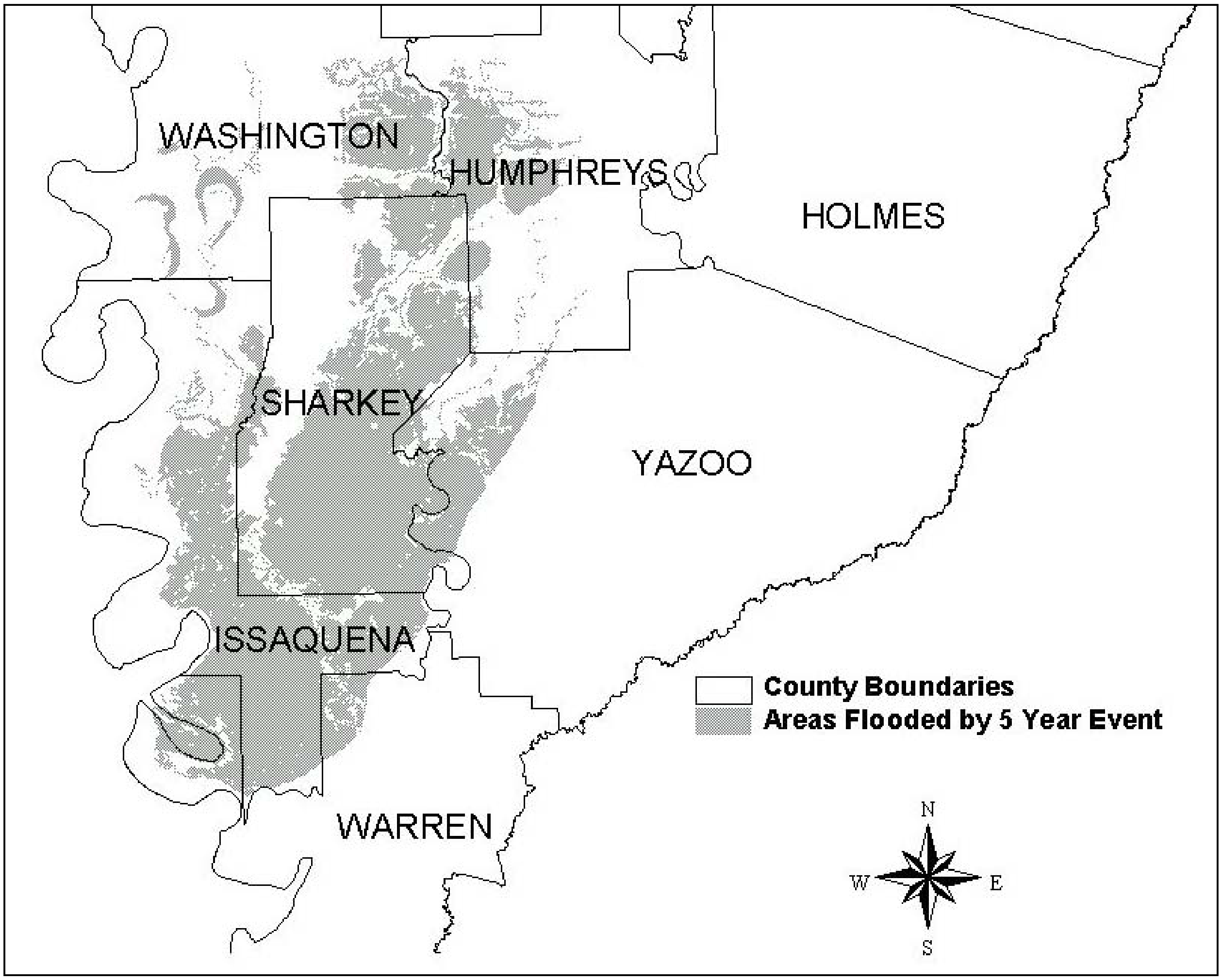


Figure 9. Areas inundated during a 5-year flood event in the Yazoo Basin (from USACE Vicksburg District 1997)

| Key To Wetland Classes in the Yazoo Basin of the Lower Mississippi River Alluvial Valley | |
|---|---|
| **Key Characteristics (see discussions on criteria for individual subclasses in Chapter 3)** | **Class** |
| 1. Wetland is not within the 5-year floodplain of a stream (including both overbank and backwater areas) | Go To #2 |
| 2. Wetland is associated with a topographic depression with extended (permanent or seasonal) ponding | Go To #3 |
| 2. Wetland not associated with a depression as above, but may include depressional areas subject to short-term ponding of precipitation or floodwaters | Flat |
| 1. Wetland is within the 5-year floodplain of a stream | Go To #3 |
| 3. ...... Wetland is associated with a topographic depression with extended (permanent or seasonal) ponding | Go To #4 |
| 4. Wetland is associated with a depression with permanent water at least 2 m deep | Fringe |
| 4. Wetland is associated with a depression with permanent water less than 2 m deep, or with seasonal ponding | Depression |
| 3. Wetland not associated with a depression as above, but may include depressional areas subject to short-term ponding of precipitation or floodwaters | Riverine |

Figure 10. Key to the wetland classes in the Yazoo Basin

| Key To Regional Wetland Subclasses of the Yazoo Basin of the Lower Mississippi River Alluvial Valley | |
|---|---|
| **Key Characteristics (see discussions on criteria for individual subclasses in Chapter 3)** | **Subclass** |
| 1. Wetland is a topographic depression with permanent water or seasonal ponding | Go To #2 |
| 2. Wetland is a topographic depression with permanent water at least 2 m deep | Go To #3 |
| 3. Wetland is within the 5-year floodplain of a stream | Connected Fringe |
| 3. Wetland is not within the 5-year floodplain of a stream | Isolated Fringe |
| 2. Wetland is a topographic depression with permanent water <2 m deep or seasonal ponding (see additional criteria under isolated and connected depression discussions) | Go To# 4 |
| 4. Wetland is within the 5-year floodplain of a stream | Connected Depression |
| 4. Wetland is not within the 5-year floodplain of a stream | Isolated Depression |
| 1. Wetland not a topographic depression as above, but may include small depression areas subject to short-term ponding of precipitation or floodwaters | Go To #5 |
| 5. Wetland is not within the 5-year floodplain of a stream | Flat |
| 5. Wetland is within the 5-year floodplain of a stream | Go To #6 |
| 6. Floodwaters typically flow parallel to channel during a 5-year event (moderate- to high- velocity downstream flow predominates) | Riverine Overbank |
| 6. Floodwaters typically back up into wetland due to high water downstream during a 5-year event (slack-water conditions and slow drainage predominate) | Riverine Backwater |

Figure 11. Key to the regional wetland subclasses in the Yazoo Basin

# 4 Wetland Functions and Assessment Models

A variety of functions are performed by wetlands in the Yazoo Basin of the Mississippi Alluvial Valley. This Regional Guidebook contains models for assessing five of the seven regional wetland subclasses identified in the Yazoo Basin including the Flats, Riverine Overbank, Riverine Backwater, Isolated Depression, and Connected Depression regional wetland subclasses. Note that no assessment models were developed for the Isolated Fringe and Connected Fringe subclasses. This is because these subclasses are subjected to little impact in the Yazoo Basin. The following functions were selected for assessment in the five regional wetland subclasses:

*a.* Detain Floodwater.

*b.* Detain Precipitation.

*c.* Cycle Nutrients.

*d.* Export Organic Carbon.

*e.* Remove Elements and Compounds.

*f.* Maintain Plant Communities.

*g.* Provide Fish and Wildlife Habitat.

It should be noted that not all functions are assessed for each regional wetland subclass, and the form of the assessment model that is used to assess functions can vary from subclass to subclass.

In this chapter, each of the functions identified above is discussed generally in terms of the following topics:

*a.* **Definition and Applicability:** This section defines the function, identifies the subclasses where the function is assessed, and identifies an independent quantitative measure that can be used to validate the functional index.

*b.* **Rationale for Selecting the Function:** This section provides the rationale for why a function was selected and discusses onsite and offsite effects that may occur as a result of lost functional capacity.

*c.* **Characteristics and Processes that Influence the Function**: This section describes the characteristics and processes of the wetland and the surrounding landscape that influence the function and lay the groundwork for the description of assessment variables.

*d.* **General Form of the Assessment Model:** This section presents the structure of the general assessment model and briefly describes the constituent variables.

In Chapter 5, detailed descriptions of assessment variables and the methods used to measure or estimate their values are presented. In addition, the specific form of the assessment models used to assess functions for each regional wetland subclass, and the functional capacity subindex curves are presented in Chapter 5.

## Function 1: Detain Floodwater

### Definition and applicability

This function reflects the ability of wetlands to store, convey, and reduce the velocity of floodwater as it moves through a wetland. The potential effects of this reduction are a damping of the downstream flood hydrograph, maintenance of postflood baseflow, and deposition of suspended sediments from the water column to the wetland. This function is assessed for the following regional wetland subclasses in the Yazoo Basin:

*a.* Riverine Backwater

*b.* Riverine Overbank

*c.* Connected Depression

The recommended procedure for assessing this function involves estimation of "roughness" within the wetland, in addition to flood frequency. A potential independent, quantitative measure for validating the functional index is the volume of water stored per unit area per unit time ($m^3$/ha/time) at a discharge equivalent to the average annual peak event.

### Rationale for selecting the function

The capacity of wetlands to temporarily store and convey floodwater has been extensively documented (Dewey and Kropper Engineers 1964; Campbell and Johnson 1975; Dybvig and Hart 1977; Novitski 1978; Thomas and Hanson 1981; Ogawa and Male 1983, 1986; Demissie and Kahn 1993). Many benefits related to the reduction of flood damage occur as a result of wetlands performing the function. Generally, floodwater interaction with wetlands tends to dampen and broaden the flood wave, which reduces peak discharge downstream. Similarly, wetlands can reduce the velocity of water currents and, as a result, reduce erosion (Ritter, Kochel, and Miller 1995). Some portion of the floodwater volume detained within floodplain wetlands is likely to be evaporated or transpired, reducing the overall volume of water moving downstream. The portion of the detained flow that infiltrates into the alluvial aquifer, or which returns to the channel very slowly via low-gradient surface routes, may be sufficiently delayed that it contributes significantly to the maintenance of baseflow in some streams long after flooding has ceased (Saucier 1994, O'Hara 1996). Retention of particulates also is an important component of the flood detention function because sediment deposition directly alters the physical characteristics of the wetland (including hydrologic attributes) and influences downstream water quality.

This function deals specifically with the physical influences on flow and sediment dynamics described earlier. Floodwater interaction with floodplain wetlands influences a variety of other wetland functions in the Yazoo Basin, including nutrient mobility and storage and the quality of habitat for plants and animals. The role of flooding in maintenance of these functions is considered separately in other sections of this chapter.

### Characteristics and processes that influence the function

The capacity of a wetland to detain and moderate floodwaters is related to antecedent conditions, the characteristics of the particular flood event, the configuration and slope of the floodplain and channel, and the physical obstructions present within the wetland that interfere with flows. The intensity, duration, and spatial extent of precipitation events affect the magnitude of the stream discharge response. Typically, rainfall events of higher intensity, longer duration, and greater spatial extent result in greater flood peaks. Watershed characteristics such as size and shape, channel and watershed slopes, drainage density, and the presence of wetlands and lakes have a pronounced effect on the stormflow response (Brooks et al. 1991; Dunne and Leopold 1978; Ritter, Kochel, and Miller 1995; Leopold 1994; Patton 1988). The larger the watershed, the greater the volume and stream discharge peak that result from a rainfall event. Watershed shape affects how quickly surface and subsurface flows reach the outlet to the watershed. For example, a round-shaped watershed concentrates runoff more quickly than an elongated one and will tend to have higher peak flows. Steeper hillslopes and channel gradients also result in quicker response and higher peak flows. The higher the drainage density (i.e., the sum of all the channel lengths divided by the watershed area), the faster water is concentrated at the watershed outlet and the higher the peak discharge. As the percentage of wetland area and/or reservoirs increases, the greater the flattening effect (i.e., attenuation) will be on the stormflow hydrograph. In general, these climatic and watershed characteristics are consistent within a given region and are considered constant for the purposes of rapid assessment.

The physical characteristics of the floodplain and the stream channel also are important determinants of floodflow interactions. The morphology of the stream channel and its floodplain reflects the discharges and sediment loads that have occurred in the past. Under stable flow and sediment conditions, the stream and its floodplain will eventually achieve equilibrium. Alteration to the stream channel or its watershed may cause instability that results in channel aggradation or degradation and a change in depth, frequency, and duration of overbank flow events (Dunne and Leopold 1978; Rosgen1994). As the stream channel aggrades, available water storage in the channel decreases, resulting in greater depth, frequency, and duration of flooding (on the floodplain) and an increase in amount of surface water stored in the wetland over an annual cycle. Conversely, as the stream channel degrades, available water storage in the channel increases, resulting in less depth, frequency, and duration of flooding and a decrease in the amount of surface water stored in the wetland over an annual cycle. The duration of water storage is secondarily influenced by the slope and roughness of the floodplain. Slope refers to the gradient of the floodplain across which floodwaters flow. Roughness refers to the resistance to flow created by vegetation, debris, and topographic relief. In general, duration increases as roughness increases and slope decreases.

Of all of the characteristics described above, only flood frequency and the roughness component can be reasonably incorporated into a rapid assessment. The extensive channel modifications and levee construction that have taken place in the region make it difficult to ascribe detailed flood characteristics to any particular point on the ground, particularly if it is not directly adjacent to a channel and near a stream gage. At best, we can estimate flood frequency for some sites, at least to the extent needed to classify a wetland as Riverine or Connected (i.e., within the 5-year floodplain). In cases where flood frequency can be estimated more specifically, that information can be used in the assessment of this function. Otherwise, the only element of the Floodwater Detention function that is assessed is roughness.

### General form of the assessment model

The model for assessing the Detain Floodwater function includes the following assessment variables that are discussed in greater detail in Chapter 6:

$V_{FREQ}$: Frequency of flooding

$V_{LOG}$: Log density

$V_{GVC}$: Ground vegetation cover

$V_{SSD}$: Shrub-sapling density

$V_{TDEN}$: Tree density

The general form of the assessment model is:

$$FCI = V_{FREQ} \times \left[ \frac{(V_{LOG} + V_{GVC} + V_{SSD} + V_{TDEN})}{4} \right] \quad (2)$$

The assessment model has two components: frequency of flooding ($V_{FREQ}$) and a compound expression that represents flow resistance (roughness) within the wetland. The flood frequency variable is employed as a multiplier, such that the significance of the roughness component is proportional to how often the wetland is inundated.

The compound expression of flow resistance includes the major physical components of "roughness" that can be characterized readily at the level of a field assessment. They include elements that influence flow velocity differently depending on flood depth and time of year. For example, ground vegetation cover ($V_{GVC}$) and log density ($V_{LOG}$) can effectively disrupt shallow flows, while shrub and sapling density ($V_{SSD}$) have their greatest influence on flows that intercept understory canopies (usually 1-3 m deep), and tree stems ($V_{TDENS}$) interact with a full range of flood depths. Both tree stems and logs are equally effective in disrupting flows at all times of the year, while understory and ground cover interactions are less effective during winter floods than during the growing season. Other components of wetland structure contribute to roughness, but are not assessed here (e.g. surface micro-relief) because they cannot be estimated rapidly and reliably or they do not commonly influence flows to the same degree as the components described above (e.g., snag density).

# Function 2: Detain Precipitation

### Definition and applicability

This function is defined as the capacity of a wetland to prevent or slow runoff of rainfall to streams. This is accomplished chiefly by micro-depression storage and infiltration and absorption by organic material and soils. Both flood-prone (riverine) wetlands and nonflooded wetlands (flats) are assessed for this function. Depression wetlands also perform a precipitation storage function, but are not assessed for that function within the Yazoo Basin. This is partly because it is difficult to consistently define source areas and available storage volumes in the context of a rapid field assessment; but more simply, impacts to this function in depression wetlands generally are directly reflected in lost wetland acreage. Wetland subclasses that are assessed for the precipitation detention function in the Yazoo Basin include:

*a.* Riverine Backwater

*b.* Riverine Overbank

*c.* Flat

The recommended procedure for assessing this function in the Yazoo Basin is estimation of available micro-depression storage and characterization of the extent of organic surface accumulations available to improve absorption and infiltration. A potential independent direct measure would be calculation of onsite storage relative to runoff predicted by a storm hydrograph for a given rainfall event.

### Rationale for selecting the function

Like the Floodwater Detention function, capture and detention of precipitation prevents erosion, dampens runoff peaks following storms, and helps maintain baseflow in streams. The stream hydrograph has a strong influence on the development and maintenance of habitat structure and biotic diversity of adjacent ecosystems (Bovee 1982, Estes and Orsborn 1986, Stanford et al. 1996). In addition, onsite storage of precipitation may be important in maintaining wetland conditions on the site, independent of the influence of flooding. The presence of ponded surface water and recharge of soil moisture also have implications for plant and animal communities within the wetland, but these effects are assessed separately.

### Characteristics and processes that influence the function

Flats and riverine wetlands capture precipitation and local runoff in micro-depressions, vernal pools, and ridge and swale topography. Micro-depressions are usually formed by channel migration processes and tree windthrow, which creates small, shallow depressions when root systems are pulled free of the soil. In addition, the presence of surface organic accumulations reduces runoff and promotes infiltration. Therefore, sites with large amounts of micro-depression storage and a thick, continuous litter or duff layer will most effectively reduce the movement of precipitation as overland flow. Instead, the water is detained onsite, where it supports biological processes and contributes to subsurface water storage and, eventually, to maintenance of baseflow in nearby streams. Clearing of natural vegetation cover will remove the source of litter and the mechanism for developing new micro-depressions. Land use practices that involve ditching or land leveling can eliminate existing micro-depression storage and promote rapid runoff of precipitation.

### General form of the assessment model

The assessment model for the Detain Precipitation function includes the following assessment variables that are discussed in greater detail in Chapter 6:

$V_{POND}$: Micro-depressional ponding

$V_{OHOR}$: "O" horizon thickness

The general form of the assessment model is:

$$FCI = \frac{\left(V_{POND} + V_{OHOR}\right)}{2} \tag{3}$$

The assessment model has two components, which are equally weighted. The percentage of the assessment area subject to ponding ($V_{POND}$) is based on a field estimate. The thickness of the O horizon ($V_{OHOR}$) is directly measured in the field.

## Function 3: Cycle Nutrients

### Definition and applicability

This function refers to the ability of the wetland to convert nutrients from inorganic forms to organic forms and back through a variety of biogeochemical processes such as photosynthesis and microbial decomposition. The nutrient cycling function encompasses a complex web of chemical and biological activities that sustain the overall wetland ecosystem, and it is assessed in all wetland subclasses. Within the Yazoo Basin, the applicable subclasses discussed within this document include the following:

*a.* Riverine Backwater

*b.* Riverine Overbank

*c.* Connected Depression

*d.* Isolated Depression

*e.* Flats

The assessment procedure described here utilizes indicators of the presence and relative magnitude of organic material production and storage, including living vegetation strata, dead wood, detritus, and soil organic matter. Potential independent, quantitative measures for validating the functional index include net annual primary productivity ($gm/m^2$), annual litterfall ($gm/m^2$), or standing stock of living and/or dead biomass ($gm/m^2$).

### Rationale for selecting the function

In functional wetlands, nutrients are transferred among various components of the ecosystem, such that materials stored in each component are sufficient to maintain ecosystem processes (Ovington 1965, Pomeroy 1970, Ricklefs 1990). For example, an adequate supply of nutrients in the soil profile supports primary production, which makes it possible for the plant community to develop and be maintained (Bormann and Likens 1970, Whittaker 1975, Perry 1994). The plant community, in turn, provides a pool of nutrients and source of energy for secondary production and also provides the habitat structure necessary to maintain the animal community (Fredrickson 1978, Crow and MacDonald 1978, Wharton et al. 1981). Plant and animal communities serve as the source of detritus, which provides nutrients and energy necessary to maintain a characteristic community of decomposers to break down organic material into simpler elements and compounds that can then reenter the nutrient cycle (Reiners 1972; Dickinson and Pugh 1974; Pugh and Dickinson 1974; Schlesinger 1977; Singh and Gupta 1977; Hayes 1979; Harmon, Franklin, and Swanson 1986; Vogt, Grier, and Vogt 1986).

### Characteristics and processes that influence the function

In wetlands, nutrients are stored within, and cycled among, four major compartments: (a) the soil, (b) primary producers such as vascular and nonvascular plants, (c) consumers such as animals, fungi, and bacteria, and (d) dead organic matter, such as leaflitter or woody debris, referred to as detritus. The transformation of nutrients within each compartment and the flow of nutrients between compartments are mediated by a complex variety of biogeochemical processes. For example, plant roots take up nutrients from the soil and detritus and incorporate them into the organic matter in plant tissues. Nutrients incorporated into herbaceous or deciduous parts of plants will turn over more rapidly than those incorporated into the woody parts of plants. However, ultimately, all plant tissues are either consumed or die and fall to the ground where they are decomposed by fungi and microorganisms and mineralized to again become available for uptake by plants.

Many of the processes involved in nutrient cycling, such as primary production and decomposition, have been studied extensively in wetlands (Brinson, Lugo, and Brown 1981). In forested riverine wetlands of the Southeast specifically, there is a rich literature on the standing stock, accumulation, and turnover of aboveground biomass in successional and mature stages (Brinson 1990). For example, the annual production of leaves is well documented through litterfall studies (Conner and Day 1976, Day 1979, Mulholland 1981, Elder and Cairns 1982, Brown and Peterson 1983, Conner and Day 1992). Until recently, less attention has been paid to woody (Harmon, Franklin, and Swanson 1986; Symbula and Day 1988) and belowground components (Raich and Nadelhoffer 1989, Nadelhoffer and Raich 1992) of these systems.

The ideal approach for assessing nutrient cycling would be to measure the rate at which nutrients are transformed and transferred between compartments over the period of a year (Kuenzler et al. 1980; Brinson, Bradshaw, and Kane 1984; Harmon, Franklin, and Swanson 1986). However, the time and effort required to make these measurements are well beyond a rapid assessment procedure. The alternative is to estimate the standing stocks of living and dead biomass in each of the four compartments and assume that nutrient cycling is taking place at a characteristic level if the biomass in each compartment is similar to that in reference standard wetlands. In this case, estimation of consumer biomass (animals, etc.) is too complex for a rapid assessment approach, thus, the presence of these organisms is assumed based on the detrital and living plant biomass components.

### General form of the assessment model

The model for assessing the Cycle Nutrients function includes the following assessment variables that are discussed in greater detail in Chapter 6:

$V_{TBA}$: Tree basal area

$V_{SSD}$: Shrub-sapling density

$V_{GVC}$: Ground vegetation cover

$V_{OHOR}$: O horizon thickness

$V_{AHOR}$: A horizon biomass

$V_{WD}$: Woody debris biomass

$V_{SNAG}$: Snag density

The general form of the assessment model is:

$$FCI = \frac{\left[\frac{(V_{TBA} + V_{SSD} + V_{GVC})}{3} + \frac{(V_{OHOR} + V_{AHOR} + V_{WD} + V_{SNAG})}{4}\right]}{2} \quad (4)$$

The two constituent expressions within the model reflect the two major production and storage compartments: living and dead organic material. The first expression is comprised of indicators of living biomass, expressed as tree basal area ($V_{TBA}$), shrub and sapling density ($V_{SSD}$), and ground vegetation cover ($V_{GVC}$). These various living components also reflect varying levels of nutrient availability and turnover rates, with the aboveground portion of ground cover biomass being largely recycled on an annual basis, while understory and tree components incorporate both short-term storage (leaves) and long-term storage (wood). Similarly, the second expression includes organic storage compartments that reflect various degrees of decay. Snag density ($V_{SNAG}$) and woody debris volume ($V_{WD}$) represent relatively long-term storage compartments that are gradually transferring nutrients into other components of the ecosystem through the mediating activities of fungi, bacteria, and higher plants. The thickness of the O horizon ($V_{OHOR}$) represents a shorter-term storage compartment of largely decomposed, but nutrient rich, organics on the soil surface. The thickness of the A horizon (actually, the portion of the A where organic accumulation is apparent) ($V_{AHOR}$) represents a longer-term storage compartment, where nutrients that have been released from other compartments are held within the soil and are available for plant uptake but are generally conserved within the system and not readily subject to export by runoff or floodwater. All of these components are combined here in a simple arithmetic model that weights each element equally.

# Function 4: Export Organic Carbon

## Definition and applicability

This function is defined as the capacity of the wetland to export dissolved and particulate organic carbon, which may be vitally important to downstream aquatic systems. Mechanisms involved in mobilizing and exporting nutrients include leaching of litter, flushing, displacement, and erosion. This assessment procedure employs indicators of organic production, the presence of organic materials that may be mobilized during floods, and the occurrence of periodic flooding to assess the organic export function of a wetland. An independent quantitative measure of this function is the mass of carbon exported per unit area per unit time ($g/m^2$ /yr).

This function is assessed in river-connected wetlands, which includes the following subclasses in the Yazoo Basin:

*a.* Riverine Backwater

*b.* Riverine Overbank

*c.* Connected Depression

## Rationale for selecting the function

The high productivity and close proximity of river-connected wetlands to streams make them important sources of dissolved and particulate organic carbon for aquatic food webs and biogeochemical processes in downstream aquatic habitats (Vannote et al. 1980; Elwood et al. 1983; Sedell, Richey, and Swanson 1989). Dissolved organic carbon is a significant source of energy for the microbes that form the base of the detrital food web in aquatic ecosystems (Dahm 1981, Edwards 1987, Edwards and Meyers 1986). Evidence also suggests that the particulate fraction of organic carbon imported from uplands or produced in situ is an important energy source for shredders and filter-feeding organisms (Vannote et al. 1980).

## Characteristics and processes that influence the function

Wetlands can be characterized as open or closed systems depending on the degree to which materials are exchanged with surrounding ecosystems (Mitsch and Gosselink 1993). River-connected wetlands normally function as open systems, primarily for two reasons. First, they occur in valley bottoms adjacent to stream channels. Since stream channels are the lowest topographic position in the landscape, water and sediments pass through the adjacent wetlands as gravity moves them toward the stream channel. Second, under natural conditions, low gradient, riverine and river-connected depression wetlands are linked to the stream channel through overbank and backwater flooding. In the case of the Export of Organic Carbon function, the latter reason is of greatest importance.

Watersheds with a large proportion of Riverine and other wetland types have generally been found to export organic carbon at higher rates than watersheds with fewer wetlands (Mulholland and Kuenzler 1979; Brinson, Lugo, and Brown 1981; Elder and Mattraw 1982; Johnston, Deten-beck, and Niemi 1990). This is attributable to several factors, including: (a) the large amount of organic matter in the litter and soil layers that comes into contact with surface water during flooding, (b) relatively long periods of inundation and, consequently, contact between surface water and organic matter, thus allowing for significant leaching, (c) the ability of the labile carbon fraction to be rapidly leached from organic matter when exposed to water (Brinson et al. 1981), and (d) the ability of floodwater to transport dissolved and particulate organic carbon from the floodplain to the stream channel.

### General form of the assessment model

The model for assessing the Export Organic Carbon function includes the following assessment variables that are discussed in greater detail in Chapter 6:

$V_{FREQ}$: Frequency of flooding

$V_{OHOR}$: O horizon thickness

$V_{WD}$: Woody debris biomass

$V_{SNAG}$: Snag density

$V_{TBA}$: Tree basal area

$V_{SSD}$: Shrub-sapling density

$V_{GVC}$: Ground vegetation cover

The general form of the assessment model is:

$$FCI = V_{FREQ} \times \frac{\left[\frac{\left(V_{OHOR} + V_{WD} + V_{SNAG}\right)}{3}\right] + \left[\frac{V_{TBA} + V_{SSD} + V_{GVC}}{3}\right]}{2} \tag{5}$$

This model is similar to the model used to assess the Internal Nutrient Cycling function in that it incorporates most of the same indicators of living and dead organic matter. The living tree, understory, and ground cover components ($V_{TBA}$, $V_{SSD}$, and $V_{GVC}$) primarily represent organic production, indicating that materials will be available for export in the future. The dead organic fraction comprises the principal current sources of exported material, represented by snags, woody debris, and accumulation of the O horizon ($V_{SNAG}$, $V_{WD}$, and $V_{OHOR}$). This model differs from the Nutrient Cycling model in that materials stored in the soil are not included due to their relative immobility, and periodic flooding is a required component of this model, because the export function is largely dependent on inundation and continuity with river flows.

## Function 5: Remove Elements and Compounds

### Definition and applicability

This function is defined as the ability of the wetland to permanently remove or temporarily immobilize nutrients, metals, and other elements and compounds that are imported to the wetland from various sources, but primarily via flooding. In a broad sense, elements include macronutrients essential to plant growth (nitrogen, phosphorus, and potassium) as well as heavy metals (zinc, chromium, etc.) that can be toxic at high concentrations. Compounds include pesticides and other imported materials. The term "removal" means the permanent loss of elements and compounds from incoming water sources (e.g., deep burial in sediments, loss to the atmosphere), and the term "sequestration" means the short- or long-term immobilization of elements and compounds. A potential independent, quantitative measure of this function is the quantity of one or more imported elements and compounds removed or sequestered per unit area during a specified period of time (e.g., $g/m^2$ /yr).

All wetlands in the Yazoo Basin are likely to perform this function to some degree. However, the indicators available to support a rapid field assessment are concerned primarily with contact between soil materials and floodwaters carrying dissolved materials. Removal of materials delivered to an area via local runoff or atmospheric sources is not considered as part of this assessment. However, materials transported to the area being assessed via the stream channel are part of the assessment. Therefore, this function is assessed in river-connected wetlands, which includes the following subclasses in the Yazoo Basin:

*a.* Riverine Backwater

*b.* Riverine Overbank

*c.* Connected Depression

### Rationale for selecting the function

The role of wetlands as interceptors of elements and compounds from upland or aquatic non-point sources is widely documented (Mitsch, Dorge, and Wiemhoff 1979, Lowrance et al. 1984; Peterjohn and Correll 1984; Cooper, Gilliam, and Jacobs 1986; Cooper et al. 1987). The primary benefit of this function is that the removal and sequestration of elements and compounds by wetlands reduce the load of nutrients, heavy metals, pesticides, and other pollutants in rivers and streams. This often translates into better water quality and aquatic habitat in rivers and streams through burial or facilitated processing of elements and compounds (e.g. denitrification).

## Characteristics and processes that influence the function

Elements and compounds are imported to wetlands by a variety of mechanisms and from a variety of sources. They include dry deposition and precipitation from atmospheric sources, stream flooding, overland flow, channelized flow, interflow, shallow groundwater flow, and colluvial material from upland sources. Some of the mechanisms, such as dry deposition and precipitation, typically account for a small proportion of the total quantity of elements and compounds imported to the wetland. The mechanisms that bring nutrients and compounds to the wetland from fluvial and terrestial sources are more significant in terms of quantities of materials imported. Once nutrients and compounds arrive in the wetland, they may be removed and sequestered through a variety of biogeochemical processes. Biogeochemical processes include complexation, chemical precipitation, adsorption, denitrification, decomposition to inactive forms, hydrolysis, uptake by plants, and other processes (Kadlec 1985, Faulkner and Richardson 1989, Johnston 1991).

A major mechanism that contributes to removal of elements and compounds from water entering a wetland is reduction. Denitrification will not occur unless the soil is anoxic and the redox potential falls below a certain level. When this occurs, nitrate ($NO^2$ ) removed by denitrification is released as nitrogen gas to the atmosphere. In addition, sulfate is reduced to sulfide, which then reacts with metal cations to form insoluble metal sulfides such as CuS, FeS, PbS, and others. Another major mechanism for removal of elements and compounds is by adsorption to electrostatically charged soil particles. Clay particles and particulate organic matter are the most highly charged soil particles and contribute the most to the cation exchange capacity (CEC) of the soil. Cation exchange is the interchange between cations in solution and other cations on the surface of any active material (i.e., clay colloid or organic colloid). The sum total of exchangeable cations that a soil can adsorb is the CEC. The CEC of a soil is a function of the amount and type of clay and the amount of organic matter in the soil. Further, organic matter is a food source for microbes involved in various microbial processes (i.e., reduction-oxidation reactions, denitrification, microbial pesticide degradation, etc.). Nitrogen in the ammonium form (NH) may be sequestered by adsorption to clay minerals in the soil. Phosphorus can only be sequestered, not truly removed. The soluble orthophosphate ion ($PO^4$) may be specifically adsorbed ("fixed") to clay and Fe and Al oxide minerals (Richardson 1985), which are generally abundant in riverine wetlands. Likewise, heavy metals can be sequestered from incoming waters by adsorption onto the charged surfaces (functional groups) of clay minerals by specific adsorption onto Fe and Al oxide minerals or by chemical precipitation as insoluble sulfide compounds. Direct measurement of concentrations of these soil components is beyond the scope of rapid assessment. However, soils with pH of 5.5 or less generally have Al oxide minerals present that are capable of adsorbing phosphorus and metals. Fe oxides are reflected in brown or red colors in surface or subsoil horizons, either as the dominant color or as redox concentrations. If the Fe oxide minerals become soluble by reduction, adsorbed phosphorus is released into solution. Annual net uptake of phosphorus by growing vegetation, although significant, usually represents a small quantity relative to other soil/sediment sinks of phosphorus (Brinson 1985). Riverine wetlands also retain nutrients and compounds by storing and cycling them among the plant, animal, detrital, and soil compartments (Patrick and Tusneem 1972; Kitchens et al. 1975; Brinson 1977; Day, Butler, and Conner 1977; Mitsch, Dorge, and Wiemhoff 1979; Yarbro 1983; Brinson, Bradshaw, and Kane 1984; Yarbro et al. 1984; Kleiss 1996).

### General form of the assessment model

The model for assessing the Remove Elements and Compounds function includes the following assessment variables that are discussed in greater detail in Chapter 6:

$V_{FREQ}$: Frequency of flooding

$V_{CEC}$: Cation exchange capacity

$V_{OHOR}$: O horizon thickness

$V_{AHOR}$: A horizon biomass

The general form of the assessment model is:

$$FCI = V_{FREQ} \times \left[ \frac{\left(V_{CEC} + V_{OHOR} + V_{AHOR}\right)}{3} \right] \tag{6}$$

The variables employed in the model reflect the importance of soil characteristics and organic matter in the complex interactions that influence removal or immobilization of materials from floodwaters. The clay component of soil CEC ($V_{CEC}$) is estimated by indirect means, and the organic fraction is estimated as the thickness of the portion of the A horizon with organic matter accumulation ($V_{AHOR}$). In addition, the role of direct interaction with surface organic accumulations and associated microbial activity is indicated by a field estimate of the thickness of the O horizon ($V_{OHOR}$). As noted above, although these ecosystem elements influence the fate of materials arriving in the wetland from a variety of sources, this model is intended only to assess the removal and sequestration of materials arriving in floodwaters. Therefore, the flood frequency variable ($V_{FREQ}$) is employed as a multiplier of the compound expression that describes soil and organic matter conditions.

## Function 6: Maintain Plant Communities

### Definition and applicability

This function is defined as the capacity of a wetland to provide the environment necessary for a characteristic plant community to develop and be maintained. In assessing this function, one must consider both the extant plant community as an indication of current conditions and the physical factors that determine whether or not a characteristic plant community is likely to be maintained in the future. A variety of approaches have been developed to describe and assess plant community characteristics that might be appropriately applied in developing independent measures of this function. These include quantitative measures based on vegetation composition and abundance such as similarity indices (Ludwig and Reynolds 1988), indirect multivariate techniques such as detrended correspondence analysis (Kent and Coker 1995), and techniques that employ both vegetation and environmental factors, such as canonical correlation analysis (ter Braak 1994). However, none of these approaches alone provides a "direct independent measure" of Plant Community function because they are tools that are employed in a more complex analysis that requires familiarity with the regional vegetation and collection of appropriate sample data.

This function is assessed in the following subclasses in the Yazoo Basin:

*a.* Riverine Backwater

*b.* Riverine Overbank

*c.* Connected Depression

*d.* Isolated Depression

*e.* Flats

### Rationale for selecting the function

The ability to maintain a characteristic plant community is important because of the intrinsic value of the plant community and the many attributes and processes of wetlands that are influenced by the plant community. For example, primary productivity, nutrient cycling, and the ability to provide a variety of habitats necessary to maintain local and regional diversity of animals are directly influenced by the plant community (Harris and Gosselink 1990). In addition, the plant community of a river-connected wetland influences the quality of the physical habitat, nutrient status, and biological diversity of downstream systems (Bilby and Likens 1979; Hawkins, Murphy, and Anderson 1982, Elder 1985; Gosselink, Lee, and Muir 1990).

### Characteristics and processes that influence the function

Numerous studies describe the environmental factors that influence the occurrence and characteristics of plant communities in lowland hardwood wetlands (Robertson, Weaver, and Cavanaugh 1978; Robertson, McKenzie, and Elliot 1984; Wharton et al. 1982; Robertson 1992; Smith 1996; Messina and Conner 1997; Hodges 1997). Hydrologic regime is usually cited as the principal factor controlling plant community attributes. Consequently, this factor is a fundamental consideration in the basic hydrogeomorphic classification scheme employed in this document. Soil characteristics are also significant determinants of plant community composition (see Soils Section in Chapter 3). In addition to physical factors, system dynamics and disturbance history are also important in determining the condition of a wetland plant community at any particular time. These include past land use, timber harvest history, hydrologic changes, sediment deposition, and events such as storms, fire, beaver activity, insect outbreaks, and disease. Clearly, some characteristics of plant communities within a particular wetland subclass may be determined by factors too subtle or variable to be assessed using rapid field estimates. Therefore, this function is assessed primarily by considering the degree to which the existing plant community structure and composition are appropriate to site conditions and the expected stage of maturity for the site. Secondarily, in some subclasses, soil and hydrologic conditions are assessed to determine if fundamental requirements are met to maintain wetland conditions appropriate to the geomorphic setting.

### General form of the assessment model

The model for assessing the Maintain Plant Communities function includes the following assessment variables that are discussed in greater detail in Chapter 6:

$V_{TBA}$: Tree basal area

$V_{TDEN}$: Tree density

$V_{COMP}$: Composition of tallest woody stratum

$V_{SOIL}$: Soil integrity

$V_{POND}$: Micro-depressional ponding

The general form of the assessment model is:

$$FCI = \left\langle \left\{ \frac{\left[ \frac{(V_{TBA} + V_{TDEN})}{2} + V_{COMP} \right]}{2} \right\} \times \left[ \frac{(V_{SOIL} + V_{POND})}{2} \right] \right\rangle^{1/2} \qquad (7)$$

The first expression of the model has two components. One component describes the structure of the overstory stratum of the plant community in terms of tree basal area and density ($V_{TBA}$ and $V_{TDENS}$). Together these indicate whether the stand has a structure typical of a mature forest with "gap" regeneration processes in place. The second term of the expression ($V_{COMP}$) considers the species composition of the dominant stratum, which will be the overstory in most instances, but which may be the shrub or ground cover layers in communities that are in earlier (or arrested) stages of development. This allows recognition of the faster recovery trajectory likely to take place in planted restoration sites (versus abandoned fields).

The second expression of the model considers two specific site factors that may be crucial to plant community maintenance under certain conditions. $V_{SOIL}$ is a simple comparison of the soil on the site to the mapped or predicted soil type for the area and geomorphic setting. As described in Chapter 3, plant communities of the Yazoo Basin are strongly affiliated with particular soil types, which in turn are the product of distinct alluvial processes. The $V_{SOIL}$ variable allows recognition of sites where the native soils have been replaced or buried by sediments inappropriate to the site, or where the native soils have been damaged significantly, as by compaction. The $V_{POND}$ variable focuses on a specific aspect of site alteration, the removal of microtopography and related ponding of water on flats and riverine wetlands. As described previously, ponding of precipitation is a crucial mechanism for maintaining wetland character in many wetlands in the Yazoo Basin. Flooding is also critical for the maintenance of many plant communities within the basin, but this relationship is considered separately as a basic classification factor. As noted elsewhere, characterization of flood frequency and duration in the Yazoo Basin is difficult and cannot often be interpreted in a way that would add meaningfully to the assessment of plant community maintenance.

## Function 7: Provide Fish and Wildlife Habitat

### Definition and applicability

This function is defined as the ability of a wetland to support the fish and wildlife species that utilize wetlands during some part of their life cycles. Potential independent, quantitative measures of this function are animal inventory approaches, with data analysis usually employing comparisons between sites using a similarity index calculated from species composition and abundance (Odum 1950, Sorenson 1948).

This function is assessed in the following subclasses in the Yazoo Basin:

*a.* Riverine Backwater

*b.* Riverine Overbank

*c.* Connected Depression

*d.* Isolated Depression

*e.* Flats

### Rationale for selecting the function

Terrestrial, semi-aquatic, and aquatic animals use wetlands extensively. Maintenance of this function ensures habitat for a diversity of vertebrate organisms, contributes to secondary production, and maintains complex trophic interactions. Habitat functions span a range of temporal and spatial scales and include the provision of refugia and habitat for wide-ranging or migratory animals as well as highly specialized habitats for endemic species. However, most wildlife and fish species found in wetlands of the Yazoo Basin depend on certain aspects of wetland structure and dynamics, such as periodic flooding or ponding of water, specific vegetation composition, and proximity to other habitats.

### Characteristics and processes that influence the function

The quality and availability of habitats for fish and wildlife species in wetlands of the Yazoo Basin are dependent on a variety of factors operating at different scales. Habitat components that can be considered in a rapid field assessment include vegetation structure and composition, detrital elements, availability of water, both from precipitation and flooding, and spatial attributes such as patch size and connectivity.

Forested wetlands typically are floristically and hydrologically complex (Wharton et al. 1982). Structural diversity in the vertical plane generally increases with vegetation maturity (Hunter 1990). Complexity of vegetation diversity on the horizontal plane derives from the patterns of alluvial deposition that form the substrate, resulting in a high interspersion of low ridges, swales, abandoned channel segments, and other features that differentially flood or pond rainwater, and support distinctively different plant communities (see Chapter 3). This structural diversity provides a myriad of habitat conditions for animals and allows numerous species to coexist in the same area (Schoener 1986). The composition of the various plant communities found in these wetlands is also an important factor relative to utilization by some wildlife species. Lowland forests commonly are highly diverse and may contain hundreds of plant species, but members of the genus *Quercus* (the oaks) often are particularly valuable to many species of wildlife. This significance is due to the importance of acorns as a major dietary component for many wildlife species. While oaks provide the bulk of the hard mast utilized by wildlife in forested wetlands of the southeast, hickories *(Carya* spp.) are very important also, especially to squirrels (Allen 1987).

Detrital components of the ecosystem are of considerable significance to animal populations in lowland hardwood wetlands. Litter provides ideal habitat for small animals such as salamanders (Johnson 1987) and has a distinctive invertebrate fauna (Wharton et al. 1982) that is vital to some of the more visible members of the community. For example, prior to laying eggs, wood ducks forage extensively on macro-invertebrates found in the floodplain. Similarly, mallards heavily utilize the abundant litter invertebrate populations associated with flooded bottomland forests during winter (Batema, Henderson, and Fredrickson 1985). Logs and other woody debris provide cover and a moist environment for many species including invertebrates, small mammals, reptiles, and amphibians (Hunter 1990). Animals found in forested wetlands use logs as resting sites, cover, feeding platforms, and sources of food (Harmon, Franklin, and Swanson 1986, Loeb 1993). Standing dead trees (snags) are used by numerous bird species, and several species are dependent on snags for their existence (Scott et al. 1977). Stauffer and Best (1980) found that most cavity-nesting birds, particularly the primary cavity nesters such as woodpeckers, preferred snags versus live trees. Mammals such as bats, squirrels, and raccoon also are dependent on snags to varying extents (Howard and Allen 1989), and most species of forest-dwelling mammals, reptiles, and amphibians, along with numerous invertebrates, seek shelter in cavities, at least occasionally (Hunter 1990).

In wetlands of the Yazoo Basin, hydrology is one of the major factors influencing wildlife habitat quality. A significant hydrologic component is precipitation, particularly where it is captured in vernal pools and small puddles. These sites are a source of surface water for various terrestrial animals and provide reproductive habitat for insects and amphibians, many of which are utilized as a food source by other animals (Wharton et al. 1982, Johnson 1987). Ponded breeding sites without predatory fish populations are very important for some species of salamanders and frogs (Johnson 1987).

While temporary ponding of precipitation is important to many species precisely because it provides an aquatic environment that is isolated from many aquatic predators, wetlands that are periodically river-connected also provide vital habitat for some species. Wharton et al. (1982) provided an overview of fish use of bottomland hardwoods in the Piedmont and eastern Coastal Plain and stated that at least 20 families and up to 53 species of fish use various portions of the floodplain for foraging and spawning. Baker and Killgore (1994) reported similar results from the Cache River drainage in Arkansas, where they found that most fish species exploit floodplain habitats at some time during the year, many for spawning and rearing. In addition to flooding itself, the complex environments of floodplains are of significance to fish. Wharton et al. (1982) listed numerous examples of fish species being associated with certain portions of the floodplain. Baker, Killgore, and Kasul (1991) noted that the different microhabitats on the floodplain typically supported different fish assemblages from those of the channel. Baker and Killgore (1994) stated that "the structurally complex environment of irregularly flooded oak-hickory forests provide optimum habitat for many wetland fish."

Just as topographic variations provide essential wetland habitats such as isolated temporary ponds and river-connected backwaters, they also provide sites that generally remain dry. Such sites are important to ground-dwelling species that cannot tolerate prolonged inundation. Wharton et al. (1982) stated that old, natural levee ridges are extremely important to many floodplain species, because they provide winter hibernacula and refuge areas during periods of high water. Similarly, Tinkle (1959) found that natural levees were used extensively as egg-laying areas by many species of reptiles and amphibians.

Landscape-level features such as forest patch size, shape, connectivity, and surrounding land use are also important attributes that affect the lowland wildlife community (Hunter 1990; Morrison, Marcot, and Mannan 1992). It is generally assumed that reduction and fragmentation of forest habitat, coupled with changes in the remaining habitat, resulted in the loss of the ivory-billed woodpecker *(Campephilus principalis*), Bachman's warbler *(Vermivora bachmanii*), and the red wolf *(Canis rufu*s) and severe declines in the black bear (*Ursus americanu*s) and Florida panther *(Puma concolo*r). The extent to which patch size affects animal populations has been most thoroughly investigated with respect to birds, with inconsistent results (Stauffer and Best 1980, Blake and Karr 1984, Howe 1984, Lynch and Whigham 1984, Askins, Philbrick, and Sugeno 1987, Sallabanks, Walters, and Collazo 1998, Keller, Robbins, and Hatfield 1993; Kilgo et al. 1997). However, the negative effects of forest fragmentation on some species of birds have been well documented (Finch 1991). These species, referred to as "forest interior" species, apparently respond negatively to unfavorable environmental conditions or biotic interactions in fragmented forests (Ambuel and Temple 1983). The point at which fragmentation effects begin to be realized has yet to be defined, and study results have been inconsistent (e.g. Temple 1986, Wakeley and Roberts 1996). Thus, the area needed to accommodate all the species typically associated with large patches of forested wetlands in the region can only be approximated. One such approximation (Mueller, Loesch, and Twedt 1995) identified three groups of birds that breed in the Mississippi Alluvial Valley with (presumably) similar needs relative to patch size. They suggested that to sustain source breeding populations of individual species within the 3 groups, that 44 patches of 4,000 - 8,000 ha, 18 patches of 8,000 - 40,000 ha, and 12 patches larger than 40,000 ha are needed. Species such as the Swainson's warbler are in the first group; more sensitive species such as the cerulean warbler *(Dendroica cerule*a) are in the second group; and those with very large home ranges (e.g., raptors such as the red-shouldered hawk *(Buteo lineatu*s) are in the third group.

The land-use surrounding a tract of forest also has a major effect on avian populations. Recent studies (Thompson et al. 1992; Welsh and Healy 1993; Sallabanks, Walters, and Collazo 1998; Robinson et al. 1995) suggest that bird populations respond to fragmentation differently in forest-dominated landscapes than in those in which the bulk of the forests have been permanently lost to agriculture or urbanization. Generally, these studies indicate that as the mix of feeding habitats (agricultural and suburban lands) and breeding habitats (forests and grasslands) increases, predators and nest parasites become increasingly successful, even if large blocks of habitat remain. Thus, in more open landscapes, block sizes need to be larger than in mostly forested ones. Conversely, Robinson (1996) estimated that as the percentage of the landscape that is forested increases above 70 percent (approximately), the size of the forest blocks within that landscape becomes less significant to bird populations.

In landscapes that are fragmented, corridors have been suggested as a means of ameliorating many of the anticipated negative effects of fragmentation (Harris 1985, Noss and Harris 1986), although there is disagreement over the benefits of corridors (Simberloff et al. 1992). In bottomland forest communities, probably the most significant habitat connection for many species is between flood-prone areas and nonflooded habitats of similar structure in the adjacent uplands, which allows terrestrial species to seek refuge during periods of high water (Wharton et al. 1982). In general, connections between different wetland types, and between uplands and wetlands, help maintain higher animal and plant diversity across the landscape than if habitats were more isolated from one another (Sedell et al. 1990).

## General form of the assessment model

The model for assessing the Provide Fish and Wildlife Habitat function includes the following assessment variables that are discussed in greater detail in Chapter 6:

$V_{FREQ}$: Frequency of flooding

$V_{POND}$: Micro-depressional ponding

$V_{TCOMP}$: Tree composition

$V_{SNAG}$: Snag density

$V_{TBA}$: Tree basal area

$V_{LOG}$: Log density

$V_{OHOR}$: O horizon thickness

$V_{TRACT}$: Wetland tract size

$V_{CONNECT}$: Habitat connections

$V_{CORE}$: Core area

The general form of the assessment model is:

$$FCI = \left\{ \left[ \frac{\left(V_{FREQ} + V_{POND}\right)}{2} \right] \times \left[ \frac{\left(V_{TCOMP} + V_{SNAG} + V_{TBA}\right)}{3} \right] \times \left[ \frac{\left(V_{LOG} + V_{OHOR}\right)}{2} \right] \times \left[ \frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE}\right)}{3} \right] \right\}^{1/4} \quad (8)$$

The expressions within the model reflect the major habitat components described above. The first expression concerns hydrology and includes indicators of both extensive seasonal inundation and river access by aquatic organisms ($V_{FREQ}$) as well as the periodic occurrence of temporary, isolated aquatic conditions ($V_{POND}$). The second expression is comprised of three indicators of forest structure and diversity, specifically overstory basal area ($V_{TBA}$), overstory tree species composition ($V_{TCOMP}$), and snag density ($V_{SNAG}$). Together these variables reflect a variety of conditions of importance to wildlife, including forest maturity and complexity and the availability of food and cover. Habitat structure for animals associated with detrital components is indicated by two variables: the volume of logs per unit area ($V_{LOG}$) and the thickness of the O horizon ($V_{OHOR}$). Landscape-level variables are incorporated within the model to reflect the importance of habitat fragmentation and interhabitat continuity as considerations in determining habitat quality for a large percentage of wildlife species within the Yazoo Basin. These variables include: the size of the overall wetland complex independent of the boundaries of the assessment area ($V_{TRACT}$); the proportion of the assessment area that is buffered from surrounding land uses and edge effects ($V_{CORE}$); and the proportion of the assessment area boundary that is connected to other suitable habitat types via appropriate movement corridors ($V_{CONNECT}$).

# 5 Model Applicability and Reference Data

The assessment models described in Chapter 4 are applied to individual wetland subclasses in different ways. This is because not all the assessment models and variables are applicable to all of the regional wetland subclasses. For example, the Export Organic Carbon function is applicable only to the Overbank and Backwater Riverine and Connected Depression subclasses and is not assessed in subclasses having no export mechanism (flooding) or channel outflow exits (i.e. Isolated Depressions and Flats). Similarly, some variables are not used in assessment models for subclasses where they cannot be consistently evaluated. For example, ground vegetation cover ($V_{GVC}$) and thickness of the O and A horizons ($V_{OHOR}$ and $V_{AHOR}$) are not included in models that are otherwise applicable to the depression subclasses (e.g., the Nutrient Cycling function), because depresssional sites are often flooded and the variable metrics that require the observation of soil and ground-level conditions often cannot be assessed consistently.

Assessment models also differ among subclasses with regard to their associated reference data. Each subclass was the focus of detailed sampling during development of this guidebook, and the reference data collected for each subclass have been independently summarized for application. The following sections present information for each wetland subclass with regard to model applicability and reference data. For each subclass, each of the 7 potential functions available for assessment is listed, and the applicability of the assessment model is described. The model is presented as described in Chapter 4 if it is applicable in its general and complete form; it is presented in a modified form if certain variables cannot be consistently assessed in certain subclasses; and the function is identified as "Not Applicable" in cases where the wetland subclass does not perform the function as described in Chapter 4. For each wetland subclass, functional capacity subindex curves are presented for every assessment variable used in the applicable assessment models, based on reference data.

## Subclass: Flats

Four functions are assessed for this subclass. The applicable assessment models have not been changed from the general model form presented in Chapter 4. Figure 12 provides the relationship between the variable metrics and

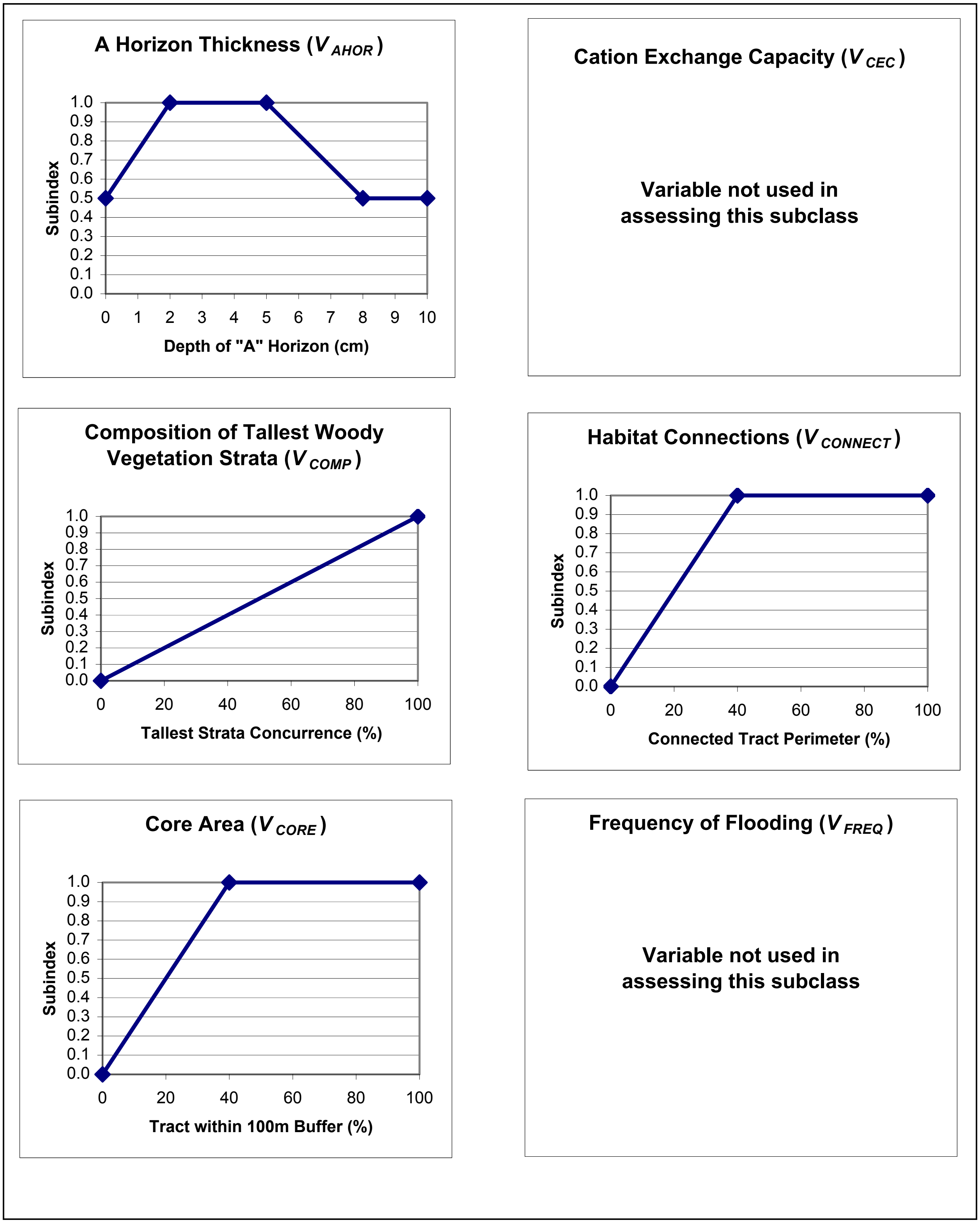


Figure 12. Subindex graphs for Flats (Sheet 1 of 3)

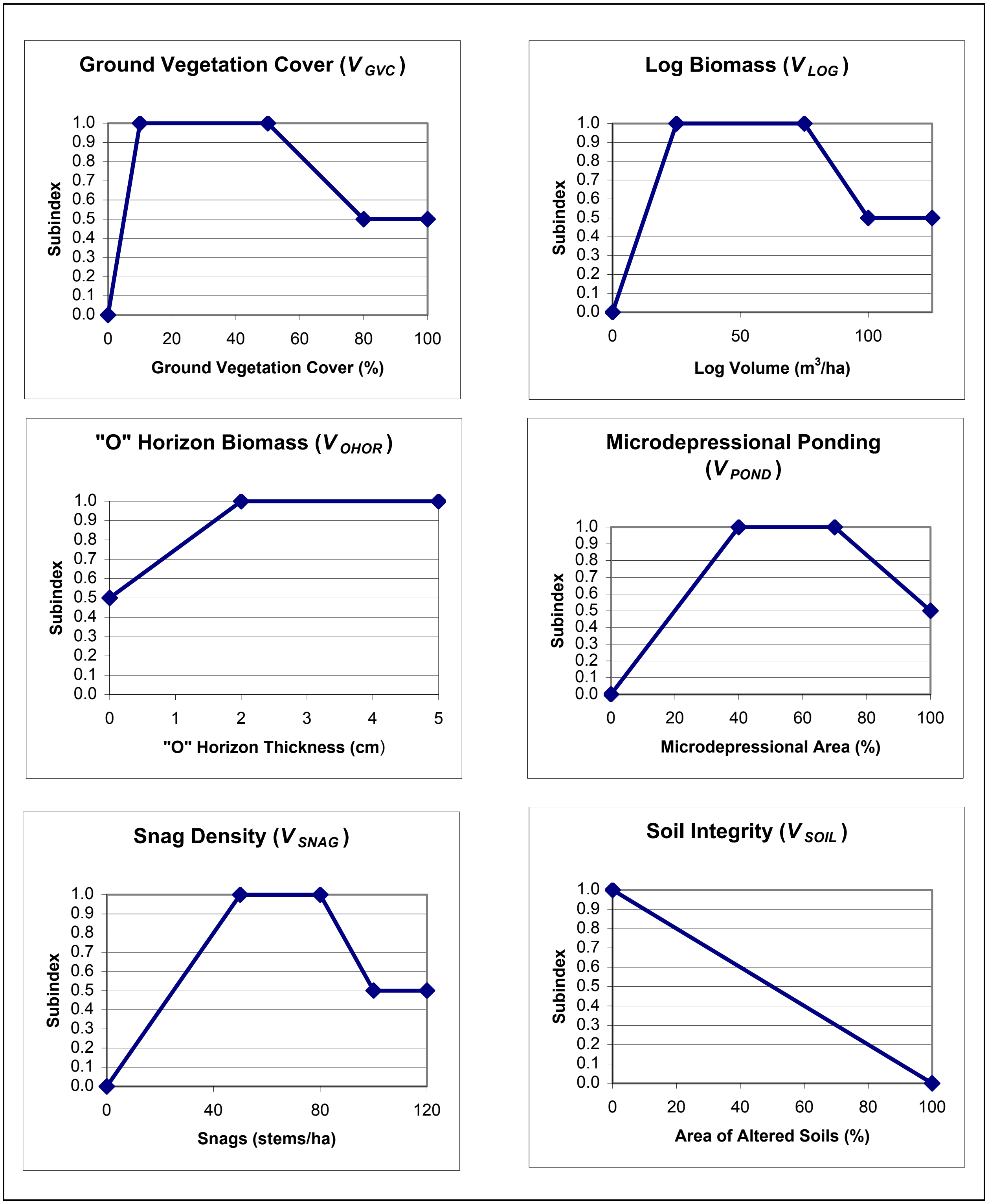


Figure 12. (Sheet 2 of 3)

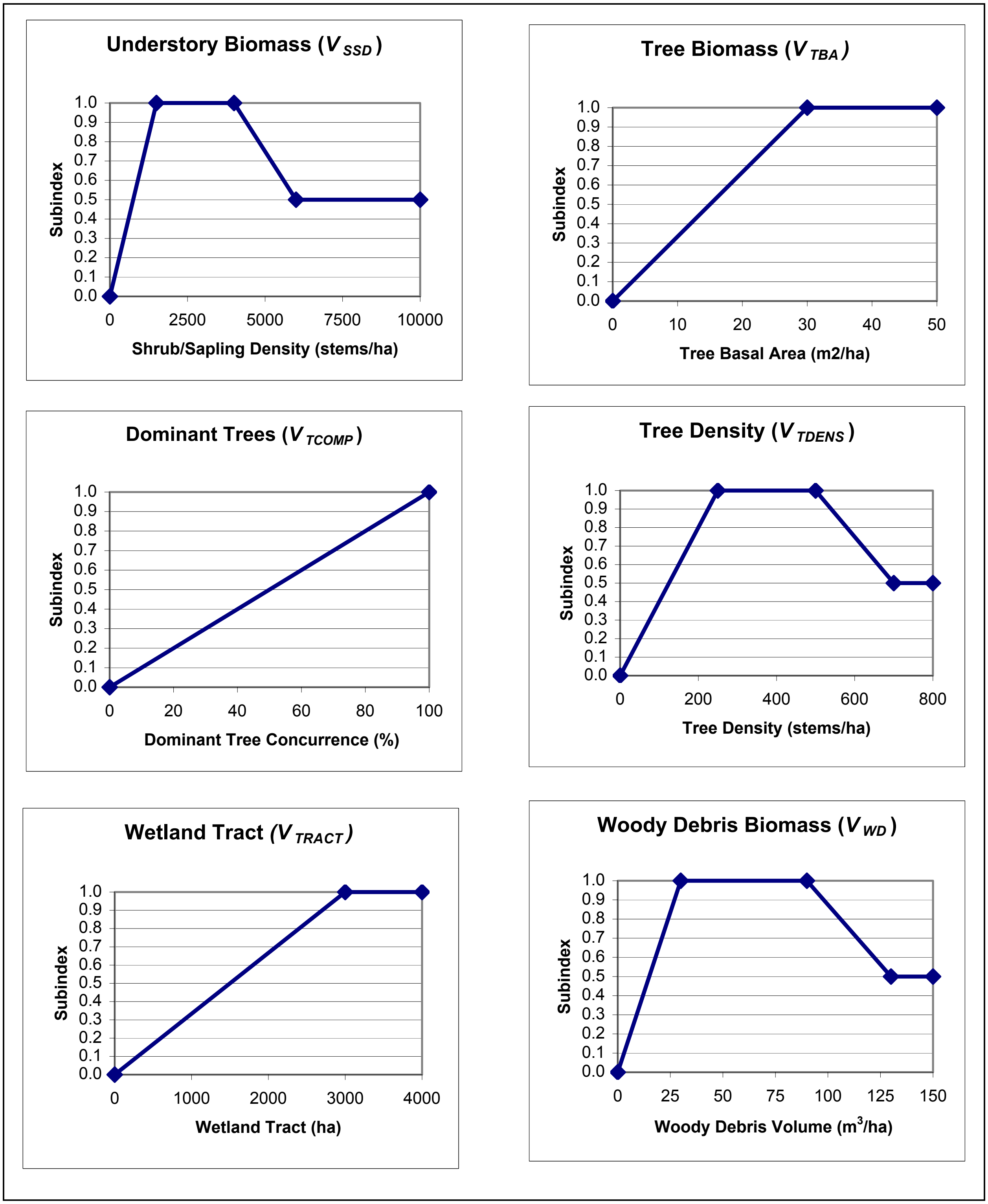


Figure 12. (Sheet 3 of 3)

the subindex for each of the assessment models based on the Flats reference data (Appendix C).

**Function 1: Detain Floodwater**

Not applicable.

**Function 2: Detain Precipitation**

$$FCI = \frac{\left(V_{POND} + V_{OHOR}\right)}{2} \tag{9}$$

**Function 3: Cycle Nutrients**

$$FCI = \frac{\left[\frac{\left(V_{TBA} + V_{SSD} + V_{GVC}\right)}{3} + \frac{\left(V_{OHOR} + V_{AHOR} + V_{WD} + V_{SNAG}\right)}{4}\right]}{2} \tag{10}$$

**Function 4: Export Organic Carbon**

Not applicable.

**Function 5: Remove Elements and Compounds**

Not applicable.

**Function 6: Maintain Plant Communities**

$$FCI = \left\langle \left\{ \frac{\left[\frac{\left(V_{TBA} + V_{TDEN}\right)}{2} + V_{COMP}\right]}{2} \right\} \times \left[\frac{\left(V_{SOIL} + V_{POND}\right)}{2}\right] \right\rangle^{1/2} \tag{11}$$

**Function 7: Provide Fish and Wildlife Habitat**

$$FCI = \left\{ V_{POND} \times \left[\frac{\left(V_{TCOMP} + V_{SNAG} + V_{TBA}\right)}{3}\right] \times \left[\frac{\left(V_{LOG} + V_{OHOR}\right)}{2}\right] \times \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE}\right)}{3}\right] \right\}^{1/4} \tag{12}$$

## Subclass: Riverine Backwater

All functions are assessed for this subclass using the general form of each assessment model presented in Chapter 4. Figure 13 provides the relationship between the variable metrics and the subindex for each of the assessment variables based on the Riverine Backwater reference data (Appendix C)

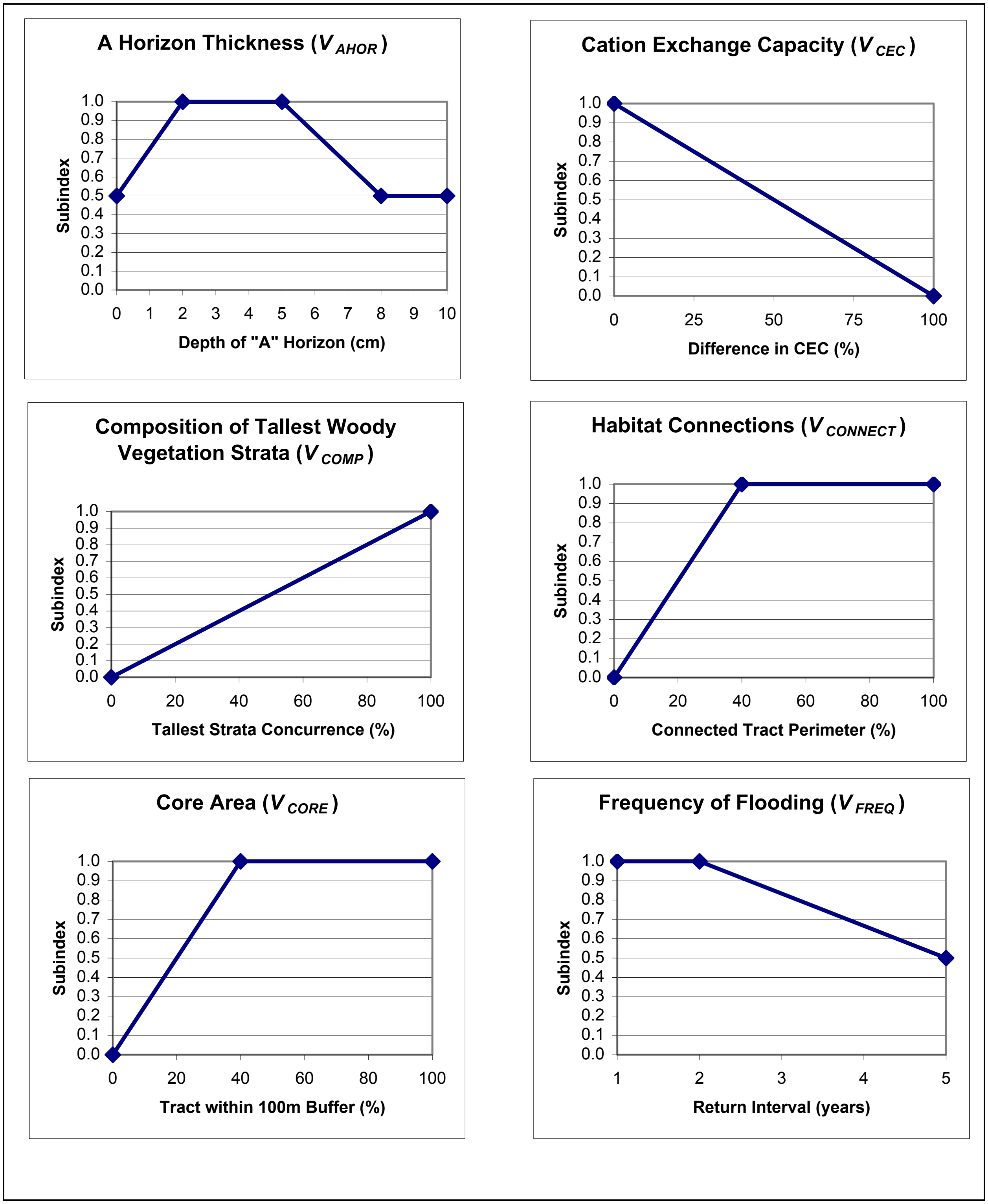


Figure 13. Subindex graphs for Riverine Backwater (Sheet 1 of 3)

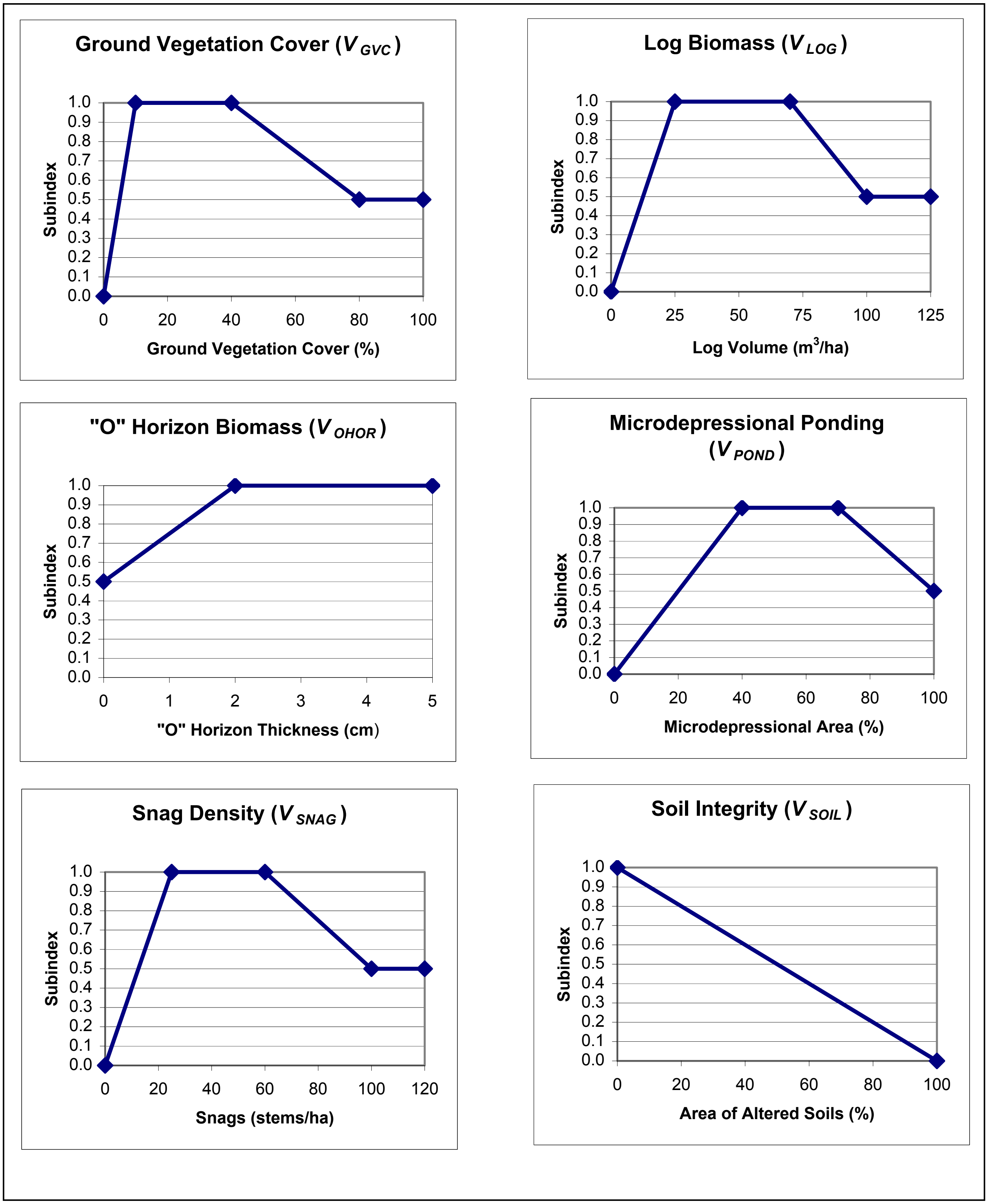


Figure 13. (Sheet 2 of 3)

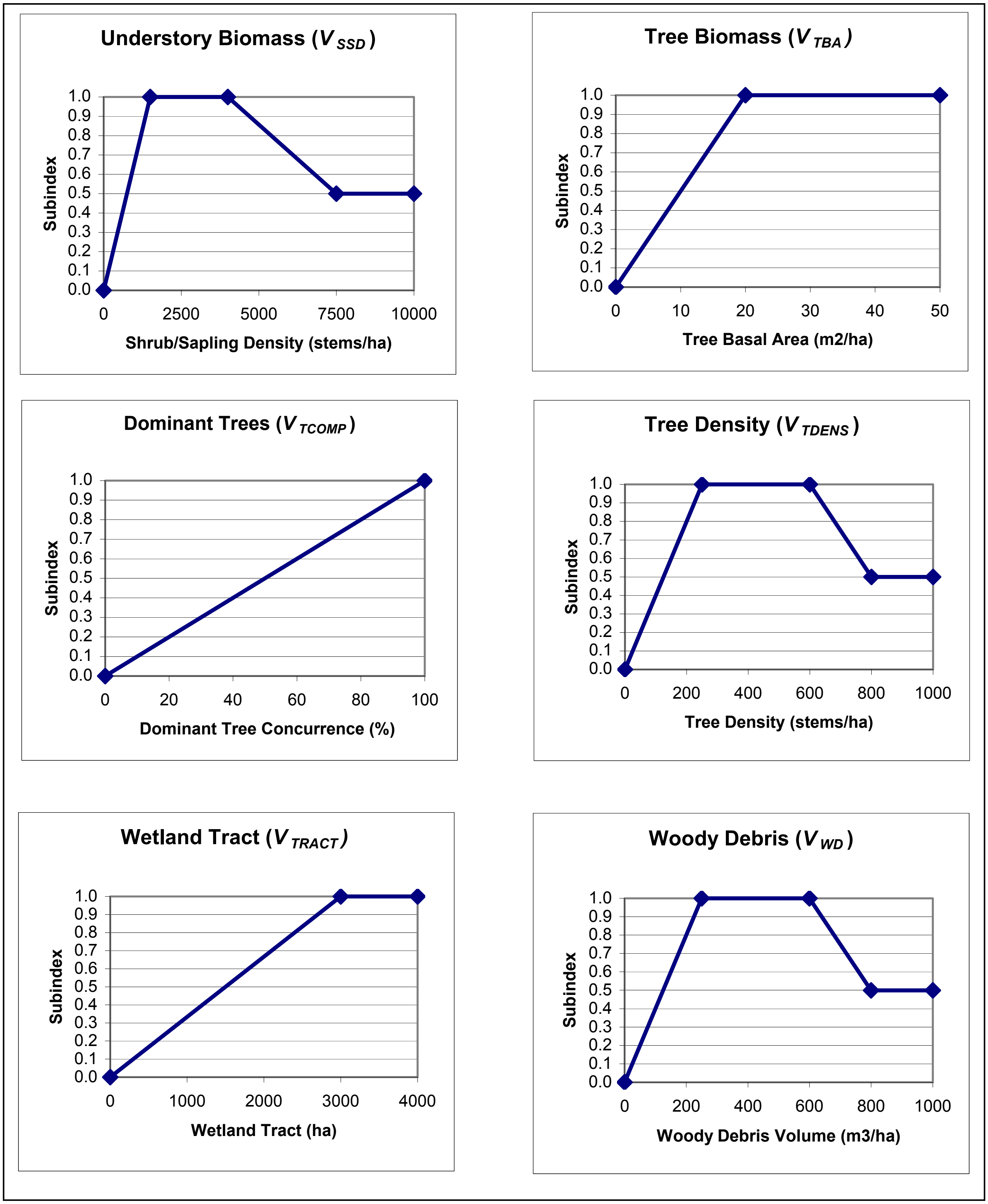


Figure 13. (Sheet 3 of 3)

**Function 1: Detain Floodwater**

$$FCI = V_{FREQ} \times \left[ \frac{\left( V_{LOG} + V_{GVC} + V_{SSD} + V_{TDEN} \right)}{4} \right] \tag{13}$$

**Function 2: Detain Precipitation**

$$FCI = \frac{\left( V_{POND} + V_{OHOR} \right)}{2} \tag{14}$$

**Function 3: Cycle Nutrients**

$$FCI = \frac{\left[ \frac{\left( V_{TBA} + V_{SSD} + V_{GVC} \right)}{3} + \frac{\left( V_{OHOR} + V_{AHOR} + V_{WD} + V_{SNAG} \right)}{4} \right]}{2} \tag{15}$$

**Function 4: Export Organic Carbon**

$$FCI = V_{FREQ} \times \frac{\left[ \frac{\left( V_{OHOR} + V_{WD} + V_{SNAG} \right)}{3} \right] + \left[ \frac{V_{TBA} + V_{SSD} + V_{GVC}}{3} \right]}{2} \tag{16}$$

**Function 5: Remove  Elements and Compounds**

$$FCI = V_{FREQ} \times \left[ \frac{\left( V_{CEC} + V_{OHOR} + V_{AHOR} \right)}{3} \right] \tag{17}$$

**Function 6:  Maintain Plant Communities**

$$FCI = \left\langle \left\{ \frac{\left[ \frac{\left( V_{TBA} + V_{TDENS} \right)}{2} + V_{COMP} \right]}{2} \right\} \times \left[ \frac{\left( V_{SOIL} + V_{POND} \right)}{2} \right] \right\rangle^{1/2} \tag{18}$$

**Function 7: Provide Fish and Wildlife Habitat**

$$FCI = \left\{ \left[ \frac{\left( V_{FREQ} + V_{POND} \right)}{2} \right] \times \left[ \frac{\left( V_{TCOMP} + V_{SNAG} + V_{TBA} \right)}{3} \right] \times \left[ \frac{\left( V_{LOG} + V_{OHOR} \right)}{2} \right] \times \left[ \frac{\left( V_{TRACT} + V_{CONNECT} + V_{CORE} \right)}{3} \right] \right\}^{1/4} \tag{19}$$

## Subclass: Riverine Overbank

All functions are assessed for this subclass using the general form of each assessment model presented in Chapter 4. Figure 14 provides the relationship between the variable metrics and the subindex for each of the assessment variables based on the Riverine Overbank reference data (Appendix C).

**Function 1: Detain Floodwater**

$$FCI = V_{FREQ} \times \left[ \frac{\left( V_{LOG} + V_{GVC} + V_{SSD} + V_{TDEN} \right)}{4} \right] \tag{20}$$

**Function 2: Detain Precipitation**

$$FCI = \frac{\left( V_{POND} + V_{OHOR} \right)}{2} \tag{21}$$

**Function 3: Cycle Nutrients**

$$FCI = \frac{\left[ \frac{\left( V_{TBA} + V_{SSD} + V_{GVC} \right)}{3} + \frac{\left( V_{OHOR} + V_{AHOR} + V_{WD} + V_{SNAG} \right)}{4} \right]}{2} \tag{22}$$

**Function 4: Export Organic Carbon**

$$FCI = V_{FREQ} \times \frac{\left[ \frac{\left( V_{OHOR} + V_{WD} + V_{SNAG} \right)}{3} \right] + \left[ \frac{V_{TBA} + V_{SSD} + V_{GVC}}{3} \right]}{2} \tag{23}$$

**Function 5: Remove Elements and Compounds**

$$FCI = V_{FREQ} \times \left[ \frac{\left( V_{CEC} + V_{OHOR} + V_{AHOR} \right)}{3} \right] \tag{24}$$

**Function 6: Maintain Plant Communities**

$$FCI = \left\langle \left\{ \frac{\left[ \frac{\left( V_{TBA} + V_{TDENS} \right)}{2} + V_{COMP} \right]}{2} \right\} \times \left[ \frac{\left( V_{SOIL} + V_{POND} \right)}{2} \right] \right\rangle^{1/2} \tag{25}$$

**Function 7: Provide Fish and Wildlife Habitat**

$$FCI = \left\{ \left[ \frac{\left( V_{FREQ} + V_{POND} \right)}{2} \right] \times \left[ \frac{\left( V_{TCOMP} + V_{SNAG} + V_{TBA} \right)}{3} \right] \times \left[ \frac{\left( V_{LOG} + V_{OHOR} \right)}{2} \right] \times \left[ \frac{\left( V_{TRACT} + V_{CONNECT} + V_{CORE} \right)}{3} \right] \right\}^{1/4} \tag{26}$$

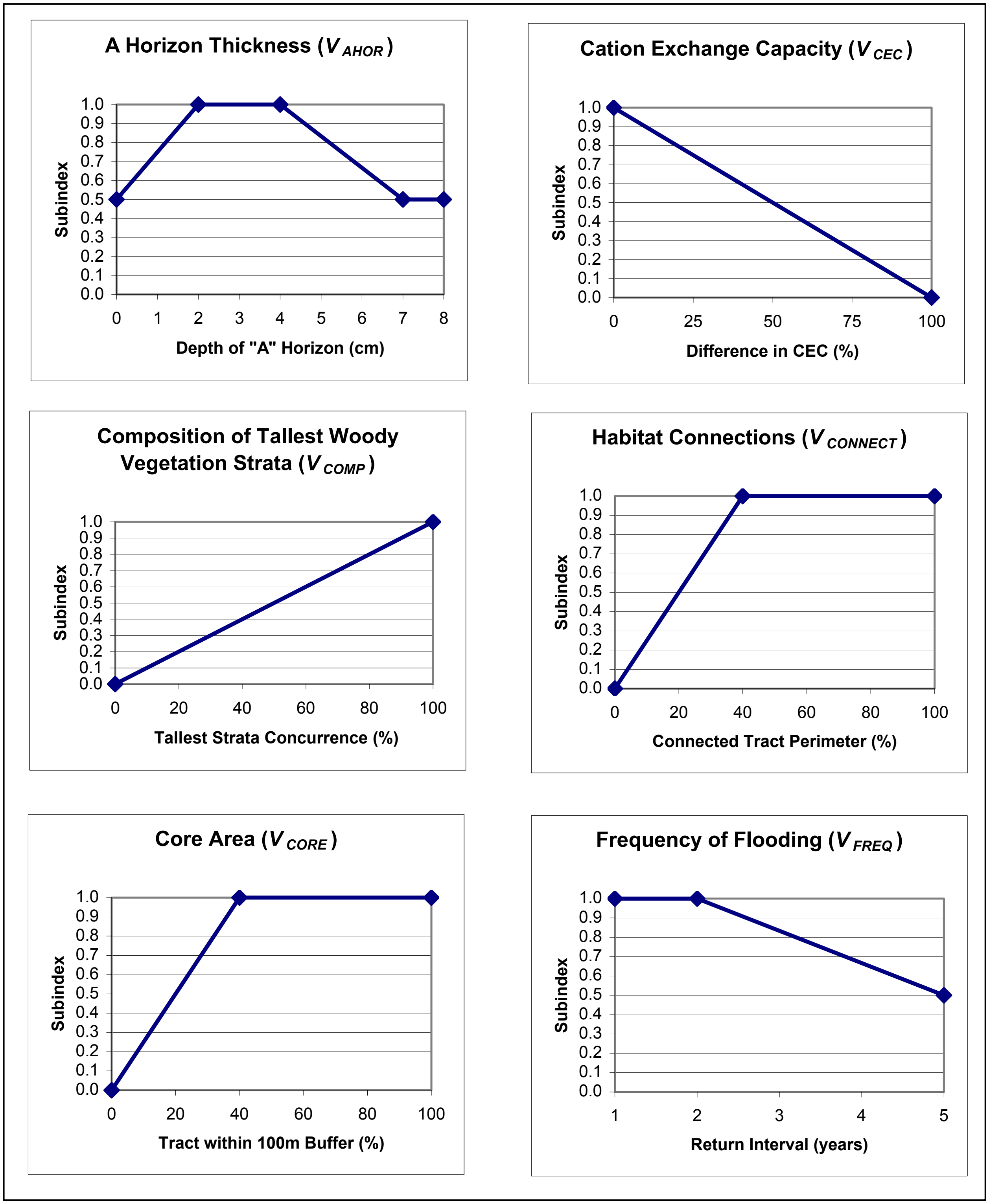


Figure 14. Subindex graphs for Riverine Overbank (Sheet 1 of 3)

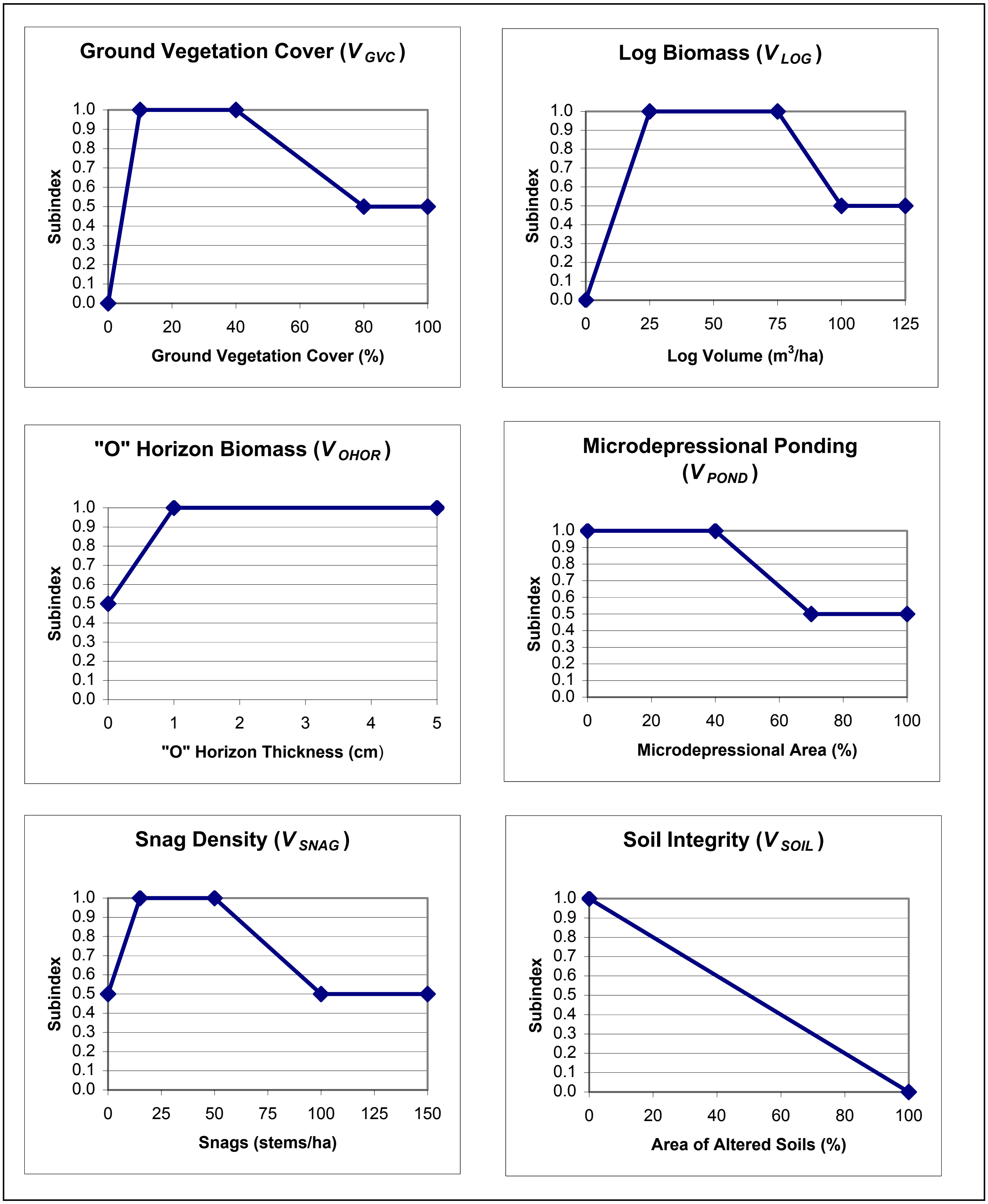


Figure 14. (Sheet 2 of 3)

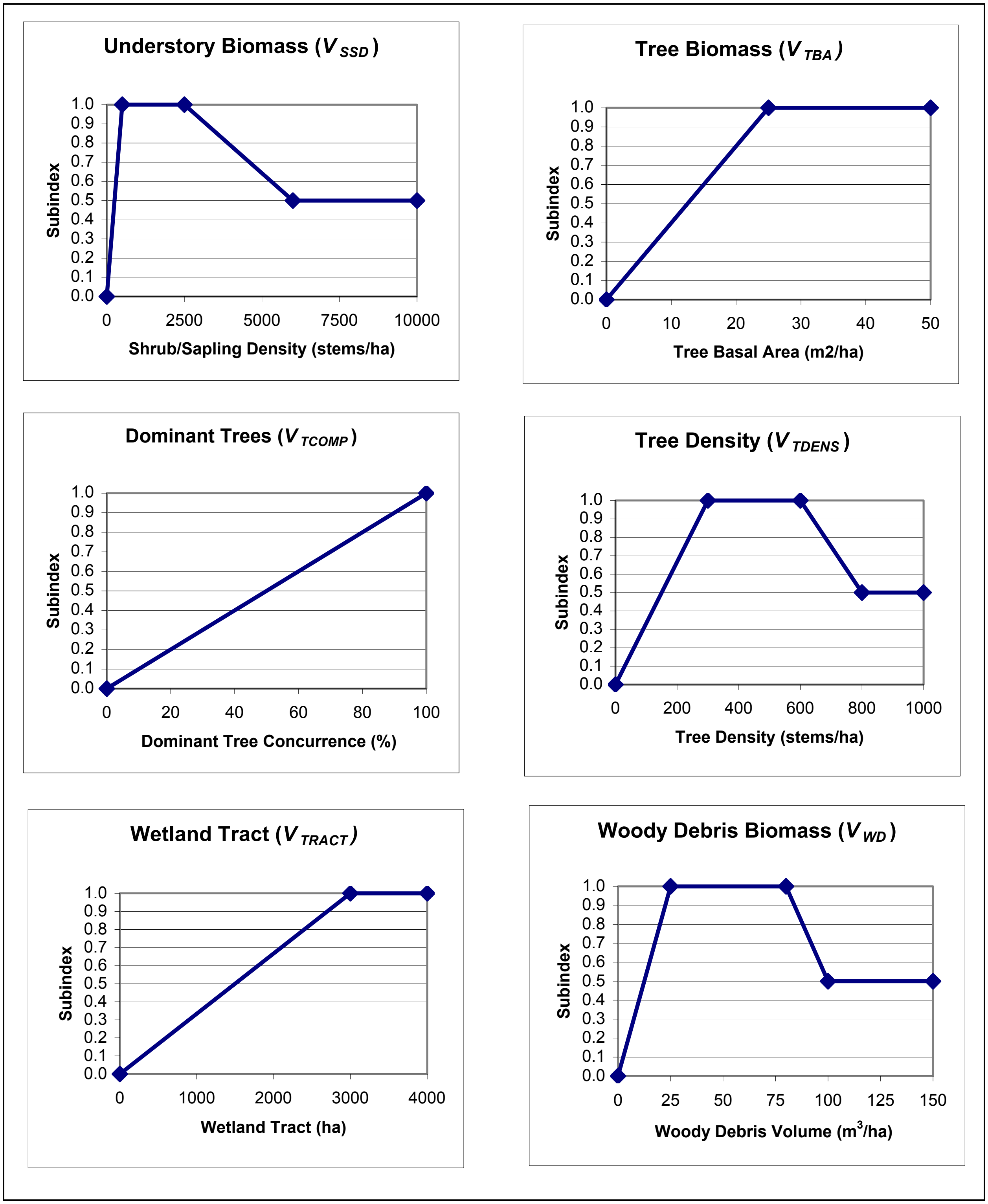


Figure 14. (Sheet 3 of 3)

## Subclass: Isolated Depression

Three functions are assessed for this subclass. All of the applicable models have been modified from the general model form presented in Chapter 4. Figure 15 provides the relationship between the variable metrics and the subindex for each of the assessment variables based on the Isolated Depression reference data (Appendix C).

**Function 1: Detain Floodwater**

Not applicable.

**Function 2: Detain Precipitation**

Not applicable.

**Function 3: Cycle Nutrients**

Applicable in the following modified form:

$$FCI = \frac{\left(V_{TBA} + V_{SSD} + V_{SNAG}\right)}{3} \tag{27}$$

**Function 4: Export Organic Carbon**

Not applicable.

**Function 5: Remove Elements and Compounds**

Not applicable.

**Function 6: Maintain Plant Communities**

Applicable in the following modified form:

$$FCI = \left\langle \left\{ \frac{\left[\frac{\left(V_{TBA} + V_{TDENS}\right)}{2} + V_{COMP}\right]}{2} \right\} \times V_{SOIL} \right\rangle^{1/2} \tag{28}$$

**Function 7: Provide Fish and Wildlife Habitat**

Applicable in the following modified form:

$$FCI = \left\{ \left[\frac{\left(V_{TCOMP} + V_{SNAG} + V_{TBA}\right)}{3}\right] \times \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE}\right)}{3}\right] \right\}^{1/2} \tag{29}$$

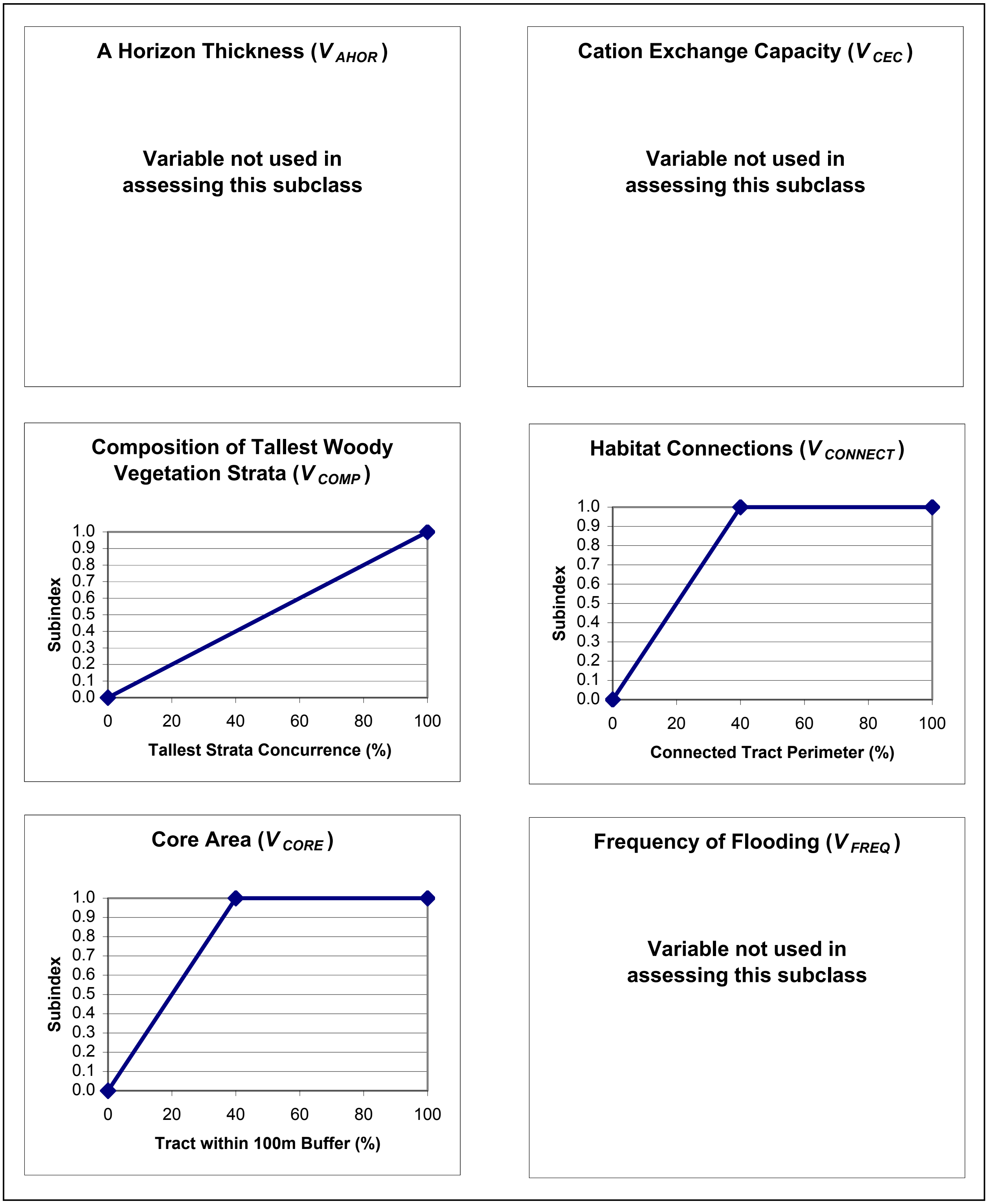


Figure 15. Subindex graphs for Isolated Depression (Sheet 1 of 3)

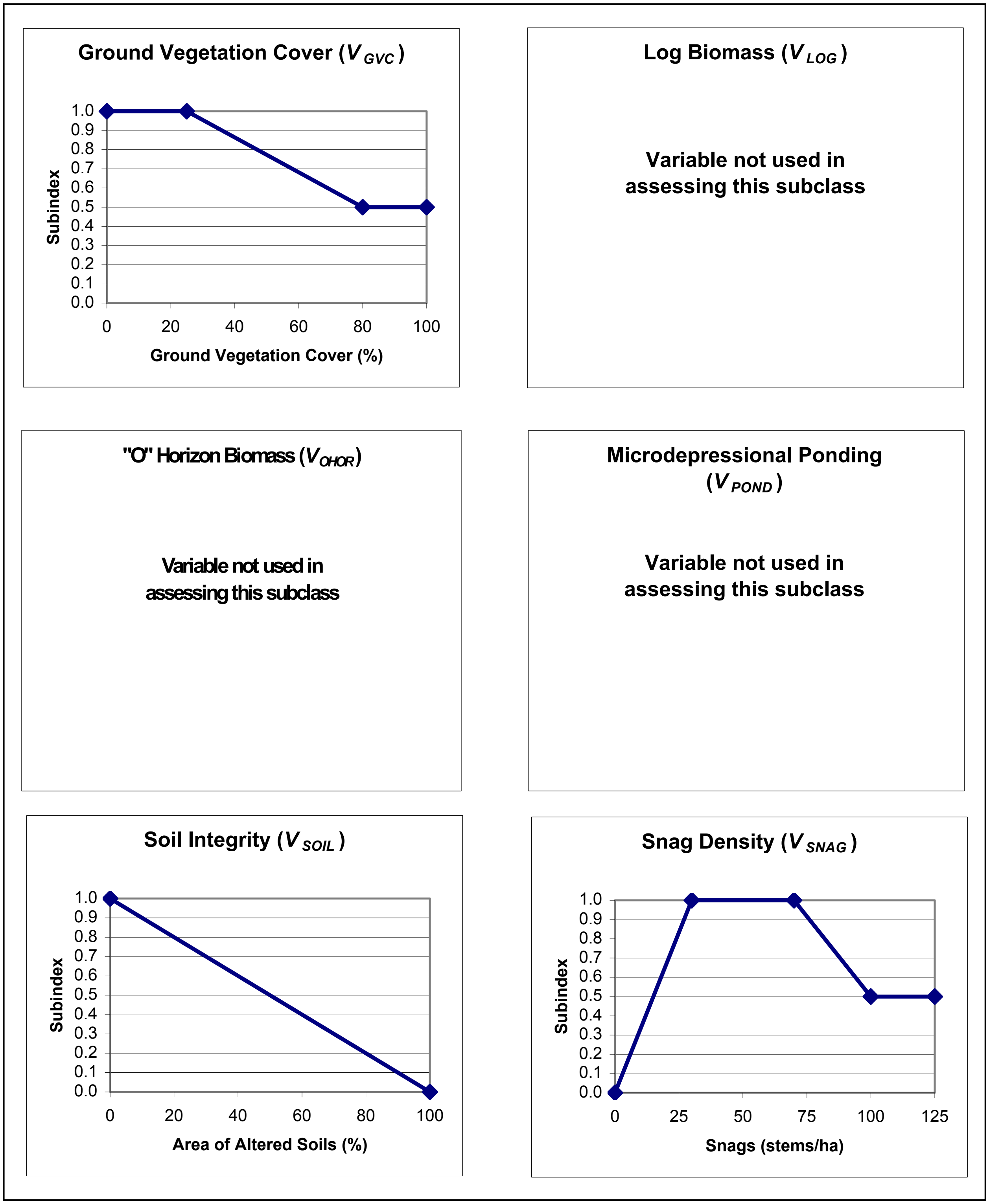


Figure 15. (Sheet 2 of 3)

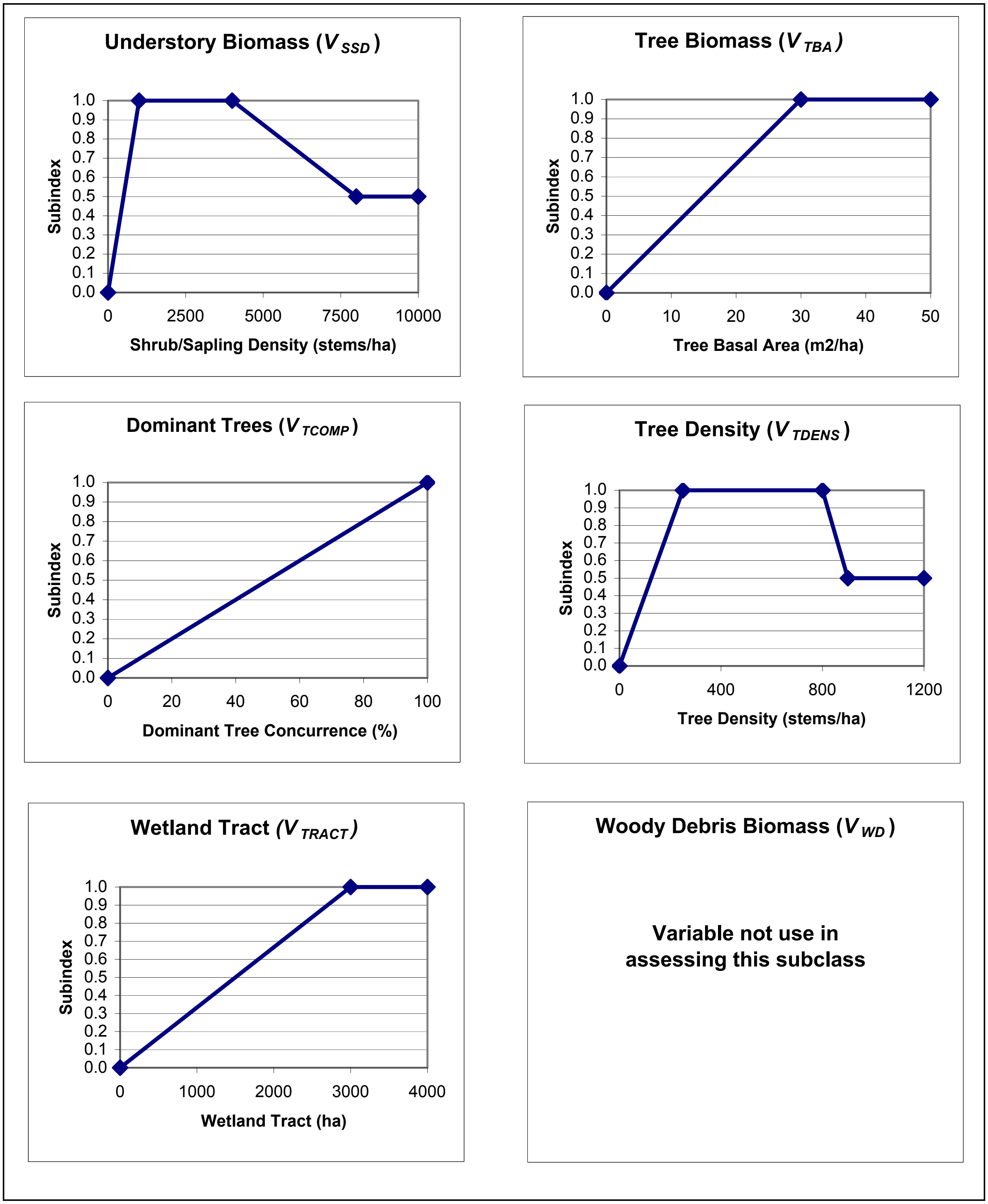


Figure 15. (Sheet 3 of 3)

## Subclass: Connected Depression

Six functions are assessed for this subclass. All of the models have been modified from the general model form presented in Chapter 4. Figure 16 provides the relationship between the variable metrics and the subindex for each of the assessment variables based on the Connected Depression reference data (Appendix C).

**Function 1: Detain Floodwater**

Applicable in the following modified form:

$$FCI = V_{FREQ} \times \left[ \frac{\left(V_{SSD} + V_{TDEN}\right)}{2} \right] \tag{30}$$

**Function 2: Detain Precipitation**

Not applicable.

**Function 3: Cycle Nutrients**

Applicable in the following modified form:

$$FCI = \frac{\left(V_{TBA} + V_{SSD} + V_{SNAG}\right)}{3} \tag{31}$$

**Function 4: Export Organic Carbon**

Applicable in the following modified form:

$$FCI = V_{FREQ} \times \left[ \frac{\left(V_{TBA} + V_{SSD} + V_{SNAG}\right)}{3} \right] \tag{32}$$

**Function 5: Remove Elements and Compounds**

Applicable in the following modified form:

$$FCI = V_{FREQ} \times V_{CEC} \tag{33}$$

**Function 6: Maintain Plant Communities**

Applicable in the following modified form:

$$FCI = \left\langle \left\{ \frac{\left[ \frac{\left( V_{TBA} + V_{TDEN} \right)}{2} + V_{COMP} \right]}{2} \right\} \times V_{SOIL} \right\rangle^{1/2} \tag{34}$$

**Function 7: Provide Fish and Wildlife Habitat**

Applicable in the following modified form:

$$FCI = \left\{ V_{FREQ} \times \left[ \frac{\left( V_{TCOMP} + V_{SNAG} + V_{TBA} \right)}{3} \right] \times \left[ \frac{\left( V_{TRACT} + V_{CONNECT} + V_{CORE} \right)}{3} \right] \right\}^{1/3} \tag{35}$$

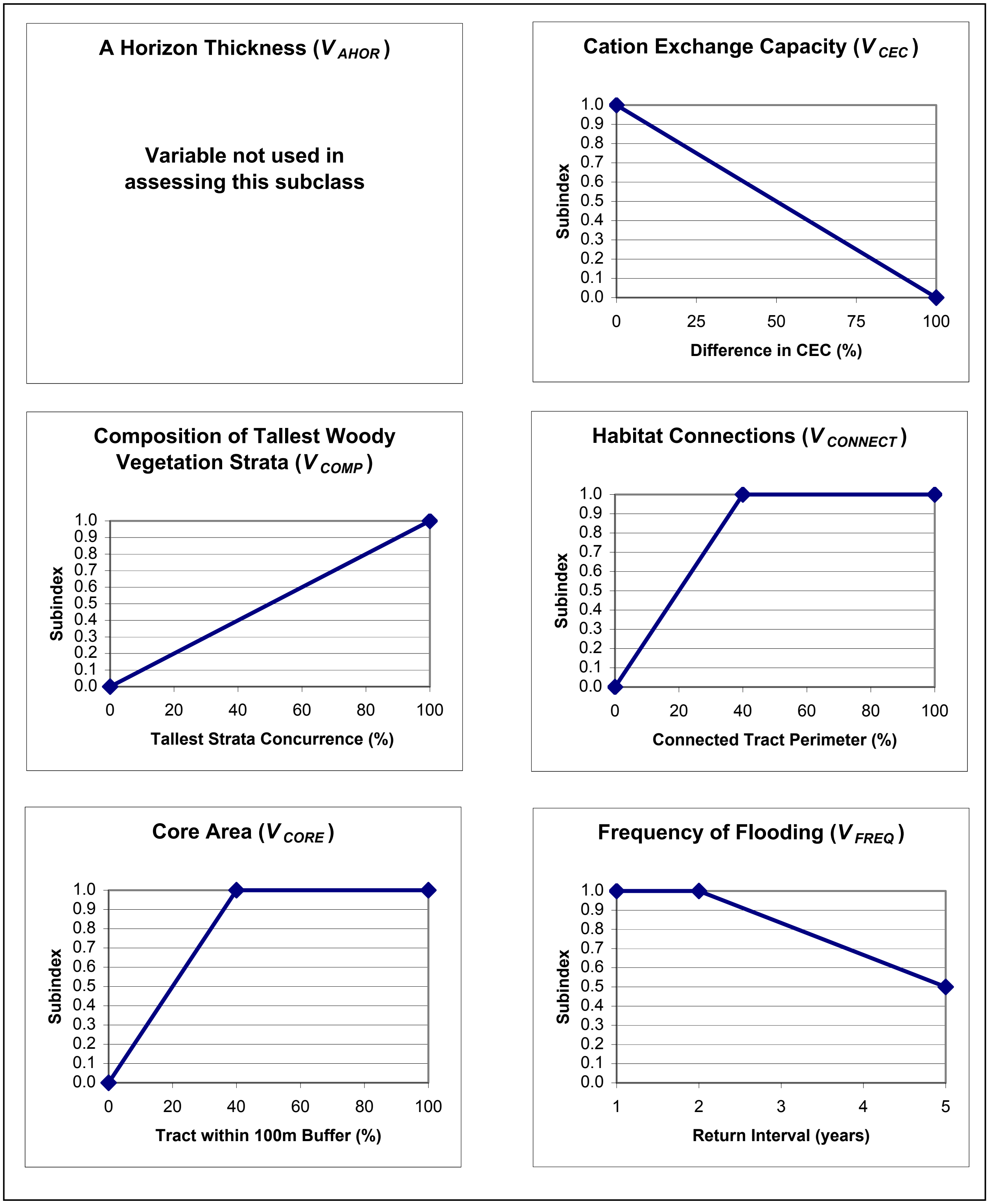


Figure 16. Subindex graphs for Connected Depression (Sheet 1 of 3)

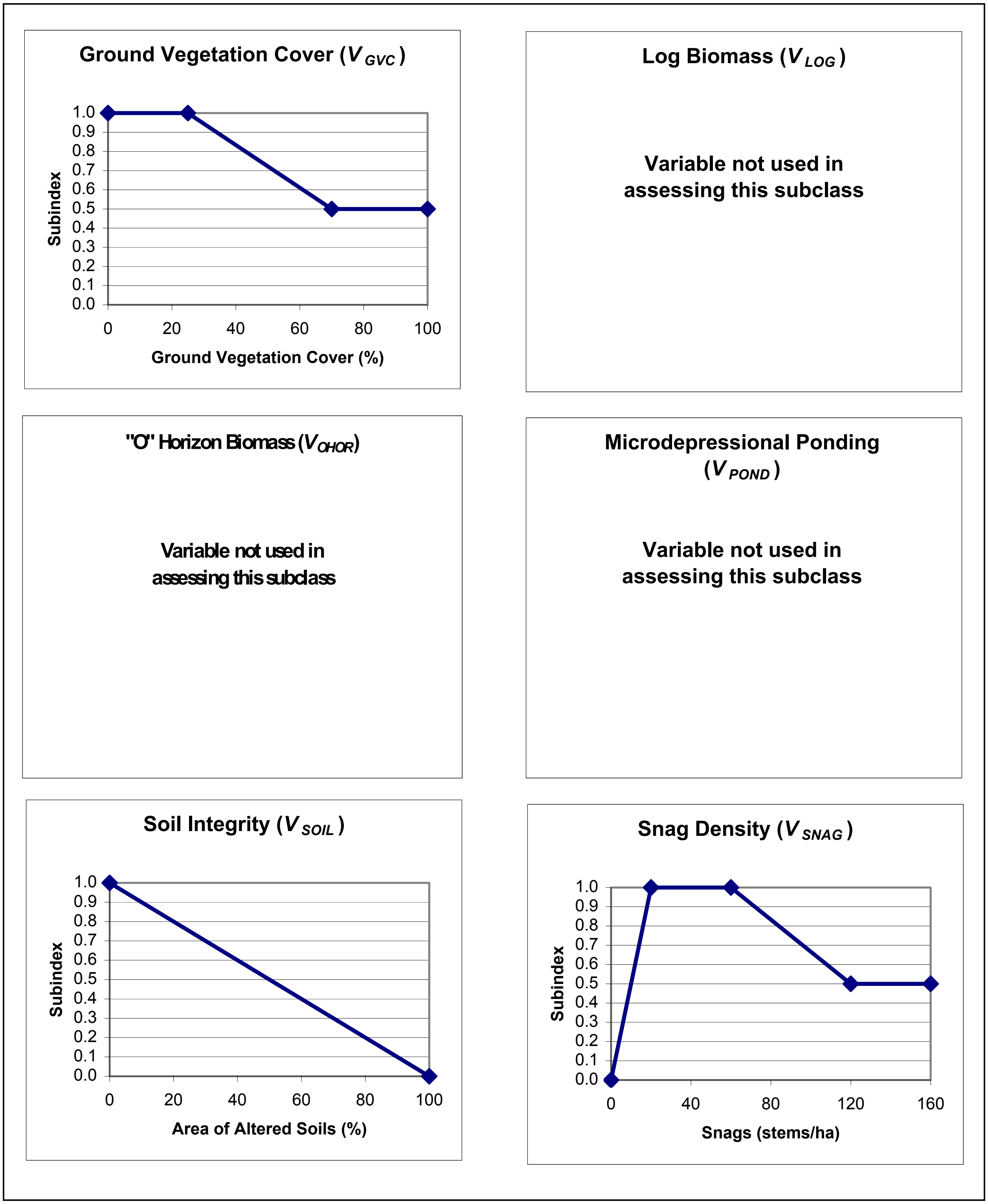


Figure 16. (Sheet 2 of 3)

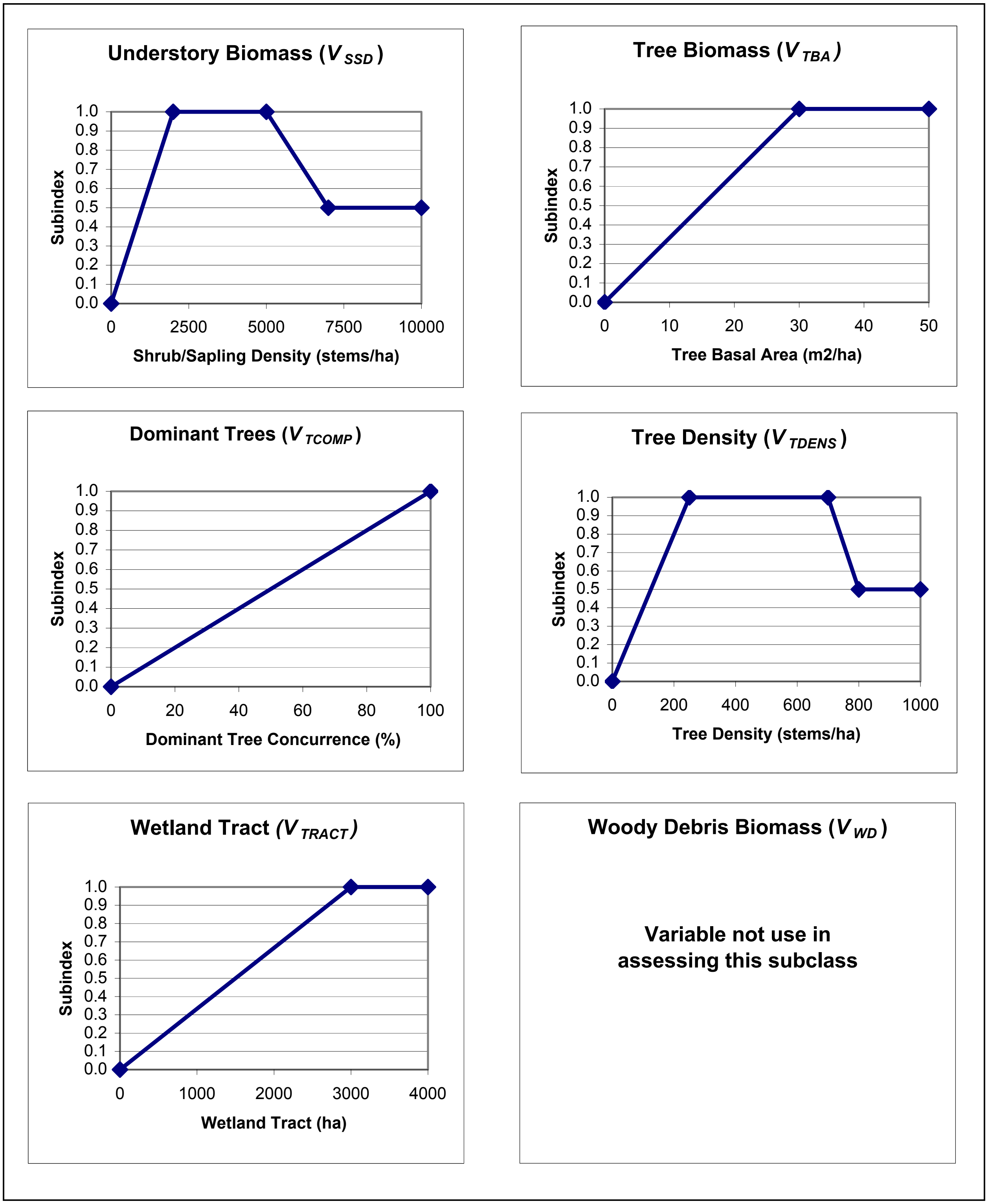


Figure 16. (Sheet 3 of 3)

# 6 Assessment Protocol

## Introduction

Previous chapters of this Regional Guidebook have provided background information on the HGM Approach, characterized regional wetland subclasses, and documented variables, metrics, and assessment models/functional indices used to assess regional wetland subclasses in the Yazoo Basin. This chapter outlines the procedures for collecting and analyzing the data required to conduct an assessment in the context of a 404 Permit review process or similar assessment situation.

A typical individual 404 Permit review requires that a comparison be made between pre- and postproject conditions of wetlands at the project site. This analysis provides a measure of the loss or gain of function as a result of project impacts. Both the pre- and postproject assessments should be completed at the project site before the proposed project has begun. Data for the pre-project assessment represent existing conditions at the project site, while data for the post-project assessment are normally based on a prediction of the conditions that can reasonably be expected to exist following proposed project impacts. A well-documented set of assumptions should be provided with the assessment to support the predicted postproject conditions used in making an assessment.

The tasks required to assess regional wetland subclasses in the Yazoo Basin using the HGM Approach include:

*a.* Define assessment objectives.

*b.* Identify regional wetland subclasses.

*c.* Characterize the project area.

*d.* Screen for red flags.

*e.* Define the wetland assessment areas.

*f.* Collect field data.

*g.* Analyze field data.

*h.* Apply assessment results.

The following sections discuss each of these tasks in greater detail.

## Define Assessment Objectives

Begin the assessment process by unambiguously stating the objective of conducting the assessment. This might be as simple as, "The purpose of this assessment is to determine how the proposed project will impact wetland functions." Other potential objectives might be to:

*a.* Compare several wetlands as part of an alternatives analysis.

*b.* Identify specific actions that can be taken to minimize project impacts.

*c.* Document baseline conditions at the wetland site.

*d.* Determine mitigation requirements.

*e.* Determine mitigation success.

*f.* Determine the effects of a wetland management technique.

Frequently, there will be multiple objectives, and defining these objectives in a clear and concise manner will facilitate communication and understanding between those involved in conducting the assessment as well as other interested parties. In addition, it will help to define the specific approach and level of effort that will be required to conduct assessments. For example, the specific approach and level of effort will change depending on whether the project is an individual 404 Permit review, an Advanced Identification (ADID), a Special Area Management Plan (SAMP), or some other assessment scenario.

## Identify Regional Wetland Subclasses

Identify the regional wetland subclasses that wetlands in the project area belong to using the dichotomous key in Figure 11. Depending on the subclasses represented, determine which variables must be collected based on the information provided in Table 9.

## Characterize the Project Area

Characterizing the project area involves describing the project area in terms of its project name, location, assessment objectives, hydrogeomorphic and

**Table 9**
**Use of Assessment Variables by Regional Wetland Subclass**

| Variable Code | Flat | Riverine Backwater | Riverine Overbank | Isolated Depression | Connected Depression |
|---|---|---|---|---|---|
| $V_{AHOR}$ | * | * | * | not used | not used |
| $V_{CEC}$ | not used | * | * | not used | * |
| $V_{COMP}$ | * | * | * | * | * |
| $V_{CONNECT}$ | * | * | * | * | * |
| $V_{CORE}$ | * | * | * | * | * |
| $V_{FREQ}$ | not used | * | * | not used | * |
| $V_{GVC}$ | * | * | * | * | not used |
| $V_{LOG}$ | * | * | * | not used | not used |
| $V_{OHOR}$ | * | * | * | not used | not used |
| $V_{POND}$ | * | * | * | not used | not used |
| $V_{SNAG}$ | * | * | * | * | * |
| $V_{SOIL}$ | * | * | * | * | * |
| $V_{SSD}$ | * | * | * | * | * |
| $V_{TBA}$ | * | * | * | * | * |
| $V_{TCOMP}$ | * | * | * | * | * |
| $V_{TDEN}$ | * | * | * | * | * |
| $V_{TRACT}$ | * | * | * | * | * |
| $V_{WD}$ | * | * | * | not used | not used |

wetland classification, climate, surficial geology, geomorphic setting, surface and groundwater hydrology, vegetation, soils, land use, existing cultural alteration, proposed impacts, and any other characteristics and processes that have the potential to influence how wetlands at the project area perform functions. The characterization should be written and should be accompanied by maps and figures that show project area boundaries, jurisdictional wetlands, wetland assessment areas (see below), proposed impacts, roads, ditches, buildings, streams, soil types, plant communities, threatened or endangered species habitat, and other important features. Figure 17 provides an example of a project area characterization.

Some information sources that will be useful in characterizing a project area include:

*a.* Aerial photographs

*b.* Topographic maps

*c.* National Wetland Inventory maps

**Project Area Characterization**

**Project Name and Location:** Little Muddy River access road bridge crossing. Four miles west of Valley Park, Issaquena County, Mississippi. Range 5W, Township 9N, Section 6.

**Nature of Project:** The project will improve a road crossing over the Little Muddy River damaged during recent flooding. The road provides year-round access to the local boat launch. In addition, one-half acre of forested wetland will be cleared in order to construct a boathouse.

**Assessment Objective:** The objective is to determine the impact of the proposed discharge of dredged or fill material on the functions performed by the jurisdictional wetlands in the project area.

**Hydrogeomorphic and National Wetland Inventory Classification Category:**

Regional Subclass = Riverine Backwater.

NWI Class = Palustrine forested, seasonally flooded (PFO1a)

**Description of Project Area and Surrounding Landscape:**

This project is located on the alluvial floodplain of a third order reach of the Little Muddy River in Issaquena County, Mississippi. The active, annual floodplain in this reach ranges from one-quarter to one-third mile wide. The main channel of the Little Muddy is presently near the center of the annual floodplain. The Little Muddy is a tributary of the Yazoo River, and the project area is located approximately 4 miles north of the Yazoo River main channel. The area normally floods to a depth of 2-3 feet several times during the winter and spring each year.

Most of the floodplain is forested with the Cypress-Tupelo (Type 102), Overcup Oak-Bitter Pecan (Type 96), and Sweetgum-Willow Oak (Type 92) cover types dominating (U.S. Forest Service 1982). Terraces (i.e., historical floodplains) adjacent to the active floodplain are mostly cleared and dedicated to the cultivation of cotton and soybeans. Soils on the active floodplain are hydric and belong to the Sharkey Series with a predominance of the Sharkey and Dowling Clays (Sr) map unit (U.S. Soil Conservation Service 1961).

Site Map:

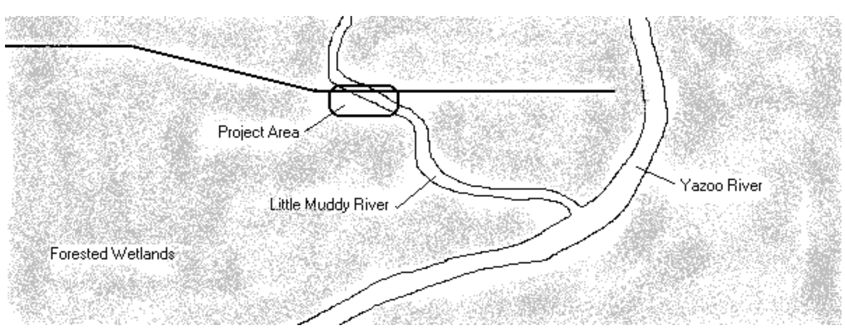


Figure 17. Example of project area description

*d.* Geomorphic maps (Kolb et al. 1986)

*e.* County Soil Survey

*f.* Chapter 3 of this Regional Guidebook

## Screen for Red Flags

Red flags are features in the vicinity of the project area to which special recognition or protection has been assigned on the basis of objective criteria (Table 10). Many red flag features, based on national criteria or programs, are similar from region to region. Other red flag features are based on regional or local criteria. Screening for red flag features determines if the wetlands or other natural resources around the project area require special consideration or attention that may preempt or postpone conducting a wetland assessment. For example, if a proposed project has the potential to impact threatened or endangered species habitat, an assessment may be unnecessary since the project may be denied or modified based on the impacts to threatened or endangered species or habitat.

**Table 10**
**Red Flag Features and Respective Program/Agency Authority**

| Red Flag Features | Authority[1] |
|---|---|
| Native Lands and areas protected under the American Indian Religious Freedom Act | A |
| Hazardous waste sites identified under CERCLA or RCRA | I |
| Areas protected by a Coastal Zone Management Plan | E |
| Areas providing Critical Habitat for Species of Special Concern | B, C, F |
| Areas covered under the Farmland Protection Act | K |
| Floodplains, floodways, or flood-prone areas | J |
| Areas with structures/artifacts of historic or archeological significance | G |
| Areas protected under the Land and Water Conservation Fund Act | K |
| Areas protected by the Marine Protection Research and Sanctuaries Act | B, D |
| National wildlife refuges and special management areas | C |
| Areas identified in the North American Waterfowl Management Plan | C, F |
| Areas identified as significant under the RAMSAR Treaty | H |
| Areas supporting rare or unique plant communities | C, H |
| Areas designated as Sole Source Groundwater Aquifers | I, L |
| Areas protected by the Safe Drinking Water Act | I, L |
| City, County, State, and National Parks | D, F, H, L |
| Areas supporting threatened or endangered species | B, C, F, H, I |
| Areas with unique geological features | H |
| Areas protected by the Wild and Scenic Rivers Act or Wilderness Act | D |

[1] Program Authority / Agency
A = Bureau of Indian Affairs
B = National Marine Fisheries Service
C = U.S. Fish and Wildlife Service
D = National Park Service
E = State Coastal Zone Office
F = State Departments of Natural Resources, Fish and Game, etc.
G = State Historic Preservation Office
H = State Natural Heritage Offices
I = U.S. Environmental Protection Agency
J = Federal Emergency Management Administration
K = National Resource Conservation Service
L = Local Government Agencies

# Define the Wetland Assessment Areas

The wetland assessment area (WAA) is an area of wetland within a project area that belongs to a single regional wetland subclass and is relatively homogeneous with respect to the criteria used to assess wetland functions (i.e., hydrologic regime, vegetation structure, topography, soils, successional stage). In many project areas, there will be just one WAA as illustrated in Figure 18. However, as the size and heterogeneity of the project area increases, it is more likely that it will be necessary to define and assess multiple WAAs within a project area.

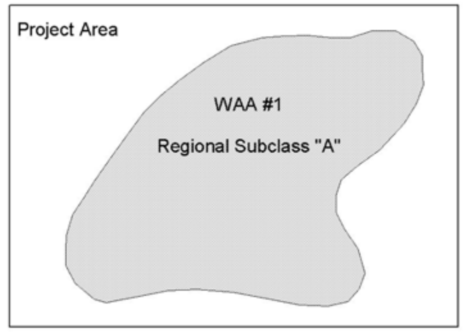


Figure 18. A single WAA within a project area

At least three situations can be identified that necessitate defining and assessing multiple WAAs within a project area. The first situation occurs when widely separated areas of wetland, belonging to the same regional subclass, occur in the project area (Figure 19).

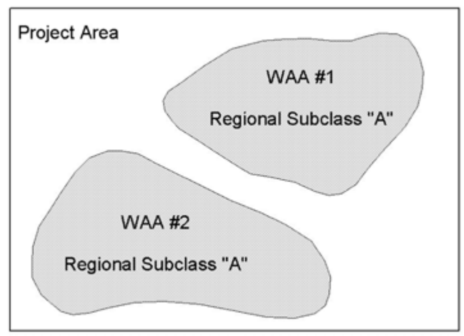


Figure 19. Spatially separated WAAs from the same regional wetland subclass within a project area

The second situation occurs when more than one regional wetland subclass occurs within a project area (Figure 20), and the third situation occurs when a contiguous wetland area of the same regional subclass exhibits spatial heterogeneity in terms of hydrology, vegetation, soils, or other assessment criteria (Figure 21).

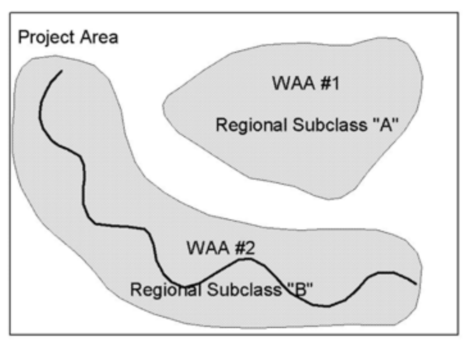


Figure 20. Spatially separated WAAs from different regional wetland subclasses within a project area

The differences may be a result of natural variability (e.g., zonation on large river floodplains) or cultural alteration (e.g., logging, surface mining, hydrologic alterations). Each significantly different portion of the contiguous area should be designated as a separate WAA and assessed separately.

There are elements of subjectivity and practicality in determining what constitutes “significantly different” portions of a contiguous wetland area. Field experience with the regional wetland subclass under consideration should provide a sense of the range of variability that typically occurs and the “common sense” necessary to make reasonable decisions in defining multiple WAAs.

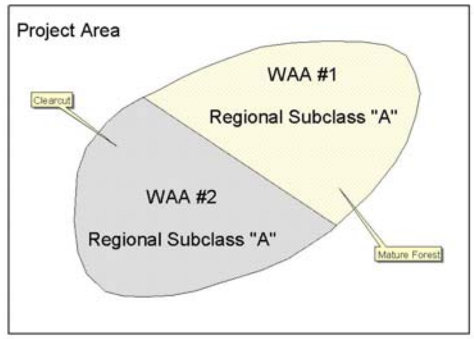


Figure 21. WAA defined based on differences in site-specific characteristics

In the Yazoo Basin, recently abandoned cropland and land harvested for timber will be two common criteria for designating multiple WAAs in a project area. Splitting a project area into many WAAs, based on relatively minor differences, will lead to a rapid increase in sampling and analysis requirements. In general, differences resulting from natural variability should not be used as a basis for dividing a project area into multiple WAAs. However, zonation caused by different hydrologic regimes or disturbances caused by rare and destructive natural events (e.g., hurricanes) should be used as a basis for defining WAA.

## Collect Field Data

The following equipment is necessary to collect field data.

*a.* Plant identification keys

*b.* Soil probe/sharpshooter shovel

*c.* County Soil Survey

*d.* Munsell color book and hydric soil indicator list (U.S. Department of Agriculture, NRCS 1998b)

*e.* Diameter tape or calipers for measuring tree basal area

*f.* 50-m distance measuring tape and meter sticks, stakes, and flagging.

Information on the variable and metrics used to assess the functions of regional wetland subclasses in the Yazoo Basin is collected at several different spatial scales. The Data Form 1 shown in Figure 22 is organized to facilitate data collection at each of these spatial scales. For example, the first group of variables, which includes $V_{TRACT}$, contains information about landscape scale characteristics collected using aerial photographs, maps, and field reconnaissance of the area surrounding the WAA. Information on the second group of variables, which

| | | |
|---|---|---|
| Data Form 1: Yazoo Basin Regional Guidebook - Variable / Metric Summary<br>(Important Note: Use a separate Data Form 1 for each assessment area sampled) | | |
| Assessment Team: | Regional Subclass: | |
| Project Name / Location: | Date: | |
| Quantify the following variables with field recon, aerials, topographic maps, or GIS | | |
| $V_{TRACT}$ | Size of forested wetland that is contiguous with the WAA | ha |
| $V_{CORE}$ | Size of wetland tract that is core area | % |
| $V_{CONNECT}$ | Percent of wetland tract that is connected to "suitable habitat" | % |
| $V_{FREQ}$ | Overbank flood recurrence interval in the WAA | years |
| Sample the following variables based on a walking field reconnaissance of the WAA | | |
| $V_{POND}$ | Percent of the wetland assessment area with topographic micro-depressions that pond water | % |
| $V_{SOIL}$ | Percent of the wetland assessment area with culturally unaltered soils | % |
| $V_{CEC}$ | Percent difference in CEC in WAA (from Data Form 2) | % |
| Transfer plot values for the following variables to this sheet from the Data Forms 3-6 | | |
| $V_{TBA}$ | Average tree basal area plot values below (Data Form 3), record at right<br>Plot 1 ____ m3/ha Plot 2 ____ m3/ha Plot 3 ____ m3/ha Plot 4 ____ m3/ha | m2/ha |
| $V_{TDEN}$ | Average tree density plot values below (Data Form 3), record at right<br>Plot 1 __ stems/ha Plot 2 __ stems/ha Plot 3 __ stems/ha Plot 4 __ stems/ha | stems/ha |
| $V_{SNAG}$ | Average snag density plot values below (from Data Form 3), record at right<br>Plot 1 __ stems/ha Plot 2 __ stems/ha Plot 3 __ stems/ha Plot 4 __ stems/ha | stems/ha |
| $V_{TCOMP}$ | Average percent concurrence with dominant trees plot values below (Data Form 4), record at right<br>Plot 1 ___ % Plot 2 ___ % Plot 3 ___ % Plot 4 ___ % | % |
| $V_{COMP}$ | Average percent concurrence with dominant species in tallest woody stratum plot values below (Data Form 4), record at right<br>Plot 1 ___ % Plot 2 ___ % Plot 3 ___ % Plot 4 ___ % | % |
| $V_{WD}$ | Average volume of woody debris plot values below (Data Form 5), record at right<br>Plot 1___ m3/ha Plot 2 ___ m3/ha Plot 3 ___ m3/ha Plot 4 ___ m3/ha | m3/ha |
| $V_{LOG}$ | Average volume of log plot values below (Data Form 5), record at right<br>Plot 1___ m3/ha Plot 2 ___ m3/ha Plot 3 ___ m3/ha Plot 4 ___ m3/ha | m3/ha |
| $V_{SSD}$ | Average density of shrub-sapling strata plot values below (Data Form 6), record at right<br>Plot 1 __ stems/ha Plot 2 __ stems/ha Plot 3 __ stems/ha | stems/ha |
| $V_{GVC}$ | Average ground vegetation cover plot values below (Data Form 6), record at right<br>Plot 1 ___ % Plot 2 ___ % Plot 3 ___ % Plot 4 ___ % | % |
| $V_{OHOR}$ | Average thickness of O horizon plot values below (Data Form 6), record at right<br>Plot 1 ___ cm Plot 2 ___ cm Plot 3 ___ cm Plot 4 ___ cm | cm |
| $V_{AHOR}$ | Average thickness of A horizon plot values below (Data Form 6), record at right<br>Plot 1 ___ cm Plot 2 ___ cm Plot 3 ___ cm Plot 4 ___ cm | cm |

Figure 22. Data Form 1: Variable/Metric Summary

includes $V_{POND}$, is collected during a walking reconnaissance of the WAA. Data collected for these two groups of variables are entered directly on the Data Form 1. Information on the next group of variables is collected in sample plots and along transects placed in representative locations throughout the WAA. A typical layout for these plots and transects is shown in Figure 23.

As in defining the WAA, there are elements of subjectivity and practicality in determining the number of sample locations for collecting plot-based and transect-based site-specific data. The exact numbers and locations of the plots and transects are dictated by the size and heterogeneity of the WAA. For example, if the WAA is relatively small (i.e., less than 2-3 acres) and homogeneous with respect to the characteristics and processes that influence wetland function, then three or four 0.04-ha plots, with nested transects and subplots in representative locations, are probably adequate to characterize the WAA. However, as the size and heterogeneity of the WAA increases, more sample plots are required to accurately represent the site.

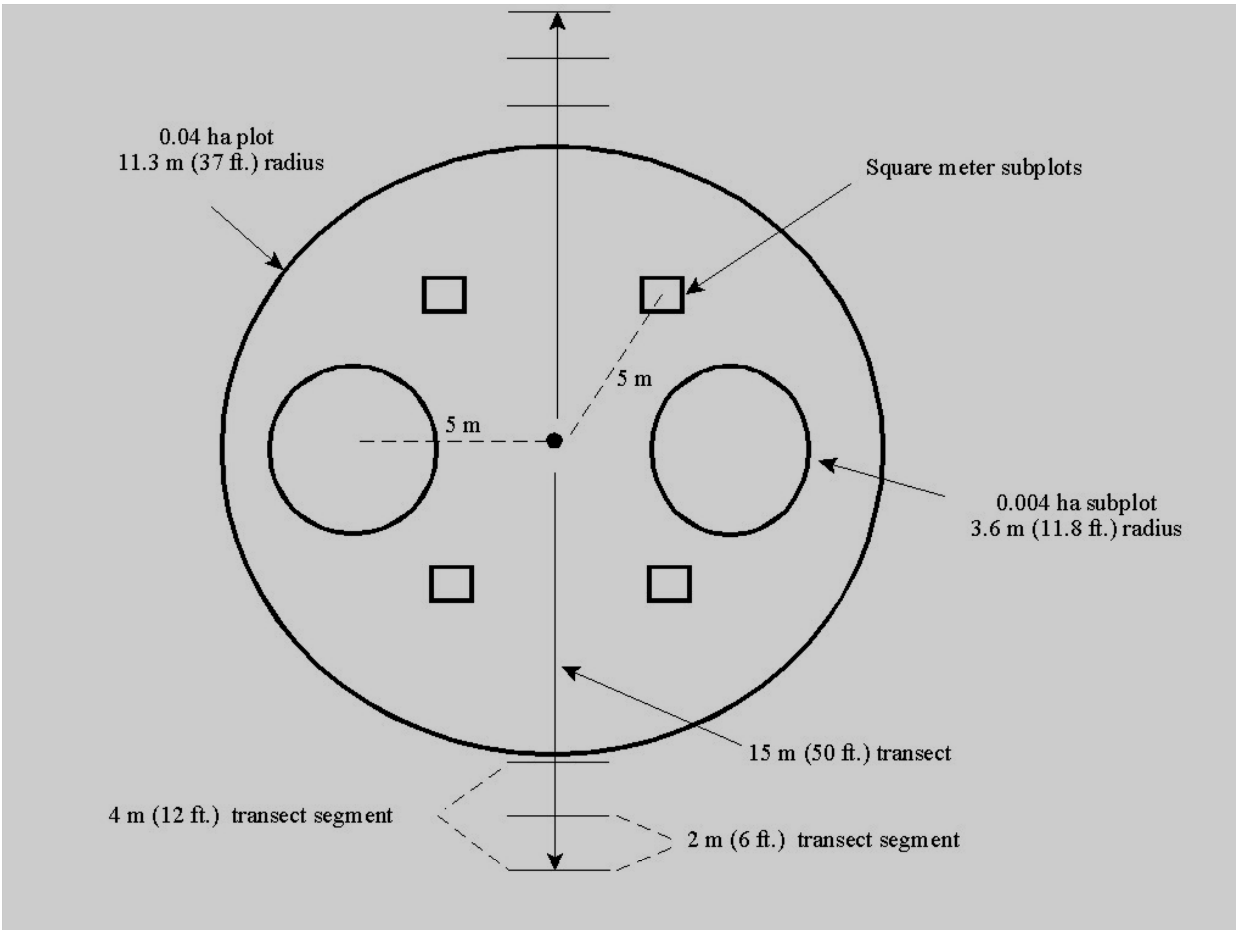


Figure 23. Sample plot and subplot dimensions and layouts for field sampling

The data collected for each of the variable metrics sampled in a plot or along a transect are entered on Data Forms 2-6 shown in Figures 24 through 32. Once these data have been collected and manipulated on the data form, specific information is transferred to Data Form 1 (Figure 22). Additional manipulation takes place on Data Form 1 that consists of taking plot averages. Based on the averageing, a final metric value is entered in the box at the right-hand side of the page. Detailed instructions on collecting variable metric information are provided in the following paragraphs. Variables are listed in alphabetical order by variable codes to facilitate locating them.

Experience has shown that the time required to complete an assessment at a several-acre WAA where 3-4 plots are sampled is 2-4 hr. Training and experience will reduce the required time to the lower end of this range.

| **Data Form 2: Yazoo Basin Regional Guidebook<br>Cation Exchange Capacity ($V_{CEC}$)** | | | | | |
|---|---|---|---|---|---|
| **Assessment Team:** | | | | | |
| **Project Name / Location:** | | | **Plot:** | | **Date:** |
| **Field Procedure** | | | | | |
| **(1)** For each altered area, in the assessment area, record CEC before and after alteration in the Columns 2 and 3 below based on the information in the table below or the "feel method" for determining soil texture (Figure 33) | | | | | |
| **(2)** For each altered area, calculate the percent of the assessment area that the altered area represents, and record in Column 5 as a decimal fraction | | | | | |
| **Office Procedure** | | | | | |
| **(1)** Subtract Column 2 from Column 3 and enter the absolute value of the result in Column 4 | | | | | |
| **(2)** Multiply Column 4 by Column 5 and record result in Column 6 | | | | | |
| **(3)** Sum the values in Column 6 | | | | | |
| **(4) Record resulting value on the Data Form 1 in the box at the right of the $V_{CEC}$ row** | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 |
| Altered Areas | CEC After Alteration | CEC Before Alteration | Absolute Value of Column 3 minus Column 2 | Percent of Assessment Area (0-1.0) | Column 4 times Column 5 |
| Altered Area 1 | | | | . | |
| Altered Area 2 | | | | | |
| Altered Area 3 | | | | | |
| Altered Area 4 | | | | | |
| **Total of Column 6 = __________** | | | | | |

| **Soil Texture or Map Unit Symbol** | **CEC Range<br>meq / 100 grams** | **Midpoint of CEC Range<br>meg / 100 grams** |
|---|---|---|
| Sand | 1-5 | 2.5 |
| Fine Sandy Loam | 5-10 | 7.5 |
| Loam | 5-15 | 10 |
| Silt Loam | 5-15 | 10 |
| Clay Loam | 15-30 | 22.5 |
| Clay | 30-150 | 90 |
| Add other texture classes / map units | | |

Figure 24. Data Form 2: Cation Exchange Capacity ($V_{CEC}$)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Data Form 3 (Page 1 of 2): Yazoo Basin Regional Guidebook**<br>**Tree Basal Area, Density, and Snags (*$V_{TBA}$* , *$V_{TDEN}$* , and *$V_{SNAG}$* )** | | | | | | | |
| Assessment Team: | | | | | | | |
| Project Name / Location: | | | | | | **Plot:** | **Date:** |
| **Sample $V_{TBA}$ , $V_{TDEN}$ , and $V_{SNAG}$ in at least two 0.04-ha circular plots 11.3-m (37-ft) radius** | | | | | | | |
| Field Procedure | | | | | | | |
| **(1)** Record the species and dbh (cm) of all trees (i.e., woody stems ≥ 10 cm (4 in.) in the plot in Columns 1 and 2 in the table below. | | | | | | | |
| 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Species Code | dbh (cm) | area ($cm^2$) | area ($m^2$) | Species Code | dbh (cm) | area ($cm^2$) | area ($m^2$) |
| | | | | | | | |
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| | | | | | | | |
| **(2)** Tally standing dead stems (i.e., snags) ≥ 10 cm dbh in each 0.04-ha plot ________________ | | | | | | | |

Figure 25. Data Form 3: Tree Basal Area, Density, and Snags (*$V_{TBA}$* , *$V_{TDEN}$* , and *$V_{SNAG}$* ) (Continued)

| Data Form 3 (Page 2 of 2): Yazoo Basin Regional Guidebook<br>Tree Basal Area, Density, and Snags ($V_{TBA}$, $V_{TDEN}$, and $V_{SNAG}$) | | |
|---|---|---|
| **Assessment Team:** | | |
| **Project Name / Location:** | **Plot:** | **Date:** |
| **Office Procedure (Use Appendix B spreadsheet or calculate manually with steps below)** | | |
| **(1)** Convert dbh values above to $cm^2$ using the equation: (dbh ∗ dbh) ∗ 0.785 = $cm^2$ and record in Column 3 of the above table. | | |
| **(2)** Convert $cm^2$ values above to $m^2$ using the equation: $cm^2$ ∗ 0.0001 = $m^2$ and record in Column 4 of the above table. | | |
| **(3)** Sum $m^2$ values in Column 4 above to get tree basal area _______ $m^2$ / 0.04 ha | | |
| **(4)** Multiply by 25 = tree basal area _______ $m^2$ / ha | | |
| **(5) Record $m^2$ / ha on Data Form 1 in the $V_{TBA}$ row as a plot value** | | |
| **(6)** Count the number of tree stems recorded in plot from above table to determine tree stems / 0.04 ha ___ | | |
| **(7)** Multiply tree stems / 0.04 ha by 25 = ____ tree stems / ha | | |
| **(8) Record tree stems / ha on Data Form 1 in the $V_{TDEN}$ row as a plot value** | | |
| **(9)** Sum the snags tallied in the plot = ____ snags / 0.04 ha | | |
| **(10)** Multiply snags / 0.04 ha by 25 = ____ snags / ha | | |
| **(11) Record snags / ha on Data Form 1 in the $V_{SNAG}$ row as a plot value** | | |

Figure 25. (Concluded)

## Procedures for Measuring Assessment Variables

### $V_{AHOR}$ - A horizon biomass

This variable represents total mass of organic matter in the A soil horizon. The A soil horizon is defined as a mineral soil horizon that occurs at the ground surface, below the O soil horizon, that consists of an accumulation of unrecognizable decomposed organic matter mixed with mineral soil (U.S. Department of Agriculture SCS 1993). In practice, the A horizon is identified in the field as a zone of darkened soil.

Thickness of the A horizon is the metric used to quantify this variable. Measure it using the procedure outlined below.

(1) Measure the thickness of the A horizon in each of four, 1-$m^2$ subplots placed in representative areas of each quadrant of the 0.04-ha plot (Figure 23). Record measurements on Data Form 6.

(2) Average the A-horizon thickness measurements from each of the $m^2$ subplots, and record the average on Data Form 1 in the $V_{AHOR}$ row as a plot value.

(3) On Data Form 1, average the A-horizon thickness plot values, and record the average value in the box at the right hand side of the $V_{AHOR}$ row.

| Data Form 4a (Page 1 of 2): Yazoo Basin Regional Guidebook<br>Woody Vegetation Composition ($V_{TCOMP}$ and $V_{COMP}$ ) for Riverine Backwater | | |
|---|---|---|
| Assessment Team: | | |
| **Project Name / Location:** | **Plot:** | **Date:** |
| **Determine $V_{TCOMP}$ in the 0.04-ha plot** | | |
| **Field Procedure** | | |
| (1) Using the 50/20 rule and the data recorded on the Data Form 3, circle the tree species that are dominant in Columns A, B, and C below. If no trees are present, circle nothing. Note: If a dominant does not appear on the list, use local knowledge or literature to assign that species to the appropriate column. | | |
| **A:** Common dominants in reference standard sites | **B:** Species commonly present in reference standard sites, but dominance generally indicates heavy selective harvest, land abandonment, or other disturbances | **C:** Uncommon or shrub species in reference standard sites, but may dominate in severely damaged systems |
| *Carya aquatica* | *Acer drummondii* | *Carpinus caroliniana* |
| *Carya cordiformis* | *Acer rubrum* | *Cornus drummondii* |
| *Carya ovata* | *Carya illinoisensis* | *Cornus foemina* |
| *Carya tomentosa* | *Celtis laevigata* | *Cretaegus spp.* |
| *Fraxinus tomentosa* | *Diospyros virginiana* | *Forestiera acuminata* |
| *Gleditsia aquatica* | *Fraxinus pennsylvanica* | *Ilex deciduas* |
| *Populus heterophylla* | *Liquidambar styraciflua* | *Planera aquatica* |
| *Quercus falcata* | *Salix nigra* | |
| *Quercus lyrata* | *Ulmus americana* | |
| *Quercus michauxii* | *Ulmus crassifolia* | |
| *Quercus nigra* | | |
| *Quercus nuttallii* | | |
| *Quercus pagoda* | | |
| *Quercus phellos* | | |
| *Quercus stellata* | | |
| *Taxodium distichum* | | |
| **Office Procedure** | | |
| (1) Using the circled dominant trees in the list of species in Columns A, B, and C above, calculate percent concurrence using the following formula:<br>[( 1.0 * number of circled dominants in Column A ) + ( 0.66 * number of circled dominants in Column B) + (0.33 * number of circled dominants in Column C)] / total number of circled dominants in all columns = _____ % | | |
| (2) **Record % concurrence on Data Form 1 in the $V_{TCOMP}$ row as a plot value** | | |

Figure 26. Data Form 4a: Woody Vegetation Composition ($V_{TCOMP}$ and $V_{COMP}$ ) for Riverine Backwater (Continued)

**Data Form 4a (Page 2 of 2): Yazoo Basin Regional Guidebook**
**Woody Vegetation Composition ($V_{TCOMP}$ and $V_{COMP}$ ) for Riverine Backwater**

Assessment Team:

| **Project Name / Location:** | **Plot:** | **Date:** |
|---|---|---|

**Determine $V_{COMP}$ in the 0.04-ha plot**

**Field Procedure**

(1) If tree cover is ≥ 20%, use the 50/20 rule and circle the dominant trees in Columns A, B, and C below. Note: In this step and Step 2 below, if a dominant does not appear on the list, use local knowledge or literature to assign that species to the appropriate column.

(2) If tree cover is < 20%, identify the next tallest woody stratum with at least 10% cover. Use the 50/20 rule and circle the dominants in the next tallest woody stratum in Columns A, B, and C below.

| **A:** Common dominants in reference standard sites | **B:** Species commonly present in reference standard sites, but dominance generally indicates heavy selective harvest, land abandonment, or other disturbances | **C:** Uncommon or shrub species in reference standard sites, but may dominate in severely damaged systems |
|---|---|---|
| *Carya aquatica* | *Acer drummondii* | *Carpinus caroliniana* |
| *Carya cordiformis* | *Acer rubrum* | *Cornus drummondii* |
| *Carya ovata* | *Carya illinoisensis* | *Cornus foemina* |
| *Carya tomentosa* | *Celtis laevigata* | *Cretaegus spp.* |
| *Fraxinus tomentosa* | *Diospyros virginiana* | *Forestiera acuminata* |
| *Gleditsia aquatica* | *Fraxinus pennsylvanica* | *Ilex decidua* |
| *Populus heterophylla* | *Liquidambar styraciflua* | *Planera aquatica* |
| *Quercus falcata* | *Salix nigra* | |
| *Quercus lyrata* | *Ulmus americana* | |
| *Quercus michauxii* | *Ulmus crassifolia* | |
| *Quercus nigra* | | |
| *Quercus nuttallii* | | |
| *Quercus pagoda* | | |
| *Quercus phellos* | | |
| *Quercus stellata* | | |
| *Taxodium distichum* | | |

**Office Procedure**

(1) Using the dominants circled in Columns A, B, and C above, calculate percent concurrence using the following formula:
[( 1.0 * number of circled dominants in Column A ) + ( 0.66 * number of circled dominants in Column B) + (0.33 * number of circled dominants in Column C)] / total number of circled dominants in all columns = _____ %

(2) **Record % concurrence on Summary Data Form 1 in the $V_{COMP}$ row as a plot value**

Figure 26. (Concluded)

| **Data Form 4b (Page 1 of 2): Yazoo Basin Regional Guidebook**<br>**Woody Vegetation Composition ($V_{TCOMP}$ and $V_{COMP}$) for Riverine Overbank** | | | |
|---|---|---|---|
| **Assessment Team:** | | | |
| **Project Name / Location:** | | **Plot:** | **Date:** |
| **Determine $V_{TCOMP}$ in the 0.04-ha plot** | | | |
| **Field Procedure** | | | |
| (1) Using the 50/20 rule and the data recorded on the Data Form 3, circle the tree species that are dominant in Columns A, B, and C below. If no trees are present, circle nothing. If a dominant does not appear on the list, use local knowledge or literature to assign that species to the appropriate column. | | | |

| **A:** Common dominants in reference standard sites | **B:** Species commonly present in reference standard sites, but dominance generally indicates heavy selective harvest, land abandonment, or other disturbances | **C:** Uncommon or shrub species in reference standard sites, but may dominate in severely damaged systems |
|---|---|---|
| *Carya aquatica* | *Acer rubrum* | *Acer negundo* |
| *Carya illinoisensis* | *Celtis laevigata* | *Carpinus caroliniana* |
| *Gleditsia aquatica* | *Fraxinus pennsylvanica* | *Forestiera acuminata* |
| *Platanus occidentalis* | *Liquidambar styraciflua* | *Planera aquatica* |
| *Populus deltoids* | *Ulmus americana* | |
| *Quercus lyrata* | | |
| *Quercus nuttallii* | | |
| *Quercus pagoda* | | |
| *Quercus phellos* | | |
| *Salix spp.* | | |
| *Taxodium distichum* | | |

| **Office Procedure** |
|---|
| (1) Using the circled dominant trees in the list of species in Columns A, B, and C above, calculate percent concurrence using the following formula:<br>[( 1.0 * number of circled dominants in Column A ) + ( 0.66 * number of circled dominants in Column B) + (0.33 * number of circled dominants in Column C)] / total number of circled dominants in all columns = ______ % |
| (2) **Record % concurrence on Data Form 1 in the $V_{TCOMP}$ row as a plot value** |

Figure 27. Data Form 4b: Woody Vegetation Composition ($V_{TCOMP}$ and $V_{COMP}$) for Riverine Overbank (Continued)

| **Data Form 4b (Page 2 of 2): Yazoo Basin Regional Guidebook<br>Woody Vegetation Composition ($V_{TCOMP}$ and $V_{COMP}$ ) for Riverine Overbank** | | |
|---|---|---|
| **Assessment Team:** | | |
| **Project Name / Location:** | **Plot:** | **Date:** |
| **Determine $V_{COMP}$ in the 0.04-ha plot** | | |
| **Field Procedure** | | |
| (1) If tree cover is ≥ 20%, use the 50/20 rule and circle the dominant trees in Columns A, B, and C below. Note: In this step and Step 2 below, if a dominant does not appear on the list, use local knowledge or literature to assign that species to the appropriate column. | | |
| (2) If tree cover is < 20%, identify the next tallest woody stratum with at least 10% cover. Use the 50/20 rule and circle the dominants in the next tallest woody stratum in Columns A, B, and C below. | | |
| **A:** Common dominants in reference standard sites | **B:** Species commonly present in reference standard sites, but dominance generally indicates heavy selective harvest, land abandonment, or other disturbances | **C:** Uncommon or shrub species in reference standard sites, but may dominate in severely damaged systems |
| *Carya aquatica* | *Acer rubrum* | *Acer negundo* |
| *Carya illinoisensis* | *Celtis laevigata* | *Carpinus caroliniana* |
| *Gleditsia aquatica* | *Fraxinus pennsylvanica* | *Forestiera acuminata* |
| *Platanus occidentalis* | *Liquidambar styraciflua* | *Planera aquatica* |
| *Populus deltoids* | *Ulmus americana* | |
| *Quercus lyrata* | | |
| *Quercus nuttallii* | | |
| *Quercus pagoda* | | |
| *Quercus phellos* | | |
| *Salix spp.* | | |
| *Taxodium distichum* | | |
| **Office Procedure** | | |
| (1) Using the dominants circled in Columns A, B, and C above, calculate percent concurrence using the following formula:<br>[( 1.0 * number of circled dominants in Column A ) + ( 0.66 * number of circled dominants in Column B) + (0.33 * number of circled dominants in Column C)] / total number of circled dominants in all columns = _____ % | | |
| (2) **Record % concurrence on Summary Data Form 1 in the $V_{COMP}$ row as a plot value** | | |

Figure 27. (Concluded)

| Data Form 4c (Page 1 of 2): Yazoo Basin Regional Guidebook<br>Woody Vegetation Composition ($V_{TCOMP}$ and $V_{COMP}$) for Flats | | |
|---|---|---|
| **Assessment Team:** | | |
| **Project Name / Location:** | **Plot:** | **Date:** |
| **Determine $V_{TCOMP}$ in the 0.04-ha plot** | | |
| **Field Procedure** | | |
| (1) Using the 50/20 rule and the data recorded on the Data Form 3, circle the tree species that are dominant in Columns A, B, and C below. If no trees are present, circle nothing. If a dominant does not appear on the list, use local knowledge or literature to assign that species to the appropriate column. | | |
| **A:** Common dominants in reference standard sites | **B:** Species commonly present in reference standard sites, but dominance generally indicates heavy selective harvest, land abandonment, or other disturbances | **C:** Uncommon or shrub species in reference standard sites, but may dominate in severely damaged systems |
| *Carya aquatica* | *Acer negundo* | *Cephalanthus occidentalis* |
| *Carya cordiformis* | *Acer rubrum* | *Cornus foemina* |
| *Carya laciniosa* | *Carya illinoisensis* | *Cretaegus spp.* |
| *Carya ovata* | *Celtis laevigata* | *Forestiera acuminata* |
| *Carya texana* | *Diospyros virginiana* | *Maclura pomifera* |
| *Carya tomentosa* | *Fraxinus pennsylvanica* | *Morus rubra* |
| *Nyssa aquatica* | *Fraxinus tomentosa* | *Sassafras albidum* |
| *Platanus occidentalis* | *Gleditsia aquatica* | *Ulmus alata* |
| *Quercus falcata* | *Liquidambar styraciflua* | |
| *Quercus lyrata* | *Populus deltoides* | |
| *Quercus michauxii* | *Ulmus americana* | |
| *Quercus nigra* | *Ulmus crassifolia* | |
| *Quercus nuttallii* | *Ulmus rubra* | |
| *Quercus pagoda* | | |
| *Quercus phellos* | | |
| *Quercus stellata* | | |
| *Taxodium distichum* | | |
| **Office Procedure** | | |
| (1) Using the circled dominant trees in the list of species in Columns A, B, and C above, calculate percent concurrence using the following formula:<br>[( 1.0 * number of circled dominants in Column A ) + ( 0.66 * number of circled dominants in Column B) + (0.33 * number of circled dominants in Column C)] / total number of circled dominants in all columns = ______ % | | |
| (2) **Record % concurrence on Data Form 1 in the $V_{TCOMP}$ row as a plot value** | | |

Figure 28. Data Form 4c: Woody Vegetation Composition ($V_{TCOMP}$ and $V_{COMP}$) for Flats (Continued)

**Data Form 4c (Page 2 of 2): Yazoo Basin Regional Guidebook**
**Woody Vegetation Composition ($V_{TCOMP}$ and $V_{COMP}$) for Flats**

Assessment Team:

| **Project Name / Location:** | **Plot:** | **Date:** |
|---|---|---|

**Determine $V_{COMP}$ in the 0.04-ha plot**

**Field Procedure**

(1) If tree cover is ≥ 20%, use the 50/20 rule and circle the dominant trees in Columns A, B, and C below. Note: In this step and Step 2 below, if a dominant does not appear on the list, use local knowledge or literature to assign that species to the appropriate column.

(2) If tree cover is < 20%, identify the next tallest woody stratum with at least 10% cover. Use the 50/20 rule and circle the dominants in the next tallest woody stratum in Columns A, B, and C below.

| **A:** Common dominants in reference standard sites | **B:** Species commonly present in reference standard sites, but dominance generally indicates heavy selective harvest, land abandonment, or other disturbances | **C:** Uncommon or shrub species in reference standard sites, but may dominate in severely damaged systems |
|---|---|---|
| *Carya aquatica* | *Acer negundo* | *Cephalanthus occidentalis* |
| *Carya cordiformis* | *Acer rubrum* | *Cornus foemina* |
| *Carya laciniosa* | *Carya illinoisensis* | *Cretaegus spp.* |
| *Carya ovata* | *Celtis laevigata* | *Forestiera acuminata* |
| *Carya texana* | *Diospyros virginiana* | *Maclura pomifera* |
| *Carya tomentosa* | *Fraxinus pennsylvanica* | *Morus rubra* |
| *Nyssa aquatica* | *Fraxinus tomentosa* | *Sassafras albidum* |
| *Platanus occidentalis* | *Gleditsia aquatica* | *Ulmus alata* |
| *Quercus falcata* | *Liquidambar styraciflua* | |
| *Quercus lyrata* | *Populus deltoides* | |
| *Quercus michauxii* | *Ulmus americana* | |
| *Quercus nigra* | *Ulmus crassifolia* | |
| *Quercus nuttallii* | *Ulmus rubra* | |
| *Quercus pagoda* | | |
| *Quercus phellos* | | |
| *Quercus stellata* | | |
| *Taxodium distichum* | | |

**Office Procedure**

(1) Using the dominants circled in Columns A, B, and C above, calculate percent concurrence using the following formula:
[( 1.0 * number of circled dominants in Column A ) + ( 0.66 * number of circled dominants in Column B) + (0.33 * number of circled dominants in Column C)] / total number of circled dominants in all columns = ______ %

(2) **Record % concurrence on Summary Data Form 1 in the $V_{COMP}$ row as a plot value**

Figure 28. (Concluded)

| **Data Form 4d (Page 1 of 2): Yazoo Basin Regional Guidebook**<br>**Woody Vegetation Composition ($V_{TCOMP}$ and $V_{COMP}$ ) for Connected Depression** | | | |
|---|---|---|---|
| **Assessment Team:** | | | |
| **Project Name / Location:** | | **Plot:** | **Date:** |
| **Determine $V_{TCOMP}$ in the 0.04-ha plot** | | | |
| **Field Procedure** | | | |
| (1) Using the 50/20 rule and the data recorded on the Data Form 3 circle the tree species that are dominant in Columns A and B below. If no trees are present, circle nothing. If a dominant does not appear on the list, use local knowledge or literature to assign that species to the appropriate column. | | | |
| **A:** Common dominants in reference standard sites | **B:** Species commonly present in reference standard sites, but dominance generally indicates heavy selective harvest, land abandonment, or other disturbances | | |
| *Acer rubrum* | *Celtis laevigata* | | |
| *Carya aquatica* | *Cephalanthus occidentalis* | | |
| *Diospyros virginiana* | *Forestiera acuminata* | | |
| *Fraxinus pennsylvanica* | *Liquidambar styraciflua* | | |
| *Fraxinus tomentosa* | *Planera aquatica* | | |
| *Gleditsia aquatica* | *Salix nigra* | | |
| *Nyssa aquatica* | *Ulmus americana* | | |
| *Platanus occidentalis* | *Ulmus crassifolia* | | |
| *Populus heterophylla* | | | |
| *Quercus lyrata* | | | |
| *Quercus nuttallii* | | | |
| *Quercus phellos* | | | |
| *Taxodium distichum* | | | |
| **Office Procedure** | | | |
| (1) Using the circled dominant trees in the list of species in Columns A and B above, calculate percent concurrence using the following formula:<br>[( 1.0 * number of circled dominants in Column A ) + ( 0.66 * number of circled dominants in Column B)] / total number of circled dominants in all columns = _____ % | | | |
| (2) **Record % concurrence on Data Form 1 in the $V_{TCOMP}$ row as a plot value** | | | |

Figure 29. Data Form 4d: Woody Vegetation Composition ($V_{TCOMP}$ and $V_{COMP}$ ) for Connected Depressions (Continued)

| **Data Form 4d (Page 2 of 2): Yazoo Basin Regional Guidebook**<br>**Woody Vegetation Composition ($V_{TCOMP}$ and $V_{COMP}$) for Connected Depression** | | |
|---|---|---|
| **Assessment Team:** | | |
| **Project Name / Location:** | **Plot:** | **Date:** |
| **Determine $V_{COMP}$ in the 0.04-ha plot** | | |
| **Field Procedure** | | |
| (1) If tree cover is ≥ 20%, use the 50/20 rule and circle the dominant trees in Columns A and B below. Note: In this step and Step 2 below, if a dominant does not appear on the list, use local knowledge or literature to assign that species to the appropriate column. | | |
| (2) If tree cover is < 20%, identify the next tallest woody stratum with at least 10% cover. Use the 50/20 rule and circle the dominants in the next tallest woody stratum in Columns A and B below. | | |

| **A:** Common dominants in reference standard sites | **B:** Species commonly present in reference standard sites, but dominance generally indicates heavy selective harvest, land abandonment, or other disturbances |
|---|---|
| *Acer rubrum* | *Celtis laevigata* |
| *Carya aquatica* | *Cephalanthus occidentalis* |
| *Diospyros virginiana* | *Forestiera acuminata* |
| *Fraxinus pennsylvanica* | *Liquidambar styraciflua* |
| *Fraxinus tomentosa* | *Planera aquatica* |
| *Gleditsia aquatica* | *Salix nigra* |
| *Nyssa aquatica* | *Ulmus americana* |
| *Platanus occidentalis* | *Ulmus crassifolia* |
| *Populus heterophylla* | |
| *Quercus lyrata* | |
| *Quercus nuttallii* | |
| *Quercus phellos* | |
| *Taxodium distichum* | |

| **Office Procedure** |
|---|
| (1) Using the dominants circled in Columns A and B above, calculate percent concurrence using the following formula:<br>[( 1.0 * number of circled dominants in Column A ) + ( 0.66 * number of circled dominants in Column B)] / total number of circled dominants in all columns = _____ % |
| (2) **Record % concurrence on Summary Data Form 1 in the $V_{COMP}$ row as a plot value** |

Figure 29. (Concluded)

| **Data Form 4e (Page 1 of 2): Yazoo Basin Regional Guidebook**<br>**Woody Vegetation Composition ($V_{TCOMP}$ and $V_{COMP}$ ) for Isolated Depression** | | |
|---|---|---|
| **Assessment Team:** | | |
| **Project Name / Location:** | **Plot:** | **Date:** |
| **Determine $V_{TCOMP}$ in the 0.04-ha plot** | | |
| **Field Procedure** | | |
| (1) Using the 50/20 rule and the data recorded on the Data Form 3, circle the tree species that are dominant in Columns A and B below. If no trees are present, circle nothing. If a dominant does not appear on the list, use local knowledge or literature to assign that species to the appropriate column. | | |

| **A:** Common dominants in reference standard sites | **B:** Species commonly present in reference standard sites, but dominance generally indicates heavy selective harvest, land abandonment, or other disturbances |
|---|---|
| *Acer rubrum* | *Acer negundo* |
| *Carya aquatica* | *Celtis laevigata* |
| *Carya illinoisensis* | *Cephalanthus occidentalis* |
| *Diospyros virginiana* | *Crataegus spp.* |
| *Fraxinus pennsylvanica* | *Forestiera acuminata* |
| *Fraxinus tomentosa* | *Liquidambar styraciflua* |
| *Gleditsia aquatica* | *Planera aquatica* |
| *Nyssa aquatica* | *Salix nigra* |
| *Quercus lyrata* | *Ulmus alata* |
| *Quercus nuttallii* | *Ulmus americana* |
| *Quercus phellos* | *Ulmus crassifolia* |
| *Taxodium distichum* | |

| **Office Procedure** |
|---|
| (1) Using the circled dominant trees in the list of species in Columns A and B above, calculate percent concurrence using the following formula:<br>[( 1.0 * number of circled dominants in Column A ) + ( 0.66 * number of circled dominants in Column B)] / total number of circled dominants in all columns = _____ % |
| (2) **Record % concurrence on Data Form 1 in the $V_{TCOMP}$ row as a plot value** |

Figure 30. Data Form 4e: Woody Vegetation Composition ($V_{TCOMP}$ and $V_{COMP}$ ) for Isolated Depressions (Continued)

| **Data Form 4e (Page 2 of 2): Yazoo Basin Regional Guidebook**<br>**Woody Vegetation Composition (*$V_{TCOMP}$* and *$V_{COMP}$*) for Isolated Depression** | | | |
|---|---|---|---|
| **Assessment Team:** | | | |
| **Project Name / Location:** | | **Plot:** | **Date:** |
| **Determine $V_{COMP}$ in the 0.04-ha plot** | | | |
| **Field Procedure** | | | |
| (1) If tree cover is ≥ 20%, use the 50/20 rule and circle the dominant trees in Columns A, B, and C below. Note: In this step and Step 2 below, if a dominant does not appear on the list, use local knowledge or literature to assign that species to the appropriate column. | | | |
| (2) If tree cover is < 20%, identify the next tallest woody stratum with at least 10% cover. Use the 50/20 rule and circle the dominants in the next tallest woody stratum in Columns A and B below. | | | |
| **A:** Common dominants in reference standard sites | **B:** Species commonly present in reference standard sites, but dominance generally indicates heavy selective harvest, land abandonment, or other disturbances | | |
| *Acer rubrum* | *Acer negundo* | | |
| *Carya aquatica* | *Celtis laevigata* | | |
| *Carya illinoisensis* | *Cephalanthus occidentalis* | | |
| *Diospyros virginiana* | *Crataegus spp.* | | |
| *Fraxinus pennsylvanica* | *Forestiera acuminata* | | |
| *Fraxinus tomentosa* | *Liquidambar styraciflua* | | |
| *Gleditsia aquatica* | *Planera aquatica* | | |
| *Nyssa aquatica* | *Salix nigra* | | |
| *Quercus lyrata* | *Ulmus alata* | | |
| *Quercus nuttallii* | *Ulmus americana* | | |
| *Quercus phellos* | *Ulmus crassifolia* | | |
| *Taxodium distichum* | | | |
| **Office Procedure** | | | |
| (1) Using the dominants circled in Columns A and B above, calculate percent concurrence using the following formula:<br>[( 1.0 * number of circled dominants in Column A ) + ( 0.66 * number of circled dominants in Column B)] / total number of circled dominants in all columns = _____ % | | | |
| (2) **Record % concurrence on Summary Data Form 1 in the $V_{COMP}$ row as a plot value** | | | |

Figure 30. (Concluded)

| Data Form 5 (Page 1 of 2): Yazoo Basin Regional Guidebook<br>Woody Debris and Logs ($V_{WD}$ and $V_{LOG}$ ) | | | | | |
|---|---|---|---|---|---|
| **Assessment Team:** | | | | | |
| **Project Name / Location:** | | | **Plot:** | | **Date:** |
| **Sample $V_{WD}$ and $V_{LOG}$ along two 15-m transects in each 0.04-ha plot** | | | | | |
| **Field Procedure** | | | | | |
| (1) Count stems in Size Class 1 (0.6-2.5 cm (0.25-1 in.)) that intersect a vertical plane above a 6 ft segment of Transect 1 __ and Transect 2 ___ Average these two values ___ | | | | | |
| (2) Count number of stems in Size Class 2 (2.5 - 7.6 cm (1-3 in.)) that intersect a vertical plane above a 12 ft segment of Transect 1 ___ and Transect 2 ___ Average these two values ____ | | | | | |
| (3) Record diameter of stems of Size Class 3 (> 7.6 cm (>3 in.)) that intersect a plane above a 50-ft section of Transect 1 and Transect 2 in the table below: | | | | | |
| **Transect 1** | | | **Transect 2** | | |
| **Stem No.** | **Diameter (cm)** | **Area ($cm^2$)** | **Stem No.** | **Diameter (cm)** | **Area ($cm^2$)** |
| Stem 1 | | | Stem 1 | | |
| Stem 2 | | | Stem 2 | | |
| Stem 3 | | | Stem 3 | | |
| Stem 4 | | | Stem 4 | | |
| Stem 5 | | | Stem 5 | | |
| Stem 6 | | | Stem 6 | | |
| Stem 7 | | | Stem 7 | | |
| Stem 8 | | | Stem 8 | | |
| Stem 9 | | | Stem 9 | | |
| Stem 10 | | | Stem 10 | | |
| Stem 11 | | | Stem 11 | | |
| Stem 12 | | | Stem 12 | | |
| Stem 13 | | | Stem 13 | | |
| Stem 14 | | | Stem 14 | | |
| Stem 15 | | | Stem 15 | | |
| Stem 16 | | | Stem 16 | | |
| Stem 17 | | | Stem 17 | | |
| Stem 18 | | | Stem 18 | | |
| Stem 19 | | | Stem 19 | | |
| Stem 20 | | | Stem 20 | | |
| Sum | | | Sum | | |

Figure 31. Data Form 5: Woody Debris and Logs ($V_{WD}$ and $V_{LOG}$ ) (Continued)

| Data Form 5 (Page 2 of 2): Yazoo Basin Regional Guidebook<br>Woody Debris and Logs ($V_{WD}$ and $V_{LOG}$) | | |
|---|---|---|
| Assessment Team: | | |
| **Project Name / Location:** | **Plot:** | **Date:** |
| **Office Procedure (Use Appendix B spreadsheet or calculate using steps below)** | | |
| (1) Convert Size Class 1 average value from (1) in Field Procedure above to tons /acre:<br>0.187 ∗ number of stems = ______ tons / acre | | |
| (2) Convert Size Class 2 average value from (2) in Field Procedure above to tons / acre:<br>0.892 ∗ total number of stems = Size Class 2 tons / acre _____ | | |
| (3) Convert Size Class 3 diameter values to area and enter values on Page 1 of Data Sheet 5:<br>diameter$^2$ ∗ 0.785 = cm$^2$ | | |
| (4) Sum Size Class 3 stem areas (cm$^2$) (for Transect 1 ____ and Transect 2 _____<br>Average these two values _______ | | |
| (5) Convert Size Class 3 area average to tons / acre using:<br>0.0687 ∗ area (cm$^2$) = Size Class 3 stems tons / acre _____ | | |
| (6) Sum tons / acre for all size classes = tons / acre _______ | | |
| (7) Convert tons / acre for all size classes to ft$^3$ / acre using:<br>(32.05 ∗ tons / acre) / 0.58 = ft$^3$ / acre _____ | | |
| (8) Convert ft$^3$ / acre for all size classes to m$^3$ / ha using:<br>cubic feet / acre ∗ 0.069 = m$^3$ / ha _____ | | |
| (9) **Record m$^3$ / ha (all size classes) on the Data Form 1 in the $V_{WD}$ row as a plot value** | | |
| (10) Convert tons / acre **for Size Class 3 only** to ft$^3$ / acre using:<br>(32.05 ∗ tons / acre) / 0.58 = ft$^3$ / acre _____ | | |
| (11) Convert ft$^3$ / acre **for Size Class 3 only** to m$^3$ / ha using:<br>cubic feet / acre ∗ 0.069 = m$^3$ / ha _____ | | |
| (12) **Record m$^3$ / ha on Data Form 1 in the $V_{LOG}$ row as a plot value** | | |

Figure 31. (Concluded)

### $V_{CEC}$ - Cation exchange capacity

The variable represents the change in CEC of a soil as indicated by the total change in clay content in the top 50 cm (20 in.) of the soil profile. Most impacts do not significantly change the CEC of the soil profile. However, some impacts such as the placement of fill material or the excavation and replacement of soil can significantly alter CEC and increase or decrease the capacity of a wetland area to retain elements and compounds.

The percent difference in CEC in the top 50 cm (20 in.) of the soil profile in the WAA is used to quantify this variable. Measure it using the following procedure.

| Data Form 6: Yazoo Basin Regional Guidebook<br>Shrub-Sapling, Ground Cover, and Organic Horizons ($V_{SSD}$, $V_{GVC}$, $V_{OHOR}$, and $V_{AHOR}$) | | |
|---|---|---|
| **Assessment Team:** | | |
| **Project Name / Location:** | **Plot:** | **Date:** |
| **Sample $V_{SSD}$ in two 0.004 ha circular subplots (3.6 m or 11.8 ft radius) in the 0.04 ha plot.<br>Note: Shrub-Saplings are stems 1.4 m ( 4.5 ft) tall and <10 cm ( 4 in.) dbh** | | |
| **Field Procedure** | | |
| (1) Count shrub-sapling stems in each subplot and record number of stems below:<br>Subplot 1 ___ Subplot 2 ___ | | |
| **Office Procedure** | | |
| (1) Average shrub-sapling stems from the two subplots above: ___ stems / 0.004 ha | | |
| (2) Convert average shrub-sapling units of stems / 0.004 ha to units of stems / ha using:<br>stems / 0.004 ha ∗ 250 = _____ stems / ha | | |
| (3) **Record stem density in stems / ha on Data Form 1 in the $V_{SSD}$ row as a plot value** | | |

| **Sample $V_{GVC}$, $V_{OHOR}$, and $V_{AHOR}$ in four $m^2$ subplots, with one $m^2$ subplot in each quadrant of the 0.04-ha plot.** |
|---|
| **Field Procedure** |
| (1) Estimate the percent cover of ground vegetation in each subplot and record below:<br>Subplot 1 ____ % Subplot 2 ____ % Subplot 3 ____ % Subplot 4 ____ % |
| (2) Measure the thickness of the "O" Horizon in each subplot and record below:<br>Subplot 1 ____ cm Subplot 2 ____ cm Subplot 3 ____ cm Subplot 4 ____ cm |
| (3) Measure the thickness of the "A" Horizon in each subplot and record below:<br>Subplot 1 ____ cm Subplot 2 ____ cm Subplot 3 ____ cm Subplot 4 ____ cm |
| Office Procedure |
| (1) Average the percent cover of ground vegetation from the four $m^2$ subplots above: ___ % |
| (2) **Record percent cover of ground vegetation on Data Form 1 in the $V_{GVC}$ row as a plot value** |
| (3) Average the thickness of "O" horizon from the four $m^2$ subplots above: ___ cm |
| (4) **Record average thickness on Data Form 1 in the $V_{OHOR}$ row as a plot value** |
| (5) Average the thickness of "A" horizon from the four $m^2$ subplots above: ___ cm |
| (6) **Record Average Thickness of "A" horizon on Data Form 1 in the $V_{AHOR}$ row as a plot value** |

Figure 32. Data Form 6: Shrub-Sapling, Ground Cover, and Organic Horizons ($V_{SSD}$, $V_{GVC}$, $V_{OHOR}$, and $V_{AHOR}$)

(1) Determine if the native soil in any of the area being assessed has been covered with fill material, excavated, replaced, or subjected to any other types of impact that significantly change the clay content of the soil profile. If no such alteration has occurred, record a zero percent difference on the Data Form 1 in the box on the right-hand side of the $V_{CEC}$ row. A value of zero, indicates that the CEC of soils in the assessment area has not been altered as a result of changes in clay content.

(2) If areas of disturbed soil exist in the WAA, determine what percentage of the WAA each area represents, and record the percent of the area as a decimal fraction on Data Form 2 in Column 5. If multiple altered areas occur, record what percentage of the WAA each area represents on a separate row in Data Form 2 (i.e., Altered Area 1, Altered Area 2, etc.).

(3) Determine what the CEC of the soil in each altered area would have been prior to disturbance. Do this based on the map unit identified in the county soil survey and the CEC values in Table 11. Record this value on Data Form 2 in Column 3 of the appropriate altered area row.

**Table 11**
**Values of Cation Exchange Capacity (CEC) for Soil Texture Classes**

| Soil Texture or Map Unit Symbol | CEC Range meq/100 grams | Midpoint of CEC Range meg/100 grams |
|---|---|---|
| Sand | 1-5 | 2.5 |
| Fine Sandy Loam | 5-10 | 7.5 |
| Loam | 5-15 | 10 |
| Silt Loam | 5-15 | 10 |
| Clay Loam | 15-30 | 22.5 |
| Clay | 30-150 | 90 |
| Conversion to pond or lakes | 0 | 0 |

(4) Determine the CEC of the disturbed soil in the altered area. This is accomplished by estimating soil texture class based on the "feel" method (Figure 33). Record this value on Data Form 2 in Column 2 of the appropriate altered area row.

(5) Calculate the difference in CEC between the natural and disturbed soils for each altered area using the following formula. The vertical bars in the formula indicate absolute value.

Percent difference = | CEC after alteration - CEC before alteration |

On Data Form 2 this is accomplished by taking the absolute value of Column 3 – Column 2. Record this value on Data Form 2 in Column 4 of the appropriate altered area row.

(6) Now calculate how each altered area contributes to the percent difference in CEC for the entire WAA. On the data form this translates into multiplying Column 4 by Column 5 and recording the results in Column 6.

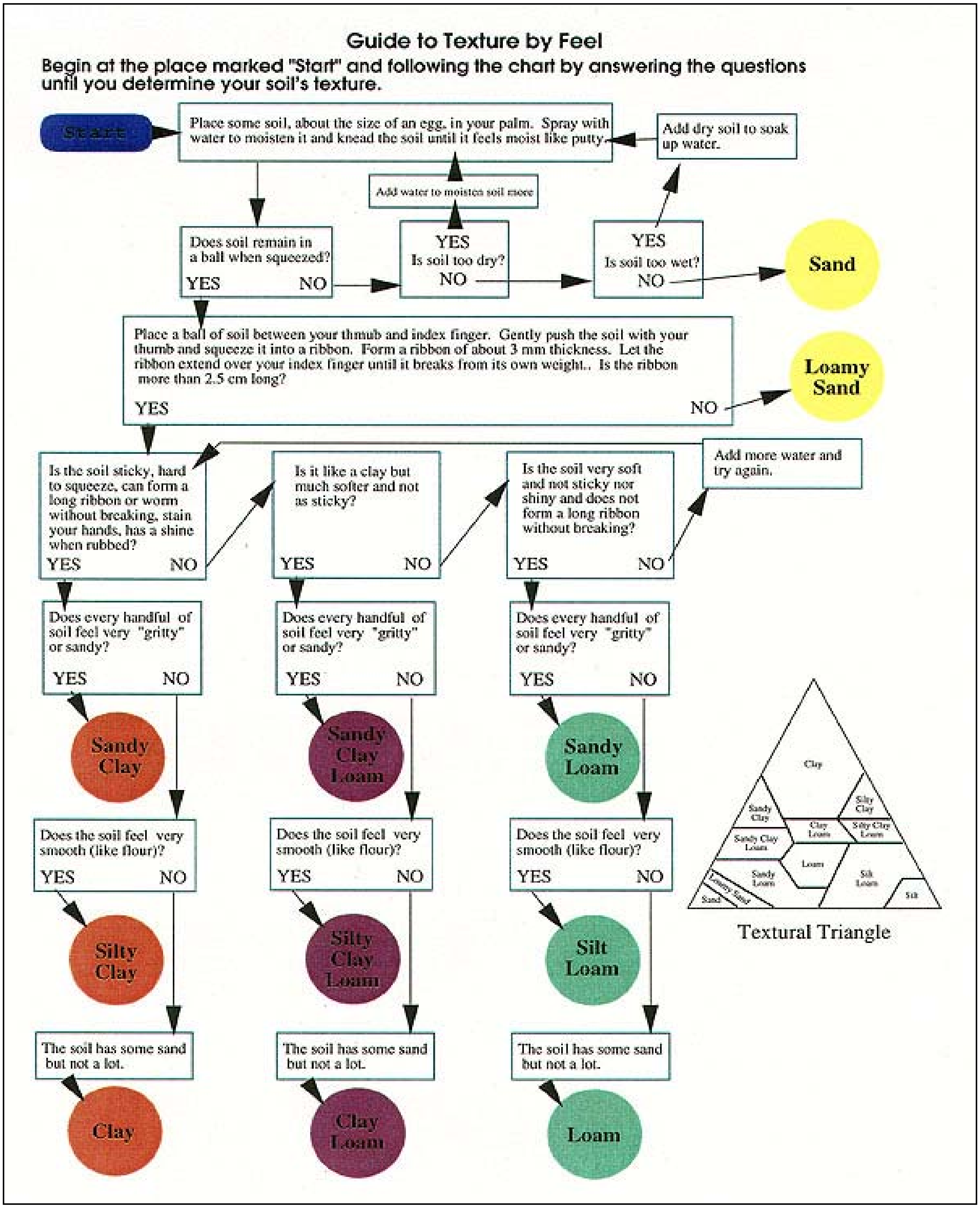


Figure 33. Estimating soil texture by feel (from Thien 1979). Diagram available online at http://ltpwww.gsfc.nasa.gov/globe/tbf/tbfguide.htm

(7) Sum the values in Data Form 2, Column 6, to obtain the percent difference in CEC for the entire WAA.

(8) Record the percent difference in CEC on the Data Form 1 in the box on the right-hand side of the $V_{CEC}$ row.

### $V_{COMP}$ - Composition of tallest woody vegetation stratum

This variable represents the species composition of the tallest woody stratum present in the assessment area. This could be the tree, shrub-sapling, or seedling stratum. Percent concurrence with the dominant species in the dominant vegetation stratum is used to quantify this variable. Measure it using the procedure outlined below.

(1) Determine percent cover of the tree stratum by visually estimating what percentage of the sky is blocked by leaves and stems of the tree stratum, or vertically projecting the leaves and stems to the forest floor. If the percent cover of the tree stratum is estimated to be at least 20 percent go to Step 2. If the percent cover of the tree stratum is estimated to be <20 percent, skip Step 2 and go directly to Step 3.

(2) If the tree stratum has at least 20 percent cover, then the value for $V_{COMP}$ will be the same as the value for $V_{TCOMP}$. In this case, skip the remaining steps and simply enter the value on the right-hand side of the $V_{TCOMP}$ row on Data Form 1 in the box at the right-hand side of the $V_{COMP}$ row on Data Form 1.

(3) If the tree stratum does not have at least 20 percent, cover identify the dominant species in the tallest woody stratum based on percent cover and circle them in Columns A, B, and C on Data Form 4 of the appropriate wetland subclass. Apply the 50/20 rule (U. S. Army Corps of Engineers 1992), and rank species in descending order of percent cover. Identify dominants by summing relative dominance in descending order until 50 percent is exceeded. Additional species with 20 percent relative dominance should also be included as dominants. Accurate identification of woody species is critical for determining the dominant species in each plot. Sampling during the dormant season may require proficiency in recognizing plant form, bark, or dormant/dead plant parts. Users who do not feel confident in identifying trees should get help.

(4) Calculate percent concurrence using the following formula: {[ ( 1.0 * number of dominants in Column A ) + ( 0.66 * number of dominants in Column B) + (0.33 * number of dominants in Column C)] / total number of dominant species * 100} = _____ Percent Concurrence

(5) Record this value as percent concurrence on the Data Form 1 on the $V_{COMP}$ row as a plot value.

(6) Average the plot values on the Data Form 1 and record the result in the box on the right-hand side of the $V_{COMP}$ row.

### $V_{CONNECT}$ - Habitat connections

This variable is defined as the proportion of the perimeter of a forested wetland tract that is connected to suitable wildlife habitat such as upland forests or other wetlands (Figure 34). Agricultural fields, clear cuts, mined areas, or developed areas are examples of unsuitable habitats.

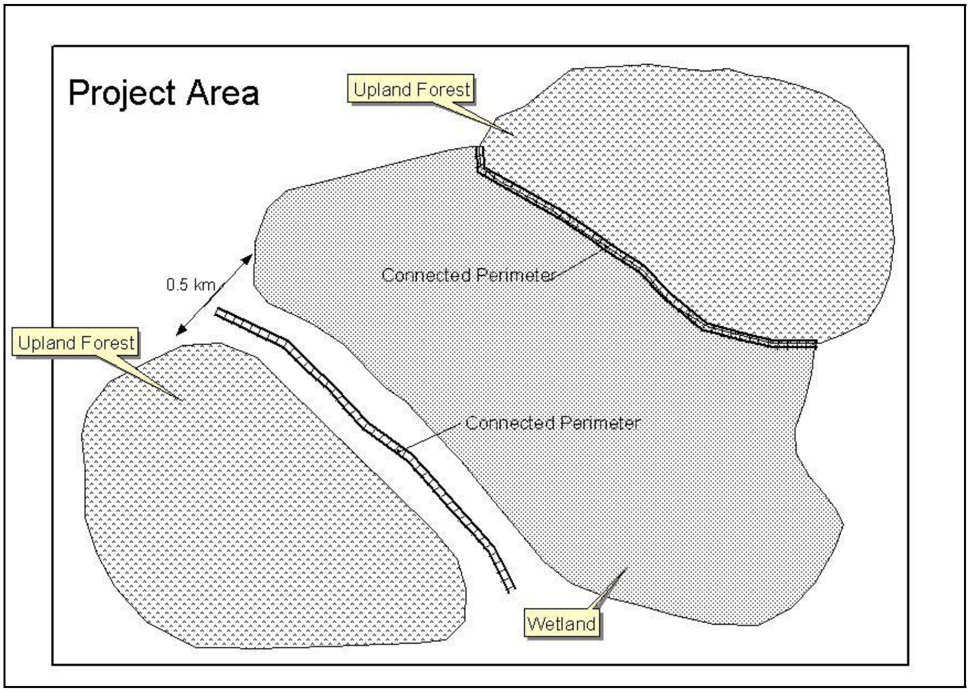


Figure 34. Connected wetland forest tract boundary

The percentage of the forested wetland tract boundary that is "connected" is used to quantify this variable. An adjacent habitat is considered connected if it is within 0.5 km (0.31 mile) of the boundary of the forested wetland tract. Measure it using the procedure outlined below

(1) Calculate the length of the forested wetland tract boundary. Use field reconnaissance, topographic maps, aerial photography, GIS, or another method or tool.

(2) Calculate the length of the forested wetland tract boundary that is within 0.5 km (0.31 mile) of suitable habitats like those described above.

(3) Divide the length of "connected" forested wetland tract boundary by the length of the total forested wetland tract boundary, and then multiply by 100. The resulting number is the percent of the wetland tract boundary that is connected.

(4) Record this percentage on Data Form 1 in the box on the right-hand side of the $V_{CONNECT}$ row.

### $V_{CORE}$ - Core area

This variable is defined as the portion of a wetland tract that lies inside of a 100-m (330-ft) buffer inside the boundary of the wetland tract (Figure 35).

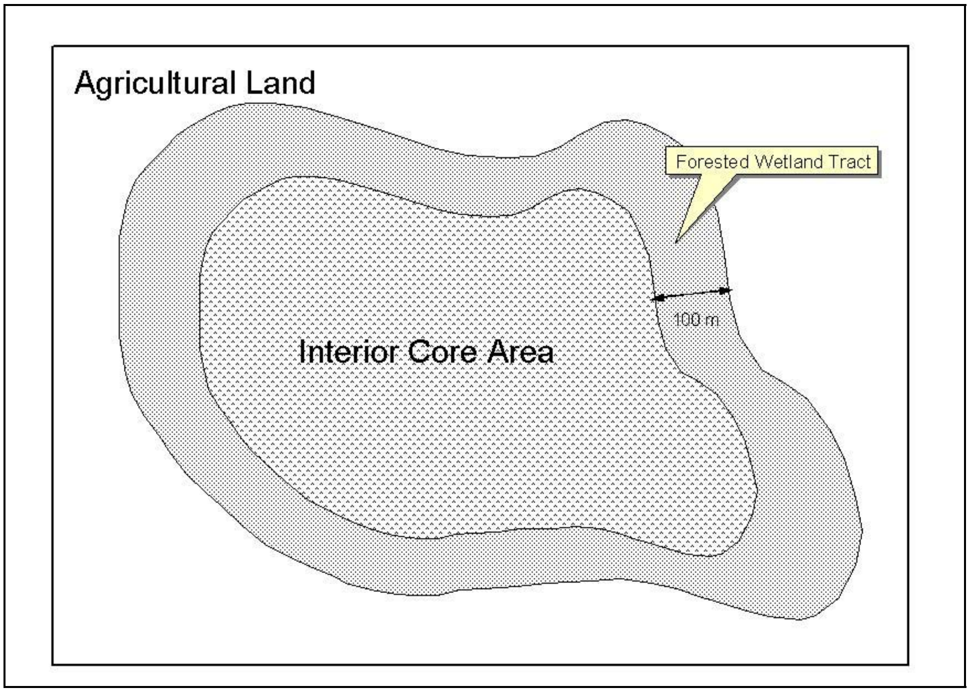


Figure 35. Interior core area and buffer zone

The percentage of a wetland tract inside this 100-m (330-ft) buffer zone is the metric used to quantify this variable. Determine the value of this metric using the following procedure.

(1) Draw a continuous line 100 m inside the wetland tract boundary.

(2) Calculate the size of the area inside of this line. This is the core area.

(3) Divide the size of the core area by size of the wetland tract and then multiply by 100. The resulting number is the percent of the wetland tract that is core area.

(4) Record the percentage on Data Form 1 in the box on the right-hand side of the $V_{CORE}$ row.

### $V_{FREQ}$ - Frequency of flooding

Frequency of flooding refers to the frequency with which overbank or backwater flooding from an adjacent stream inundates the assessment area. Ideally, characterization of hydrologic regimes would also consider flood depth and duration. However, obtaining these data for a particular assessment area typically requires considerably more time and effort than is normally available under a rapid assessment scenario. Consequently, recurrence interval in years is used to quantify this variable. Determine the value of this metric using the following procedure.

(1) Determine recurrence interval using one of the following methods. Specific guidelines are provided in Appendix C:

*a.* Recurrence interval map

*b.* Data from a nearby stream gage

*c.* Regional flood frequency curves developed by local and state offices of USACE, USGS-Water Resources Division, State Geologic Surveys, or NRCS (Jennings, Thomas, and Riggs 1994)

*d.* Hydrologic models such as HEC-2 (USACE 1981, 1982), HECRAS (USACE 1997), or HSPF (Bicknell et al. 1993)

*e.* Local knowledge

*f.* A regional dimensionless rating curve

(2) Record recurrence interval on the Data Form 1 in the box at the right hand side of the $V_{FREQ}$ row.

### $V_{GVC}$ - Ground vegetation cover

Ground cover is defined as herbaceous and woody vegetation ≤ 1.4 m (4.5 ft) in height. Percent cover of ground vegetation is used to quantify this variable. Determine the value of this metric using the procedure outlined below.

(1) Visually estimate the proportion of the ground surface that is covered by ground vegetation by mentally projecting the leaves and stems of ground vegetation to the ground surface. Do this in each of four 1-$m^2$ subplots, placed in representative portions of each quadrant of a 0.04-ha plot as illustrated in Figure 23. Record measurements on Data Form 6.

(2) Average the percent ground vegetation cover from each of the $m^2$ sub-plots, and record the average on Data Form 1 in the $V_{GVC}$ row as a plot value.

(3) On Data Form 1, average the percent ground vegetation cover plot values, and record the average value in the box at the right-hand side of the $V_{GVC}$ row.

### $V_{LOG}$ - Log biomass

See discussion in the Woody Debris ($V_{WD}$) and Log Biomass ($V_{LOG}$) section.

### $V_{OHOR}$ - O horizon biomass

The O horizon is defined as the soil layer dominated by organic material that consists of partially decomposed organic matter such as leaves, needles, sticks or twigs < 0.6 cm in diameter, flowers, fruits, insect frass, dead moss, or detached lichens on or near the surface of the ground (U.S. Department of Agriculture SCS 1993). The O horizon does not include recently fallen material or material that has been incorporated into the mineral soil.

Thickness of the O soil horizon is the metric used to quantify this variable. Measure it using the procedure outlined below.

(1) Measure the thickness of the O horizon at multiple sample points in each of the four 1-$m^2$ subplots placed in representative portions of each quadrant of a 0.04-ha plot (see Figure 23) and record measurements on Data Form 6.

(2) Average the O horizon thickness measurements from each of the $m^2$ subplots, and record the average on Data Form 1 in the $V_{OHOR}$ row as a plot value.

(3) On Data Form 1, average the O horizon thickness plot values, and record the average value in the box at the right-hand side of the $V_{OHOR}$ row.

### $V_{POND}$ - Micro-depressional ponding

Micro-depressional ponding refers to small topographic depressions that collect and hold rainwater for short periods of time. These small depressions are usually a result of tree “tip ups” and the scouring of effects of moving water. Larger vernal pools occur in the broad swales typical of meander scroll topography. These areas are included when estimating micro-depressional ponding.

This variable is measured as the proportion of the assessment area exhibiting micro-depressions. Measure it with the following procedure

(1) Estimate the percentage of the WAA exhibiting microtopographic depressions and vernal pools capable of ponding rainwater. Evidence of these depressions may be the presence of water in micro-depression, silt on litter, stained leaves, or unvegetated patches.

(2) Report the percent of the assessment area with micro-depressions on the Data Form 1 in the box on the right hand side of the $V_{POND}$ row.

### $V_{SNAG}$ - Snag density

Snags are standing dead woody stems with a dbh ≥ 10 cm (4 in.). The density of snag stems per hectare is the metric used to quantify this variable. Measure it using the procedure outlined below.

(1) Count the number of snag stems in at least three 0.04-ha circular plots located in representative areas of the WAA. Additional 0.04-ha circular plots may be necessary if the WAA is large and heterogenous. Record the number of snag stems from the 0.04-ha plot at the bottom of Data Form 3.

(2) Multiply the number of snags by 25 to convert to a per hectare basis. For example, if the number of snags from the 0.04-ha circular plot is 2 snags, then $2 * 25 = 50$ snags / ha.

(3) Record this value as snags / ha on the Data Form 1 as a plot value on the $V_{SNAGS}$ row.

(4) Average the plot values on the Data Form 1 and record the result in the box on the right-hand side of the $V_{SNAGS}$ row.

### $V_{SOIL}$ - Soil integrity

It is difficult in a rapid assessment context to assess soil integrity for two reasons. First, there are a variety of soil properties contributing to integrity that must be measured (i.e., structure, horizonation, texture, bulk density). Second, the spatial variability of soils within riverine wetlands makes it difficult to collect the number of samples necessary to adequately characterize a site. Therefore, the approach used here is to assume that soil integrity exists where evidence of alteration is lacking. Stated another way, if the soils in the assessment area do not exhibit any of the characteristics associated with alteration, it is assumed that soils are similar to those occurring in the reference standard wetlands and have the potential to support a characteristic plant community.

This variable is measured as the proportion of the assessment area with altered soils. Measure it with the following procedure.

(1) Determine if any of the soils in the area being assessed have been altered. In particular, look for alteration to a normal soil profile, such as evidence of excavation or fill, severe compaction, or other types of impact that significantly alter soil integrity. Presence of a plow layer should not be considered to be a soil alteration. (Note: the influence of past tilling is accounted for in the assessment of A horizon thickness.)

(2) If no altered soils exist, the percent of the assessment area with altered soils is zero. This indicates that all of the soils in the assessment area are similar to soils in reference standard sites.

(3) If altered soils exist, determine what percent of the assessment area has soils that have been altered.

(4) Report the percent of the assessment area with altered soils on the Data Form 1 in the box on the right of the $V_{SOIL}$ row.

### $V_{SSD}$ - Shrub-sapling density

Shrubs and saplings are woody stems < 10 cm (4 in.) dbh and > 1.2 m (4 ft) in height. Density of shrub-sapling stems per hectare is the metric used to quantify this variable. Measure it using the procedure outlined below.

(1) Count woody stems < 10 cm (4 in.) and > 1.4 m (4.5 ft) in height in two 0.004-ha circular plots (radius 3.6 m (11.8 ft)) nested within the 0.04-ha plot. If the 0.04-ha plot is heterogeneous, more 0.004-ha plots can be sampled. Record the number of stems in each 0.004-ha plot on Data Form 6.

(2) Average the number of stems from the 0.004-ha plots in the 0.04-ha plot.

(3) Multiply by 250 to convert from the units of stems/0.004-ha to the units of stems/ha. For example, if the average of the 0.004-ha plots is 23 stems, then 23 $*$ 250 = 5,750 stems/ha.

(4) Record this value as stems/ha on Data Form 1 as a plot value in the $V_{SSD}$ row.

(5) Average the plot values on Data Form 1 and record the result in the box on the right-hand side of the $V_{SSD}$ row.

### $V_{TBA}$ - Tree basal area

Trees are defined as living woody stems ≥ 10 cm (4 in.) dbh. Tree basal area is a common measure of abundance and dominance in forest ecology that has been shown to be proportional to tree biomass (Whittaker 1975, Whittaker et al. 1974, Spurr and Barnes 1981, Tritton and Hornbeck 1982, Bonham 1989). Tree basal area per hectare is the metric used to quantify this variable. Measure it using the procedure outlined below.

(1) Measure the diameter of all trees (living woody stems ≥ 10 cm or 4 in.) at breast height (dbh) in a circular 0.04-ha plot with a radius of 11.3 m (37 ft). Record tree species with corresponding diameter measurement in the table on Data Form 3. Accurate identification of woody species is critical for determining the dominant species in each plot. Sampling during the dormant season may require proficiency in recognizing plant form, bark, or dormant/dead plant parts. Users who do not feel confident in identifying trees should seek assistance.

A spreadsheet is available to complete the calculations in Steps 2-5 below (see Appendix B).

(2) Convert the dbh measurement for each woody stem to square centimeters using the following formula: $(dbh * dbh) * 0.25 * 3.14 = cm^2$.

(3) Convert the area of each woody stem in $cm^2$ to square meters using the following formula: $cm^2 * 0.0001 = m^2$.

(4) Sum the $m^2$ measurements of all woody stems from the 0.04 ha plots to give $m^2$/0.04 ha.

(5) Multiply by 25 to convert to $m^2$/ha.

(6) Record this value as basal area/ha on the Data Form 1 as a plot value in the $V_{TBA}$ row.

(7) Average the plot values on the Data Form 1 and record the result in the box on the right-hand side of the $V_{TBA}$ row.

An alternative rapid method: use an appropriate basal area prism at each plot center point to estimate stand basal area and enter as plot values in the $V_{TBA}$ row. Average all basal area measurements and record the result in the box on the right hand side.

### $V_{TCOMP}$ - Tree composition

Tree composition represents the composition of tree species in the forest canopy. Percent concurrence with the dominant species in each vegetation stratum is the metric used to quantify this variable. Measure it with the procedure outlined below.

(1) Use the data on tree basal area on Data Form 3 and the 50/20 rule to identify the dominant species in the tree stratum (U. S. Army Corps of Engineers 1992). To apply the 50/20 rule, rank species in descending order of dominance. Basal area for each species can be calculated manually or accomplished by entering species sequentially in the tree basal area spreadsheet. Identify dominants by summing relative dominance beginning with the most dominant species in descending order until 50 percent is exceeded. Additional species with >20 percent relative dominance should also be included as dominants.

(2) Calculate percent concurrence using the following formula: [( 1.0 * number of dominants in Column A ) + ( 0.66 * number of dominants in Column B) + (0.33 * number of dominants in Column C)] / total number of dominant species = _____ Percent Concurrence

(3) Record this value as percent concurrence on the Data Form 1 on the $V_{TCOMP}$ row as a plot value.

(4) Average the plot values on the Data Form 1 and record the result in the box on the right-hand side of the $V_{TCOMP}$ row.

An alternative rapid method: use cover estimation in lieu of basal area calculations to determine dominant species. See methodology for determining $V_{COMP}$ above.

### $V_{TDEN}$ - Tree density

Tree density is the number of trees (i.e., living woody stems ≥ 10 cm (4 in.)). The density of tree stems per hectare is the metric used to quantify this variable. Measure it using the procedure outlined below.

(1) Count the number of tree stems in the 0.04-ha plot using the data recorded for tree basal area on Data Form 1. If the rapid prism method for basal area sampling was employed, then directly count all trees within the 0.04-ha plot.

(2) Multiply the value by 25 to convert to units of stems/ha.

(3) Record stems/ha on the Data Form 1 as a plot value on the $V_{TDEN}$ row.

(4) Average the plot values on the Data Form 1 and record the result in the box on the right hand side of the $V_{TDEN}$ row.

### $V_{TRACT}$ - Wetland tract

This variable is defined as the area of forested wetland that is contiguous and directly accessible to the WAA (Figure 36). Wetlands need not be in the same regional subclass as the assessment area to be considered.

The size of the forested wetland area contiguous with the WAA is the metric used to quantify this variable. Determine the value of this metric using the following procedure.

(1) Determine the size of the forested wetland area (ha) that is contiguous and directly accessible to wildlife utilizing the WAA. Use field reconnaissance, topographic maps, aerial photography, GIS, or another method.

(2) Record the forested wetland area in hectares on the Data Form 1 in the box at the right-hand side of the $V_{TRACT}$ row.

### $V_{WD}$ - Woody debris biomass and $V_{LOG}$ - log biomass

Woody debris is an important habitat and nutrient cycling component of forests. Volume of woody debris and log biomass per hectare is the metric used

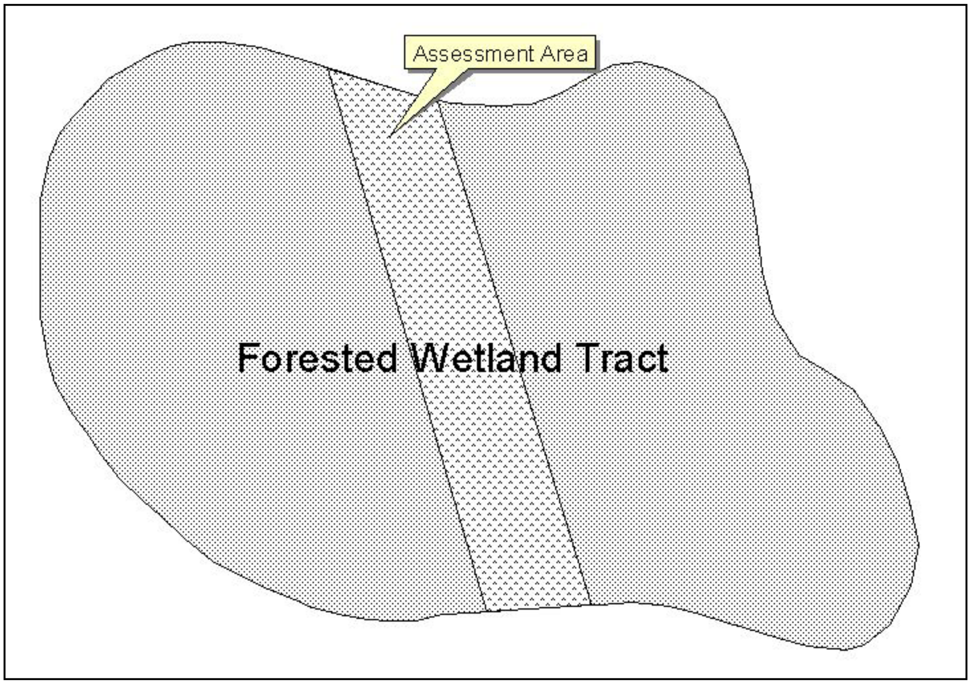


Figure 36. Wetland tract

to quantify these variables. Measure them with the procedure outlined below (Brown 1974; Brown Oberheu, and Johnston 1982).

(1) Lay out two 15.24-m (50-ft) east-west transects, originating at the 0.04-ha plot center point (Figure 23).

(2) Count the number of nonliving stems in Size Class 1 (≥0.6 and <2.5 cm (≥0.25 and <1 in.)) that intersect the vertical plane above the 6-ft segment farthest from the plot center point on each 50-ft transect. Record the number of Size Class 1 stems on Data Form 5. (Note: all stem diameter criteria and the measurements for all size classes refer to diameter at the point of intersection with the transect line).

(3) Count the number of nonliving stems in Size Class 2 (≥2.5 cm and < 7.6 cm (≥ 1 and < 3 in.)) that intersect the plane above the 12-ft segment farthest from the plot center point on each 50-ft transect. Record the number of Size Class 2 stems on Data Form 5.

(4) Measure and record the diameter of nonliving stems in Size Class 3 (≥ 7.6 cm (≥3 in.)) that intersect the plane above the entire length of the 50-ft transect. Record the diameter of individual stems in Size Class 3 on Data Form 5.

A spreadsheet is available to complete the calculations in Steps 5-16 below (Appendix B).

(5) Convert stem counts for Size Classes 1 and 2 using the following formulas.

Size Class 1: $0.187 * \text{number of stems} = \_\_\_\_\_$ tons/acre

Size Class 2: $0.892 * \text{number of stems} = \_\_\_\_\_$ tons/acre

(6) Convert stems diameters for Size Class 3 into area using the formula: $(\text{dbh} * \text{dbh}) * 0.785 = \text{cm}^2$.

(7) Sum the area of the Size Class 3 stems, and convert to tons/acre using the formula: area $(\text{cm}^2) * 0.0687 = \text{tons/acre}$

(8) Sum the tons/acre for Size Classes 1, 2, and 3 for Transect 1.

(9) Repeat Steps 1-8 for Transect 2

(10) Average the summed tons/acre for all Size Classes Transects 1 and 2

(11) Convert tons/acre to $\text{ft}^3$/acre using the formula: $(32.05 * \text{tons/acre})/0.58 = \text{ft}^3/\text{acre}$

(12) Convert $\text{ft}^3$/acre to $\text{m}^3$/ha using the formula: $0.069 * \text{ft}^3/\text{acre} = \text{m}^3/\text{ha}$

(13) Record $\text{m}^3$/acre on the Data Form 1 as a plot value on the $V_{WD}$ row

(14) Average tons/acre for Size Class 3 from Transects 1 and 2.

(15) Convert tons/acre to $\text{ft}^3$/acre using the formula: $(32.05 * \text{tons/acre})/0.58 = \text{ft}^3/\text{acre}$

(16) Convert $\text{ft}^3$/acre to $\text{m}^3$/ha using the formula: $0.069 * \text{ft}^3/\text{acre} = \text{m}^3/\text{ha}$

(17) Record $\text{m}^3$/acre on the Data Form 1 as a plot value on the $V_{LOG}$ row

(18) Average the plot values on the Data Form 1 for $V_{WD}$ and $V_{LOG}$ and record the result in the boxes on the right-hand side of the $V_{WD}$ and $V_{LOG}$ rows.

## Analyze Field Data

The analysis of field data requires two steps. The first step is to transform the measure of each assessment variable into a variable subindex. This can be done using the graphs at the end of Chapter 5 or in a spreadsheet that has been set up to do these tedious calculations (see Appendix B). The second step is to insert the variable subindices into the assessment model and calculate the FCI using the relationships defined in the assessment models. Again, these tedious calculations can be done manually using the assessment model equations in Chapter 5 or using a spreadsheet set up to do the calculations (see Appendix B).

Figure 37 shows the spreadsheet that has been set up to do both steps of the analysis. The data from the boxes on the right hand side of Data Form 1 are entered in the second column labeled "Variable Metric Values" in the lower portion of the spreadsheet to the right of the variable names. The calculated variable subindex is displayed in the fourth column of the lower half of the spreadsheet. The variable subindices are then used to calculate the FCI using the appropriate assessment model. The resulting FCI is displayed in the first column of the top half of the spreadsheet to the left of each function name. The spreadsheet format allows the user to instantly ascertain how a change in the metric value of a variable will affect the FCI of a particular function by simply entering a new metric value in the bottom half of the spreadsheet.

## Apply Assessment Results

Once the assessment and analysis phases are complete, the results can be used to: (a) compare the same WAA at different points in time, (b) compare different WAAs at the same point in time, (c) compare different alternatives to a project, or (d) compare different hydrogeomorphic classes or subclasses (Smith et al. 1995).

## Special Issues in Applying the Assessment Results

Users of this document must recognize that not all situations can be anticipated or accounted for in developing a rapid assessment method. In particular, users must be able to adapt the material presented here to special or unique situations encountered in the field. For example, most of the reference standard conditions identified in the field were mature forests with high species diversity, and typically they were dominated by oak species. Sites that deviate from this reference condition typically produce low scores for some functions. However, there are situations where deviation from the reference standard condition is appropriate and should be recognized as such. In most of these cases, alternative reference standards have been identified in the discussions of assessment variables (such as where cottonwood or willow dominate on new substrates, this is recognized as an appropriate $V_{COMP}$ condition). In other instances, however, professional judgment in the field is essential to proper application of the models. For example, some sites with near-permanent flooding are dominated by buttonbush. Where this occurs because of water control structures, it should be recognized as having arrested functional status, at least for some functions. However, where the same situation occurs because of beaver activity or changes in channel courses, the buttonbush swamp should be recognized as a functional and temporary component of a larger wetland complex. Other such situations that require special consideration include areas affected by fire, sites damaged by ice storms, and similar occurrences.

Another potential consideration in the application of the assessment models presented here concerns projection of future conditions. This may be particularly important in determining the rate at which functional status will improve as a result of restoration actions intended to offset impacts to jurisdictional wetlands. The graphs in Figure 38 represent general recovery trajectories for forested sites within the Yazoo Basin, based on a subset of the reference data collected to develop this guidebook. In selected stands, individual trees were aged using an increment corer to develop a general relationship between the age of sampled stands and the site-specific variables employed in the assessment models. Thus, a user can estimate the overstory basal area, shrub density, woody debris volume, and other functional indictors for various time intervals and calculate functional capacity indices for all applicable functions. These curves are specifically constructed to reflect wetland recovery following restoration of agricultural land, which is the most common restoration scenario in the Yazoo Basin. Thus, they assume that the initial site condition includes bare ground that has been tilled (hence the deeper initial A horizon). Note that landscape variables are not included here, because they require site-specific knowledge to project future conditions. Ponding development rates also are not estimated, because ponding is the result of both geomorphic and biotic factors and the initial site conditions (i.e., extent of land leveling). The degree of microtopographic relief will be dependent on the extent of site contouring work done prior to planting, in most cases. Similarly, the rates of compositional change ($V_{COMP}$ and $V_{TCOMP}$) are dependent on initial site conditions; generally, a site planted with appropriate species should have an initial FCI score of 1.0 for the compositional variables and maintain that fully functional status indefinitely. Estimation of future composition for unplanted areas will require site-specific evaluation of seed sources and probable colonization patterns. Note also that the graphs in Figure 38 are amalgams of data from all wetland subclasses. In situations where a site is expected to be unusual in one or more respects (such as a cottonwood stand, where basal areas are likely to increase more quickly than in hardwood forests), more specific data may exist and should be substituted for these general curves as appropriate.

**FCI Calculation for the Riverine Backwater Regional Subclass in the Yazoo Basin (12-12-00)**

**Enter quantitative or categorical measure from Field Data Sheet in the shaded cells below**

| Variable | Metric Value | Units | Subindex |
|---|---|---|---|
| 1. $V_{TRACT}$ | 1 | ha | 0.0 |
| 2. $V_{CORE}$ | 1 | % | 0.1 |
| 3. $V_{CONNECT}$ | 1 | % | 0.1 |
| 4. $V_{FREQ}$ | 5 | years | 0.3 |
| 5. $V_{POND}$ | 1 | % | 0.1 |
| 6. $V_{SOIL}$ | 1 | % | 1.0 |
| 7. $V_{CEC}$ | 1 | % | 1.0 |
| 8. $V_{TBA}$ | 1 | $m^2$ / ha | 0.0 |
| 9. $V_{TDEN}$ | 1 | stems / ha | 0.0 |
| 10. $V_{SNAG}$ | 1 | stems / ha | 0.0 |
| 11. $V_{TCOMP}$ | 1 | % | 0.0 |
| 12. $V_{COMP}$ | 1 | % | 0.0 |
| 13. $V_{WD}$ | 1 | $m^3$ / ha | 0.5 |
| 14. $V_{LOG}$ | 1 | $m^3$ / ha | 0.0 |
| 15. $V_{SSD}$ | 1 | stems / ha | 0.0 |
| 16. $V_{GVC}$ | 1 | % | 0.1 |
| 17. $V_{OHOR}$ | 1 | cm | 0.6 |
| 18. $V_{AHOR}$ | 1 | cm | 0.6 |

| FCI | Function |
|---|---|
| 0.0 | Detain Floodwater |
| 0.3 | Detain Precipitation |
| 0.2 | Cycle Nutrients |
| 0.1 | Export Organic Carbon |
| 0.2 | Remove Elements and Compounds |
| 0.0 | Maintain Plant Communities |
| 0.0 | Provide Fish and Wildlife Habitat |

Figure 37. Example of an FCI calculation spreadsheet

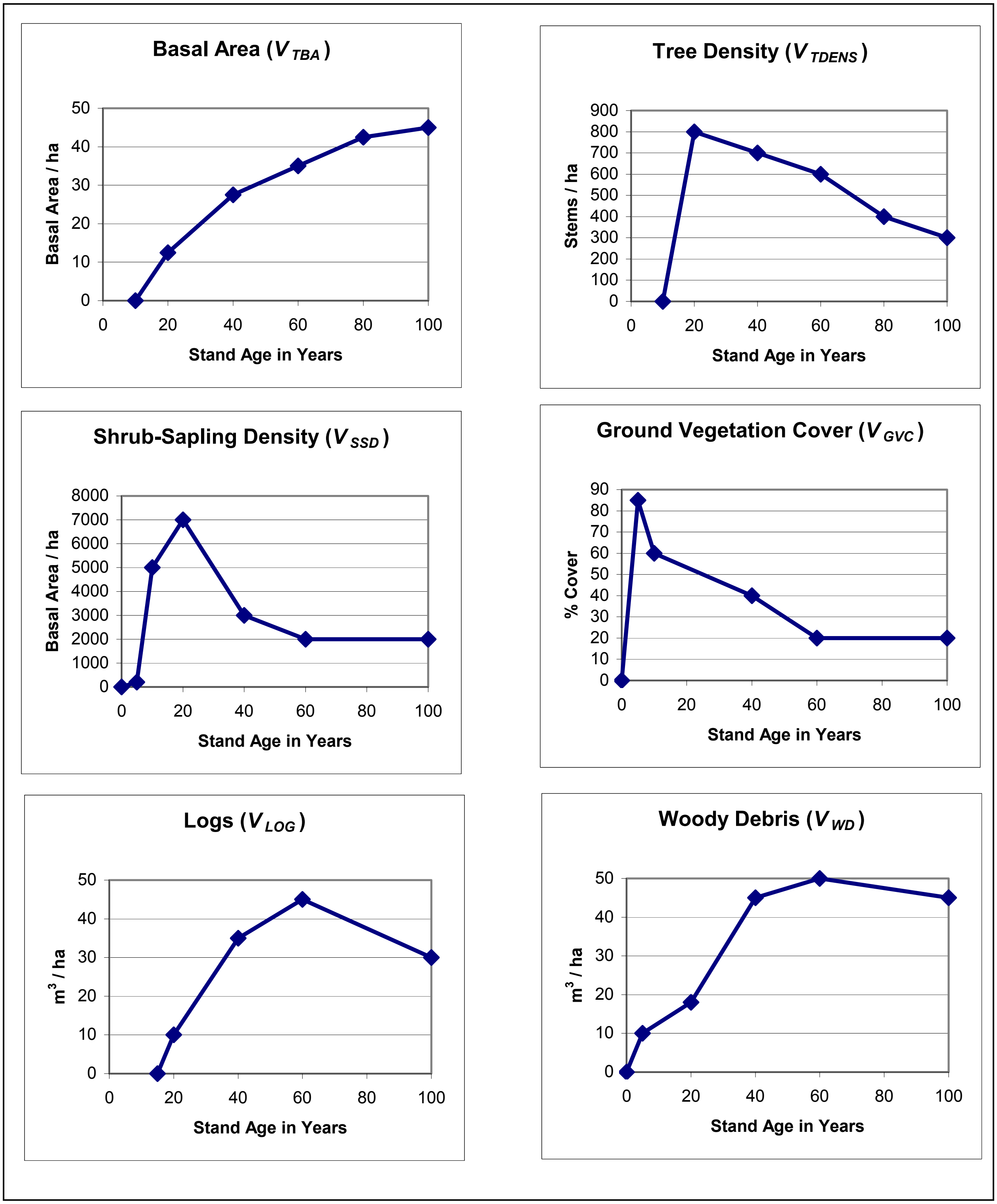


Figure 38. Recovery trajectories for selected assessment variables (Continued)

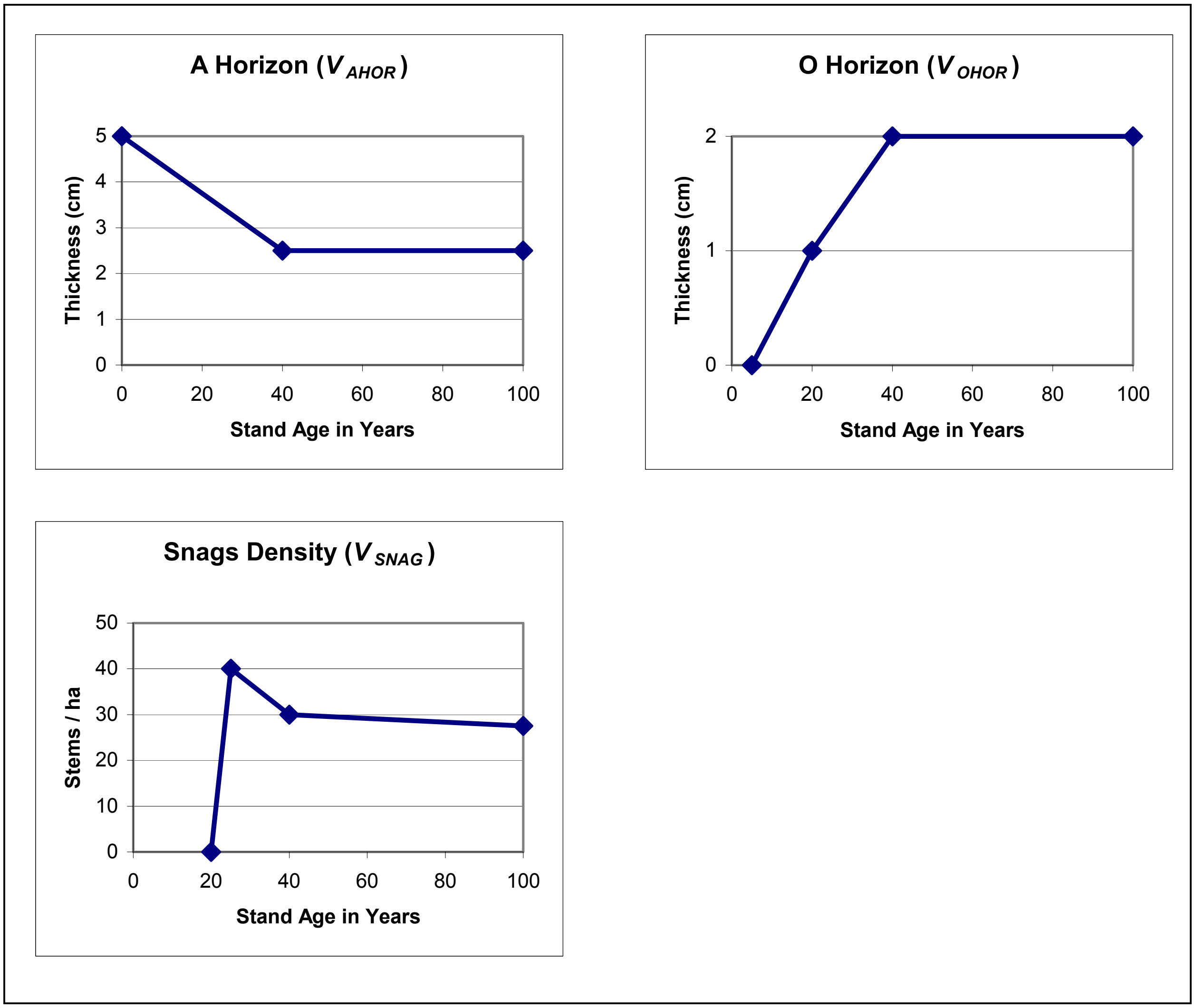


Figure 38. (Concluded)

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# Appendix A
# Glossary

**"A" horizon:** A mineral soil horizon at the soil surface or below an "O" horizon characterized by accumulation of humified organic matter intricately mixed with the mineral fraction.

**Assessment model:** A simple model that defines the relationship between ecosystem and landscape scale variables and functional capacity of a wetland. The model is developed and calibrated using reference wetlands from a reference domain.

**Assessment objective:** The reason that an assessment of wetland functions is being conducted. Assessment objectives normally fall into one of three categories. These include: documenting existing conditions, comparing different wetlands at the same point in time (e.g., alternatives analysis), and comparing the same wetland at different points in time (e.g., impact analysis or mitigation success).

**Assessment team (A-Team):** An interdisciplinary group of regional and local scientists responsible for classification of wetlands within a region, identification of reference wetlands, construction of assessment models, definition of reference standards, and calibration of assessment models.

**Channel:** A natural stream or river, or an artificial feature, such as a ditch or canal, that exhibits features of bed and bank and conveys water primarily unidirectionally downgradient.

**Colluvial:** Colluvium is a heterogeneous mixture of soil and parent material that has moved down a slope and settled at its base as a result of gravitational action.

**Direct impacts:** Project impacts that result from direct physical alteration of a wetland, such as the placement of dredge or fill.

**Direct measure:** A quantitative measure of an assessment model variable.

**Functional assessment:** The process by which the capacity of a wetland to perform a function is measured. This approach measures capacity using an assessment model to determine a functional capacity index.

**Functional capacity:** The rate or magnitude at which a wetland ecosystem performs a function. Functional capacity is dictated by characteristics of the wetland ecosystem, the surrounding landscape, and the interaction between the two.

**Functional capacity index (FCI):** An index of the capacity of a wetland to perform a function relative to other wetlands from a regional wetland subclass in a reference domain. Functional capacity indices are by definition scaled from 0.0 to 1.0. An index of 1.0 indicates that a wetland performs a function at the highest sustainable functional capacity, the level equivalent to a wetland under reference standard conditions in a reference domain. An index of 0.0 indicates the wetland does not perform the function at a measurable level and will not recover the capacity to perform the function through natural processes.

**Frass:** Dead insect biomass and insect secretions.

**Highest sustainable functional capacity:** The level of functional capacity achieved across the suite of functions by a wetland under reference standard conditions in a reference domain. This approach assumes that the highest sustainable functional capacity is achieved when a wetland ecosystem and the surrounding landscape are undisturbed.

**Hydrogeomorphic wetland class:** The highest level in the hydrogeomorphic wetland classification. There are five basic hydrogeomorphic wetland classes, including depression, fringe, slope, riverine, and flat.

**Indicator:** Indicators are observable characteristics that correspond to identifiable variable conditions in a wetland or the surrounding landscape.

**Indirect measure:** A qualitative measure of an assessment model variable that corresponds to an identifiable variable condition.

**Indirect impacts:** Impacts resulting from a project that occur concurrently, or at some time in the future, away from the point of direct impact. For example, indirect impacts of a project on wildlife can result from an increase in the level of activity in adjacent, newly developed areas, even though the wetland is not physically altered by direct impacts.

**In-kind mitigation:** Mitigation in which lost functional capacity is replaced in a wetland of the same regional wetland subclass.

**Interflow:** The lateral movement of water in the unsaturated zone during and immediately after a precipitation event. The water, moving as interflow, discharges directly into a stream or lake.

**Jurisdictional wetland:** Areas that meet the soil, vegetation, and hydrologic criteria described in the "Corps of Engineers Wetlands Delineation Manual" (Environmental Laboratory 1987) or its successor.

**Mitigation:** Restoration or creation of a wetland to replace functional capacity that is lost as a result of project impacts.

**Mitigation plan:** A plan for replacing lost functional capacity resulting from project impacts.

**Mitigation wetland:** A restored or created wetland that serves to replace functional capacity lost as a result of project impacts.

**Model variable:** A characteristic of the wetland ecosystem or surrounding landscape that influences the capacity of a wetland ecosystem to perform a function.

**"O" horizon:** A layer with more than 12 to 18 percent organic C (by weight; 50 percent by volume). Form of the organic material may be recognizable plant parts (Oi) such as leaves, needles, twigs, moss, etc., partially decomposed plant debris (Oe), or totally decomposed organic material (Oa) such as muck.

**Off-site mitigation:** Mitigation that is done at a location physically separated from the site at which the original impacts occurred, possibly in another watershed.

**Out-of-kind mitigation:** Mitigation in which lost function capacity is replaced in a wetland of a different regional wetland subclass.

**Project alternatives:** Different ways in which a given project can be done. Alternatives may vary in terms of project location, design, method of construction, amount of fill required, and other ways.

**Project area:** The area that encompasses all activities related to an ongoing or proposed project.

**Project target:** The level of functioning identified for a restoration or creation project. Conditions specified for the functioning are used to judge whether a project reaches the target and is developing toward site capacity.

**Red flag features:** Features of a wetland or the surrounding landscape to which special recognition or protection is assigned on the basis of objective criteria. The recognition or protection may occur at a Federal, State, regional, or local level and may be official or unofficial.

**Reference domain:** The geographic area from which reference wetlands are selected. A reference domain may, or may not, include the entire geographic area in which a regional wetland subclass occurs.

**Reference standards:** Conditions exhibited by a group of reference wetlands that correspond to the highest level of functional capacity (highest, sustainable level of functioning) across the suite of functions performed by the regional wetland subclass. The highest level of functional capacity is assigned an index value of 1.0 by definition.

**Reference wetlands:** Wetland sites that encompass the variability of a regional wetland subclass in a reference domain. Reference wetlands are used to establish the range of conditions for construction and calibration of functional indices and establish reference standards.

**Region:** A geographic area that is relatively homogeneous with respect to large-scale factors such as climate and geology that may influence how wetlands function.

**Regional wetland subclass:** Wetlands within a region that are similar, based on hydrogeomorphic classification factors. There may be more than one regional wetland subclass identified within each hydrogeomorphic wetland class, depending on the diversity of wetlands in a region and the assessment objectives.

**Site potential:** The highest level of functioning possible, given local constraints of disturbance history, land use, or other factors. Site capacity may be equal to or less than levels of functioning established by reference standards for the reference domain, and it may be equal to or less than the functional capacity of a wetland ecosystem.

**Soil horizon:** A layer, approximately parallel to the surface of the soil that is distinguishable from adjacent layers by a distinctive set of properties produced by soil forming processes (Soil Survey Staff 1981 cited in Fanning and Balluff-Fanning 1989).

**Solum**: A set of related soil horizons (Soil Survey Staff 1981 cited in Fanning and Balluff-Fanning 1989).

**Throughflow:** The lateral movement of water in an unsaturated zone during and immediately after a precipitation event. The water from throughflow seeps out at the base of slopes and then flows across the ground surface as return flow, ultimately reaching a stream or lake. See Interflow for comparison.

**Value of wetland function:** The relative importance of a wetland function to an individual or group.

**Variable:** An attribute or characteristic of a wetland ecosystem or the surrounding landscape that influences the capacity of the wetland to perform a function.

**Variable condition:** The condition of a variable as determined through quantitative or qualitative measure.

**Variable index:** A measure of how an assessment model variable in a wetland compares to the reference standards of a regional wetland subclass in a reference domain.

**Wetland:** See Wetland ecosystems.

**Wetland assessment area (WAA):** The wetland area to which results of an assessment are applied.

**Wetland banking:** The process of creating a "bank" of created, enhanced, or restored wetland to serve at a future date as mitigation for project impacts.

**Wetland ecosystems:** In 404: ".......areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas" (Corps Regulation 33 CFR 328.3 and EPA Regulations 40 CFR 230.3). In a more general sense, wetland ecosystems are three dimensional segments of the natural world where the presence of water, at or near the surface, creates conditions leading to the development of redoxomorphic soil conditions, and the presence of a flora and fauna adapted to the permanently or periodically flooded or saturated conditions.

**Wetland functions:** The normal activities or actions that occur in wetland ecosystems, or simply, the things that wetlands do. Wetland functions result directly from the characteristics of a wetland ecosystem and the surrounding landscape and their interaction.

**Wetland creation:** The process of creating a wetland in a location where a wetland did not previously exist. Wetland creation is typically done for mitigation.

**Wetland enhancement:** The process of increasing the capacity of a wetland to perform one or more functions. Wetland enhancement can increase functional capacity to levels greater than the highest sustainable functional capacity achieved under reference standard conditions, but usually at the expense of sustainability, or at a reduction of functional capacity of other functions. Wetland enhancement is typically done for mitigation.

**Wetland restoration:** The process of restoring wetland function in a degraded wetland. Restoration is typically done as mitigation.

**Wetland tract:** The area of forested wetland that is contiguous and directly accessible to the WAA.

**Wetland values:** See Value of wetland functions.

# Appendix B Spreadsheets

This appendix contains information for using the spreadsheet for calculation of tree basal area, woody debris and log volume, and functional capacity indices. The spreadsheets are available on the HGM website at http://www.wes.army.mil/el/wetlands/hgmhp.html

## Tree Basal Area Spreadsheet

This spreadsheet is used to calculate tree basal areas from the data recorded in the table on Data Form 3. Two different spreadsheets are available. One for dbh measurements made in centimeters and one for dbh measurements made in inches. An example of the spreadsheet for measurements made in centimeters is shown in Figure B1.

To use the spreadsheet, enter the species code and dbh in cm from Columns 1 and 2 of Data Form 3 into the first two columns of the spreadsheet. The spreadsheet will automatically calculate area of each tree in units of $cm^2$/0.04 ha and $m^2$/0.04 ha, and then convert $m^2$/0.04 ha, to $m^2$/ha in Columns 3, 4, and 5, respectively. The spreadsheet sums Column 5 in the bottom right-hand corner to give total $m^2$/ha based on the 0.04-ha plot data. This value should be entered on Data Form 1 as a plot value in the $V_{TBA}$ row.

If species are entered sequentially, the total basal area can be recorded for each species and used to determine dominants for the $V_{TCOMP}$ using the 50/20 rule. For example, enter all FRPE stems and record the $m^2$/ha from the bottom right cell. Then enter all the QULY stems and record the $m^2$/ha from the bottom right-hand cell, and subtract the $m^2$/ha of the FRPE stems to get $m^2$/ha for QULY. Continue until all species have been entered. Use the $m^2$/ha values recorded for each species, after subtracting previously entered species, to determine dominance using the 50/20 rule.

| If you measured tree diameters in centimeters, enter species name in A5-A32 and diameter values in the shaded cells B5-B26 | | | | |
|---|---|---|---|---|
| **Enter individual tree species code in cells A5-A32** | **Enter individual tree diameters (cm) in cells B5-B26** | **Converts to $cm^2$ / 0.04 ha** 0.25 * 3.14 * tree diameter$^2$ = $cm^2$ | **Converts to $m^2$ / 0.04 ha** Column B * 0.0001 = $m^2$ | **Converts to $m^2$ / ha** Column C * 25 = $m^2$/ha |
| FRPE | 45.00 | 1589.63 | 0.16 | 3.97 |
| FRPE | 20.00 | 314.00 | 0.03 | 0.79 |
| FRPE | 12.00 | 113.04 | 0.01 | 0.28 |
| FRPE | 8.00 | 50.24 | 0.01 | 0.13 |
| QULY | 13.00 | 132.67 | 0.01 | 0.33 |
| QULY | 23.00 | 415.27 | 0.04 | 1.04 |
| QULY | 25.00 | 490.63 | 0.05 | 1.23 |
| CAAQ | 21.00 | 346.19 | 0.03 | 0.87 |
| CAAQ | 14.00 | 153.86 | 0.02 | 0.38 |
| QUNU | 23.00 | 415.27 | 0.04 | 1.04 |
| QUNU | 45.00 | 1589.63 | 0.16 | 3.97 |
| QUNU | 34.00 | 907.46 | 0.09 | 2.27 |
| QUNU | 17.00 | 226.87 | 0.02 | 0.57 |
| | | 0.00 | 0.00 | 0.00 |
| | | 0.00 | 0.00 | 0.00 |
| | | 0.00 | 0.00 | 0.00 |
| | | 0.00 | 0.00 | 0.00 |
| | | 0.00 | 0.00 | 0.00 |
| | | 0.00 | 0.00 | 0.00 |
| | | | **Total Tree Basal Area in $m^2$/ha =** | 16.86 |

Figure B1. Example of the tree basal area spreadsheet

## Woody Debris and Log Volume Spreadsheet

This spreadsheet is used to calculate the volume of wood debris ($V_{WD}$) and logs ($V_{LOG}$). An example of the spreadsheet is shown in upper portion of Figure B2 which includes the cells for data entry of Size Class 1 and 2 and other calculations, and the lower portion of Figure B2 which includes the cells for data entry of Size Class 3.

To use the spreadsheet, enter the values Size Class 1 and 2 stem counts from Data Form 5 in Columns 2 and 5 of the spreadsheet, respectively. The spreadsheet calculates the average of Transects 1 and 2 for Size Class 1 stems in Column 3, and tons/acre for Size Class 1 stems in Column 4. Similarly, the spreadsheet calculates the average of Transects 1 and 2 for Size Class 2 stems in Column 6, and tons/acre for Size Class 2 stems in Column 7.

Now, enter the diameter values for Size Class 3 stems from Data Form 5 in the appropriate Columns in the lower portion of the spreadsheet. The spreadsheet calculates the stem area in the units of $cm^2$, sums these values at the bottom of the column, and inserts this information into Column 8 in the upper part of the spreadsheet. Then, as with Size Class 1 and 2, the spreadsheet calculates the average of Transects 1 and 2 for Size Class 3 stems in Column 9, and tons/acre for Size Class 3 stems in Column 10. The spreadsheet then calculates $ft^3$/acre for Size Class 3 in Column 11, and $m^3$/acre for Size Class 3 in Column 13 which is the final variable metric value for $V_{LOG}$. This value should be entered on Data Form 1 as a plot value in the $V_{LOG}$ row.

The spreadsheet then calculates $ft^3$/acre for the Size Classes 1 and 2 in Columns 14 and 15, respectively. These values are summed with the $ft^3$/acre value for logs in Column 11 and then $m^2$/ha are calculated for all three size classes in Column 17. This is the final variable metric value for $V_{WD}$ and should be entered on Data Form 1 as a plot value in the $V_{WD}$ row.

## Functional Capacity Index Spreadsheet

This spreadsheet is used to calculate the functional capacity indices for the functions assessed for each regional wetland subclass. Five separate spreadsheets are included in the Excel spreadsheet file, one for each regional wetland subclass. An example of the spreadsheet is shown in Figure B3.

To use the spreadsheet, enter values from the boxes on the right-hand side of Data Form 1 in the second column labeled "Variable Metric Values" in the lower portion of the spreadsheet to the right of the variable names. The sequence of variables on Data Form 1 corresponds to the sequence of variables in the spreadsheet.

The calculated variable subindex is displayed in the fourth column of the lower portion of the spreadsheet and is based on the relationships defined by the graphs in Chapter 5. Variable subindices are then used to calculate the FCI using the appropriate assessment model from Chapter 5. The resulting FCI is displayed in the first column of the top half of the spreadsheet to the left of each function name. The spreadsheet format allows the user to instantly ascertain how a change in the metric value of a variable will affect the FCI of a particular function by simply entering a new metric value measure in the bottom half of the spreadsheet.

Fill in Size Class 1, Size Class 2, and Size Class 3 in appropriate light green shaded areas below.

Read $V_{LOG}$ and $V_{WD}$ subindices in yellow shaded areas to the right.

| 1 | 2 | | 3 | 4 | 5 | | 6 | 7 | 8 | | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Size Class 1 No. of Stems/ Transect | | Size Class 1 Average No. Stems/ Transect | Size Class 1 tons/acre | Size Class 2 No. of Stems/ Transect | | Size Class 2 Average No. Stems/ Transect | Size Class 2 tons/ acre | Size Class 3 Sum of Stem Area (cm2) | | Size Class 3 Average of Stem Area (cm2) | Size Class 3 tons/acre | Size Class 3 ft3/acre | | (VLOG) Size Class 3 m3/ha | Size Class 1, 2, and 3 ft3/acre | Size Class 1, 2, and 3 ft3/acre | | (VWD) Size Class 1, 2, and 3 m3/ha |
| | Transect 1 | Transect 2 | | | Transect 1 | Transect 2 | | | Transect 1 | Transect 2 | | | | | | | | | |
| Plot 1 | 5 | 9 | 7 | 0.6545 | 2 | 6 | 4 | 1.784 | 3573.32 | 9012.59 | 6292.95 | 432.33 | 23889.73 | Plot 1 | 1648.39 | 434.76 | 24024.48 | Plot 1 | 1657.69 |
| Plot 2 | | | 0 | 0 | | | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | Plot 2 | 0.00 | 0.00 | 0.00 | Plot 2 | 0.00 |
| Plot 3 | | | 0 | 0 | | | 0 | 0 | 3.14 | 0.00 | 1.57 | 0.11 | 5.96 | Plot 3 | 0.41 | 0.11 | 5.96 | Plot 3 | 0.41 |
| Plot 4 | | | 0 | 0 | | | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | Plot 4 | 0.00 | 0.00 | 0.00 | Plot 4 | 0.00 |
| Plot 5 | | | 0 | 0 | | | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | Plot 5 | 0.00 | 0.00 | 0.00 | Plot 5 | 0.00 |
| Plot 6 | | | 0 | 0 | | | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | Plot 6 | 0.00 | 0.00 | 0.00 | Plot 6 | 0.00 |
| Plot 7 | | | 0 | 0 | | | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | Plot 7 | 0.00 | 0.00 | 0.00 | Plot 7 | 0.00 |
| Plot 8 | | | 0 | 0 | | | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | Plot 8 | 0.00 | 0.00 | 0.00 | Plot 8 | 0.00 |
| Plot 9 | | | 0 | 0 | | | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | Plot 9 | 0.00 | 0.00 | 0.00 | Plot 9 | 0.00 |
| Plot 10 | | | 0 | 0 | | | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | Plot 10 | 0.00 | 0.00 | 0.00 | Plot 10 | 0.00 |

Figure B2. Example of the woody debris and log volume spreadsheet showing data entry for Size Classes 1 and 2 and calculations (Continued)

| Size Class 3 Stem Diameters Plot 1 | | Size Class 3 Stem Area (cm2) Plot 1 | | Size Class 3 Stem Diameters Plot 2 | | Size Class 3 Stem Area (cm2) Plot 2 | | Size Class 3 Stem Diameters Plot 3 | | Size Class 3 Stem Area (cm2) Plot 3 | | Size Class 3 Stem Diameters Plot 4 | | Size Class 3 Stem Area (cm2) Plot 4 | | Size Class 3 Stem Diameters Plot 5 | | Size Class 3 Stem Area (cm2) Plot 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Transect 1 | Transect 2 | Transect 1 | Transect 2 | Transect 1 | Transect 2 | Transect 1 | Transect 2 | Transect 1 | Transect 2 | Transect 1 | Transect 2 | Transect 1 | Transect 2 | Transect 1 | Transect 2 | Transect 1 | Transect 2 | Transect 1 | Transect 2 |
| 4.00 | 34.00 | 12.56 | 907.46 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 |
| 10.00 | 4.00 | 78.50 | 12.56 | | | 0.00 | 0.00 | | | 3.14 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 |
| 20.00 | 56.00 | 314.00 | 2461.76 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 |
| 30.00 | 78.00 | 706.50 | 4775.94 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 |
| 56.00 | 33.00 | 2461.76 | 854.87 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 |
| 0.00 | 0.00 | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 |
| 0.00 | 0.00 | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 |
| 0.00 | 0.00 | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 |
| 0.00 | 0.00 | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 |
| 0.00 | 0.00 | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 |
| 0.00 | 0.00 | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 |
| 0.00 | 0.00 | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 |
| | | 3573.32 | 9012.59 | | | 0.00 | 0.00 | | | 3.14 | 0.00 | | | 0.00 | 0.00 | | | 0.00 | 0.00 |

Figure B2. (Concluded)

| | | | |
|---|---|---|---|
| **FCI Calculation for Riverine Overbank Regional Subclass in the Yazoo Basin** | | | |
| **FCI** | **Function** | | |
| | | | |
| **0.1** | **Detain Floodwater** | | |
| **0.3** | **Detain Precipitation** | | |
| **0.4** | **Cycle Nutrients** | | |
| **0.4** | **Export organic Carbon** | | |
| **0.2** | **Remove Elements and Compounds** | | |
| **0.6** | **Maintain Plant Communities** | | |
| **0.3** | **Provide Fish and Wildlife Habitat** | | |
| | | | |
| **Enter quantitative or categorical measure from Field Data Sheet in shaded cells** | | | |
| **Variables** | **Variable Metric Value** | **Units** | **Subindex** |
| **1. Vtract** | **1000** | **ha** | **0.3** |
| **2. Vcore** | **22** | **%** | **1.0** |
| **3. Vconnect** | **22** | **%** | **1.0** |
| **4. Vfreq** | **5** | **years** | **0.3** |
| **5. Vpond** | **100** | **%** | **0.0** |
| **6. Vsoil** | **1** | **%** | **0.6** |
| **7. Vcec** | **25** | **%** | **0.8** |
| **8. Vtba** | **15** | **m2/ha** | **0.4** |
| **9. Vtden** | **1000** | **stems/ha** | **0.5** |
| **10. Vsnag** | **120** | **stems/ha** | **0.4** |
| **11. Vtcomp** | **80** | **%** | **0.8** |
| **12. Vwd** | **120** | **m3/ha** | **0.2** |
| **13. Vlog** | **120** | **m3/ha** | **0.6** |
| **14. Vssd** | **1000** | **stems/ha** | **0.5** |
| **15. Vcomp** | **80** | **%** | **0.8** |
| **16. Vgvc** | **100** | **%** | **0.2** |
| **17. Vohor** | **1** | **cm** | **0.6** |
| **18. Vahor** | **1** | **cm** | **0.6** |

Figure B3. Example of an FCI calculation spreadsheet for the Riverine Backwater subclass

# Appendix C
# Reference Wetland Data and Spatial Data

This appendix provides the information necessary to access the data collected from reference wetland stands in the Yazoo Basin reference domain and information collected for use in ArcView.

## Reference Wetland Data

General information on plot numbering, regional subclass, and variables is contained in the Excel spreadsheet with the name “lmv-env.xls.” This spreadsheet is available on the HGM website http://www.wes.army.mil/el/wetlands/hgmhp.html. A list of the fields in this spreadsheet is provided below:

| | | |
|---|---|---|
| Stand No. | Ponding | $V_{TBA}$ |
| Plot No. | $V_{POND}$ | $V_{TDEN}$ |
| Regional Subclass | A Horizon | $V_{SSD}$ |
| Condition class | A Horizon | GC-1 |
| Date | $V_{AHOR}$ | GC-2 |
| State | LC-1 | GC-3 |
| County | LC-2 | GC-4 |
| 7.5 Quad | LC-3 | GC-1 |
| Township | LC-4 | GC-2 |
| Range | LC-1 | GC-3 |
| Section | LC-2 | GC-4 |
| 1/4 Section | LC-3 | $V_{GVC}$ |
| 1/16 Section | LC-4 | $V_{SNAG}$ |
| UTM Lat | $V_{OHOR}$ | WD1-1 |
| UTM Long | $V_{CEC}$ | WD1-2 |
| $V_{TRACT}$ | $V_{SOIL}$ | WD1-3 |
| $V_{CORE}$ | $V_{COMP}$ | WD1-4 |
| $V_{CONNECT}$ | $V_{TCOMP}$ | WD2-1 |
| $V_{FREQ}$ | $V_{DIVERSITY}$ | WD2-2 |

| | | |
|---|---|---|
| WD2-3 | WD3-4 | Perm. (in/hr) |
| WD2-4 | $V_{WD}$ | Surface Connect. |
| WD3-1 | $V_{LOG}$ | Condition Class Original |
| WD3-2 | Microtopographic Relief | Regional Subclass Original |
| WD3-3 | Vegetation Density | Stand Age |
| WD3-4 | Subsurface Connections | Species |
| WD3-1 | Depth to RF (cm) | Tree Age |
| WD3-2 | RF Indicator | Diameters (cm) |
| WD3-3 | Depth SHWT (cm) | Notes |

## ArcView Shape Files

Numerous spatial data layers were compiled and collected from a variety of sources during the course of this project. Most of the coverages are for the entire Yazoo Basin. Some of the coverages are for the Lower Mississippi River Valley. This information is available on the HGM website (http://www.wes.army.mil/el/wetlands/hgmhp.html) in the form of ArcView shape files. A list of shape files contents and file names that are available on the website is provided below:

County Boundaries (all_counties.*)

Geology (all_geology.*)

100 Year Flood Elevation (base100yr.*)

10 Year Flood Elevation (base10yr.*)

5 Year Flood Elevation (base5yr.*)

2 Year Flood Elevation (base2yr.*)

1 Year Flood Elevation (base1yr.*)

Land Use / Land Cover (lulc.*)

Geomorphology (saucier.*)

Reference Wetland Plot Locations (smith_plots.*)

Streets (streets.*)

Yazoo Basin County Boundaries (yb_county_bound.*)

Yazoo Basin Streams (yb_streams.*)

Yazoo Basin STATSGO Soils (yb_statsgo.*)

Yazoo Basin Watershed Boundaries (yb_watersheds.*)

Hydric Soils (yb_hydric.*)

## Digital Geomorphology Maps

During the course of this project we relied heavily on the geomorphic mapping of the Yazoo Basin summarized by Saucier (1994a, 1994b). The 15-in. geomorphic maps developed by Kolb et al. (1968) were found to be an important resource for reading the landscape and developing the regional wetland subclasses. Copies of these maps are available, but they are rare. We scanned the 15-ft quad maps in the Kolb et al. (1968) folio as high-resolution geotiff files and are willing to make them available to interested parties. Contact Dan Smith by e-mail if you are interested in these digital maps (smithr1@wes.army.mil).

# REPORT DOCUMENTATION PAGE

*Form Approved*
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**1. REPORT DATE** *(DD-MM-YYYY)*
April 2002

**2. REPORT TYPE**
Final report

**3. DATES COVERED** *(From - To)*

**4. TITLE AND SUBTITLE**
A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Selected Regional Wetland Subclasses, Yazoo Basin, Lower Mississippi River Alluvial Valley

**5a. CONTRACT NUMBER**

**5b. GRANT NUMBER**

**5c. PROGRAM ELEMENT NUMBER**

**6. AUTHOR(S)**

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**5d. PROJECT NUMBER**

**5e. TASK NUMBER**

**5f. WORK UNIT NUMBER**

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**

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Environmental Laboratory
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Vicksburg, MS 39180-6199

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12301 Second Avenue NE
Seattle, WA 98125

**8. PERFORMING ORGANIZATION REPORT NUMBER**

ERDC/EL TR-02-4

**9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)**
U.S. Army Corps of Engineers
Washington, DC 20314-1000

**10. SPONSOR/MONITOR'S ACRONYM(S)**

**11. SPONSOR/MONITOR'S REPORT NUMBER(S)**

**12. DISTRIBUTION / AVAILABILITY STATEMENT**
Approved for public release; distribution is unlimited.

**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT**

The Hydrogeomorphic (HGM) Approach is a method for developing functional indices and the protocols used to apply these indices to the assessment of wetland functions at a site-specific scale. The HGM Approach was initially designed to be used in the context of the Clean Water Act Section 404 Regulatory Program permit review to analyze project alternatives, minimize impacts, assess unavoidable impacts, determine mitigation requirements, and monitor the success of compensatory mitigation. However, a variety of other potential uses have been identified, including the determination of minimal effects under the Food Security Act, design of wetland restoration projects, and management of wetlands.

This report uses the HGM Approach to develop a Regional Guidebook for assessing the functions of five regional wetlands subclasses that occur in the Yazoo Basin of the Lower Mississippi River Alluvial Valley. The five regional subclasses include Flats, Riverine Overbank, Riverine Backwater, Isolated Depression, and Connected Depression. The report begins with an overview of the HGM Approach and then classifies and characterizes these wetland subclasses in the context of the Yazoo Basin reference domain. It then discusses for each wetland subclass (a) the rationale used to select functions, (b) the rationale used to select model variables, (c) the rationale used to develop assessment models, and (d) the data from reference wetlands used to calibrate model variables and assessment models. Finally, it outlines an assessment protocol for using the model variables and functional indices to assess each of the wetland subclasses.

**15. SUBJECT TERMS**

| | | | | |
|---|---|---|---|---|
| 404 Regulatory Program | Classification | Ecosystem | Function | Functional profile |
| Assessment | Clean Water Act | Evaluation | Functional assessment | Geomorphology |

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| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| a. REPORT | b. ABSTRACT | c. THIS PAGE | | | 19b. TELEPHONE NUMBER *(include area code)* |
| UNCLASSIFIED | UNCLASSIFIED | UNCLASSIFIED | | 185 | |

**15. (Concluded)**

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