Appendix E
Part 1

Natural Resource Conservation Service Farmed Wetland and Prior Converted Cropland Assessment Methodology

U.S. Army Corps of Engineers
Memphis District

United States Department of Agriculture

NRCS

Natural Resources Conservation Service
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June 20, 2013

Edward P. Lambert
Chief, Environmental Compliance Branch
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Regional Planning and Environmental Division South
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Dear Mr. Lambert,

As requested, Natural Resources Conservation Service (NRCS) is providing the assessment of farmed wetlands for the St. John's Bayou and New Madrid Floodway Project. The enclosed Farmed Wetland Evaluation, dated September 29, 2005, was originally provided to the Memphis District Corps of Engineers on October 5, 2005.

In order to add additional clarity to this information, in the fall of 2011, NRCS made another effort to estimate the number of farmed wetlands, this time digitally. This information is attached in the spreadsheet and map. We have included a summary of the wetland acres and associated methodology (attached). The map provides a graphic of the mapped wetlands in the St. John's Bayou and New Madrid Floodway Project.

If you have any questions please contact Harold Deckerd, Assistant State Conservationist-Water Resources, at (573) 876-0912.

Sincerely,

J.R. Flores
State Conservationist

Enclosures

cc:
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Wetland Type	New Madrid Watershed Wetlands (Ac)	St. John's Bayou Watershed Wetlands (Ac)	Combined (Ac)
Artificial Wetland (AW)	1112.7	1026.7	2139.4
Converted Wetland (CW)	29.6	32	61.6
Farmed Wetland (FW)	306	791.5	1097.5
Mitigated Wetland (MW)	0	6.5	6.5
Wetland Emergent (WE)	245.4	257.3	502.7
Wetland Open Water (WO)	233.3	62.8	296.1
Wetland Scrub-Shrub (WS)	202	296.8	498.8
Wooded Wetland (WW)	5212.9	3855.6	9068.5
TOTAL	**7341.9**	**6329.2**	**13671.1**

Notes on how these wetland acres were acquired: Wetland polygons were originally marked on circa 1986 hard copy base photography using non-certified, remote sensing techniques following the 1985 Food Security Act (as referred to in the report "USDA-Natural Resources Conservation Service's Farmed Wetland Evaluation for the U.S. Army Corps of Engineer's St. John's Bayou/New Maddrid Floodway Project" dated September 29, 2005). Because of being hard copy, acres figures from these photos could only be estimated. The referrenced report describes using a transect method in the field to substantiate these estimates. Subsequently, the wetland polygons were heads-up transferred to digital photography (1996 digital orthophotography, the closest in age digital base photography to the original information). Recent digital imagery, including the 2009 CIR and 2010 NC NAIP imagery, were also consulted to aid in the digital transfer, however the original mapping polygons were not altered despite visible changes in the newer photography. Once digital, the wetland acres could be summarized as presented above.

USDA – Natural Resources Conservation Service's Farmed Wetland Evaluation for the U. S. Army Corps of Engineer's St. John's Bayou/New Madrid Floodway Project

Pat Graham, Biologist
Clayton Lee, Soil Scientist
Nancy Ayers, Wetland Team Coordinator (SE-MO)
September 29, 2005

Background Information:
The Missouri NRCS conducted its original Food Security Act wetland inventory (non-certified determinations) using remote sensing techniques that referenced 1984-1989 Farm Service Agency compliance slides, 1980 base photography, color infrared photography, Fish & Wildlife Service National Wetland Inventory Maps, and soil surveys.

The COE's St. John's Bayou/New Madrid Floodway Project, Environmental Impact Statement included an estimate of impacts to wetlands [including those that meet the NRCS Farmed Wetland (FW) definition].

Since the project would impact wetlands (including FWs), questions about USDA program participant eligibility arose. NRCS and the Farm Service Agency make program eligibility determinations based on certified wetland determinations. Because of this, Missouri NRCS was advised to review the original wetland inventory (non-certified wetland determinations) for accuracy.

Follow-up Actions:
NRCS assembled a three person team and evaluated the original wetland inventory (within the COE's project area) from September 26-29, 2005 for its use in this project's planning stage.

The COE estimated/identified impacted farmed wetlands (backwater flooding in the New Madrid floodway and headwater flooding in the St. John Bayou) using an elevation of 290.5 feet. This elevation was chosen as a conservative level and is noted in narratives in the impact statement.

Staff assembled remote sensing resource materials and noted the climatic conditions:

A. Mississippi County – Farm Service Agency "compliance slides," we used three (3) wet and two (2) dry/normal years. Aerial photos: 1975 soil survey (dry), 1980 wetland inventory (dry), March 1988 Farm Service Agency base maps (dry), and June 2003 color infrared.

B. New Madrid County – Farm Service Agency "compliance slides," we used two (2) wet and two (2) dry/normal years. Aerial photos: 1974 soil survey (normal), 1980 wetland inventory (dry), March 1992 Farm Service Agency base maps (dry), and June 2003 color infrared.

We selected three one-mile wide transects/sample areas to evaluate the accuracy and applicability to the Wetland Conservation provisions (the sample areas represent ~20% of the project area as outlined by the COE):

1. Transect #1 – East edge starts at: T. 24 N., R. 14 E., Section 11 and ends at T. 24 N., R. 17 E., Section 10 (~17 ½ miles).
2. Transect #2 – East edge starts at: T. 23 N., R. 15 E., Section 6 and ends at T. 23 N., R. 17 E., Section 2 (~17 miles).
3. Transect #3 – East edge starts at: T. 23 N., R. 14 E., Section 35 and ends at T. 23 N., R. 17 E., Section 35 (~7 miles).

Findings:
Our sampling shows the original wetland inventory to be adequate for delineating farmed wetlands (FW) for planning purposes in the project area.

None of the slides available for our sample showed any wide spread effects of backwater flooding or river level stages that would initiate gate closure for the St. John's Bayou (no headwater flooding was observed). Most wetland signatures were due to inundation or moisture due to precipitation & local flooding events.

NRCS reviewed the difference between NRCS and the COE in elevations used for determining FWs. NRCS' elevation (281.0 feet) was completed in 1989 by determining a 2 year 15 day elevation at the Chester, Illinois and Memphis, Tennessee gages; profiles were plotted between these points by paralleling COE profiles on the Mississippi river.

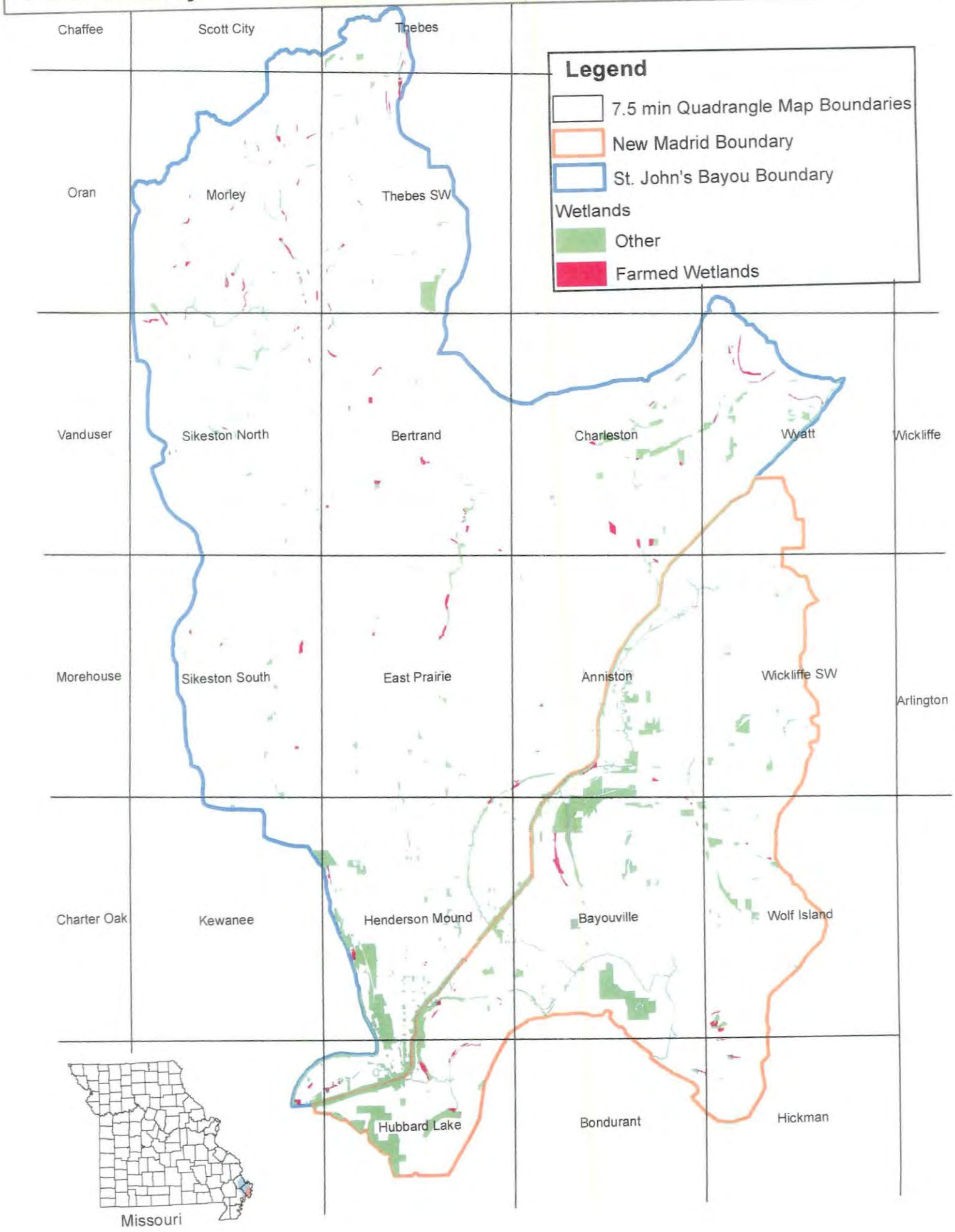
The COE elevation (290.5 feet) represents a 2 year peak discharge elevation. Since the COE is more conservative, NRCS used it to outline the greatest possible area affected; this area was then spot checked using remote sensing techniques as outlined above. For planning purposes, NRCS supports the COE's elevation.

Summary:
This sampling procedure verified that the original Food Security Act wetland inventory is adequate for estimating FWs in the project area. The most reliable method is to conduct an acre by acre analysis with current mapping conventions to obtain exact data. Due to the lack of landowner requests, this method is not possible at this point.

The observation that the use of new mapping conventions would yield greater amounts of wetlands did not hold true in our sample. Wetland kinds and acres provided in previous NRCS correspondence are valid.

The COE's projections of the affected wetlands and the resulting mitigation are more than adequate for NRCS wetland conservation provisions of the Food Security Act.

Food Security Act Farmed Wetlands - New Madrid and St. John's Bayou



Appendix E
Part 2

Wetland Goods and Services

U.S. Army Corps of Engineers
Memphis District

Wetland Goods and Services

Ecosystem services, as defined by the Millennium Ecosystem Assessment [Millennium Ecosystem Assessment (MEA), 2005], are the "benefits" people obtain from ecosystems. These include provisioning services such as food and water; regulating services, such as regulation of floods, drought, land degradation, and disease; supporting services, such as soil formation and nutrient cycling; and cultural services, such as recreational, spiritual, religious, and other nonmaterial benefits." Bottomland hardwood forest once covered nearly 25 million acres in the Mississippi Alluvial Valley (MAV). During the 1950's through 1970's, vast quantities of bottomland wetlands and forest were cleared, drained, and filled to aid in agricultural production, and by the 1980's, only 7 million acres remain and much of the remaining habitat is highly fragmented and hydrologically altered. (King et al 2006). The current dominating land use in the MAV, analogous to the project area, is agriculture, dominated by soybeans, corn, cotton and rice. In suitable conditions, converting agricultural fields back to their original composition of hydric vegetation and soil can result in a gain of ecosystem services, which in turn benefits society and the nation (Jenkins 2010).

Most scientists, regulatory agencies, and the general public would tend to agree that wetlands, in their natural state, provide valuable ecological services. Likewise, most scientist, regulatory agencies, and the general public would agree that agriculture provides little to no ecological services/value and in fact likely provides "negative value". For example, wetlands provide a vital ecosystem service of treating and removing a variety of waste products and some wetlands have been reported to reduce concentrations of nitrate by more than 80 percent (MEA), 2005. Excessive nutrient loading is a contributor to the Gulf of Mexico hypoxia problem. Based on SPARROW (Spatially Referenced Regression on Watershed attributes) data, the project area was ranked by Robertson et al (2009), with 95% certainty for Total Nitrogen and 90% certainty for Total Phosphorus, as being a top 15 watershed (out of 847) contributor of nutrients to the Mississippi Alluvial Valley. Thus, the majority of land in the project area results in "anti-wetland" goods and services in regards to nutrients and is seen as a persistent problem.

Zedler (2003) stated the following:

- When large areas of wetlands are drained for agriculture, the ecosystem services these wetlands performed are lost.
- Lost services include flood abatement, improved water quality, and support for biodiversity.

Likewise, Mitsch *et al.* (2001) stated:

> "Because of extensive artificial drainage over the past 200 years, many of the once-ubiquitous freshwater wetlands and riparian zones associated with the streams and rivers of the basin no longer exist. Gone with them is their capacity to mitigate water pollution. In the Mid-Western states, water quality is particularly degraded by nutrients, pesticides, and sediments from farms and urban areas, in these states, 80% of the wetland acreage has been drained. In seven states in the upper Mississippi River Basin (Indiana, Illinois, Iowa, Minnesota, Missouri, Ohio, and Wisconsin), about 18.6 million ha (46 million

acres) of land has been drained (Zucker and Brown 1998), much of which was wetlands at some time. In total, 14.1 million ha (35 million acres) of wetlands were lost in these states between the 1780s and the 1980s (Dahl 1990). Thus, the landscape has lost part of its ability to maintain a biochemical balance, and the stream and rivers are no longer buffered from runoff from upland regions".

Ecosystem services provided by or derived from wetlands (MEA, 2005) consist of the following:

- Provisioning
  - Food
  - Fresh Water
  - Fiber and Fuel
  - Biochemical
  - Genetic Materials
- Regulating
  - Climate Regulation
  - Water Regulation (hydrologic flows)
  - Water Purification and Waste Treatment
  - Erosion Regulation
  - Natural Hazard Regulation
  - Pollination
- Cultural
  - Spiritual and Inspirational
  - Recreational
  - Aesthetic
  - Educational
- Supporting
  - Soil Formation
  - Nutrient Cycling

It is generally accepted that wetlands provide favorable goods and services. Although agriculture can contribute some ecosystem services, they also are a source of disservices, particularly to loss of biodiversity, agrochemical contamination and sedimentation of waterways, pesticide poisoning of non-target organisms, and emissions of greenhouse gases and pollutants (Power, 2010, Dale and Polasky, 2007; Zhang *et al.*, 2007). It is generally accepted that agriculture, including wetlands in agricultural areas, impacts aquatic ecosystems (Blann *et al.*, 2009). Table 1 provides a comparison of goods and services provided by wetlands and disservices provided by "wetlands in agricultural areas." Locations with some wetland characteristics, but not subject to regulation under the Clean Water Act or the Food Security Act, and identified here as "wetlands in agricultural areas" result in greater net disservices than services.

Table 1. Ecosystem services and disservices provided by wetlands and "wetlands in agriculture."

	wetland[1]		"wetland in agriculture"	
Service/Disservice	Relative Magnitude	Comment/Example	Relative Magnitude	Comment/Example
Food	+++	Production of fish, wild game, fruits, grains, and so on	+++	"Agriculturists are the de facto managers of the most productive lands on Earth" (Tilman *et al.*,2002)
Freshwater	+	Storage and retention of water; provision of water for irrigation and for drinking	--	Croplands in intensively managed agricultural landscapes typically store less water, and runoff is higher and more flashy (Blann *et al.*, 2009) Agriculture depletes freshwater supplies (Kenny *et al.*, 2009).
Fiber and Fuel	+++	Production of timber, fuel wood, peat, fodder, aggregates	+++	Bio-fuels, alternative sources of energy, etc.
Biochemical Products	?	Extraction of material from biota	-	Agrochemical contamination (Power, 2010)
Genetic Materials	+	Medicine, genes for resistance to plant pathogens, ornamental species, and so on	+/-	Agriculture is used to promote beneficial plants necessary for medicine, ornamental species, and so on. However, agriculture destroys native vegetation that *could* provide new technologies.
Climate Regulation	+++	Regulation of greenhouse gases, temperature, precipitation, and other climatic processes; chemical composition of the atmosphere	---	The global increase in crop production may account for declines in air quality regulation and climate regulation (MEA, 2005, Dale and Polasky, 2007). Agricultural practices affect net greenhouse gas emissions through burning of fossil fuels and through the release of greenhouse gases in plant material (Dale and Polasky, 2007). Agricultural activities are estimated to be responsible for 12-14% of global anthropogenic emissions of greenhouse gases, not including emissions that arise from land clearing (Power, 2010, EPA, 2006).
Hydrologic Regimes	++	Groundwater recharge and discharge, storage of water for agriculture and industry	---	Depletion of groundwater aquifers necessary for irrigation (Kenny *et al.*, 2009).
Pollution Control and Detoxification	++	Retention, recovery, and removal of excess nutrients and pollutants	---	Agriculture and nitrogen fertilizer is a leading contributor to Gulf of Mexico hypoxia (Mitsch *et al.*, 2001 and numerous other citations). Agrochemical contamination (Power, 2010)
Erosion Protection	++	Retention of soils and prevention of structural change	--	Although farming practices have improved drastically, it has long been established that conversion of lands from native vegetation to

		(such as coastal erosion, bank slumping, and so on)		croplands generally results in elevated sediment loss (Blann *et al.*, 2009). Morphological changes resulting from drainage networks that alter discharge result in stream incision, bank erosion, and channel widening (Blann *et al.*, 2009).
Natural Hazards	++	Flood control, storm protection	--	Croplands in intensively managed agricultural landscapes typically store less water, and runoff is higher and more flashy (Blann *et al.*, 2009). Agriculture, especially soybeans, in the Mississippi River increases base flow and stream flow (Zhang and Schilling, 2005). In intensively drained landscapes, such as the agricultural Midwest of the United States, the connection of isolated basins has inflated total surface water discharge and increased the density of linear drainage networks (Blann *et al.* 2009).
Spiritual and Inspirational	++	Personal feelings and well-being; religious significance	+/-	Depending on one's culture, agriculture can also be considered a positive for personal feelings and well-being, as well as religious significance. However, a large segment of society is of the opinion that cleared agricultural lands do not prove spiritual and inspirational value.
Recreational	+	Opportunities for tourism and recreational activities	--	Agricultural is responsible for impacting recreational opportunities and remaining activities are limited.
Aesthetic	++	Appreciation of natural features	+/-	Depending on one's personal feelings, agriculture can also be considered aesthetically pleasing. However, a large segment of society is of the feeling that clearing, ditching, and leveling of the vegetated floodplain for agricultural purposes is an aesthetic impact.
Educational	++	Opportunities for formal and informal education and training	+/-	With the exception of agriculturally based education, conversion to agriculture has impacted educational opportunities.
Biodiversity	++	Habitats for resident and transient species	---	Since agricultural practices can harm biodiversity pathways, agriculture is often considered anathema to conservation (Power, 2010)
Soil Formation	++	Sediment retention and accumulation of organic matter	--	Although farming practices have improved drastically, it has long been established that conversion of lands from native vegetation to croplands generally results in elevated sediment loss (Blann *et al.*, 2009). Morphological changes resulting from drainage networks that alter discharge result in stream incision, bank erosion, and channel widening (Blann *et al.*, 2009).

Nutrient Cycling	+++	Storage, recycling, processing, and acquisition of nutrients	---	Agriculture and nitrogen fertilizer is a leading contributor to Gulf of Mexico hypoxia (Mitsch *et al.*, 2001 and numerous other citations).
Pollination	+	Support for pollinators	--	Pesticide poisoning of non-target organisms (Power 2010; Dale and Polasky, 2007)

[1]Seasonal Lakes, Marshes, and Swamps, including Floodplains (MEA, 2009)

Goods and services conclusions for project alternatives are listed below.

Alternative 1

The project area would maintain the same ecological services from vegetated wetlands as well as still experience the impacts attributed to ecological disservices from "wetlands in agricultural" areas. However, disservices attributed to "wetlands in agriculture" would be reduced when lands are converted to WRP which would result in a greater ecological service. Any measure that would take land out of production and reforest it would reduce ecological disservices attributed from the "wetlands in agriculture."

Alternatives 2 – 4

Goods and services would benefit as a result of the project. This is solely due to the fact that the vast majority of the project area is made up of agricultural land. Although these areas have been classified as "wetlands in agriculture" by the EPA, farmland mostly contributes negative ecological functions (*i.e.*, ecological disservices). Goods would benefit from the reduction in flood frequency.

Food – Vegetated wetlands provide fish, wild game, fruits, grains and so on. The project would negatively impact this service (MEA, 2005). Impacts to this ecological service are quantified by the utilization of a variety of fish and wildlife ecologic models. "wetlands in agricultural" areas are the de facto managers of the most productive lands on Earth (Tilman *et al.*, 2002). The project would benefit this ecological good by optimizing agricultural production on farmland by managing flood risks.

Freshwater – Vegetated wetlands store and retain water for irrigation and drinking. However, the majority of the project area water and irrigation supply is extracted from groundwater sources. Therefore, the project would not impact fresh-surface water supplies. Contrary to vegetated wetlands, "wetlands in agricultural" lands are a disservice to freshwater supplies. The vast majority of the project area would still be irrigated regardless of the project. Therefore, disservices far outweigh any ecological services provided. No additional impact to freshwater services is anticipated as a result of the project.

Fiber and Fuel – With the exception of direct impacts, project alternatives are not expected to impact fiber and fuel ecological services of vegetated wetlands. These areas would still be able to perform this service. Project alternatives would benefit the ecological goods provided by "wetlands in agriculture." Managing flood risks in the project area would benefit agricultural

management which in turn would optimize the production of bio-fuels, alternative energy sources, etc.

Biochemical Products- The ecological service provided from freshwater vegetated wetlands is currently not assessed (MEA, 2005). However, any biochemical products produced in agricultural areas would be benefited from the project.

Genetic Materials – There are no *known* significant sources of medicine, genes for resistance, ornamental species, and so on that exist in vegetated wetlands within the project area. Therefore, no significant impact is anticipated. Agriculture is used to produce pharmaceutical compounds. It is likely that this would be further expanded with research and technology. Therefore, since the project would benefit agricultural areas, this ecological good would also benefit. "wetlands in agricultural" areas is considered an ecological disservice because it destroys native plants. However, with the exception of direct impacts, project alternatives are not expected to result in any vegetation conversions. Therefore, no additional disservices are anticipated.

Climate Regulation – Although vegetated wetlands provide a service to climate regulation, "wetlands in agricultural" provide a disservice. The carbon footprint of the project was quantified and a discussion is found in Section 4.12.

Hydrologic Regimes – Vegetated wetlands perform a service by recharging groundwater supplies that can be used for municipal, industrial, or agricultural purposes. Project alternatives could partially impact this service. For example, this service would still be provided from project area vegetated wetlands that perform this service due to precipitation. However, any groundwater recharge due to impounded interior runoff or backwater flooding could be slightly impacted. Detention of precipitation and floodwaters was quantified with the HGM model. Contrary to vegetated wetlands, "wetlands in agricultural" areas provide a disservice to hydrologic regimes. Agriculture is a leading cause of groundwater depletion (Kenny *et al.,* 1999) and the network of drainage ditches in the project area result in relatively little storage/detention (*i.e.,* the project area has been engineered and the hydrologic regime manipulated to quickly drain water not retain it). Disservices far outweigh any services provided.

Pollution Control and Detoxification – It is well established that wetlands provide a service by removing excess nutrients and pollutants (MEA, 2005). It is also well established that "wetlands in agriculture" perform a disservice by being a leading contributor to Gulf of Mexico hypoxia (Mitsch *et al.,* 2001, numerous others). Water quality is assessed in Section 4.10.

Erosion Protection – Although vegetated wetlands perform a service by retaining soils and preventing them from entering waterways (MEA, 2005), "wetlands in agriculture" perform a disservice (Blann *et al.,* 2009). The disservices generated by the project area, which is over 80 percent agricultural, far outweigh any services provided. No significant impacts are anticipated as a result of project alternatives.

Natural Hazards – Vegetated wetlands perform a service by detaining flood waters and precipitation. However, "wetlands in agriculture" are a leading contributor to increasing discharge (Blann *et al.,* 2009; Zhang and Schilling, 2005). For example, all of the drainage

ditches, storm water improvements to East Prairie funded by the EPA, leveled cleared agricultural lands, and any other hydrologic modification all cumulatively result in a flood problem in the St. Johns Bayou Basin. Likewise, any hydrologic improvements upstream in the Mississippi River watershed all contribute to the flood problem in the New Madrid Floodway. The purpose of the project is to reduce natural hazards by managing flood risk. Therefore, project alternatives would alleviate the natural hazard in the project area. This can be considered a service to the population.

Although constructing flood risk management features would be a service to the project area, an argument can be made that it would be a disservice for downstream communities. The ecological services provided by detain floodwater/precipitation functions were quantified in the HGM model. The potential impact to downstream areas was assessed in Section 4.19. In summary, the project area would still perform a valuable service, any loss of services generated from project alternatives are either mitigated (see HGM model) or no significant impact is anticipated.

Spiritual and Inspirational – Depending on one's culture project alternatives could either be a service or disservice. No significant impacts are anticipated.

Recreational – "wetlands in agricultural" is one of the primary reasons that recreation is limited in the project area. Recreation is limited in vegetated wetlands as a result of flooding. For example, flood waters isolate public lands which prevent the public from being able to access them. Therefore, one can consider project alternatives a benefit to this good.

Aesthetic – Depending on one's culture "wetlands in agriculture" can be considered aesthetically pleasing or displeasing. The tentatively recommended plan would not impact underlying land use. Therefore, no significant impact is anticipated.

Educational – No significant impacts or benefits are anticipated to educational services or disservices are anticipated.

Biodiversity – Significant fish and wildlife resources were assessed with a variety of ecological models (*i.e.*, HGM, shorebirds, waterfowl, and fish).

Soil Formation – No significant impact or benefit to soil retention services from vegetated wetlands or disservices attributed to erosion from "wetlands in agriculture" is anticipated.

Nutrient Cycling – Nutrient cycling is assessed in Section 4.12.

Pollination – No significant impact or benefits are anticipated to ecological services provided by vegetated wetlands or disservices provided by "wetlands in agricultural" areas.

Appendix E
Part 3

A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Functions of Forested Wetlands in the Delta Region of Arkansas, Lower Mississippi River Alluvial Valley, Version 2.0

U.S. Army Corps of Engineers
Memphis District

ERDC/EL TR-11-12

Environmental Laboratory

US Army Corps of Engineers®
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Ecosystem Management and Restoration Research Program

A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Functions of Forested Wetlands in the Delta Region of Arkansas, Lower Mississippi River Alluvial Valley, Version 2.0

Charles V. Klimas, Elizabeth O. Murray, Jody Pagan, Henry Langston, and Thomas Foti

September 2011

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Ecosystem Management and Restoration
Research Program

ERDC/EL TR-11-12
September 2011

A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Functions of Forested Wetlands in the Delta Region of Arkansas, Lower Mississippi River Alluvial Valley, Version 2.0

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Final report

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Abstract: The Hydrogeomorphic (HGM) Approach is a method for developing and applying indices for the site-specific assessment of wetland functions. The HGM Approach was initially designed to be used in the context of the Clean Water Act Section 404 Regulatory Program permit review process 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 design of wetland restoration projects, and management of wetlands.

This is Version 2.0 of a Regional Guidebook that presents the HGM Approach for assessing the functions of most of the wetlands that occur in the Delta Region of Arkansas, which is part of the Lower Mississippi River Alluvial Valley. The report begins with an overview of the HGM Approach and then classifies and characterizes the principal wetlands that have been identified within the Delta Region of Arkansas. Detailed HGM assessment models and protocols are presented for six of those wetland types, or subclasses, representing all of the forested wetlands in the region other than those associated with lakes and impoundments. The following wetland subclasses are treated in detail: Flat, Mid-gradient Riverine, Low-gradient Riverine Backwater, Low-gradient Riverine Overbank, Headwater Depression, Isolated Depression, and Connected Depression. For each wetland subclass, the guidebook presents (a) the rationale used to select the wetland functions considered in the assessment process, (b) the rationale used to select assessment model variables, (c) the rationale used to develop assessment models, and (d) the functional index calibration curves developed from reference wetlands that are used in the assessment models. The guidebook outlines an assessment protocol for using the model variables and functional indices to assess each of the wetland subclasses. The appendices provide field data collection forms, spreadsheets for making calculations, and a variety of supporting spatial data intended for use in the context of a Geographic Information System.

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Preface

This Regional Guidebook is a revision of one published in 2004. This report was prepared in accordance with guidelines established by the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS. The original Regional Guidebook was developed as a cooperative effort between the Arkansas Multi-Agency Wetland Planning Team (MAWPT) and Region 6 of the U.S. Environmental Protection Agency, which provided funding through the Wetland Grants 104(b)(3) program for States, Tribes, and Local Governments. Charles V. Klimas (Charles Klimas and Associates, Inc., currently with ERDC) directed the field studies and prepared the guidebook manuscript, under contract to the Arkansas Game and Fish Commission MAWPT Coordination Office. Elizabeth O. Murray (MAWPT Coordinator, Arkansas Game and Fish Commission, currently with ERDC) prepared most of the figures. All of the persons listed as authors of this guidebook were involved in every aspect of the project, including classification, field sampling, and model testing, and otherwise contributed materially to production of the document. The affiliations of the other authors are as follows: Thomas Foti (Arkansas Natural Heritage Commission), Jody Pagan (Natural Resources Conservation Service, currently with 5-Oaks Wildlife Services), and Henry Langston (Arkansas State Highway and Transportation Department). Other representatives of the MAWPT member agencies provided technical oversight for the project and, together with other organizations, participated in the field studies and workshops that produced the wetland classification system, community characterizations, and assessment models used in this document. D. J. Klimas archived and summarized the field data and generated the data summary graphs in this report.

The original Regional Guidebook for the Delta Region of Arkansas was the first of five guidebooks developed for the state of Arkansas (Klimas et al. 2004, 2005, 2006, 2008a, 2008b) largely with the personnel listed above. During the development of subsequent Regional Guidebooks, some approaches were altered and variables improved. This Regional Guidebook is being revised to make it consistent with later Guidebooks, and to improve it based upon later experiences. New Excel-based data sheets have been created to ease FCI and FCU calculations. The revisions were done primarily by Elizabeth O. Murray and Charles V. Klimas.

Participants in the original project included representatives of federal agencies (U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, Natural Resources Conservation Service); Arkansas state agencies (Arkansas Natural Heritage Commission, Arkansas Game and Fish Commission, Arkansas Soil and Water Conservation Commission, Arkansas State Highway and Transportation Department, Arkansas Forestry Commission, Arkansas Department of Environmental Quality, and University of Arkansas Cooperative Extension Service); state university personnel; and private sector representatives. All of the individuals involved are too numerous to list here, but some people contributed a particularly large amount of time and effort: Ken Brazil (Arkansas Soil and Water Conservation Commission); Rob Holbrook (Arkansas Game and Fish Commission); Joe Krystofik (formerly of Soil and Water Conservation Commission, currently with U.S. Fish and Wildlife Service); Gary Tucker (FTN Associates, Ltd.); Phillip Moore (Arkansas State Highway and Transportation Department); Jeff Raasch (formerly MAWPT Coordinator, Arkansas Game and Fish Commission, currently with Texas Parks and Wildlife); Bill Richardson (Arkansas State Highway and Transportation Department); and Theo Witsell (Arkansas Natural Heritage Commission). Ken Brazil, Tom Foti, Elizabeth Murray, and Jeff Raasch provided administrative continuity and coordination among participating and funding agencies, in addition to their direct technical participation.

This report is published by ERDC as part of the Hydrogeomorphic (HGM) Guidebook series under the Ecosystem Management and Restoration Program (EMRPP). EMRPP Program Manager was Glenn Rhett. Chris V. Noble, Wetlands and Coastal Ecology Branch, Ecosystem Evaluation and Engineering Division, Environmental Laboratory (EL), ERDC, reviewed the report for consistency with HGM guidelines. In addition, the methods and protocols used to prepare this report were closely coordinated with a study simultaneously undertaken in the Delta Region of Mississippi (the Yazoo Basin). Therefore, portions of the text and some figures are similar or identical to sections of the Yazoo Basin Guidebook ("A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Selected Regional Wetland Subclasses, Yazoo Basin, Lower Mississippi River Alluvial Valley," by R. D. Smith and C. V. Klimas, ERDC/EL TR-02-4, U.S. Army Engineer Research and Development Center, Vicksburg, MS). Note also that the Western Kentucky Regional Guidebook ("A Regional Guidebook for Assessing the Functions of Low Gradient, Riverine Wetlands of Western Kentucky," by W. B. Ainslie et al.

1999, Technical Report WRP-DE-17, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS) served as a template for the development of both this and the Yazoo Basin document. Parts of the discussion in the Western Kentucky document are included here without significant modification, particularly portions of the wildlife section (originally developed by Tom Roberts, Tennessee Technological University) and basic information on the HGM Approach and wetland functions (originally developed by R. Daniel Smith, EL). Many aspects of the classification system, field methods, and guidebook structure used here were based on reconnaissance studies in the Yazoo Basin and the Arkansas Delta conducted by Charles Klimas and R. Daniel Smith prior to initiation of this project.

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 initially was designed to be used in the context of the Clean Water Act, Section 404 Regulatory Program, 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), U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), Federal Highway 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 a specific 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 report is a Regional Guidebook developed for assessing the most common types of wetlands that occur in the Delta Region of Arkansas in 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 terminology); however, a different approach has been employed in this Regional Guidebook: 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 Delta Region of

Arkansas specifically and 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 contiguous with one another. Further, massive flood control and drainage works instituted in the twentieth century have dramatically affected nearly all of the wetlands in the Lower Mississippi River Alluvial Valley. Because these wetland systems have closely related origins, and have been universally influenced by flood protection and drainage 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 hydrogeomorphic classes and regional wetland subclasses are lumped for assessment purposes, but rather 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 was developed for multiple regional wetland subclasses that commonly occur together in a subbasin. It is expected that the classification of regional wetland subclasses, assessment variables, and the assessment models developed for the Delta Region of Arkansas will have general applicability in other subbasins of the Lower Mississippi River Alluvial Valley. However, development of Regional Guidebooks for other subbasins will require collection of additional reference data that reflect regional variation in wetland characteristics within a particular subbasin.

This Regional Guidebook addresses various objectives:

- To characterize selected regional wetland subclasses in the Delta Region of Arkansas within the Lower Mississippi River Alluvial Valley.
- To present the rationale used to select functions to be assessed in these regional subclasses.
- To present the rationale used to select assessment variables and metrics.
- To present the rationale used to develop assessment models.
- To describe the protocols for applying the functional indices to the assessment of wetland functions.

This report 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 Approach, including the procedures recommended for development and application of Regional Guidebooks. Chapter 3 characterizes the regional wetland

subclasses in the Delta Region of Arkansas included in this guidebook. Chapter 4 discusses the wetland functions, assessment variables, and functional indices used in the guidebook from a generic perspective. Chapter 5 applies the assessment models to specific regional wetland subclasses and defines the relationship of assessment variables to reference data. Chapter 6 outlines the assessment protocol for conducting a functional assessment of regional wetland subclasses in the Delta Region of Arkansas. Appendix A presents preliminary project documentation and field sampling guidance. Field data sheets are presented in Appendix B. Appendix C contains alternate field sheets, and Appendix D contains demonstration printouts of calculation spreadsheets. Appendix E presents spatial data. Common and scientific names of plant species referenced in the text and data sheets are listed in Appendix F.

While it is possible to assess the functions of selected regional wetland subclasses in the Delta Region of Arkansas using only the information contained in Chapter 6 and the appendices, it is strongly suggested that, prior to conducting an assessment, users also 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: (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. An interdisciplinary Assessment Team of experts carries out the Development Phase of the HGM Approach. The task of the Assessment Team is to develop and integrate the classification, reference wetland information, assessment variables, models, and protocols of the HGM Approach into a Regional Guidebook (Figure 1).

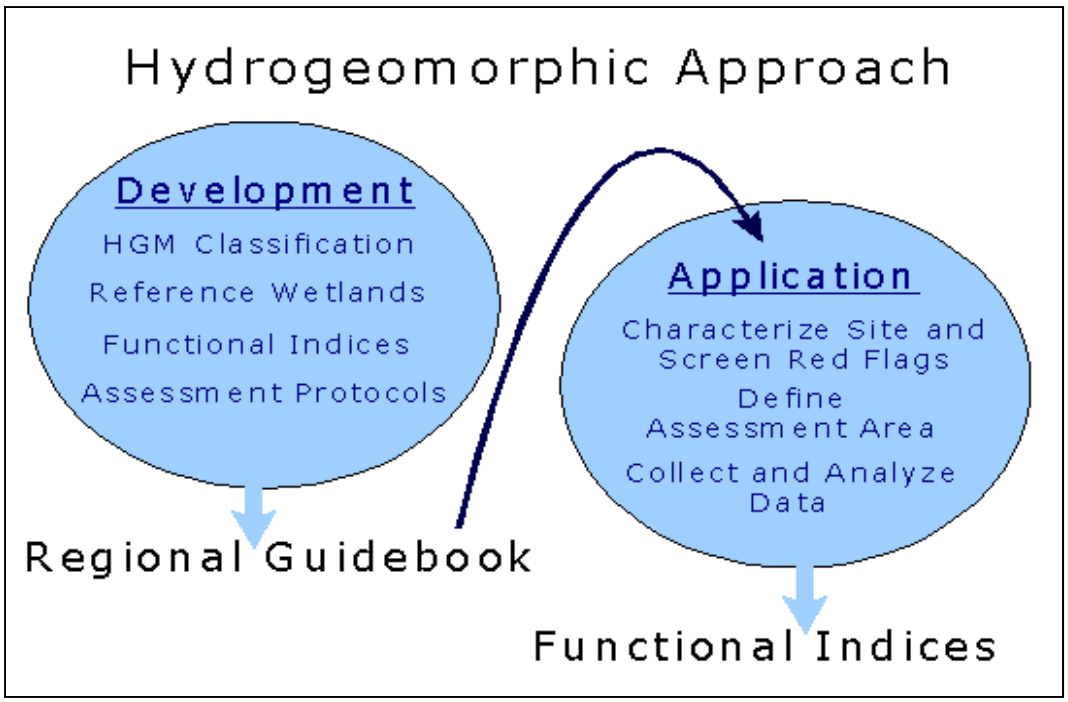


Figure 1. Development and Application Phases of the HGM Approach (from Ainslie et al. 1999)

In developing a Regional Guidebook, the team completes the tasks outlined in the National Action Plan (National Interagency Implementation Team 1996). After the team is organized and trained, its first task is to classify the wetlands of the region of interest into regional wetland subclasses using the

principles and criteria of Hydrogeomorphic Classification (Brinson 1993a; Smith et al. 1995). Next, focusing on a specific regional wetland subclass, the team develops an ecological characterization or functional profile of the subclass. The Assessment 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.

During the Application Phase, 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:

- Define assessment objectives.
- Characterize the project site.
- Screen for red flags.
- Define the Wetland Assessment Area.
- Collect field data.
- Analyze field data.

The second step involves applying the results of the assessment at various decision-making points in the planning or permit review sequence, such as alternatives analysis, impact 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; 1995, 1996), Brinson et al. (1995, 1996, 1998), Hauer and Smith (1998), and Smith et al. (1995).

Hydrogeomorphic classification

Wetland ecosystems share a number of common attributes including hydrophytic vegetation, hydric soils, and relatively long periods of inundation or saturation by water. In spite of these common attributes, wetlands occur in a variety of climatic, geologic, and physiographic settings and exhibit a wide range of physical, chemical, and biological characteristics and processes (Cowardin et al. 1979; Mitch and Gosselink 1993; Semeniuk 1987). 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 quickly, but lack the resolution necessary to detect significant changes in function. One way to achieve an appropriate level of resolution within a limited time frame is to employ a wetland classification system structured to support functional assessment objectives (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: geomorphic setting, water source, and hydrodynamics. Geomorphic setting refers to the position of the wetland in the landscape. Water source refers to the primary origin of the water that sustains wetland characteristics, such as precipitation, floodwater, or groundwater. Hydrodynamics refers to the level of energy with which water moves through the wetland, and the direction of water movement.

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 hydrogeomorphic wetland classes. These were later expanded to the seven classes described in Table 1 (Smith et al. 1995).

Generally, the level of variability encompassed by wetlands at the continental scale of hydrogeomorphic classification is too great to allow development of assessment indices that can be applied rapidly and still retain the level of sensitivity necessary to detect changes in function at a level of resolution appropriate to the 404 permit review. In order to reduce both inter- and intraregional variability, the three classification criteria

Table 1. Hydrogeomorphic Wetland Classes.

HGM Wetland Class	Definition
Depression	Depressional wetlands occur in topographic depressions (i.e., closed elevation contours) that allow the accumulation of surface water. Depressional wetlands may have any combination of inlets and outlets, or lack them completely. Potential water sources are precipitation, overland flow, streams, or groundwater flow 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 may occur over a range of time, from a few days to many months. Depressional 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 depressional 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 riverflow becomes the dominant water source. Additional water sources may be groundwater discharge and precipitation. 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 or dunes. S*partina 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. 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. Lacustrine wetlands lose water by evapotranspiration and by flow returning to the lake after flooding. 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 on sites with saturated overland flow with no channel formation. They normally occur on slightly to steeply sloping land. 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 by evapotranspiration. They 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. 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 or backwater flow from the channel. 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, and evapotranspiration. Bottomland hardwood forests on floodplains are examples of riverine wetlands.

must be applied at a smaller, regional geographic scale, thus creating regional wetland subclasses. In many parts of the country, existing wetland classifications can serve as a starting point for identifying these regional subclasses (e.g., Golet and Larson 1974; Stewart and Kantrud 1971; Wharton et al. 1982). 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. In addition, certain ecosystem or landscape characteristics may be useful for distinguishing regional subclasses. For example, depression subclasses might be based on water source (i.e., groundwater versus surface water) or the degree of connection between the wetland and other surface waters (i.e., the flow of surface water in or out of the depression through defined channels). Tidal fringe subclasses might be based on salinity gradients (Shafer and Yozzo 1998). Slope subclasses might be based on the degree of slope or landscape position. Riverine subclasses might be based on 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 geomorphic setting, water sources, hydrodynamics, vegetation, soil, and other features that were taken into consideration during the classification process.

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 USA	Western USA/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

Note: Adapted from Smith et al. 1995, Rheinhardt et al. 1997.

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 anthropogenic alteration (e.g., grazing, timber harvest, clearing). The reference domain is the geographic area occupied by the reference wetlands (Smith et al. 1995, Smith 2001). 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 remeasured as needed.

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.
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.

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 influence 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. Application of assessment models results in a Functional Capacity Index (FCI) ranging from 0.0 to 1.0. 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, the following equation shows an assessment model that could be used to assess the capacity of a wetland to detain floodwater.

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

The assessment model has five assessment variables: 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_{TDEN}) that together represent resistance to flow of floodwater through the wetland.

Assessment variables occur in a variety of states or conditions. The state or condition of an assessment variable is indicated by the value of the metric used to assess a variable, and the metric used is normally one commonly used in ecological studies. For example, tree basal area (m^2/ha) is the metric used to assess tree biomass in a wetland, with larger numbers usually indicating greater stand maturity and increasing functionality for several different wetland functions where tree biomass is an important consideration.

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 documented 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 tree density (V_{TDEN}) and the variable subindex for an example wetland subclass. As shown in the graph, tree densities of 200 to 400 stems/ha represent reference standard conditions, based on field studies, and a variable subindex of 1.0 is assigned for assessment models where tree density is a component. Where tree densities are higher or lower than those found in reference standard conditions, a lesser variable subindex value is assigned.

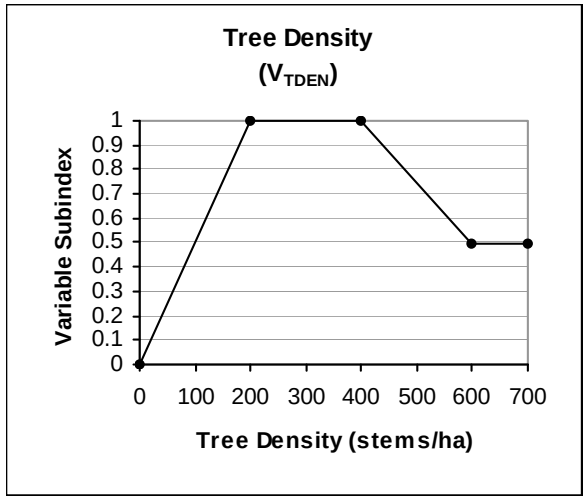


Figure 2. Example subindex graph for the Tree Density (V_{TDEN}) assessment variable for a particular wetland subclass.

Assessment protocol

All of the steps described in the preceding sections concern development of the assessment tools and the rationale used to produce this Regional Guidebook. Although users of the guidebook should be familiar with this process, their primary concern will be the protocol for application of the assessment procedures. The assessment protocol is a defined set of tasks, along with specific instructions, that allows resource professionals to assess the functions of a particular wetland area using the assessment models and functional indices in the Regional Guidebook. The first task includes characterizing 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. These steps are described in detail in Chapter 6, and the required data sheets, spreadsheets, and supporting digital spatial data are provided in Appendices A through E.

3 Characterization of Wetland Subclasses in the Delta Region of Arkansas

Reference domain

The reference domain for this guidebook (i.e., the area from which reference data were collected and to which the guidebook can be applied) is the Delta Region of Arkansas, which is that portion of the alluvial valley of the Mississippi River that lies within Arkansas, bounded on the west by the Ozark and Ouachita Mountains, the Arkansas River Valley, and the West Gulf Coastal Plain, and on the east by the Mississippi River levee (Figure 3). The area between the Mississippi River and the main-line levee system that controls Mississippi River flooding (commonly called the batture) is not included in the reference domain. Crowley's Ridge, a narrow, elongate remnant coastal plain feature of Tertiary age rising as much as 75 m above the surrounding alluvial terrain in the northeastern part of the Arkansas Delta, also is not included in the reference domain. All references to the Delta Region of Arkansas in this report are intended to reflect the limits on the reference domain as described, and do not include the Mississippi River batture or Crowley's Ridge.

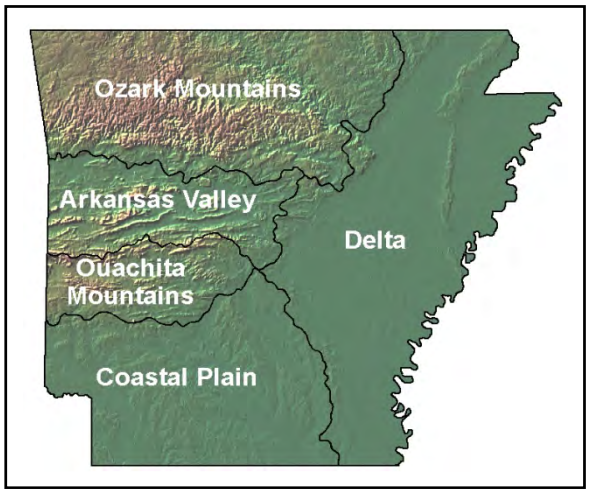


Figure 3. Wetland planning regions of Arkansas.

All of the wetlands within the reference domain are on landforms created by the action of the Mississippi River or its tributaries. In order to classify and assess wetlands in the region, it is important to understand the geology and geomorphology of both the Lower Mississippi Valley as a whole and the Delta Region of Arkansas, as well as the effects of human alterations to that landscape. The following sections review major concepts that have bearing on the classification and functions of wetlands in the modern landscape of the Delta Region of Arkansas. Descriptions of the wetland classes and subclasses that occur in the Delta and guidelines for recognizing them in the field are presented as the final section of this chapter.

Physiography and climate

The Delta Region of Arkansas is part of the Mississippi River Alluvial Valley, which is defined by Saucier (1994) as that portion of the Lower Mississippi Valley that is characterized by landforms and deposits that are primarily of Holocene and Wisconsin age. Certain pre-Wisconsin Pleistocene features of fluvial origin also are included. This definition excludes Crowley's Ridge, but includes the Grand Prairie area in Arkansas. 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. Except for the mountains in Arkansas, the Lower Mississippi Alluvial Valley is bounded on the east and west by exposures of the Coastal Plain sediments.

Climate within the Delta Region of Arkansas 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. Daily mean temperatures at Little Rock, on the west-central edge of the Delta Region, range from a low in January of 36.9 °F (2.7 °C) to a high of 81.5 °F (27.5 °C) in July, with an overall annual average of 61.8 °F (16.5 °C). Daily average maximum temperatures are 92.4 °F (33.5 °C) in July and 49.0 °F (9.4 °C) in January. Freezing temperatures reach the entire area for short periods in most years (Brown et al. 1971, Southern Regional Climate Center 2002).

Long-term average total precipitation does not vary greatly within the Delta Region of Arkansas. At Little Rock, the annual average is 50.86 in. (129.18 cm), with the most precipitation falling in April (5.49 in. or 13.94 cm), and the least in August (3.26 in. or 8.28 cm) (Southern Regional Climate Center 2002). 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 in the months of June through September.

Drainage system and hydrology

The dominant drainage feature of the Mississippi Alluvial Valley is the Mississippi River. The drainage area of the Mississippi River basin is approximately 3,227,000 sq km, 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 River 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, MS (which includes the flow from the Arkansas River and its tributaries), is 16,225 cu m/sec (573,000 cfs), and 225 million metric tons (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 64,500 cu m/sec (2,278,000 cfs) (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 (U.S. Army Engineer Division, Mississippi Valley 1998).

Prior to construction of modern levees, major Mississippi River floods would have inundated about half of the Delta Region of Arkansas (Moore 1972). Although modern mainstem levees generally prevent overbank Mississippi River flooding, they do not completely eliminate the influence of the river on hydrology of the region. High stages on the Mississippi River impede drainage of tributary streams, which results in backwater flooding. Under certain conditions, backwater flooding may be aggravated by levees that block return flows as mainstem water levels fall. Major backwater areas in the Arkansas Delta are in the St. Francis Basin and along the lower Arkansas and White Rivers.

The second-largest stream in the Delta Region is the Arkansas River, which traverses the Delta in a southeasterly direction from Little Rock to its junction with the Mississippi River about 30 km above Arkansas City. There are about 225 km of Arkansas River channel in the Delta, but the vast majority of its 416,000-sq-km drainage basin is outside of Arkansas in Oklahoma, Kansas, Texas, Colorado, and New Mexico (Moore 1972).

Neither the Mississippi River nor the Arkansas receive much direct overland runoff as they traverse the Delta Region because of the effects of both natural and man-made levees. Rather, most of the area drains to those rivers through tributaries that gather runoff within defined basins. The Arkansas Multi-Agency Wetland Planning Team has grouped the Delta drainage basins into Wetland Planning Areas (WPA), which are briefly described in the following paragraphs and illustrated in Figure 4.

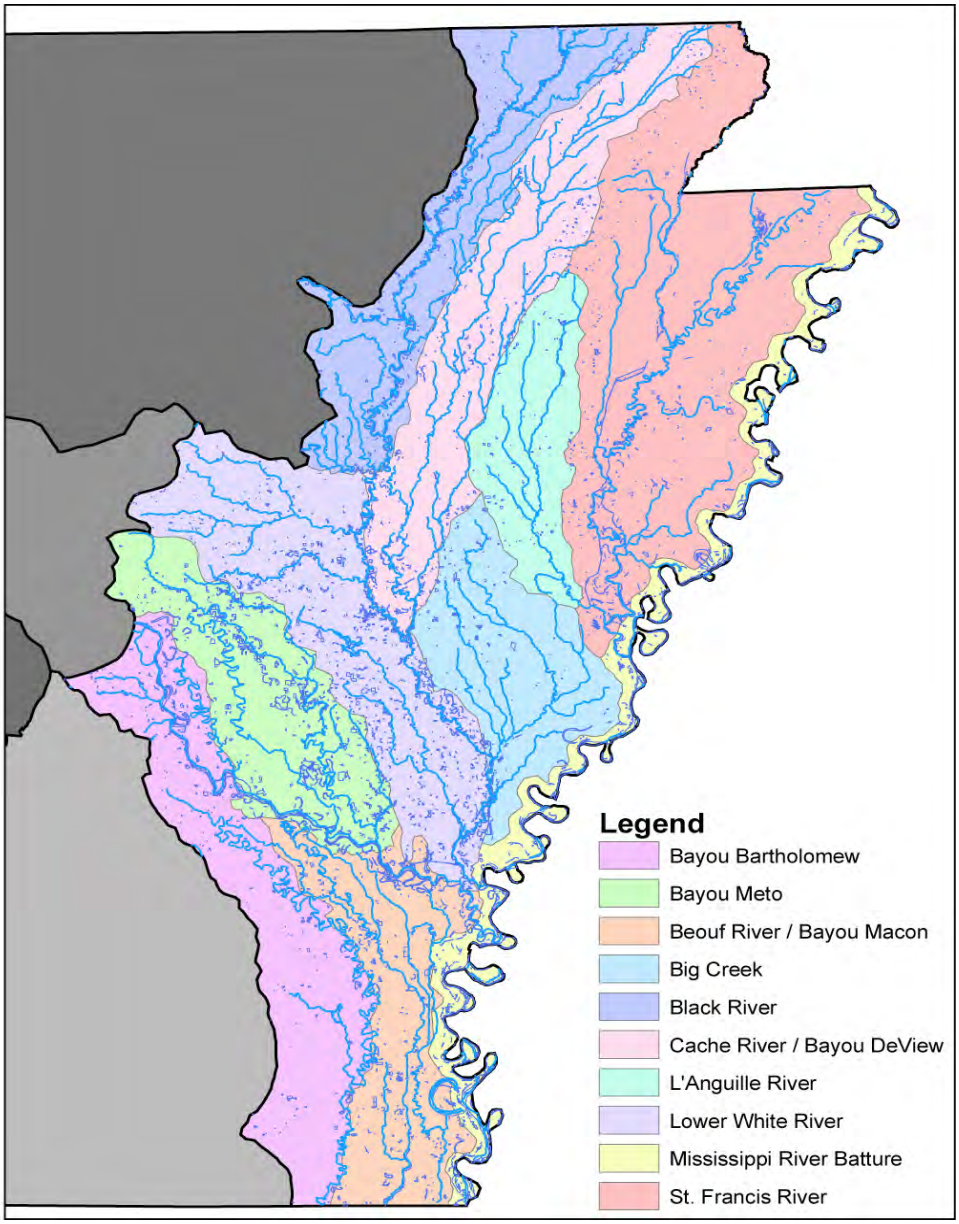


Figure 4. Wetland Planning Areas of the Delta Region of Arkansas.

Streams arising south and west of the Arkansas River occupy the Bayou Bartholomew and Boeuf River/Bayou Macon basins. These areas drain generally southward, eventually discharging to the Mississippi in Louisiana via the Ouachita and Red River systems.

The Bayou Meto basin drains most of the lowlands immediately north and east of the Arkansas River, as well as parts of the Grand Prairie. The principal internal streams are Bayou Meto and Bayou Two Prairie. It is the only major basin within the Delta that discharges directly to the Arkansas River.

Most of the Delta north of the Arkansas River drains to the Mississippi via the White River. The White River arises in the Ozarks and enters the Delta near Newport, then flows generally southward to join the Mississippi in the same vicinity as the confluence of the Arkansas River. The lower White River receives drainage from a variety of small streams on its western flank, including most of the drainage from the Grand Prairie. In addition, there are three other basins (or WPAs) within the Delta that discharge to the White River, and from there to the Mississippi: the Black River, which lies along the flank of the Ozarks and includes the White River above its confluence with the Little Red River; the Cache River/Bayou DeView basin, which lies between the Black River WPA and Crowley's Ridge; and Big Creek, which drains the area between the lower White River and the Mississippi.

The St. Francis River system in northeastern Arkansas arises in southeastern Missouri and empties into the Mississippi River north of Helena. Most of its internal tributaries have been straightened and deepened and incorporated into a massive drainage system. Near the point where the St. Francis discharges into the Mississippi River, it receives the flow of the L'Anguille River WPA, which is a much less altered basin draining the area on the eastern flank of Crowley's Ridge.

Groundwater also is a significant component of the hydrology of the Delta Region of Arkansas. The alluvial aquifer within the Mississippi Alluvial Valley 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 it is approximately 38 m thick. It is essentially continuous throughout the Mississippi Alluvial Valley. Where the topstratum is made up of coarse sediments or thinly veneered with fine sediments, the alluvial aquifer is recharged by surface waters. Discharge is primarily to stream channels, which contributes to stream baseflow during low-flow periods (Saucier 1994, Terry et al. 1979).

All of the major elements of the drainage system and hydrology of the Delta Region of Arkansas have been modified to varying degrees in historic times. At the time of European settlement, much of the Delta Region of Arkansas 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 floodbasins due to rainfall in headwater areas in most years. During major flood events,

large-scale backwater flooding influenced tributary systems, and complete inundation of much 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.

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 following discussion 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, 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 can be seen in the Reelfoot Lake area of western Tennessee, but some surface features in northeastern Arkansas also can be traced to tectonic activity, particularly the series of earthquakes that occurred in 1811–1812. Extensive “sand blows,” streambank caving, and stream channel realignments have been attributed to those events, as well as a probable deepening of the swamps in the Big Lake region of the St. Francis 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 the major part of the western valley wall in Arkansas is made up of older (Paleozoic) rocks, as is Crowley’s Ridge (Saucier 1994). Crowley’s Ridge, portions of the uplands forming the western valley wall, and many of the older (Pleistocene) fluvial surfaces within the Delta are blanketed with multiple

layers of wind-blown fine silts (loess) that originated in the glacial outwash carried down the Mississippi Valley during waning Pleistocene glacial cycles.

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 period, 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 drainage area of the river 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.

Two fundamentally different fluvial regimes have shaped the principal landscape features of the Arkansas Delta in approximately equal proportions. Most of the northern half of the delta is made up of landforms that resulted from multiple glacial outwash events during Wisconsin glacial cycles. These areas usually exhibit surface features characteristic of braided-stream depositional environments, such as relict braid bars and gathering channels, although those features may be obscured by later alluvial or wind-blown deposits. Land surfaces in the delta established at various other times during the Pleistocene and Holocene eras are composed primarily of meandering-river depositional features (Figure 5).

Remnants of pre-Wisconsin Arkansas and Mississippi River meander belts remain in the delta as high terraces, primarily along the southwestern valley wall and as the extensive terrace peninsula known as the Grand Prairie. There are also much later, lower elevation Wisconsin-age alluvial terraces along the southern margin of the Grand Prairie and adjacent to the Cache River. All of the alluvial terraces are characterized by features such as relict meandering channel segments, rather than the braided

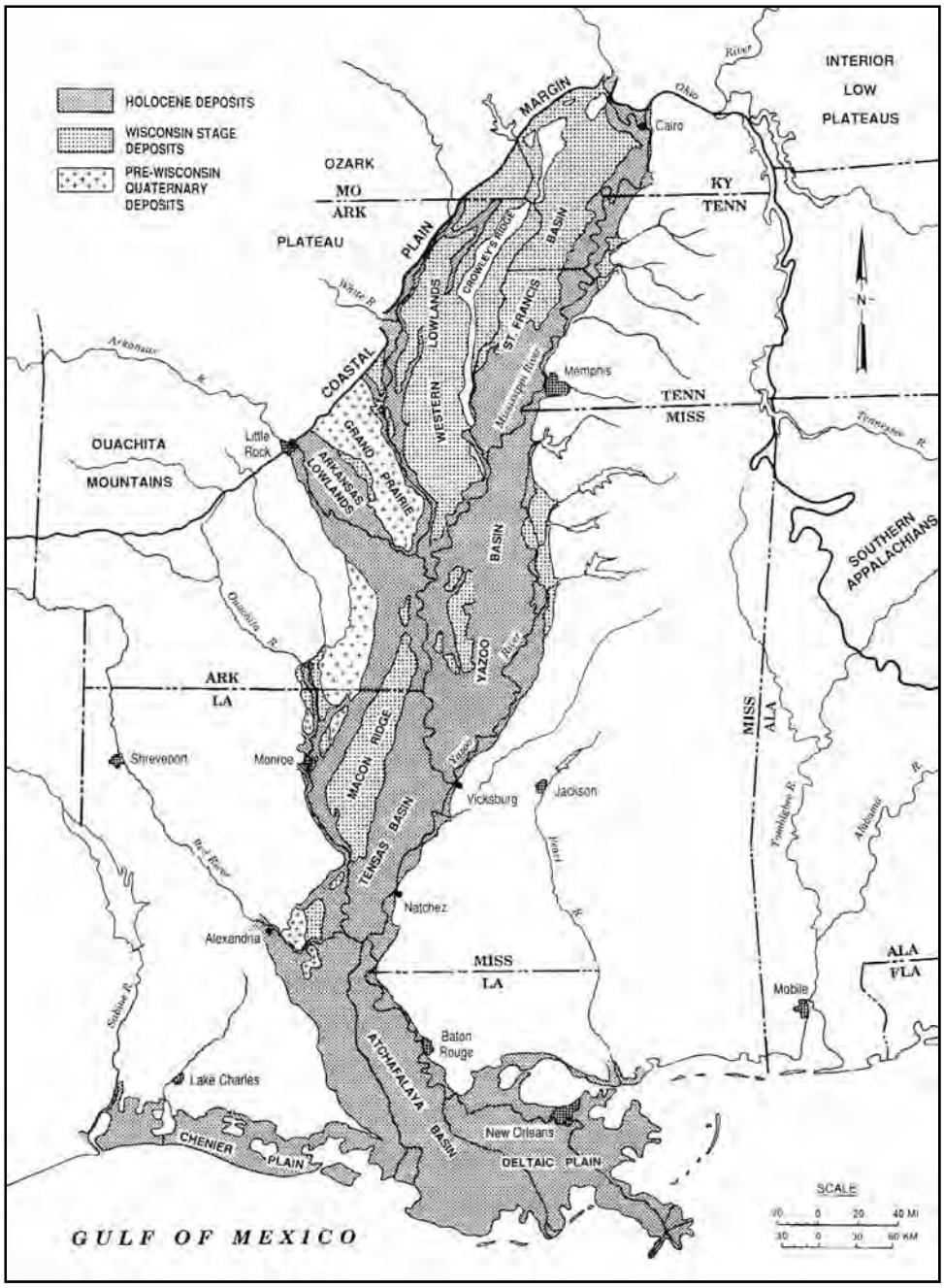


Figure 5. Distribution of the principal Quaternary deposits in the Lower Mississippi River Alluvial Valley (adapted from Saucier (1994)).

channels of the outwash or "valley train terraces," although the Wisconsin-age alluvial terraces tend to have larger meander features and thicker alluvial deposits because they formed during periods of much higher flows. A third major set of meandering-stream floodplain features was created after 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 the result primarily of meandering stream processes. 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 includes abandoned stream channels, abandoned stream courses, point bar deposits, and natural levees. The current meander belt extends into the Arkansas Delta about 5 to 30 km from the river channel, and it has been occupied and carrying the full flow of the Mississippi River for about 2000 years. Smaller remnants of several older meander belts also remain in the Arkansas Delta, primarily east of Crowley's Ridge. Segments of various smaller streams, such as the L'Anguille River and Big Creek, now occupy portions of the former Mississippi River channels (abandoned courses) that remain within the older meander belts.

Multiple meander belts of the Arkansas River and intervening backswamps dominate the landscape of the Arkansas Delta south of the Grand Prairie. The backswamps and abandoned Arkansas River courses between Grand Prairie and the modern river now carry streams such as Plum Bayou and Bayou Meto. At various times in the past, the Arkansas flowed more directly southward into Louisiana, and remnants of those meander belts are currently occupied by Bayou Bartholomew and several smaller streams.

Geomorphic features of the Delta Region of Arkansas

The combination of meandering-stream processes and glacial outwash events has resulted in distinctive landforms that have been mapped in considerable detail throughout the valley (Figure 6 and Appendix E). Within the Delta Region of Arkansas, these landforms are categorized as valley trains (comprising all outwash features), and a suite of features created by meandering streams (backswamps, point bars, abandoned channels, abandoned courses, and natural levees) that are distinctive within the Holocene meander belts, but muted on the older Pleistocene alluvial terrace surfaces (Figure 7) (Kolb et al. 1968; Saucier 1994). Each of these landforms is discussed in the following paragraphs.

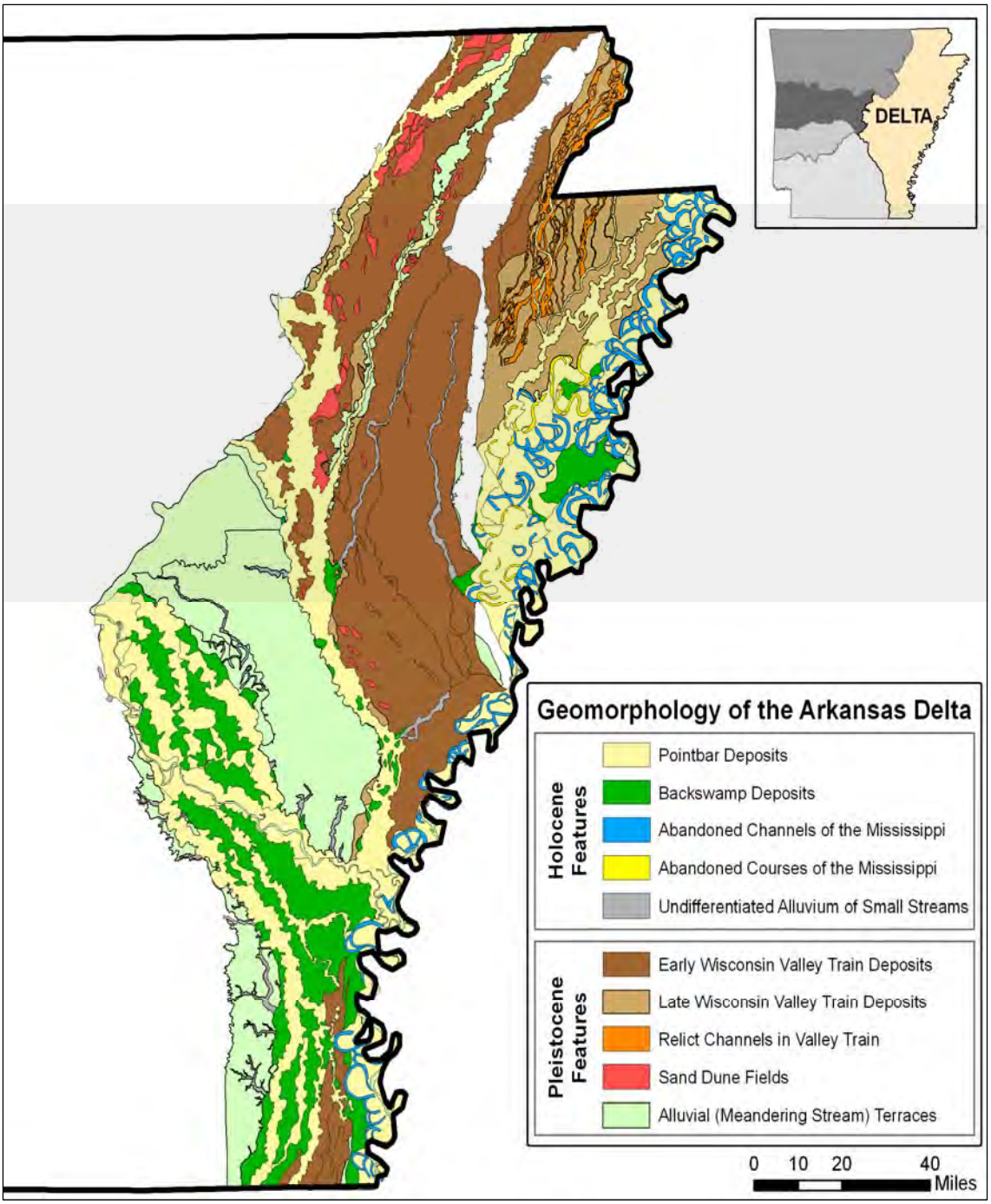


Figure 6. Distribution of the principal Quaternary deposits in the Delta Region of Arkansas (adapted from Saucier (1994)). The unlabeled inclusion is Tertiary upland (Crowley's Ridge).

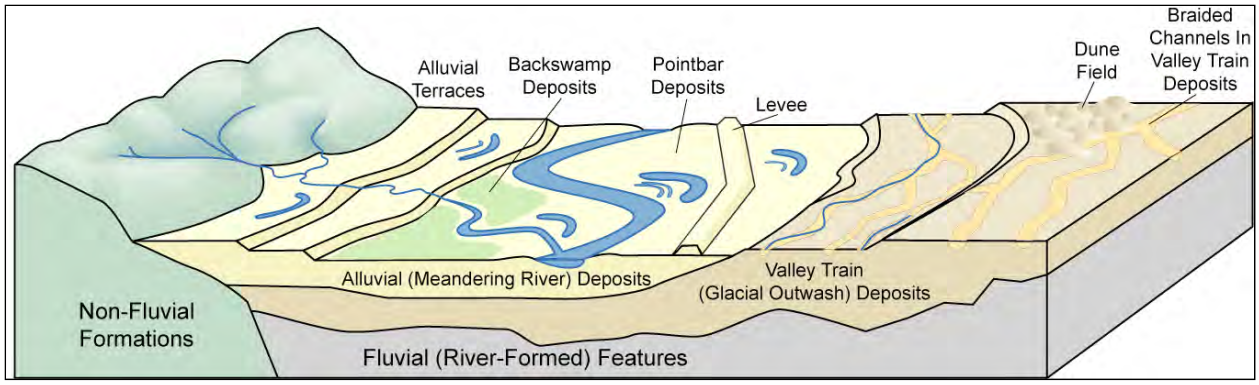


Figure 7. Principal geomorphic settings and features of the Delta Region of Arkansas.

Valley trains. Glacial outwash deposits have been episodically flushed into the Lower Mississippi Valley by the Mississippi and Ohio Rivers for more than a million years, and much of the valley fill underlying the Arkansas Delta is outwash. However, the outwash deposits that are present at the surface, generally termed *valley train* deposits, are the result of events during the various stages of Wisconsin glaciation, which spanned a period ranging from about 80,000 to 10,000 years ago. They dominate the Arkansas Delta north of the latitude of Memphis.

Valley trains consist of massive, coarse-grained deposits of relatively unsorted material deposited in a braided-stream environment. They are distinctive in that the ancient braided-stream channels are present and often recognizable at the surface. The topstratum of valley train deposits is a layer up to 3 m thick of predominantly fine-grained material that forms a continuous blanket across the relict braided channels and interfluves. 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. Other than this relatively fine-grained surface veneer, the braided channel systems on valley trains, both near-surface and at depth, tend to be filled with coarse sands deposited as flows waned in a particular channel segment. This distinguishes valley train channels from abandoned channel segments in the Holocene meander belts of the Mississippi and Arkansas Rivers, which are typically filled with clays.

There are several distinct valley train terraces in Arkansas, the oldest and highest Early Wisconsin deposits standing 10 m or more above the modern floodplain surface, while the youngest Late Wisconsin deposits are approximately contiguous with the adjacent Holocene meander belts. The remnant outwash channels are clearly visible on aerial photos on the youngest

surface, east of Crowley's Ridge, and have been mapped (Figure 8). On older valley train surfaces, outwash channels are obscured to varying degrees or have been captured by modern stream systems, but linear depressions and parallel drainage patterns remain as remnants of the Pleistocene surface channel systems.

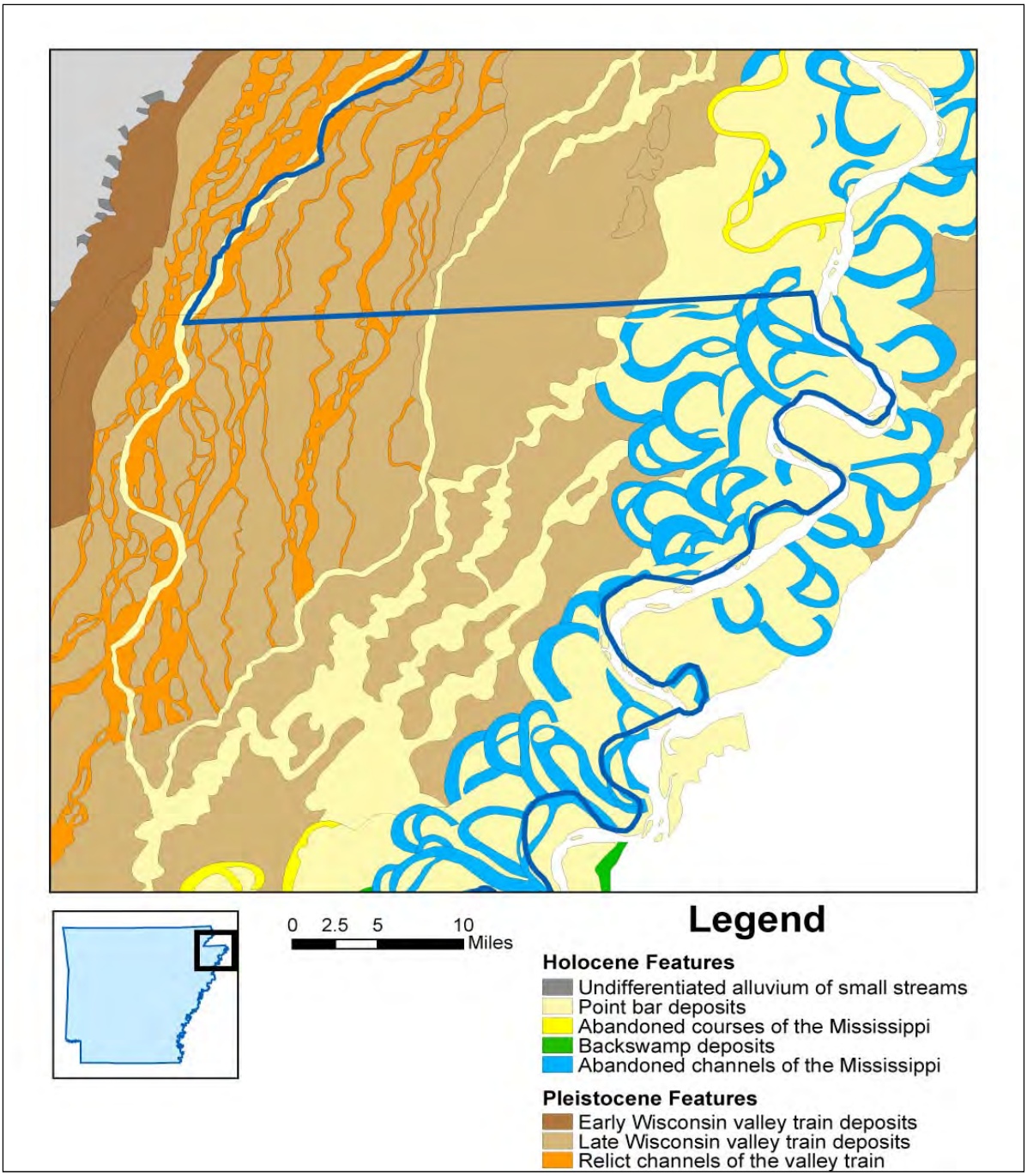


Figure 8. Geomorphic features of the Delta Region in Arkansas and parts of adjacent states, contrasting braided-stream Pleistocene outwash channels (left) and meandering-stream Holocene features (right) (adapted from Saucier (1994)).

Certain valley train surfaces are covered with extensive dunefields, made up of wind-blown sands deflated from Late Wisconsin outwash channels and deposited on the adjacent, older valley train terraces (Figures 6 and 7). These dunefields are unique to the Arkansas Delta Region of the Lower Mississippi Valley. Wind-blown silts (loess) from these and earlier outwash channels blanket much of the valley train surface in the Delta.

Backswamps. Backswamps are flat, poorly drained areas bounded by uplands and/or other features such as natural levees. In the Arkansas Delta, they are associated mostly with the multiple meander belts of the Mississippi River and especially the Arkansas River. 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 (backswamps) that collect runoff, pool floodwaters, and accumulate fine sediments. Backswamp environments in the Delta 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.

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.

Figures 7 and 9 illustrate typical locations of backswamps and other Holocene meander belt features relative to an active stream channel.

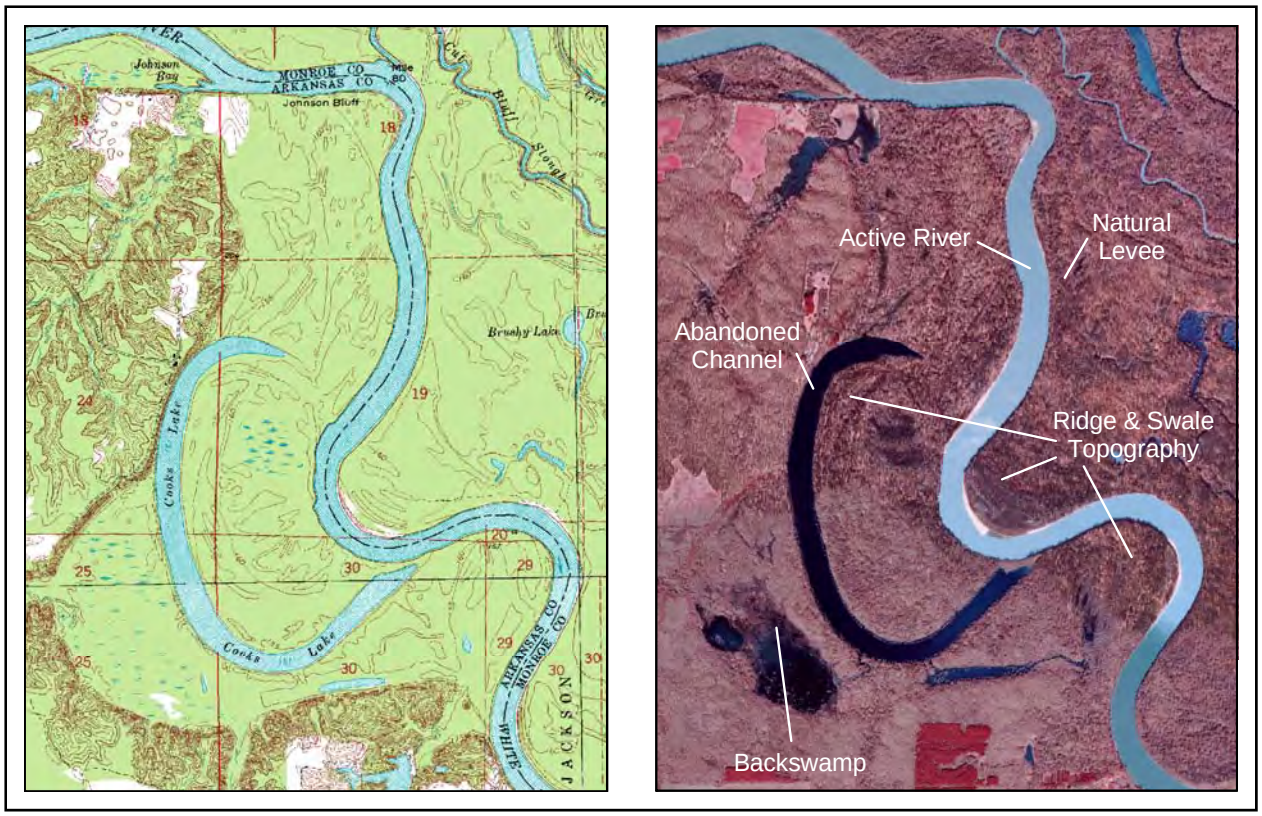


Figure 9. Topographic map and photomosaic showing typical geomorphic features of the Holocene meander belt of the lower White River. The higher terrain west of the river is part of the Grand Prairie Pleistocene alluvial terrace

Point bars. Point bar deposits predominate within the Holocene meander belts in the Arkansas Delta. They generally consist of relatively coarse-grained materials (silts and sands) laid down on the inside (convex) bend of a meandering 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 pattern of low arcuate ridges separated by swales ("ridge and swale" or "meander scroll" topography). 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.

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 usually 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 (Figures 7 and 9). 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.

Abandoned courses. An abandoned course is a stream channel segment left behind when a stream diverts flow to a new meander belt (Figure 8). 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. For example, within the Arkansas Delta, parts of the L'Anguille River and several smaller streams now flow within abandoned courses of the Mississippi River, and much of Bayou Macon and Bartholomew Bayou occupy abandoned courses of the Arkansas 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.

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 (Figure 7). 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 may be very extensive; have an irregular, hummocky surface; and are composed of very coarse sediments. They are the result of very high velocity flows, because the initial levee break releases water that has a surface elevation 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 Delta Region of Arkansas are fluvial sediments. The alternating periods of meander belt development and glacial outwash deposition produced complex but characteristic landforms where sediments were 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 Holocene 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 such as large swales and abandoned channels. Backswamp deposits between meander belts also are filled with heavy clays. Valley train deposits typically have a topstratum (upper 0.2–3 m) of fine-grained material (clays and silts) that blankets the underlying network of braided channels and interfluves. On older, higher valley train deposits, the topstratum contains considerable loess, and in some areas consists of sandy dunes. The lowest, most recent valley trains have surface soils that are derived primarily from Mississippi River flooding (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).

Within the Holocene meander belts, 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 acidic and deeper, show less depositional stratification and more horizonation, and otherwise exhibit characteristics of advanced soil development not seen in 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 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 Delta Region of Arkansas is presented in Table 4.

It should be noted that the classification of soils within the Lower Mississippi Valley has been undergoing considerable modification recently. However, the existing soil surveys do not reflect these changes; therefore, the classification and terminology used in this discussion remain consistent with the existing published resources. Detailed updated digital soils maps are provided in Appendix E. Individual soil series descriptions can be found on the Web at http://soils.usda.gov/technical/classification/scfile/index.html.

Table 4. Classification of the principal soil associations of the Delta Region of Arkansas.

Map Units	Principal Landscape Settings Within the Delta	Characteristics
Alfisols: Soils that are medium to high in bases and have gray to brown A horizons and B horizons of clay accumulation.		
DeWitt-Stuttgart	Pleistocene Alluvial Terraces (Prairie Complex).	Deep, somewhat poorly drained and moderately well drained, very slowly permeable, level to gently sloping, silty or clayey soils of the Grand Prairie.
Loring	Pleistocene Alluvial Terraces (Prairie Complex).	Deep, moderately well-drained, moderately slowly permeable, nearly level to moderately steep loamy soils of the Grand Prairie.
Foley-Jackport-Overcup	Valley Trains and Pleistocene Alluvial Terraces adjacent to the Cache River.	Deep, poorly drained and somewhat poorly drained, very slowly permeable, level to nearly level, loamy and clayey soils.
Calloway-Henry-Grenada-Calhoun	Pleistocene Valley Trains and Prairie Complex Terraces.	Deep, moderately well drained to poorly drained, slowly permeable, level to moderately sloping, loamy soils of older valley train deposits and prairie terraces
Dundee-Bosket-Dubbs	Pleistocene Valley Trains and dunefields.	Deep, somewhat poorly drained and well drained, moderately slowly permeable and moderately permeable, level to gently sloping, loamy soils.
Amagon-Dundee	Natural levees within Holocene meander belts of the White, Black, St. Francis, and other tributaries to the Mississippi River.	Deep, poorly drained and moderately poorly drained, slowly permeable and moderately slowly permeable, level to nearly level, loamy soils on bottom lands.
Rilla-Hebert	Natural levees within Holocene meander belts of the Arkansas River.	Deep, well-drained and somewhat poorly drained, moderately permeable and moderately slowly permeable, level to gently sloping soils on bottomlands.
Inceptisols: Soils that have weakly differentiated horizons; materials in the soil have been altered or removed but have not accumulated.		
Sharkey-Alligator-Tunica	Backswamp deposits within Holocene meander belts of the Mississippi River.	Deep, poorly drained, very slowly permeable, level to nearly level soils on bottomlands.
Sharkey-Steele	Point bar and backswamp deposits within Holocene mender belts of the St. Francis River.	Deep, poorly drained and moderately well drained, very slowly permeable, level to nearly level, clayey and sandy soils on broad flats and undulating areas of floodplains.
Kobel	Backswamp deposits within Holocene meander belts of the White, Black, St. Francis, and other tributaries to the Mississippi River.	Deep, poorly drained, very slowly permeable, level to nearly level, clayey soils on bottomlands.
Perry-Portland	Backswamp deposits within Holocene meander belts of the Arkansas River.	Deep, poorly drained and somewhat poorly drained, very slowly permeable, level to nearly level soils on bottomlands.
Roxanna-Dardanelle-Bruno-Roellen	Various environments of deposition within the modern meander belt of the Arkansas River.	Deep, excessively drained to poorly drained, rapidly permeable to slowly permeable, level to nearly level, loamy, sandy, and clayey soils.
Entisols: Soils that have little or no evidence of development of pedogenic horizons.		
Crevasse-Bruno-Oklared	Various environments of deposition within the modern meander belt of the Arkansas River.	Deep, excessively drained and well-drained, rapidly permeable and moderately rapidly permeable, sandy and loamy soils.
Commerce- Sharkey-Crevasse-Robinsonville	Various environments of deposition within the modern meander belt of the Mississippi River.	Deep, poorly drained to excessively drained, very slowly permeable to rapidly permeable, level to gently undulating, clayey, loamy, and sandy soils.
Note: Based on Saucier 1994; U.S. Department of Agriculture National Resources Conservation Service, Soil Survey Division (2002); U.S. Department of Agriculture Soil Conservation Service and Mississippi Agricultural and Forestry Experiment Station (1974); U.S. Department of Agriculture Soil Conservation Service and University of Arkansas Agricultural Experiment Station (1982).		

Vegetation

The Delta Region of Arkansas is in the west-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 by Braun (1950), and is classified as the Southern Floodplain Forest Type by Kuchler (1969). Forests of the basin are referred to as bottomland hardwoods, a term that incorporates a wide range of species and community types that 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 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 (Klimas 1988, Putnam 1951, Wharton et al. 1982). 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., 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 relative to flood frequency occurs in some major stream drainages within the Mississippi Alluvial Valley, such as the Cache River in Arkansas (Smith 1996). However, zonal concepts have limited utility in much of the Arkansas Delta where Pleistocene landforms and multiple abandoned Holocene meander belts dominate the landscape. In addition, 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 Delta Region of Arkansas. 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. However, stream flooding is just one of many important sources of water in the wetlands of the Arkansas Delta, 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 misleading nature of zonal models of plant community distribution, plant communities do occur on recognizable combinations of site hydrology and geomorphology within the Delta Region of Arkansas. The synthesis documents of Putnam (1951) and Putnam et al. (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 5 is based on that approach. Table 6 equates Putnam's (1951) community types with corresponding community designations in the most commonly referenced forest classification system, the Society of American Forester (SAF) cover types (Eyre 1980).

Under natural conditions, forest stands within the Delta Region of Arkansas 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 pioneer species such as black willow (*Salix nigra*), which are 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 and hickories (Meadows and Nowacki 1996; Putnam et al. 1960). Although this sequential replacement does occur, it is actually a complex process that includes changes in the elevation and composition of

Table 5. Composition and site affinities of common forest communities in the Delta Region of Arkansas (after Putnam (1951)).

Forest Cover Type	Characteristic Species	Site Characteristics
Sweetgum - Water Oaks	*Liquidambar styraciflua* *Quercus nigra* *Quercus nuttallii* *Quercus phellos* *Ulmus americana* *Celtis laevigata* *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* *Quercus similis* *Quercus pagoda* *Quercus shumardii* *Quercus falcata* var. *falcata* *Fraxinus americana* *Carya* spp. *Nyssa sylvatica* *Ulmus alata*	Fine, sandy loam and other well-drained soils on first bottom and terrace ridges.
Hackberry - Elm - Ash	*Celtis laevigata* *Ulmus americana* *Fraxinus pennsylvanica* *Carya aquatica* *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* *Carya aquatica*	Poorly drained flats, low ridges, sloughs, and backwater basins with tight soils.
Cottonwood	*Populus deltoides* *Carya illinoensis* *Platanus occidentalis* *Celtis laevigata*	Front land ridges and well-drained flats.
Willow	*Salix nigra*	Front land sloughs and low flats.
Riverfront Hardwoods	*Platanus occidentalis* *Carya illinoensis* *Fraxinus pennsylvanica* *Ulmus americana* *Celtis laevigata* *Acer saccharinum*	All front lands except deep sloughs and swamps.
Cypress - Tupelo	*Taxodium distichum* *Nyssa aquatica* *Nyssa sylvatica* var. *biflora*	Low, poorly drained flats, deep sloughs, and swamps in first bottoms and terraces.

Table 6. Correspondence between forest cover types in the Delta Region of Arkansas (Putnam 1951) and Standard Society of American Foresters Forest Cover Types.

SAF Forest Cover Types	Type No.	Putnam's Cover Type
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

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 new sediments. In the Arkansas Delta, creation and colonization of new point bars are limited because many streams have been channelized or their banks have been stabilized, both of which reduce channel migration and recruitment of sediments.

The typical natural regeneration process in established forest stands is initiated by single tree-falls, periodic catastrophic damage from fire or windstorm, and inundation mortality due to prolonged growing-season floods or beaver dams. Small forest openings occur due to windthrow, disease, lightning strikes, and similar influences that kill individual trees or small groups of trees (Dickson 1991). 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 et al. 1960).

In 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, which 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 the bottomland forest ecosystem included extensive areas that were affected by beaver and were dominated by dead timber, open water, marsh, moist soil herbaceous communities, or shrub swamp at any given time.

Alterations to environmental conditions

The physical and biological environment of the Delta Region of Arkansas has been extensively altered by human activity. Isolation and stabilization of the Mississippi and Arkansas Rivers have effectively halted the large-scale channel migration and overbank sediment deposition processes that created and continually modified the Holocene landscapes of the Arkansas Delta (Smith and Winkley 1996). At the same time, sediment input to depressions and sub-basins within the area has increased many-fold in historic times due to erosion of uplands and agricultural fields (Barnhardt 1988, Saucier 1994, Smith and Patrick 1991). The Mississippi River no longer overwhelms the landscape with floods that course through the basin, but it continues to influence large areas through backwater flooding. 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 the more influential changes that have taken place.

Land use and management

Natural levees, which commonly are the highest elevations in the landscape of the Delta Region 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 the first European explorations of the Arkansas Delta in the 16th century, natural levees of the Mississippi and Arkansas Rivers were extensively used for maize agriculture by Native Americans (Hudson 1997). By the time detailed surveys of the Mississippi River were first made in the 1880s, European settlers were farming nearly all of the natural levees adjacent to the river through the Delta (Mississippi River Commission 1881–1897). Lower terrain had not been similarly developed (Barry 1997).

In the last two decades of the 19th century, local flood control and drainage efforts began to have widespread effects in the Delta, and railroads were constructed in formerly remote areas. These changes allowed logging and agricultural development to proceed on a massive scale throughout the Lower Mississippi Valley. In the period between 1880 and 1920, nearly all virgin forests in the Arkansas Delta were cut over (Smith et al. 1984). As the 20th century progressed, improvements to farming equipment and crops and the initiation of coordinated Federal flood control efforts allowed further conversion of forested land to agriculture. From an estimated original area of 9 to 10 million hectares, Mississippi Alluvial Valley forests had been reduced by about 50 percent by 1937, and currently less than 25 percent of the original area remains forested (Smith et al. 1993). In the Arkansas Delta, the losses are more dramatic – only about 15 percent of approximately 3.2 million original wetland hectares remains. 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, such as the White and Cache River lowlands (Creasman et al. 1992, Rudis 1995). Nearly all of the remaining forests within the basin have been harvested at least once, and many have been cut repeatedly and are in degraded condition due to past high-grading practices (Putnam 1951; Rudis and Birdsey 1986).

The near-total loss of certain wetland types, the extreme reductions and fragmentation of others, and the degradation of forest structure and composition in the remaining forests have had wide-reaching and little-understood effects on various ecosystem characteristics in the region. For example, the differential conversion of higher, drier riverfront sites to agriculture may be a major contributing factor in the near disappearance of the extensive stands of cane, which many early travelers remarked upon as common features of the natural levees (Remsen 1986, Dickson 1991). In turn, the loss of the canebrakes may have contributed to the extinction of Bachman's warbler (*Vermivora bachmanii*), which likely was dependent on cane thickets for some parts of its life cycle. Other wildlife species, such as the now-extinct ivory-billed woodpecker (*Campephilus principalis*), apparently required old-growth forest (Remsen 1986, Tanner and Hamel 2001), and mammals with large home ranges such as cougars (*Felis concolor*) and black bears (*Ursus americanus*) were no doubt adversely affected by forest fragmentation and isolation.

Of the remaining wetland acreage in the Delta, most of the largest tracts are in public hands or under easements that give public agencies some degree of control over management decisions. Federal lands include some wetlands in the National Forest System and wetlands owned or managed under easement by the Natural Resources Conservation Service. However, the largest units are in the National Wildlife Refuge system administered by the U.S. Fish and Wildlife Service. The largest of these refuges is the 64,000-ha White River National Wildlife Refuge. State-controlled lands include those in the state park system, and more than 70,000 ha in Wildlife Management Areas located throughout the Delta, which are operated by the Arkansas Game and Fish Commission (Demas and Demcheck 1996). Some of the most intact and unique wetlands in the region are under the protection of the Arkansas Natural Heritage Commission, a division of the Department of Arkansas Heritage, which owns or has easements on more than a dozen forested wetland sites in the Delta (Arkansas Natural Heritage Commission 1997). Various private landowners, including commercial timberland operations, and non-government organizations such as The Nature Conservancy, Ducks Unlimited, and the Audubon Society, also own, manage, or otherwise work to protect forested wetlands in the Delta.

Many of these public and private organizations have been particularly involved in wetland restoration in recent years. Schoenholtz et al. (2001) reported that between 1968 and 1998 nearly 16,000 ha of forested wetlands were planted in the Arkansas Delta in the State Wildlife Management Areas and by the U.S. Fish and Wildlife Service and the Natural Resources Conservation Service. A particularly effective effort, the Wetlands Reserve Program conducted by the Natural Resources Conservation Service, has been responsible for restoration of approximately 36,000 ha of Delta wetlands between 1994 and early 2002.[1]

In addition to restoring some of the lost wetland acreage in the Delta, various public and private entities concerned with Delta wetlands also are addressing the problems related to differential losses of certain wetland types, lack of old growth forest, and fragmentation of the remaining forests in the region. Initiatives that recognize the importance of landscape-scale management of remaining large tracts include the Cache-Lower White Rivers Joint Venture developed under the North American Waterfowl Management Plan, which is intended to protect the largest

[1] Personal Communication, January 2002, Jody Pagan, NRCS Arkansas WRP Coordinator.

contiguous block of forested wetland in the Lower Mississippi Valley outside the Atchafalaya Basin. This area also is recognized as a wetland of international significance under the Ramsar Convention of 1971 (Demas and Demcheck 1996). Similarly, the Arkansas Natural Heritage Commission and The Nature Conservancy have developed a White River-Lower Arkansas River Megasite Plan, which addresses the potential to coordinate restoration and management activities over an ecosystem encompassing nearly half a million hectares, about half of which is in public ownership (Lynch et al. 1992). On a broader scale, six Arkansas State agencies are members of the Arkansas Multi-Agency Wetland Planning Team (MAWPT), which has an overall goal "to preserve, conserve, enhance, and restore the acreage, quality, biological diversity and ecosystem sustainability of Arkansas' wetlands for citizens present and future." With the assistance of funding provided by the USEPA, this goal has been pursued through a variety of initiatives, including efforts to characterize the composition, function, and landscape patterns of wetlands in Arkansas (e.g., this guidebook), to provide public information and education, and to improve governmental participation in wetland-related decision-making. A major product of this effort is a set of Wetland Planning Area reports emphasizing wetland preservation and restoration potential on a watershed scale (Arkansas Multi-Agency Wetland Planning Team 1997).

Hydrology

The hydrology of the Delta Region of Arkansas has been modified extensively and purposefully. Unconnected wetlands associated with the higher alluvial terraces (such as Grand Prairie) and with the valley train terraces were not subject to major river flooding in historic times, and they could be readily drained with simple ditch systems, or used as sumps to collect drainage. The lowlands were far more difficult to convert to agricultural uses. By the mid-19th century, many individual plantations along the Mississippi River were protected with low levee systems, often built with slave labor, that were sufficient to exclude most floods, but not the periodic catastrophic event (Barham 1964; Barry 1997). Additional drainage and levee-building were accomplished under the provisions of the Federal Swamp Lands Act passed in 1849 and 1850 (Holder 1970), but the first truly extensive and effective efforts were undertaken in the late 19th century and into the first few decades of the 20th century, when numerous local levee and drainage districts were created and funded by land taxes and the sale of bonds, with the St. Francis Basin the focus of the most concerted activity

(Barham 1964; Moore 1972; Sartain, undated). In Mississippi County alone, the local interests constructed more than 1,600 km of ditches, and effectively drained and cleared nearly the entire county. However, even with this level of effort, the St. Francis Basin included some areas that defied drainage efforts, and today several large blocks of forested wetlands remain, mostly under the control of the Arkansas Game and Fish Commission.

The Arkansas River lowlands, which encompass most of the Delta south of the Grand Prairie, also were ditched and drained by local interests. Those drainage districts embarked on some ambitious projects, such as the construction of an extensive levee system and floodgate to protect the Bayou Meto Basin from floods originating on the Arkansas River (Holder 1970). That levee was later incorporated into the Federal levee system constructed along the lower Arkansas River.

Of the major lowland basins in the Arkansas Delta, only the Lower White River area escaped wholesale reclamation efforts by the early 20th century local drainage districts. Effective drainage was simply impossible in the face of the combined influence of regular flooding on streams within the basin, such as Bayou DeView and the Cache, Black, and White Rivers, and periodic backwater flooding due to high water on the Mississippi. Not until the 1970s did effective drainage and levee construction start to bring about large-scale changes in land use, but by then environmental concerns had begun to influence public policy in the region and wholesale agricultural conversion was averted (Foti 1993). As a result, the lower basin continues to support the extensive forested wetlands of the Cache and White River National Wildlife Refuges, described previously.

Despite the successes of the early drainage districts, their efforts could not overcome the effects of the Mississippi and Arkansas Rivers in flood stage; and periodic widespread destruction occurred with major flood events (Barry 1997). These have been addressed primarily through a massive Federal effort conducted by the U.S. Army Corps of Engineers: the Mississippi River and Tributaries Project (MR&T), which is the largest flood-control project in the world (U.S. Army Engineer Division, Mississippi Valley 1998). In order to understand the extent to which hydrology has been modified in the Delta Region of Arkansas and the way the remaining wetlands receive and move water, it is essential to understand the development and current status of the MR&T.

Corps of Engineers activities in the Lower Mississippi Valley through most of the 1800s focused principally on survey and engineering efforts relating to navigation improvement (Barry 1997). Surveys began on the Arkansas River in 1833, and by the end of the 1880s all major streams in the Arkansas Delta had been surveyed. During this same period, an extensive program of snagging was pursued on the Arkansas River, as well as clearing of forests or individual trees (potential future snags) along the banks and some dredging. Less extensive efforts were also pursued on some other Delta streams, notably the White River. But all of these efforts were piecemeal, and not all streams in the region or the Lower Mississippi Valley received the same level of attention (Clay 1986, Rathburn 1990).

In 1879, Congress authorized the creation of the Mississippi River Commission to oversee a coordinated Federal effort, to be carried out by the Corps of Engineers, to provide reliable navigation throughout the entire Mississippi River system (Moore 1972). Over the next five decades, the authority of the Commission was expanded, and its jurisdiction gradually enveloped various tributary stream systems. But in the early 20th century, flood control remained largely a local responsibility, and by 1927, the existing levees 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 (Barry 1997).

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 modifications, bank protection works, and other features. The multiple elements of this plan and its subsequent modifications are collectively referred to as the 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, 1960s, and 1970s the project was expanded to include numerous tributary modifications, 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 were 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 reevaluated 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 (Bolton and Metzger 1998).

The cornerstone of the Federal flood-control effort in the Lower Mississippi Valley is the mainstem levee system, which is essentially continuous on the western side of the Mississippi River from Cape Girardeau, MO, to Venice, LA, about 16 km above the mouth of the river, except where tributaries enter. On the eastern bank it is discontinuous, because bluffs near the river make the levee unnecessary in some reaches. The levee system on the south bank of the Arkansas River extends about 140 km from Pine Bluff to the mainstem Mississippi River levee, and on the north bank it extends from North Little Rock approximately 90 km to a point south of Gillett. Another large Federal ring levee protects the White River Backwater Area between Helena and the mouth of the White River, and about 80 km of levees protect towns along the lower White River itself. Federal efforts in the St. Francis Basin continued the work of the local drainage districts and included several hundred kilometers of levees, plus floodways, ditches, and channel modifications. Much of the St. Francis Basin as well as the White River Backwater Area are intended to be used as water storage basins during major Mississippi River floods, and both have been fitted with pumping stations to evacuate waters trapped within the levee systems. Additional flood-control projects remain authorized under the MR&T project, including a channel modification and pump construction project currently in the planning process for the Bayou Meto Basin. Some other

elements of the MR&T have been set aside due to disinterest on the part of local sponsors or public opposition. One major change was deauthorization of a series of extensive channel modifications planned for the lower Cache River, which instead became part of the National Wildlife Refuge System (Clay 1986, Mississippi River Commission 1970, Moore 1972, Williams 1986).

River engineering influences on the Arkansas Delta involve numerous other projects, including huge reservoir systems in the Ozarks and Ouachitas, channel modifications to streams of all sizes, and local levee systems. All of these clearly have significantly influenced wetland hydrology. Often, however, river engineering causes changes to wetlands that are less apparent. Navigation works may affect the hydrology of wetlands by changing the surface elevation of river reaches behind lock and dam structures and by altering the geometry of the river channel where dredging occurs, or where channel constriction structures are employed to scour a narrow, deep channel. More fundamental changes are effected by bank stabilization projects that prevent channel meandering, which is the mechanism by which new wetlands are created within active stream meander belts (Klimas 1991).

In addition to major engineering projects, the water that enters the modern Arkansas Delta 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 drainage and supplemental irrigation common agricultural practices (Brown et al. 1971). Drainage accomplished by ditching may dry up some wetlands, but cause others to receive excessive amounts of water when they are used as sumps to which adjacent fields drain. Drainage achieved by land leveling removes the subtle microtopography that sustains many wetlands by storing precipitation, and the accelerated runoff may adversely affect downslope or downstream systems. A variety of Delta wetlands may have some dependence on groundwater, but groundwater withdrawals for irrigation and other agricultural purposes have caused depletion of the aquifer in many areas. The alluvial aquifer of the Lower Mississippi Valley is one of the largest and most heavily used freshwater sources in the United States (Saucier 1994). Overuse can cause changes in water availability and water quality (Terry et al. 1979), and may adversely affect wetlands where they are maintained by discharge from unconfined aquifers. Currently, the groundwater supply in much of the Arkansas Delta

is being depleted faster than it is replenished. More than half of the Delta has been designated or proposed for designation as a "critical groundwater area," and the remainder of the region remains under study to determine if the "critical" designation is applicable (Arkansas Soil and Water Conservation Commission 2001).

Definition and identification of the HGM classes and subclasses

Brinson (1993a) identified five wetland classes based on hydrogeomorphic criteria, as described in Chapter 2. Pilot studies conducted in 1997 and 1998 indicated that wetlands representing four of these classes (Flat, Riverine, Depression, and Fringe wetlands) and a variety of subclasses occur within the Delta Region of Arkansas. However, categorical separation of these classes is sometimes difficult because of the complexity of the landscape and hydrology within the basin and because features of wetlands intergrade and overlap among types. Therefore, a set of specific criteria has been established to assist the user in assigning any particular wetland in the Arkansas Delta to the appropriate class, subclass, and community type. These criteria are presented in the form of dichotomous keys in Figures 10 and 11. In addition, each wetland type identified in the keys is described in the following section, which also includes a series of block diagrams illustrating the major wetland types and their relationships to various landforms and man-made structures. These relationships also are summarized in Table 7.

Some of the criteria that are used in the keys in Figures 10 and 11 require some elaboration. For example, a fundamental criterion is that a wetland must be in the 5-year floodplain of a stream system to be included within the Riverine Class. This return interval is regarded as sufficient to support major functions that involve periodic connection to stream systems. It was also selected as a practical consideration, because the hydrologic models used to develop flood return interval maps generally include the 5-year return interval.

The classification system recognizes that certain sites functioning primarily as fringe or depression wetlands also are regularly 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.

Key to Wetland Classes in the Delta Region of Arkansas

1. Wetland is not within the 5-year floodplain of a stream **2**

1. Wetland is within the 5-year floodplain of a stream..... **3**

    2. Topography generally flat, principal water source is precipitation ..... **Flat**

    2. Topography is depressional, or within the 5-year floodplain of a stream **3**

3. Wetland is not in a topographic depression or impounded..... **Riverine**
3. Wetland is in a topographic depression, or impounded **4**

    4. Wetland is associated with a beaver impoundment, or with a shallow impoundment managed principally for wildlife (e.g., greentree reservoirs or moist soil units)..... **Riverine**

    4. Wetland is in an impoundment or depression other than above **5**

5. Wetland is associated with a water body that has permanent water more than 2 m deep in most years ..... **Fringe**

5. Wetland is associated with a water body that is ephemeral, or less than 2 m deep in most years ..... **Depression**

Figure 10. Key to the wetland classes in the Delta Region of Arkansas.

The classification system addresses a major confounding aspect of overlap among wetland types that arises from the characteristic topographic variation within certain wetland types. Sites that function primarily as riverine wetlands and flats often incorporate small, shallow depressions, sometimes characterized as vernal pools and microdepressions. These features are regarded as normal components of the riverine and flat ecosystems, and are not separated into the Depression Class unless they meet specific criteria. Other significant criteria relating to classification are elaborated in the wetland descriptions in the following paragraphs.

Key to Wetland Subclasses and Community Types in the Delta Region of Arkansas		
CLASS: FLAT	Subclass	Community Type
1. Soil reaction acid	Non-Alkali Flat (2)	
1. Soil reaction circum-neutral to alkaline (lake bed deposits)		
2. Vegetation dominated by graminoids		*wet tallgrass prairie*
2. Vegetation dominated by woody species		
2a. Vegetation dominated by pine		*pine flat*
2b. Vegetation dominated by post oak		*post oak flat*
2c. Vegetation dominated by hardwoods other than post oak		*hardwood flat*
3. Vegetation dominated by graminoids		*alkali wet prairie*
3. Vegetation dominated by post oak		*alkali post oak flat*
CLASS: RIVERINE	Subclass	Community Type
1. Wetland associated with low-gradient stream (Stream Orders > 6, or other alluvial streams)	3	
1. Wetland associated with mid-gradient stream (Stream Orders 4–6)	Mid-gradient Riverine (2)	
2. Water source primarily overbank flooding or lateral saturation		*mid-gradient floodplain*
2. Water source primarily backwater flooding, wetland typically located at confluence of two streams		*mid-gradient backwater*
3. Wetland not an impoundment	Low-gradient Riverine (5)	
3. Wetland an impoundment	Riverine Impounded (4)	
4. Wetland impounded by beaver		*beaver complex*
4. Wetland impounded for wildlife management (greentree reservoirs and moist soil units)		*managed wildlife impoundments*
5. Water source primarily overbank flooding (5-year zone) that falls with stream water levels, or lateral saturation from channel flow		*low-gradient overbank*
5. Water source primarily backwater flooding or overbank flows (5-year zone) that remain in the wetland due to impeded drainage after stream water levels fall		*low-gradient backwater*

Figure 11. Key to the wetland subclasses and community types in the Delta Region of Arkansas (Sheet 1 of 2).

CLASS: DEPRESSION	Subclass	Community Type
1. Depression not subject to direct stream flooding during a 5-year event; precipitation, runoff, and groundwater are the dominant inflows.....2		
1. Depression has significant direct stream inflows and outflows relative to stored volume and/or is influenced by overbank or backwater flooding during a 5-year event 4		
2. Depression discharges water to surface channels, but has no significant surface inflows relative to discharge	Headwater Depression	*headwater swamp*
2. Depression has no significant direct surface outlet to a stream channel, or outflows are minor relative to stored volume	Unconnected Depression (3)	
3a. Precipitation-dominated depression in dunefields.....		*sandpond*
3b. Depressional feature in abandoned meander features (oxbows or swales) not subject to 5-year flood flows		*unconnected alluvial depression*
3c. Depressional feature in relict glacial outwash channel		*valley train pond*
4. Significant, perennial streamflow enters and leaves depression.....	Not Depression Class: see Riverine Class	
4. Depression not subject to perennial flow, but receives overbank or backwater flooding during 5-year events	Connected Depression	*floodplain depression*
CLASS: FRINGE	**Subclass**	**Community Type**
1. Wetland on the margin of a man-made reservoir	Reservoir Fringe	*reservoir shore*
1. Wetland on the margin of water body other than a reservoir.....2		
2. Water body subject to stream flooding during 5-year flood events	Connected Lacustrine Fringe	*connected lake margin*
2. Water body not subject to flooding during a 5-year event.....	Unconnected Lacustrine Fringe	*unconnected lake margin*

Figure 11. (Sheet 2 of 2).

The following sections briefly describe the classification system developed for this guidebook for wetlands in the Delta Region of Arkansas. The system includes the four principal wetland classes that occur in the Delta, each of which comprises a number of subclasses and community types. All of the Delta wetland types are described, but assessment models and supporting reference data were developed for only a subset of these types, as described in Chapter 4. Additional details, including photos and distribution maps, for each of the wetlands described, as well as wetlands in the other regions of the state, can be found on the Arkansas Multi-Agency Wetland Planning Team Web site (http://www.mawpt.org/).

Table 7. Hydrogeomorphic Classification of Forested Wetlands in the Delta Region of Arkansas and Typical Geomorphic Settings of Community Types.

Wetland Classes, Subclasses, and Communities	Typical Geomorphic Setting
CLASS: FLAT	
SUBCLASS: ALKALI FLAT	
Alkali Post Oak Flat	Lacustrine sediments deposited in lake systems impounded by glacial outwash.
SUBCLASS: NON-ALKALI FLAT	
Hardwood Flat	Backswamp and point bar environments on Pleistocene and Holocene meander-belt topography, and on interfluves on valley trains.
Post Oak Flat	Pleistocene terraces.
CLASS: RIVERINE	
SUBCLASS: MID-GRADIENT RIVERINE	
Mid-Gradient Floodplain	Point bar and natural levee deposits within active meander belts of streams transitioning from uplands to alluvial plain, or dissecting terrace deposits.
Mid-Gradient Backwater	Backswamp and point bar deposits within active meander belts of mid-gradient streams near point of confluence with major alluvial river.
SUBCLASS: LOW-GRADIENT RIVERINE	
Low-Gradient Overbank	Point bar and natural levee deposits within active meander belts of alluvial streams.
Low-Gradient Backwater	Backswamp, point bar, and low-lying valley train deposits within and between both active and inactive meander belts of alluvial streams.
SUBCLASS: IMPOUNDED RIVERINE	
Beaver Complex	All flowing waters.
Wildlife Management Impoundment	Various settings.
CLASS: DEPRESSION	
SUBCLASS: HEADWATER DEPRESSION	
Headwater Swamp	In relict outwash channel, adjacent to scarp of a higher valley train terrace.
SUBCLASS: UNCONNECTED DEPRESSION	
Sand Pond	Eolian sand deposits (dunefields) on valley trains.
Valley Train Pond	Depressions atop buried braided outwash channels on valley trains.
Unconnected Alluvial Depression	Abandoned channels and large swales in former and current meander belts of larger rivers (including both Holocene and Pleistocene meander belt deposits).
SUBCLASS: CONNECTED DEPRESSION	
Floodplain Depression	Abandoned channels and large swales in former and current meander belts of larger rivers.
CLASS: FRINGE	
SUBCLASS: UNCONNECTED LACUSTRINE FRINGE	
Unconnected Lake Margin	Abandoned channels in meander belts and adjacent to man-made impoundments.
SUBCLASS: CONNECTED LACUSTRINE FRINGE	
Connected Lake Margin	Abandoned channels in meander belts and adjacent to man-made impoundments.

Class: Flat

Flats have little or no gradient, and the principal water source is precipitation. There is minimal overland flow into or out of the wetland except as saturated flow. Wetlands on flat areas that are subject to stream flooding during a 5-year event are classified as Riverine. Small ponded areas within flats are considered to be normal components of the Flat Class if they do not meet the criteria for the Depression Class. Sites are considered to be Slope wetlands rather than Flats if they have sufficient gradient to cause runoff in a single direction (however, slope wetlands are rare in the Delta), and as Slope or Depression wetlands if groundwater discharge is the principal water source within the wetland. There are two subclasses and six community types in the Flat Class, all of which occur within the Delta Region.

Figure 12 illustrates common landscape positions where wetlands in the Flat Class are found. See Figure 7 to identify land surfaces.

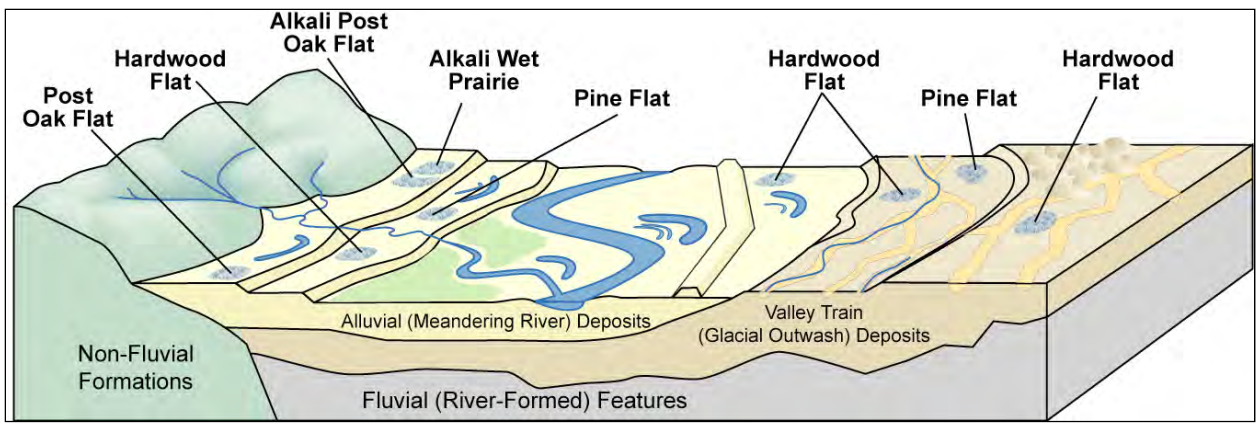


Figure 12. Common landscape positions of wetland community types in the Flat Class.

Subclass: alkali flat. Alkali flats (also called sodic or saline flats) have soils with high pH and high levels of sodium or magnesium salts in or near the surface layer. They typically have very poor drainage and a shallow hardpan. The combination of impeded drainage and unusual soil chemistry restricts the potential plant communities, and provides habitats for certain rare species. The two community types in this subclass are separated based on predominant vegetation, but in fact probably represent a continuum of change in soil conditions, where the forested community occurs on soils with deeper hardpans than the prairie community. Most sites with alkali soils are believed to be former Pleistocene lake beds.

Alkali flats are not common in the Delta, and assessment models applicable to these types are not presented in this guidebook. They are more common in the Coastal Plain Region, and will be addressed in the HGM Guidebook for that region.

Community types. The following communities occur within the alkali flats subclass:

a. *Alkali post oak flat.* Alkali post oak flats occur on sites where the soils have extremely poor drainage and concentrations of salts accumulate near or on the soil surface. These sites are believed to have been occupied by shallow lakes during the Pleistocene Epoch, when waning and waxing periods of continental glaciation to the north of Arkansas created temporary lakes within the modern Delta Region. Repeated filling and drying of the lakes caused salts to accumulate, and today the ancient lakebeds are flats that support unique wetlands with characteristic plants that are tolerant of the high salt concentrations and impeded drainage conditions. In most cases, alkali flats are a mosaic of prairie and unvegetated "slick spots" on soils with salts at or very near the surface, while soils with less surface salt or somewhat better drainage support stunted post oak trees. Alkali post oak flats have been reported from the Delta region (St. Francis County), and likely occur in other locations where soils are strongly saline.

b. *Alkali wet prairie.* The ancient Pleistocene lake beds that support alkali post oak flats also support small areas of alkali wet prairie (also called saline prairie) where soil salinity is highest or drainage is very poor. Where the salts accumulate on the surface, it is common to find a hard white or gray surface, termed a "slick spot." These areas may have salt crystals visible on the surface during dry periods, and they are largely devoid of vegetation. The perimeter of the slick spot often supports a crust of lichens, mosses, and liverworts. In Arkansas, the endangered plant species *Geocarpon minimum* is almost entirely restricted to this slick spot perimeter zone in alkali wet prairies, although it has not been reported from prairies in the Delta Region. Beyond the slick spot edge, prairie species are able to colonize as the depth to the zone of concentrated salts increases, and stunted trees and shrubs occur on still deeper soils. Species of three-awn (*Arstida* spp.) are particularly characteristic grasses of these communities.

Subclass: non-alkali flat. Flats with neutral and acid soils can support a variety of community types. They are differentiated based on predominant vegetation types, which generally reflect drainage conditions. Fire history may also be an important factor in certain instances. These wetlands are widely distributed within the Delta, and provide habitat for numerous plant and animal species. Because wet flats are maintained by precipitation rather than flooding, many were relatively easy to convert to agriculture with fairly minor changes to drainage conditions, and extensive flat areas have been cleared. In addition, many sites that were historically subject to regular flooding have been disconnected from streamflows by modern man-made levees, and these sites are now classified as flats.

This guidebook includes assessment models applicable to all of the forested non-alkali flats in the Delta Region. Assessment models were not developed for the wet tallgrass prairie type, for which few high-quality reference sites could be located in the Delta. Until such models are developed based on reference sites in other regions of Arkansas, tallgrass prairie wetlands are best assessed using a strictly floristic approach and site-specific evaluation of the drainage, soils, management programs, and proposed impacts.

Community types: The following communities are found in non-alkali flats:

a. *Wet tallgrass prairie.* The wet tallgrass prairie community type typically occurs within broad basins or headwater draws that have poor drainage, or in minor swales within larger expanses of dry prairie. All of these sites tend to stay wet, with areas of standing surface water, through spring. They usually become extremely dry in late summer. Wet tallgrass prairie is dominated by typical prairie species such as big bluestem (*Andropogon gerardii*), little bluestem (*Andropogon scoparius*), Indian grass (*Sorghastrum nutans*), switch grass (*Panicum virgatum*), and numerous perennial forbs. However, it also includes wetland species such as beakrush (*Rhynchospora* spp.), marsh fleabane (*Pluchea foetida*), sundews (*Drosera* spp.) and sphagnum moss (*Sphagnum* spp.). Wet prairie is also likely to support species that are rare or unusual in Arkansas, such as prairie cordgrass (*Spartina pectinata*). Fire is essential to maintain prairies in Arkansas — without fire, trees will gradually establish. The original extent of prairie in Arkansas has been dramatically reduced by agriculture, development, fire control, and

forest management practices. In the Delta, remnant wet prairies are found primarily in the Grand Prairie area (Lonoke and Prairie Counties).

b. *Pine flat.* Pine flats, also called pine flatwoods, are common in the Coastal Plain, but in the Delta they are restricted to a relatively small area in the vicinity of Pine City in Monroe County. There, they occur on valley train deposits, on silt loam soils that are acid to strongly acid and with a high water table throughout the winter and spring. In the modern landscape, most of these sites have been dramatically altered by forest management, drainage, and by changes in fire frequency, timing, and intensity. The remaining examples in relatively good condition have large loblolly pines, but even these sites generally have a large hardwood component, characterized by sweetgum and a variety of oaks.

c. *Hardwood flat.* Hardwood flats occur on fairly level terrain that is not within the 5-year floodplain of stream systems, but nevertheless remains wet throughout winter and spring due to rainfall that collects in small shallow pools. These pools often refill and remain wet for days or weeks following summer rains. In the Delta region, hardwood flats often are dominated by Nuttall oak (*Quercus nuttallii*) in Holocene environments, and by water or willow oaks on older surfaces, where they are sometimes called oak flatwoods. Numerous other species occur on hardwood flats and may dominate.

d. *Post oak flat.* Post oak flats occur on clay soils with poor drainage, generally on the margins of the Grand Prairie, where they may intergrade with hardwood flats, but are distinctively dominated by post oak or Delta post oak. These sites are saturated to the surface in the wet season and following rains, but become extremely dry and hard in summer. Mima (or pimple) mounds often are present, and contribute to the extensive ponding on these sites by impounding rainwater and impeding runoff. The understory and groundcover are sparse, which results in a parklike appearance in many stands, and many post oak flats probably were savanna when frequently burned prairies were widely distributed on the Grand Prairie. Tree growth tends to be very slow, although trees are not stunted as they are on alkali post oak flats.

Class: Riverine

Riverine wetlands are those areas directly flooded by streamflow, including backwater and overbank flow, at least once in five years on average (i.e., they are within the 5-year floodplain). Depressions and fringe wetlands that are within the 5-year floodplain are not included in the Riverine Class, but beaver ponds and wildlife management impoundments are usually considered to be riverine. Riverine wetlands encompass many different types of wetland communities; there are three subclasses and six community types in the Riverine Class in the Delta (Table 7, Figure 13).

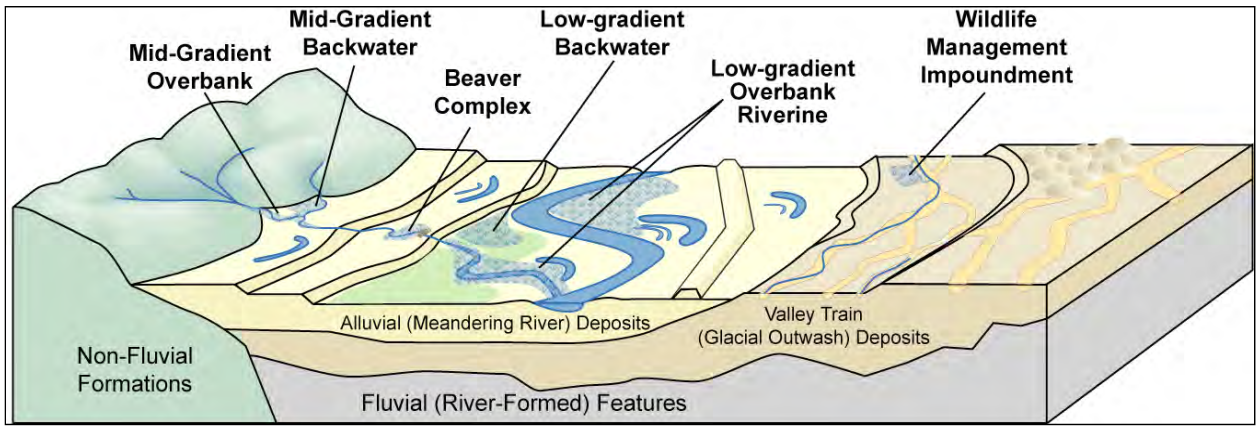


Figure 13. Common landscape positions of wetland community types in the Riverine Class.

Subclass: mid-gradient riverine. Mid-gradient riverine wetlands are associated with streams (typically 4th – 6th order) that have significant floodplain development, but are upstream of the meandering portion of a stream system. They are important sources for input of organic material to the stream system. Mid-gradient systems are of limited distribution in the Delta, being restricted to sites transitional to the Coastal Plain, Ozarks, and Ouachitas, and to some parts of the drainages flanking the Grand Prairie and Crowley's Ridge.

Due to the limited distribution of mid-gradient riverine systems in the Delta and consequent limited extent of potential reference wetlands for this subclass, no specific applicable assessment models have been developed for this guidebook. However, applicable models will be presented in the HGM Guidebooks for the Coastal Plain, Ouachitas, and the Ozarks, and can be used for adjacent mid-gradient sites in the Delta.

Community types. The following community types occur within the mid-gradient riverine subclass:

a. *Mid-gradient floodplain*. Mid-gradient floodplain wetlands occur along small streams with significant bar and floodplain formation. Riparian wetlands along mid-gradient streams are usually fairly small floodplain units that occur repeatedly, often alternating from one side of the channel to the other. They combine elements of upland and lowland forests, and can be highly diverse. Species such as river birch (*Betula nigra*), red maple (*Acer rubrum*), American elm (*Ulmus americana*), and green ash are characteristic.

b. *Mid-gradient backwater*. Mid-gradient backwater wetlands occur at the confluence of streams where high flows on the larger channel cause backwater flooding in the lower reaches of the mid-gradient tributary. They are sites where sediments accumulate rapidly, building natural levees and creating extensive backwater areas that drain slowly. Mid-gradient backwater systems tend to support plant communities that are more tolerant of flooding and sedimentation than the communities on most other mid-gradient floodplains. Species typical of adjacent hillslopes are not successful within the backwater zone, and some portions of the floodplain are occupied by species such as baldcypress (*Taxodium distichum*), that are more typical of lowland swamps.

Subclass: low-gradient riverine. Low-gradient riverine wetlands occur within the 5-year floodplain of meandering streams (usually 7th order or higher). They include a wide variety of community types, and have important functions related to habitat as well as sediment and water storage.

Community types. The following community types occur within the low-gradient riverine subclass:

a. *Low-gradient backwater*. Low-gradient backwater wetlands occupy sites that flood frequently (1- to 5-year flood frequency), but flooding is primarily by slack water, rather than by the high-velocity flows that predominate in overbank flood zones. Backwater flooding usually occurs when mainstem streams are in high stages, impeding the discharge of tributaries and causing them to back up onto their floodplains. This results in sediment accumulation and ponding that persists long after water levels have fallen in the stream channels. Sediments tend to be fine-grained, with considerable accumulation of organic material. Backwater sites that flood for long durations and

are very poorly drained are usually dominated by overcup oak (*Quercus lyrata*) and water hickory (*Carya aquatica*). Less flooded sites are often dominated by green ash, Nuttall oak or willow oak (*Quercus phellos*), and the driest backwater sites may have species such as water oak (*Quercus nigra*) and cherrybark oak (*Quercus pagoda*) as important components in the overstory. As with flats, vernal pools may be an important component of the low-gradient backwater community type. Many sites that were subject to backwater flooding in historic times are now protected by levees. Wetlands on these altered sites are classified as flats.

b. *Low-gradient overbank.* Low-gradient overbank wetlands occur on regularly flooded sites (1- to 5-year flood frequency zone) along or near streambanks and on bars and islands within channel systems. These sites are usually point bar deposits, often with a natural levee veneer. This type differs from the low-gradient backwater community type because floodwater usually moves through the overbank zone at moderate to high velocities, parallel to the channel. Sediments, nutrients, and other materials are exported downstream or imported from upstream sites differently than they are in backwater wetlands. Backwater sites may tend to accumulate fine sediments and organic material and to export dissolved materials in the water column. Overbank sites tend to be subject to scour or deep deposition of coarse sediments, and litter and other detritus may be completely swept from a site or accumulated in large debris piles. In-channel sandbars and riverfront areas usually are dominated by willows, sycamore (*Platanus occidentalis*), cottonwood, and similar pioneer species, while older and less exposed substrates support more diverse communities. In most cases, however, plant communities in the overbank flood zone tend to be dominated by species with broad tolerances for inundation, sedimentation, and high-velocity flows. Overbank sites sometimes include vernal pools, usually in the form of long, arched swales between the depositional ridges of meander-scroll topography, rather than the irregularly shaped pools typically found in backwater areas.

Subclass: impounded riverine. These wetlands occur in shallow impoundments that detain and slow stream flows, but generally remain flow-through systems. They include highly dynamic and unique beaver-dominated wetlands, as well as systems that are intensively managed to benefit particular groups of wildlife species.

There are no HGM models specific to beaver complexes, but the recommended approach is to regard them as a fully functional component of any riverine system being assessed.

Wildlife Management Impoundments are designed specifically to maximize a single wetland function (habitat) and often are targeted toward a specific wildlife group (usually waterfowl). They are intended to allow managers to flood large areas at times when water is not naturally present in those areas. Because the hydrological modifications usually imposed do not reflect the patterns observed in reference systems, this guidebook does not include models designed specifically for application to managed impoundments.

Community types. The following community types occur within the impounded riverine subclass:

a. *Beaver complex.* Beaver complexes were once nearly ubiquitous here and elsewhere in the continental United States, but became relatively uncommon during the past two centuries following the near-extirpation of beaver. In their most common form, they consist of a series of impounded pools on flowing streams. Beaver cut trees for dams and food, and they have preferences for certain species (e.g., sweetgum (*Liquidambar styraciflua*)), which alters the composition of forests within their foraging range. Tree cutting and tree mortality from flooding create patches of dead timber surrounded by open water, shrub swamps, or marshes. Beaver complexes may be abandoned when the animals exhaust local food resources or when they are trapped out. Following abandonment, the dams deteriorate, water levels fall, and different plants colonize the former ponds. When beaver reoccupy the area, the configuration changes again, the result being that systems with active beaver populations are in a constant state of flux.

b. *Wildlife management impoundment.* Wildlife management impoundments are areas managed specifically to provide habitat for waterfowl and other waterbirds. There are two versions of this management approach: greentree reservoirs and moist soil units. They are included in the Riverine Class because they usually draw water from and return it to stream systems, but the wetlands are contained within low levee systems that allow managers to create shallow flooding conditions suitable for use by foraging and resting birds. Greentree reservoirs are leveed sections of mature oak

bottomland forest, which provide access to acorns and forest invertebrates when artificially flooded to provide shallow water for waterfowl foraging. Moist soil units are leveed cleared fields where water management and farm machinery are employed to maintain marshlike conditions, which provide small seeds and different invertebrates than are found in forested wetlands.

Class: Depression

Depression wetlands occur in topographic low points where water accumulates and remains for extended periods. Sources of water include precipitation, runoff, groundwater, and stream flooding.

Depressions (both unconnected and connected) are distinguished from the ponded areas that occur within the Flat and Riverine Subclasses in several ways. Depressions tend to occur in abandoned channels, abandoned courses, and large point bar swales, while vernal pools within Flat 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. 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:

- Depressional soils may have one or both of the hydric soil indicators F2 (Loamy Gleyed Matrix) or A4 (Hydrogen Sulfide) (USDA NRCS 2010).
- Depressions are distinct, closed units with relatively abrupt transitions to flats, riverine wetlands, or uplands (as opposed to extensive riverine backwater zones).
- Vegetation in depressions usually is dominated by one or more of the following species: baldcypress, water tupelo (*Nyssa aquatica*), swamp privet (*Forestiera acuminata*), water elm (*Planera aquatica*), and buttonbush (*Cephalanthus occidentalis*). Many depressions are fringed (and some are dominated) by species such as overcup oak and water hickory.

In the Delta Region of Arkansas, there are three subclasses and five community types in the Depression Class (Table 7, Figure 14).

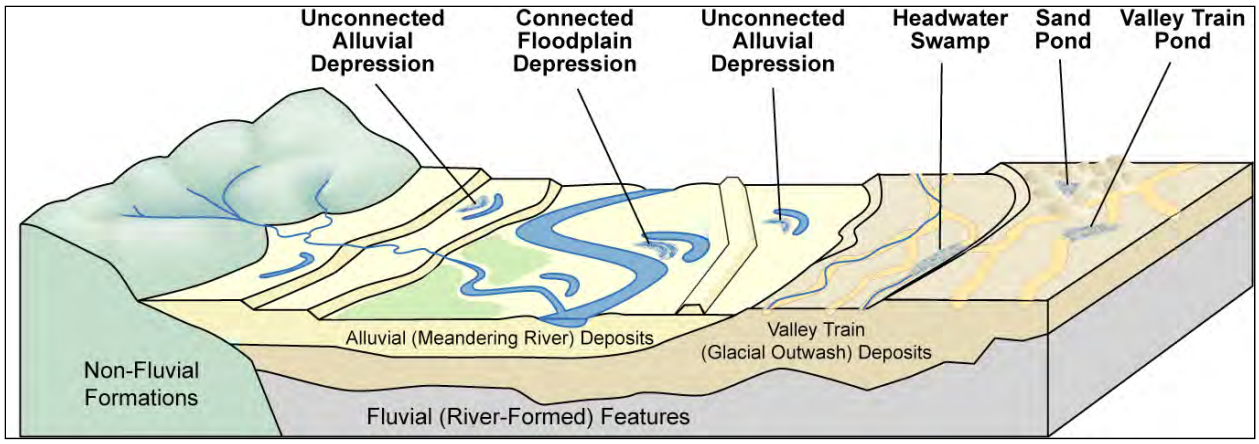


Figure 14. Common landscape positions of wetland community types in the Depression Class.

Subclass: headwater depression. Headwater depressions have one or more outlets that form the headwaters of perennial streams. They export materials such as nutrients and organic matter to downstream systems, and contribute to maintenance of stream baseflow. They differ from Connected Depressions in that they do not have a surface stream input, but rather are fed by groundwater, precipitation, and/or local runoff.

Community type. The following community type occurs within the headwater depression subclass:

a. *Headwater swamp.* Few examples of this wetland type are known, but those that have been examined appear to be restricted to basins formed in ancient glacial outwash channels that receive groundwater from adjacent higher terraces. The nearly constant water supply into the depression creates swamp conditions, where baldcypress and water tupelo are the most common tree species. Few species are present in the understory, and herbaceous species grow primarily on stumps or from a zone of mosses on tree trunks at the level where water tends to stabilize during the growing season. The perimeter forest is dominated by typical lowland species, such as green ash, overcup oak, and Nuttall oak. All known examples of this wetland type are in Monroe or Phillips Counties, including the largest example, which is located at the Louisiana Purchase State Park.

Subclass: unconnected depression. Unconnected depressions are found in a variety of landscape settings. They are maintained by precipitation, runoff, and sometimes by groundwater. Some may have small influent and outlet channels, but they are not overwhelmed by floodwaters during 5-year events; therefore, the import or export of materials is not a significant function of these wetlands except during extreme events. Their disconnection from river systems may result in very different wildlife functions than those associated with connected depressions. For example, unconnected depressions may lack predatory fish populations, and thereby provide vital habitat for certain invertebrate and amphibian species.

Community types. The following community types occur within the unconnected depressions subclass:

a. *Sand pond.* Sand ponds are depressions within dunefields. The dunes are wind-blown accumulations of sediments that were deposited in waning glacial outwash channels, and date from 12,000 and 30,000 years before present. Individual dunes typically are 3 to 5 m high, and support upland forests or have been converted to agriculture. Numerous small, enclosed depressions are confined by the dunes, resulting in a poorly drained environment that ponds rainwater and possibly intercepts local groundwater for extended durations. As a result, distinctive, unconnected wetlands form that usually include swamp species such as baldcypress or water tupelo in the deepest interior areas, and successively less water-tolerant species around the perimeter of the depression. Many sand ponds, particularly those in the northern part of their distribution, contain the shrub species pondberry (*Lindera melissifolia*) and corkwood (*Leitneria floridana*), which do not occur commonly in any other habitat in Arkansas. Sand pond wetlands occur in several distinct bands within the Delta region, and are associated with valley train deposits.

b. *Unconnected alluvial depression.* Unconnected alluvial depressions occur in major river floodplains that have been cut off from the channel by levees and on terraces (former floodplains that are higher than the modern floodplain). They are not affected by river flooding during common flood events (1- to 5-year flood frequency zone). This lack of connection to the river distinguishes this wetland type from floodplain depressions, but otherwise the two types are very similar. Unconnected alluvial depression wetlands typically

occur in abandoned river channels and large swales. Depressions that are deep enough to hold water year-round will have an open-water zone (less than 2 m deep) in the center, with baldcypress and buttonbush in areas that are rarely dry, and relatively narrow zones of progressively "drier" plants, such as overcup oak, around the depression perimeter. Many of these wetlands have been altered by agricultural activities including drainage works that either reduce or increase water storage within the depression.

c. *Valley train pond.* Valley train ponds are unconnected wetlands associated with glacial outwash ("valley train") deposits. They form in very shallow basins that are the remnants of ancient braided channel systems. Plant species in valley train ponds on the youngest outwash deposits (e.g., much of the St. Francis basin) are similar to those found in the alluvial depressions of active stream meander belts, such as baldcypress and water tupelo. Ancient sandbars within the valley train depressions may support species that are not commonly seen in swamps, but are more typical of sandy riverfront areas, such as sycamore and river birch. Older valley train deposits, where outwash channels are largely filled by stream backwater sediments, loess, or erosion from surrounding surfaces, have fewer, shallower ponds than younger surfaces, and tend to be dominated by species less tolerant of water such as willow and water oaks. Water sources for valley train ponds may include groundwater connections through the subsurface, sand-filled paleo-channel system, in addition to precipitation and local runoff. Valley train ponds have been described on outwash deposits between the White River and Crowley's Ridge, and in the St. Francis River lowlands.

Subclass: connected depression. Connected depressions occur within the 5-year floodplain of streams, and are integral components of the stream ecosystem with regard to materials exchange and storage. They often are used by fish and other aquatic organisms that move in and out of the wetland during floods.

Community type. The floodplain depression is the sole community type described within the connected depression subclass:

a. *Floodplain depression.* Floodplain depression wetlands are most commonly found in remnants of abandoned stream channels, or in broad swales left behind by migrating channels. They are usually

near the river, and are flooded by the river during the more common (1- to 5-year) flood events. They typically support swamp forests or shrub swamps in deeper water zones that remain flooded most of the time, and overcup oak-water hickory forests in areas that dry out in summer. Floodplain depression wetlands were once common in the Delta, but as effective flood-control works have been developed along major rivers, many depressions have become disconnected from stream systems and now function as unconnected alluvial depressions (discussed previously).

Class: Fringe

Fringe wetlands occur along the margins of lakes. By convention, a lake must be more than 2 m deep; otherwise associated wetlands are classified as Depressional.

In Arkansas, natural lakes occur mostly in the abandoned channels of large rivers (oxbows), but numerous man-made impoundments also support fringe wetlands. Typical examples within the Delta include the baldcypress fringe common on oxbow lakes, or the black willow fringe that is often associated with borrow pits. There are three subclasses and three community types in the Fringe Class (Table 7, Figure 15). No assessment models have been developed for any of the Fringe wetland subclasses in Arkansas, primarily because no single reference system can reflect the range of variability they exhibit. In particular, many water bodies that support fringe wetlands are subject to water-level controls, but the resulting fluctuation patterns are highly variable depending on the purpose of the control structure.

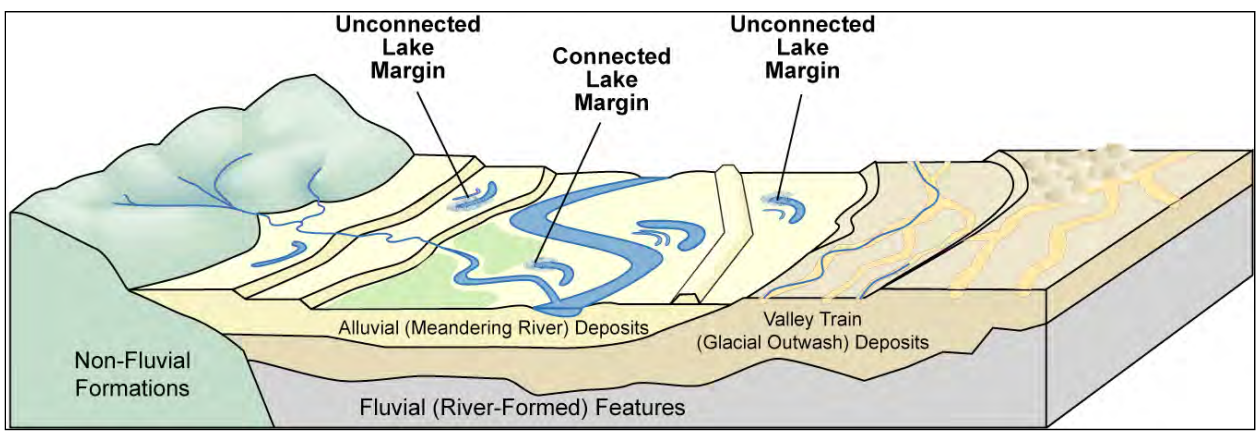


Figure 15. Common landscape positions of wetland community types in the Fringe Class.

Subclass: reservoir fringe. Wetlands that occur within the fluctuation zone of man-made reservoirs are classified as Reservoir Fringe. Reservoirs are distinguished from other man-made water bodies (such as borrow pits) in that they are specifically constructed and operated to store water for flood control, water supply, or similar purposes. As a result, they tend to have fluctuation regimes that are different from any natural pattern in the region.

Community type. The reservoir shore is the sole community type described within the reservoir fringe subclass:

a. *Reservoir shore.* Man-made reservoirs include a wide array of features, such as large farm ponds, municipal water storage reservoirs, and state recreational lakes. In almost all cases, these lakes are managed specifically to modify natural patterns of water flow; therefore their shoreline habitats are subjected to inundation at times and for durations not often found in nature. Steep reservoir shores usually support little perennial wetland vegetation other than a narrow fringe of cattails and rushes and willows. The most extensive wetlands within reservoirs usually occur where tributary streams enter the lake, and sediments accumulate to form deltas. These sites may be colonized by various marsh species, and sometimes black willow or buttonbush, but even these areas are vulnerable to extended drawdowns, ice accumulation, erosion due to boat wakes, and similar impacts.

Subclass: connected lacustrine fringe. Fringe wetlands are considered to be "connected" to other aquatic systems if they become contiguous with riverflows during a 5-year flood event. This means that aquatic organisms can move freely between the river and the lake on a regular basis; and nutrients, sediments, and organic materials are routinely exchanged between the riverine and lake systems.

Community type: The connected lake margin is the sole community type described in the connected lacustrine fringe subclass:

a. *Connected lake margin.* Connected lake margin wetlands occur primarily in oxbow lakes near large rivers, where they are frequently inundated during floods (that is, they are within the 1- to 5-year flood frequency zone). Many lakes that would have met this

criterion early in the 1900s have gradually been disconnected from riverflows due to the completion of large levees and other flood-protection works, and the wetlands in those lakes are now classified as unconnected lake margins. Connected lake margins differ from unconnected systems in that they routinely exchange nutrients, sediments, and aquatic organisms with the river system. Shoreline cypress-tupelo stands and fringe marshes are common, and the upper reaches of oxbow lakes often contain buttonbush swamps and expansive marsh systems. In addition to natural oxbows, there are man-made bodies of water, such as borrow pits, that support connected fringe wetlands. Connected lake margin fringe wetlands are common along large rivers within the Delta Region.

Subclass: unconnected lacustrine fringe. These fringe wetlands occur on lakes that are not within the 5-year floodplain of a river, although they may have small inflow and outflow streams. Many oxbow lakes that have been disconnected from big rivers by levees are in this category. Managed flood-control and water supply reservoirs are not included here, but deeply flooded borrow pits are included.

Community type. The unconnected lake margin is the sole community type described in the unconnected lacustrine fringe subclass:

a. *Unconnected lake margin.* Unconnected lakes are lakes that are not within the portion of a floodplain that is inundated by a river on a regular basis (that is, they are not within the 1- to 5-year floodplain). They are similar in appearance to connected lake margins but are classified separately because they do not regularly exchange nutrients, sediments, or fish with river systems. Most are associated with oxbow lakes, where baldcypress wetlands normally form in a narrow band along the shoreline. Shallow filled areas in the upper and lower ends of the lake sometimes develop more extensive wetland complexes of willows, buttonbush, and marsh species.

   Most of these natural lake systems have been modified in various ways. Frequently, their outlets have been fitted with control structures to allow added storage and manipulation of water. Inflows have been altered by farm drainage and other diversions, and adjacent lands have been cleared or developed in many areas.

All of these actions have caused accelerated sedimentation within the lakes.

Naturally occurring unconnected lake margins are most common in the former floodplains of large rivers, especially the Mississippi and Arkansas Rivers, where levees now prevent flooding. Man-made lakes in this subclass can occur anywhere.

4 Wetland Functions and Assessment Models

This Regional Guidebook contains seven sets of assessment models applicable to wetlands in the Delta Region of Arkansas. Not all of the wetland subclasses and community types described in Chapter 3 and Table 7 can be assessed using the models presented here. Only forested wetlands (or sites that could support forested wetlands) are intended to be assessed using these models. No assessment models were developed for the Alkali Flat subclass or the Mid-Gradient Riverine subclass, because relatively few examples of these wetlands exist in the Delta. Models for assessment of these systems will be presented in guidebooks for other regions of the state and will be applicable to Delta systems. Finally, none of the Fringe Class or Riverine Impounded subclass wetlands are addressed in this document. Impacts to these wetlands are likely to involve subtle changes in water level management, which are beyond the scope of a rapid field assessment technique.

The Delta wetlands that can be assessed with the models presented here include all of the subclasses and community types not specifically excluded in the preceding paragraph, and represent most of the common forested wetland types in the region. For simplicity, the Non-Alkali Flat subclass will be referred to simply as the Flat subclass for the remainder of this guidebook. Also, the Low-Gradient Riverine subclass is sufficiently complex that separate models have been developed for its constituent community types, Low-Gradient Overbank and Low-Gradient Backwater wetlands. To maintain consistency, they also will be referred to as separate subclasses for the remainder of this guidebook.

Based on this guidebook discussion, the six wetland subclasses for which assessment models are presented in this chapter are the following:

a. Flat.

b. Low-Gradient Riverine Overbank.

c. Low-Gradient Riverine Backwater.

d. Headwater Depression.

e. Unconnected Depression.

f. Connected Depression.

The wetland functions that can be assessed using this guidebook were identified by participants in a workshop held in Arkansas in 1997. That group selected hydrologic, biogeochemical, and habitat functions that are important and measurable in Arkansas wetlands from a suite of potential functions identified in "A Guidebook for Application of Hydrogeomorphic Assessments to Riverine Wetlands" (Brinson et al. 1995). Based on the workshop recommendations, this regional guidebook provides models and reference data required to determine the extent to which forested wetlands of the Arkansas Delta perform the following functions:

a. Detain Floodwater.

b. Detain Precipitation.

c. Cycle Nutrients.

d. Export Organic Carbon.

e. Maintain Plant Communities.

f. Provide Habitat for Fish and Wildlife.

It should be noted that not all functions are performed by each regional wetland subclass. Thus, assessment models for each subclass may not include all seven functions. In addition, the form of the assessment model that is used to assess functions can vary from subclass to subclass.

In this chapter, each of these functions 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 discusses the reasons a function was selected for assessment, and the 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 lays 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.

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. In the final chapter (Chapter 6), detailed descriptions are presented of assessment variables and the methods used to measure or estimate their values.

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 damping of the downstream flood hydrograph, maintenance of postflood base flow, and deposition of suspended sediments from the water column to the wetland. This function is assessed for the following regional wetland subclasses in the Delta Region of Arkansas: Low-Gradient Riverine Overbank, Low-Gradient Riverine Backwater, and Connected Depression.

The recommended procedure for assessing this function involves estimation of "roughness" within the wetland, in addition to a change in 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 (Campbell and Johnson 1975; Demissie and Kahn 1993; Dewey and Kropper Engineers 1964; Dybvig and Hart 1977; Novitski 1978; Ogawa and Male 1983, 1986; Thomas and Hanson 1981). Many societal benefits related to the reduction of flood damage occur as a result of wetlands performing this function. Generally, floodwater interaction with wetlands dampens and broadens the flood wave, which reduces peak discharge downstream. Similarly, wetlands can reduce the velocity of water currents and, as a result, reduce erosion (Ritter et al. 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 that returns to the channel very slowly via low-gradient surface routes may be sufficiently delayed that it

contributes significantly to the maintenance of base flow in some streams long after flooding has ceased (Saucier 1994, Terry et al. 1979). 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 these physical influences on flow and sediment dynamics. Floodwater interaction with floodplain wetlands influences a variety of other wetland functions in the Delta Region of Arkansas, 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 pronounced effects on the stormflow response (Brooks et al. 1991, Dunne and Leopold 1978, Leopold 1994, Patton 1988, Ritter et al. 1995). The larger the watershed, the greater the volume and peak stream discharge that result from a rainfall event. Watershed shape affects how quickly surface and subsurface flows reach the outlet to the watershed. For example, a rounded 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 flow. As the percentage of wetland area and/or reservoirs increases, the greater the flattening effect (i.e., attenuation) 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 flood flow interactions. The morphology of the stream channel and its floodplain reflect 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, Rosgen 1994). 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 the 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 these characteristics, only change in flood frequency and the roughness component are incorporated into a rapid assessment of the Detain Floodwater function. 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, especially if it is not directly adjacent to a channel and near a stream gauge. At best, change in flood frequency can be estimated 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.

General form of the assessment model

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

V_{FREQ} = change in frequency of flooding

V_{LOG} = log density
V_{GVC} = ground vegetation cover
V_{SSD} = shrub-sapling density
V_{TDEN} = tree density

The model can be expressed in a general form:

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

The assessment model has two components: change in the 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 the change in 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. 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_{TDEN} 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 because they do not commonly influence flows to the same degree as these components (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, infiltration, and absorption by organic material and soils. Both floodprone (riverine) wetlands and nonflooded wetlands (flats) are assessed for this function. Depressional wetlands also perform a precipitation storage function, but are not assessed for that function within

the Delta Region of Arkansas. Precipitation storage in depressions is related to local runoff to varying degrees, and it is difficult to consistently define source areas and available storage volumes in the context of a rapid field assessment. In contrast, precipitation storage in flats and riverine wetlands is more often a local effect related to microdepressional storage and infiltration capacity. Three wetland subclasses are assessed for the precipitation detention function in the Delta Region of Arkansas: Flat, Low-Gradient Riverine Overbank, and Low-Gradient Riverine Backwater.

The recommended procedure for assessing this function 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 prevent erosion, dampen runoff peaks following storms, and help 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 microdepressions and vernal pools. Microdepressions are usually formed by channel migration processes or tree wind-throw, which creates small, shallow depressions when root systems are pulled free of the soil. Vernal pools are usually found in ridge-and-swale topography, or they can be created by the gradual filling of formerly deeper depressions such as cutoffs or oxbows. In addition, the presence of surface organic accumulations reduces runoff and promotes infiltration. Therefore, sites with large amounts of microdepression and vernal pool 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 microdepressions. Land use practices that involve ditching or land leveling can eliminate onsite 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, which are discussed in greater detail in Chapter 6:

V_{POND} = percent of area subject to ponding
V_{OHOR} = O horizon thickness
V_{LITTER} = thickness of the litter layer

The model can be expressed in a general form:

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

The assessment model has two components, which are weighted equally. The percentage of the assessment area subject to ponding V_{POND} is based on a field estimate. The second component expression is an average based on field measures of organic matter accumulation on the soil surface, which are represented by the thickness of the O horizon V_{OHOR} and the percentage of the ground surface covered by litter V_{LITTER}. Litter is sometimes a problematic variable to use, because it is seasonal in nature. However, litter is an important element in precipitation detention, and may be differentially exported from some riverine sites; therefore, it is included in the model despite the inherent difficulties. If users of this guidebook determine that litter cannot be estimated reliably in the wetland being assessed (for example, if fieldwork in two areas being compared will span several seasons), then litter can be removed from the model equation, and the model structure revised appropriately.

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 six wetland subclasses.

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 litter fall (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 plant community development and maintenance possible (Bormann and Likens 1970, Perry 1994, Whittaker 1975). 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, 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. These decomposers, in turn, break down organic material into simpler elements and compounds that can then reenter the nutrient cycle (Dickinson and Pugh 1974, Harmon et al. 1986, Hayes 1979, Pugh and Dickinson 1974, Reiners 1972, Schlesinger 1977, Singh and Gupta 1977, Vogt et al. 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 non-vascular plants, (c) consumers such as animals, fungi, and bacteria, and (d) dead organic matter, such as leaf litter 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 et al. 1981). In the Southeast specifically, there is a rich literature on the standing stock, accumulation, and turnover of above- and below-ground biomass in forested wetlands (Brinson 1990, Brown and Peterson 1983, Conner and Day 1976, Day 1979, Elder and Cairns 1982, Harmon et al. 1986, Mulholland 1981, Raich and Nadelhoffer 1989, Nadelhoffer and Raich 1992, Symbula and Day 1988).

In controlled field studies, the approach for assessing nutrient cycling is usually to measure the rate at which nutrients are transformed and transferred between compartments over an annual cycle (Brinson et al. 1984, Harmon et al. 1986, Kuenzler et al. 1980), which is not feasible as part of 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, which 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 model can be expressed in a general form:

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

The two constituent expressions within the model reflect the two major production and storage compartments: living and dead organic material. The first expression is composed 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) as well as 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, which weights each element equally. Note that one detrital component, litter accumulation, is not used in this model. That is because it is a relatively transient component of the onsite nutrient capital, and may in fact be readily exported. Therefore it is used as a nutrient-related assessment variable only in the carbon export function, discussed in the next section.

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 ($g/m^2/year$).

This function is assessed in wetlands that have outflow to streams, which includes four subclasses in the Delta Region of Arkansas: Low-Gradient Riverine Overbank, Low-Gradient Riverine Backwater, Headwater Depression, and Connected Depression.

Rationale for selecting the function

The high productivity of river-connected wetlands and their interaction with streams make them important sources of dissolved and particulate organic carbon for aquatic food webs and biogeochemical processes in downstream aquatic habitats (Elwood et al. 1983, Sedell et al. 1989, Vannote et al. 1980). 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).

Characteristics and processes that influence the function

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 (Brinson et al. 1981, Elder and Mattraw 1982, Johnston et al. 1990, Mulholland and Kuenzler 1979). This is attributable to several factors: (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, which are discussed in greater detail in Chapter 6:

V_{FREQ} = change in frequency of flooding
V_{OUT} = change in outflow
V_{LITTER} = thickness of the litter layer
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 follows:

$$FCI = \begin{bmatrix} V_{FREQ} \\ \text{or} \\ V_{OUT} \end{bmatrix} \times \left\{ \frac{\left[\frac{\left(V_{LITTER} + V_{OHOR} + V_{WD} + V_{SNAG}\right)}{4}\right] + \left[\frac{\left(V_{TBA} + V_{SSD} + V_{GVC}\right)}{3}\right]}{2} \right\} \quad (5)$$

This model is similar to the model used to assess the 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}) represent primarily organic production, indicating that materials will be available for export in the future. The dead organic fraction represents the principal sources of exported material, represented by litter, snags, woody debris, and accumulation of the O horizon (V_{LITTER}, 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 flooding (for riverine or connected depression subclasses) or outflow (for headwater depressions) is a required component of this model, because the export function is largely dependent on inundation and continuity with stream flows (V_{FREQ} or V_{OUT}). This model also includes litter as a component of the dead organic fraction, despite the fact that it is a highly seasonal functional indicator that is difficult to estimate reliably, and therefore is not included in other models where it may seem appropriate. However, it is included in this model because it represents the most mobile dead organic fraction in the wetland, and because it may be the only component of that fraction that is present in young or recently restored systems. If users of this guidebook determine that litter cannot be estimated reliably in the wetland being assessed (for example, if fieldwork in two areas being compared will span several seasons), then litter can be removed from the model equation.

Function 5: Maintain plant communities

Definition and applicability

This function is defined as the capacity of a wetland to provide the environment necessary for characteristic plant community development and maintenance. 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. Various 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), and indirect multivariate techniques such as detrended correspondence analysis (Kent and Coker 1995). However, none of these approaches alone can supply 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 all six subclasses in the Delta Region of Arkansas.

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, Elder 1985, Gosselink et al. 1990, Hawkins et al. 1982).

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 (Hodges 1997; Messina and Conner 1997; Robertson 1992; Robertson et al. 1978, 1984; Smith 1996; Wharton et al. 1982). 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 guidebook. 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, which 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_{DUR} = change in growing season flood duration
V_{POND} = microdepressional ponding

The model can be expressed in a general form:

$$FCI = \left(\left\{ \left[\frac{\left[\frac{\left(V_{TBA} + V_{TDEN} \right)}{2} + V_{COMP} \right]}{2} \right] \right\} \times \left[\frac{\left(V_{SOIL} + V_{DUR} + V_{POND} \right)}{3} \right] \right)^{1/2} \tag{6}$$

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_{TDEN}). 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 three 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 the section "Vegetation" in Chapter 3, plant communities of the Delta Region of Arkansas 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 Delta Region of Arkansas. Flooding is also critical for the maintenance of many plant communities within the region, but this relationship is considered separately as a basic classification factor. Change in flood duration has a very significant impact on plant communities, and is included as well.

Function 6: Provide habitat for fish and wildlife

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 all six subclasses in the Delta Region of Arkansas.

Rationale for selecting the function

Terrestrial, semiaquatic, 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 Delta Region of Arkansas 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 Delta Region of Arkansas 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). Vegetation diversity on the horizontal plane derives from gap-phase regeneration dynamics and the complex patterns of alluvial deposition that produce 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 myriad habitat conditions for animals and allows numerous species to coexist in the same area (Schoener 1986). The compositional diversity typical of lowland forests also assures the availability of a wide variety of food resources (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 macroinvertebrates found in the floodplain. Similarly, mallards heavily utilize the abundant litter invertebrate populations associated with flooded or ponded bottomland forests during winter (Batema et al. 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 as sources of food (Harmon et al. 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 raccoons 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 Delta Region of Arkansas, 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 invertebrates and amphibians, many of which are utilized as a food source by other animals (Johnson 1987, Wharton et al. 1982). 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), who provided an overview of fish use of bottomland hardwoods in the Piedmont and eastern Coastal Plain, 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 et al. (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.” A change in flood duration can also substantially shift plant dominance and animal use of sites.

Just as topographic variations provide essential wetland habitats such as 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 et al. 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, Bachman's warbler, and the red wolf (*Canis rufus*), as well as severe declines in the black bear and Florida panther (*Puma concolor coryi*). The extent to which patch size affects animal populations has been most thoroughly investigated with respect to birds, but the results have been inconsistent (Askins et al.1987, Blake and Karr 1984, Howe 1984, Keller et al. 1993, Kilgo et al. 1997, Lynch and Whigham 1984, Sallabanks et al. 1998, Stauffer and Best 1980). 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 that occur in fragmented forests (Ambuel and Temple 1983). The point at which forest fragmentation affects different bird species 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 et al. 1995) identified three groups of birds that breed in the Mississippi Alluvial Valley with (presumably) similar needs relative to patch size. That study suggested that, to sustain source breeding populations of individual species within the three groups, 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 Swainson's warbler (*Limnothlypis swainsonii*) are in the first group; more sensitive species such as the cerulean warbler (*Dendroica cerulea*) are in the second group; and those with very large home ranges (e.g., raptors such as the red-shouldered hawk) (*Buteo lineatus*) are in the third group.

The land use surrounding a tract of forest also has a major effect on avian populations. Recent studies (Robinson et al. 1995, Sallabanks et al. 1998, Thompson et al. 1992, Welsh and Healy 1993) 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 floodprone areas and nonflooded habitats of similar structure, 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 are more isolated from one another (Sedell et al. 1990).

General form of the assessment model

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

V_{FREQ} = change in frequency of flooding
V_{DUR} = change in growing season flood duration
V_{POND} = microdepressional ponding
V_{TCOMP} = tree composition
V_{SNAG} = snag density
V_{STRATA} = number of vegetation layers
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 model can be expressed in a general form:

$$FCI = \left\{ \left[\frac{\left(V_{FREQ} + V_{DUR} + V_{POND}\right)}{3} \right] \times \left[\frac{\left(V_{TCOMP} + V_{STRATA} + V_{SNAG} + V_{TBA}\right)}{4} \right] \times \left[\frac{\left(V_{LOG} + V_{OHOR}\right)}{2} \right] \times \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE}\right)}{3} \right] \right\}^{1/4} \quad (7)$$

The expressions within the model reflect the major habitat components described. The first expression concerns hydrology, and includes indicators of both seasonal inundation, which allows river access by aquatic organisms (V_{DUR} and V_{FREQ}) as well as the periodic occurrence of temporary, isolated aquatic conditions (V_{POND}). The second expression includes four indicators of forest structure and diversity, specifically overstory basal area (V_{TBA}), overstory tree species composition (V_{TCOMP}), snag density (V_{SNAG}) and a measure of structural complexity (V_{STRATA}). 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}). Note that the litter layer, which is important to some species, is not included in the model due to its seasonality. Instead, the O horizon is used as an indicator of litter accumulation, since it is a direct result of litter decay. Three landscape-level variables are incorporated within the last term of 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 Delta Region of Arkansas: 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 of 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 Low-Gradient Riverine Overbank and Backwater, Headwater Depression, and Connected Depression subclasses, and is not assessed in subclasses having no export mechanism (flooding) (i.e., Unconnected Depressions and Flats). Similarly, some variables can be deleted from assessment models for subclasses where they cannot be consistently evaluated. For example, ground vegetation cover V_{GVC}, litter cover V_{LITTER}, woody debris and logs V_{WD} and V_{LOG}, and thickness of the O and A horizons V_{OHOR} and V_{AHOR} may be difficult to assess in depressions that are inundated, and modified versions of the models applicable to the depression subclasses are provided for use in those situations. The modified models are likely to be less sensitive than the full versions, but they are complete enough to be used when necessary.

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 seven 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 Assessed” in cases where the wetland subclass does not perform the function as described in Chapter 4, or where it cannot be assessed with the methods and model available for rapid field assessment. 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: Flat

Four functions are assessed for this subclass. Most of the applicable assessment models have not been changed 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 models based on the reference data. Note that, unlike other subclasses, the Flat subclass subindex curves for percent ponding reflect three different geomorphic settings, and it is necessary to identify the setting when assembling field data. Specific guidance is provided on the field data sheets for Non-Alkali Flat Wetlands (Flats) in Appendix B.

a. *Function 1: Detain Floodwater*. Not Assessed
b. *Function 2: Detain Precipitation*.

$$FCI = \frac{\left[V_{POND} + \frac{\left(V_{OHOR} + V_{LITTER}\right)}{2}\right]}{2} \tag{8}$$

c. *Function 3: Cycle Nutrients*.

$$FCI = \frac{\left[\frac{\left(V_{TBA} + V_{SSD} + V_{GVC}\right)}{3} + \frac{\left(V_{OHOR} + V_{AHOR} + V_{WD} + V_{SNAG}\right)}{4}\right]}{2} \tag{9}$$

d. *Function 4: Export Organic Carbon*. Not assessed.
e. *Function 5: Maintain Plant Communities*.

$$FCI = \left(\left\{\frac{\left[\frac{\left(V_{TBA} + V_{TDEN}\right)}{2} + V_{COMP}\right]}{2}\right\} \times \left[\frac{\left(V_{SOIL} + V_{POND}\right)}{2}\right]\right)^{1/2} \tag{10}$$

f. *Function 6: Provide Wildlife Habitat*. Applicable in the following modified format:

$$FCI = \left\{\begin{array}{l} V_{POND} \times \left[\frac{\left(V_{TCOMP} + V_{SNAG} + V_{STRATA} + V_{TBA}\right)}{4}\right] \\ \times \left[\frac{\left(V_{LOG} + V_{OHOR}\right)}{2}\right] \times \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE}\right)}{3}\right] \end{array}\right\}^{1/4} \tag{11}$$

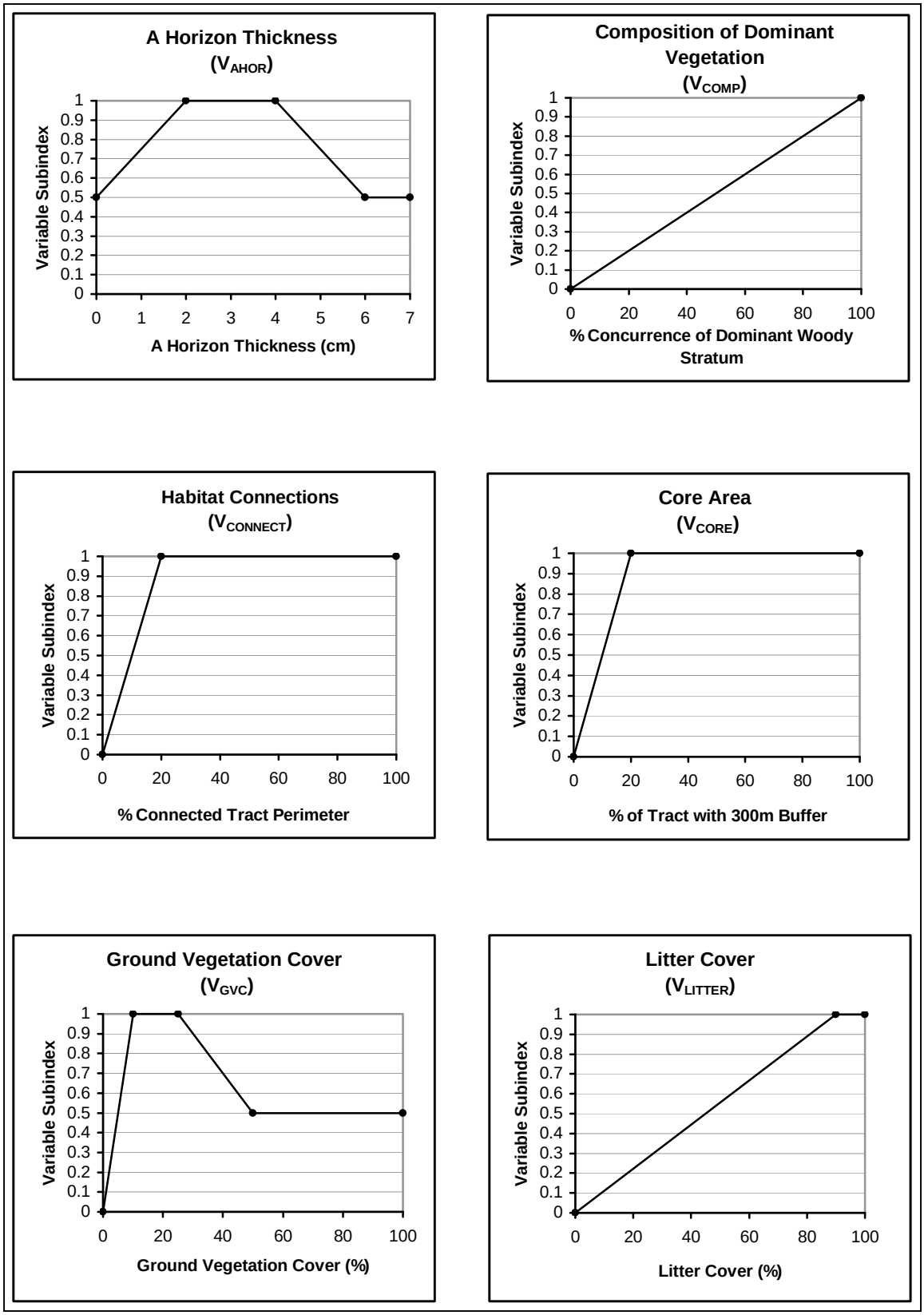


Figure 16. Subindex curves for Flat wetlands (Sheet 1 of 4).

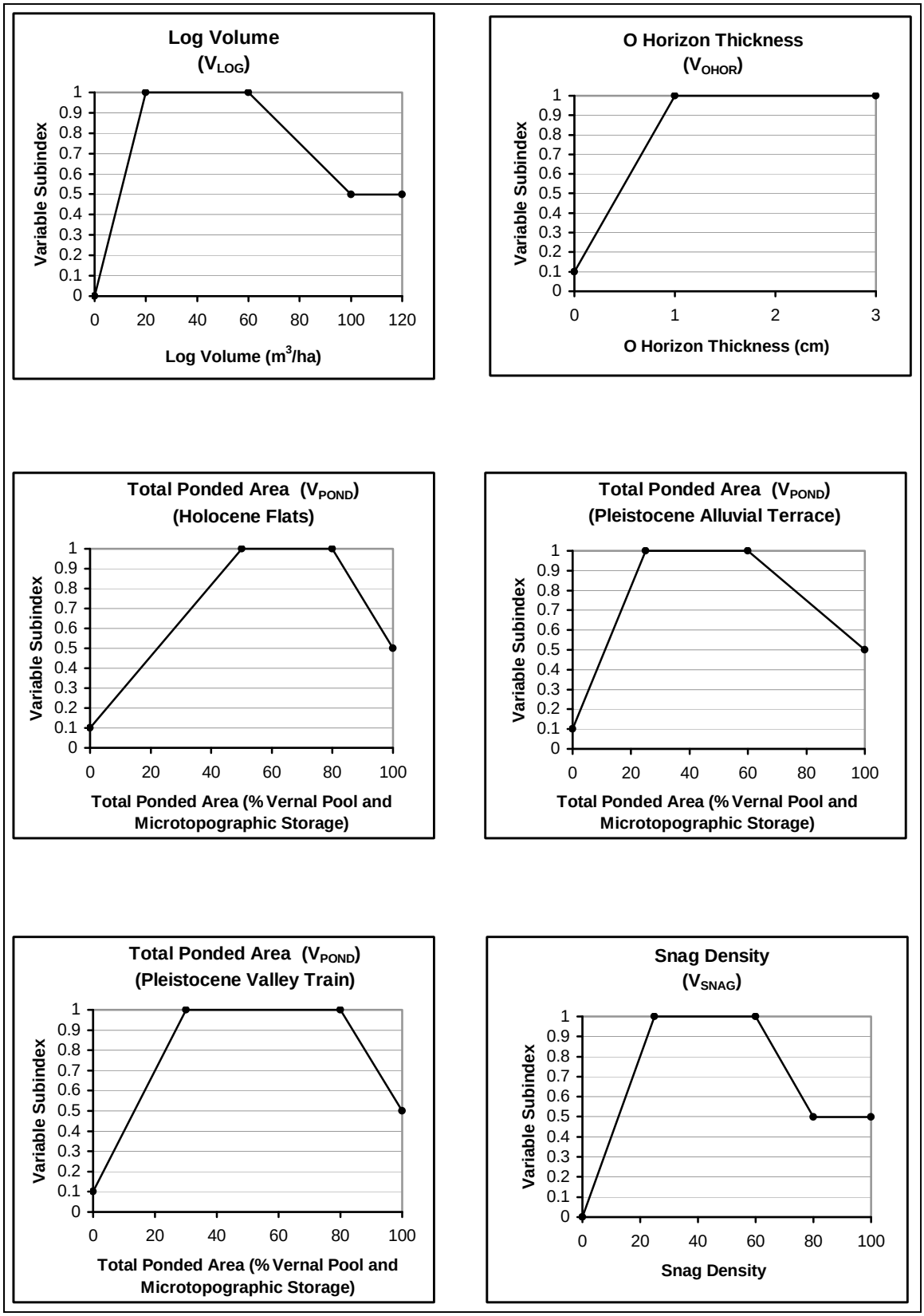


Figure 16. (Sheet 2 of 4).

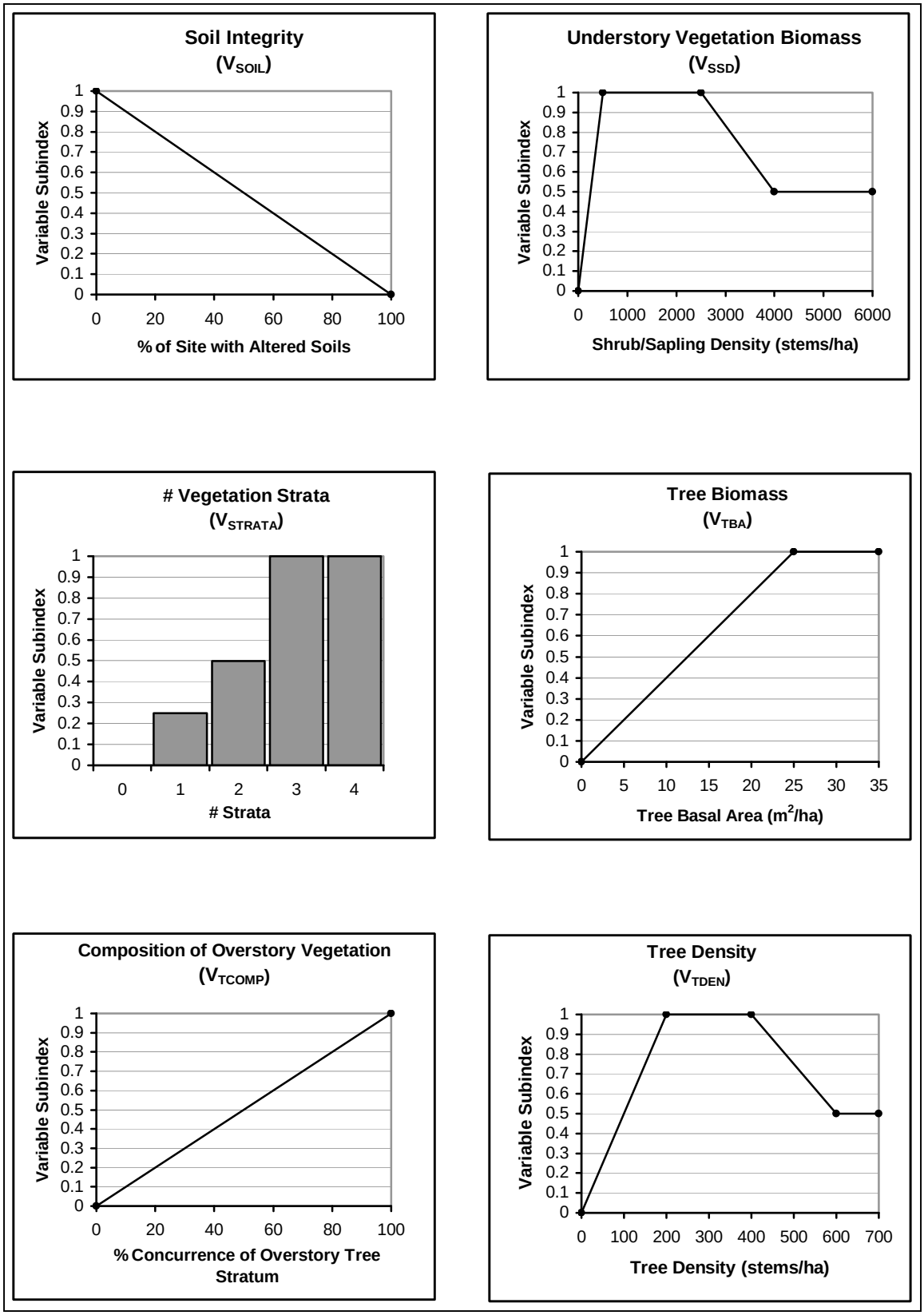


Figure 16. (Sheet 3 of 4).

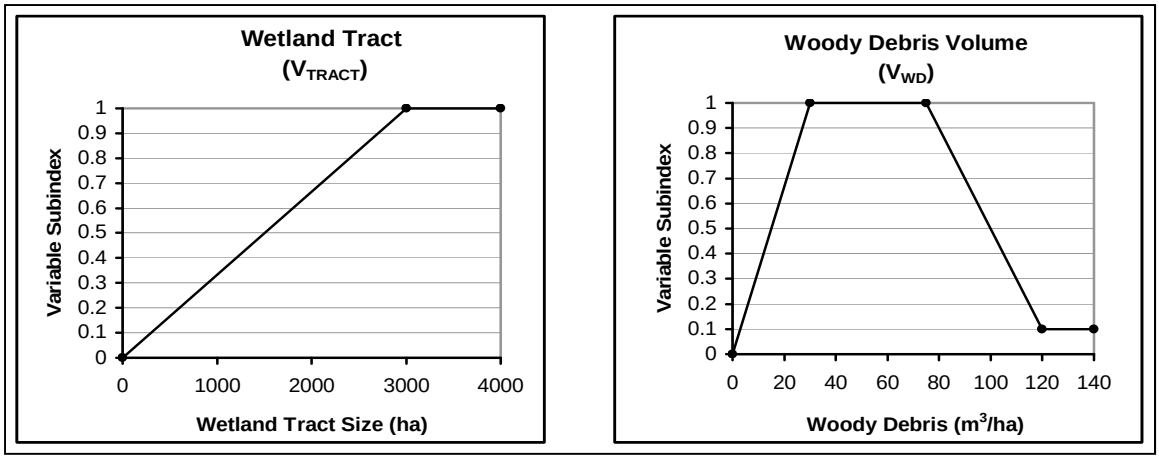


Figure 16. (Sheet 4 of 4).

Subclass: Low-Gradient Riverine Backwater

All functions are assessed for this subclass using the general form of each assessment model presented in Chapter 4 as follows. Figure 17 provides the relationship between the variable metrics and the subindex for each of the assessment variables based on the riverine backwater reference data.

a. Function 1: Detain Floodwater.

$$FCI = V_{FREQ} \times \left[\frac{\left(V_{LOG} + V_{GVC} + V_{SSD} + V_{TDEN} \right)}{4} \right] \tag{12}$$

b. Function 2: Detain Precipitation.

$$FCI = \frac{\left[V_{POND} + \frac{\left(V_{OHOR} + V_{LITTER} \right)}{2} \right]}{2} \tag{13}$$

c. Function 3: Cycle Nutrients.

$$FCI = \frac{\left[\frac{\left(V_{TBA} + V_{SSD} + V_{GVC} \right)}{3} + \frac{\left(V_{OHOR} + V_{AHOR} + V_{WD} + V_{SNAG} \right)}{4} \right]}{2} \tag{14}$$

d. Function 4: Export Organic Carbon.

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

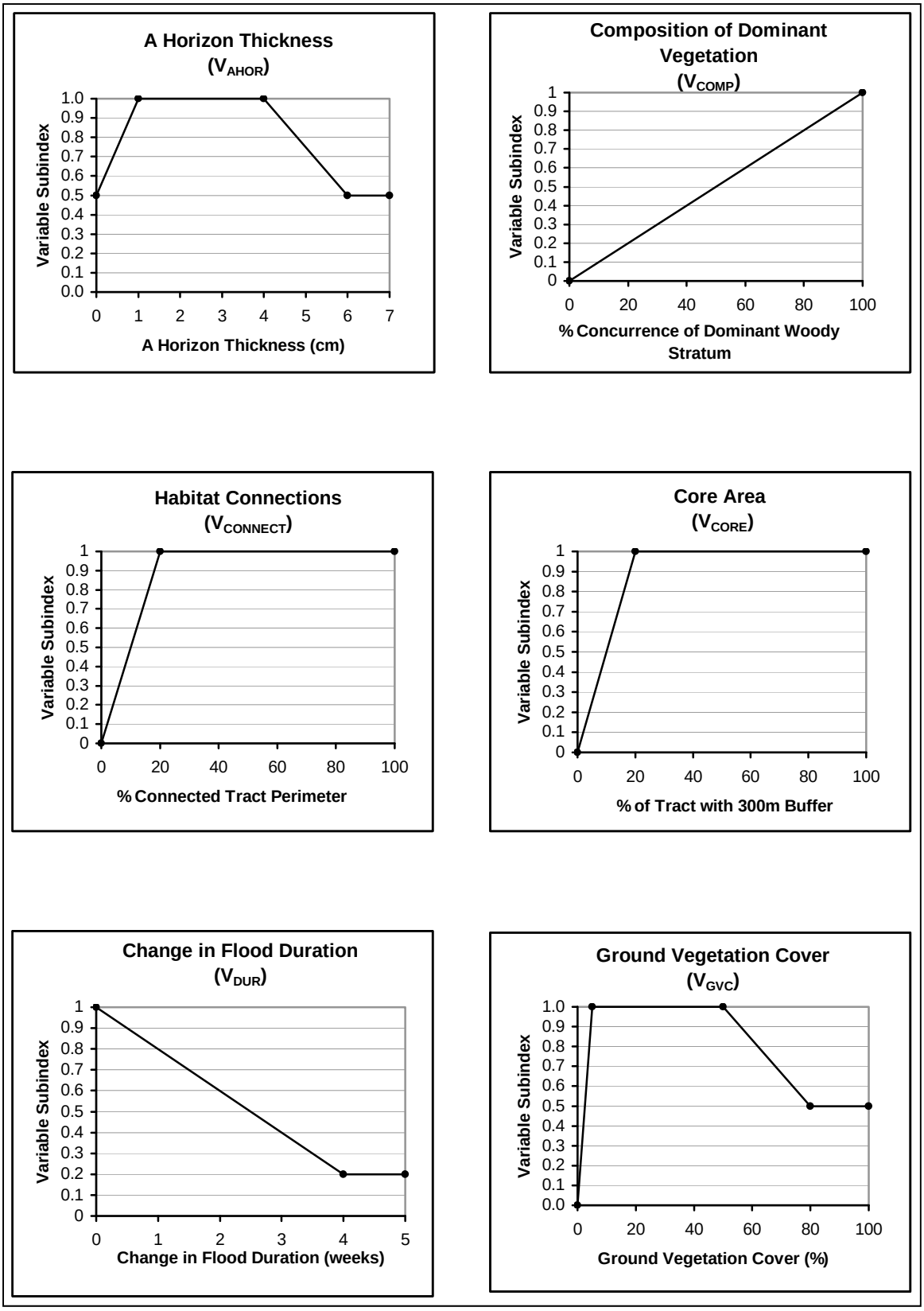


Figure 17. Subindex graphs for Low-Gradient Riverine Backwater wetlands (Sheet 1 of 4).

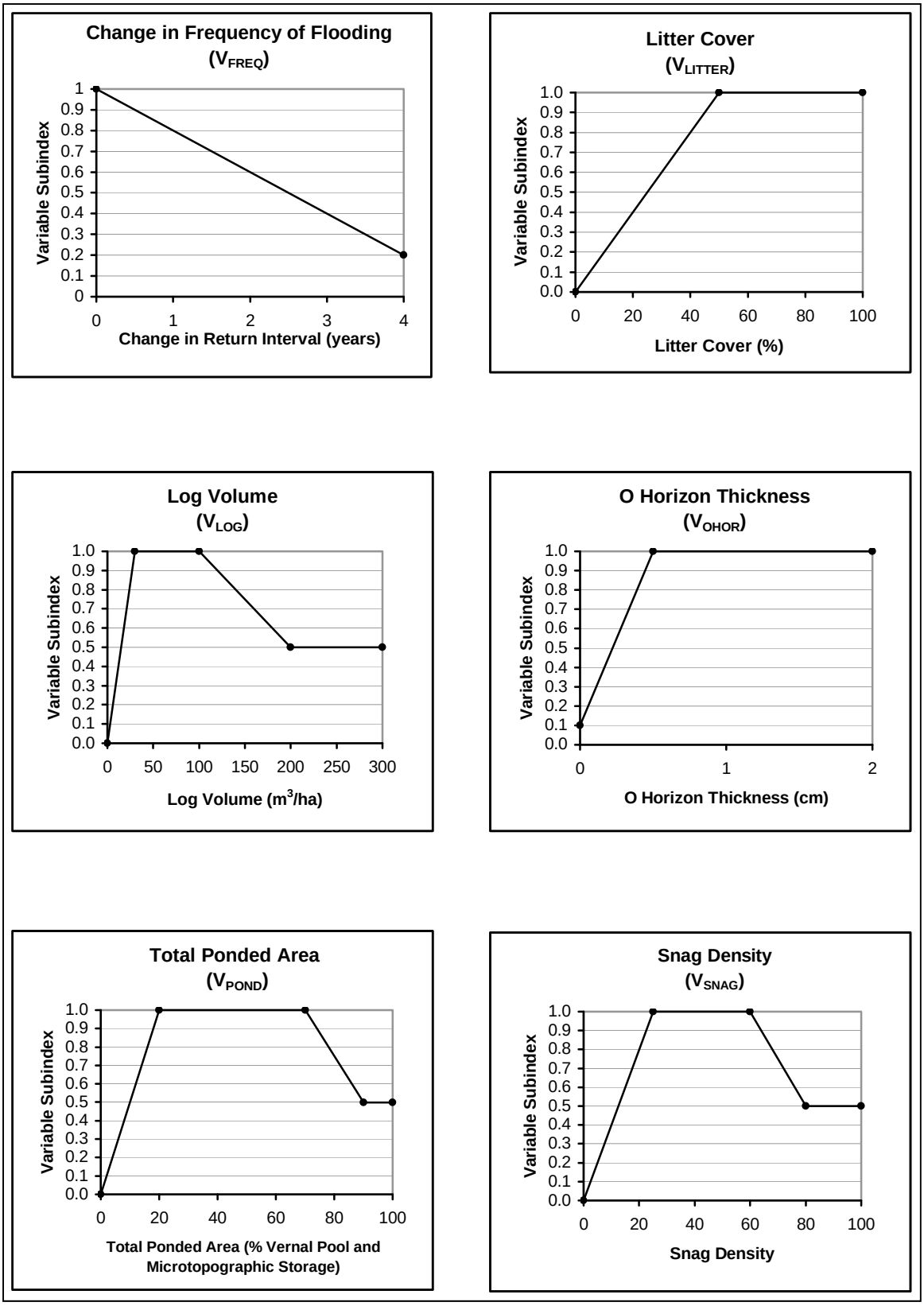


Figure 17. (Sheet 2 of 4).

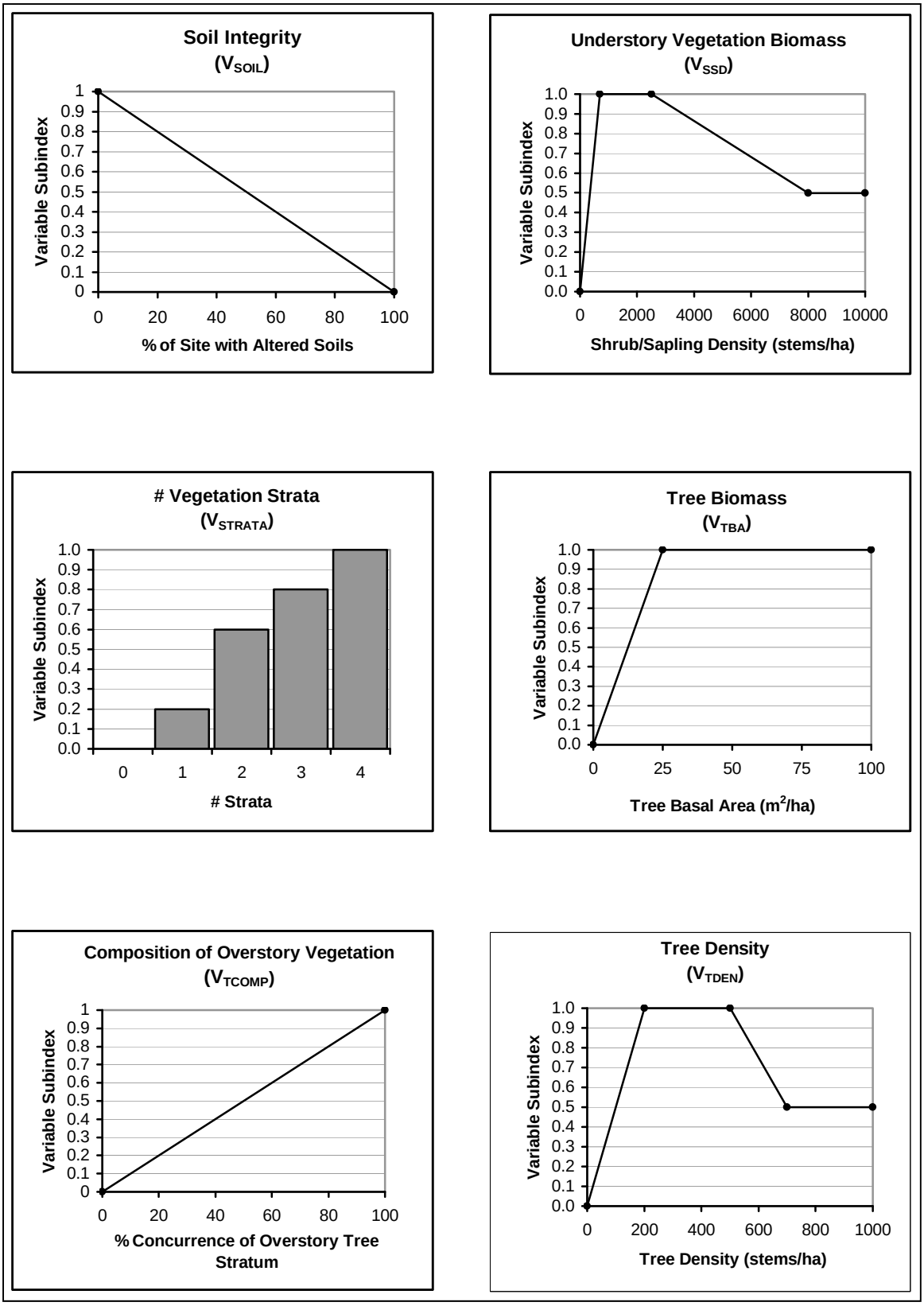


Figure 17. (Sheet 3 of 4).

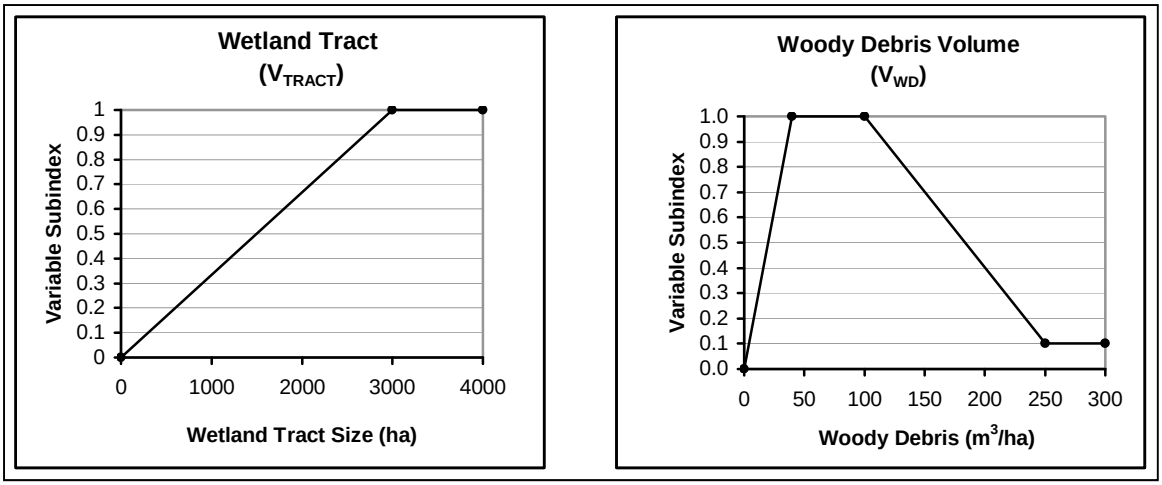


Figure 17. (Sheet 4 of 4).

e. Function 5: Maintain Plant Communities.

$$FCI = \left(\left\{ \frac{\left[\frac{\left(V_{TBA} + V_{TDEN} \right)}{2} + V_{COMP} \right]}{2} \right\} \times \left[\frac{\left(V_{SOIL} + V_{DUR} + V_{POND} \right)}{3} \right] \right)^{1/2} \tag{16}$$

f. Function 6: Provide Wildlife Habitat.

$$FCI = \left\{ \begin{array}{c} \left[\frac{\left(V_{FREQ} + V_{DUR} + V_{POND} \right)}{3} \right] \times \left[\frac{\left(V_{TCOMP} + V_{STRATA} + V_{SNAG} + V_{TBA} \right)}{4} \right] \times \\ \left[\frac{\left(V_{LOG} + V_{OHOR} \right)}{2} \right] \times \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE} \right)}{3} \right] \end{array} \right\}^{1/4} \tag{17}$$

Subclass: Low-Gradient Riverine Overbank

All functions are assessed for this subclass using the general form of each assessment model presented in Chapter 4 as follows. Figure 18 provides the relationship between the variable metrics and the subindex for each of the assessment variables based on the riverine overbank reference data.

a. Function 1: Detain Floodwater.

$$FCI = V_{FREQ} \times \left[\frac{\left(V_{LOG} + V_{GVC} + V_{SSD} + V_{TDEN} \right)}{4} \right] \tag{18}$$

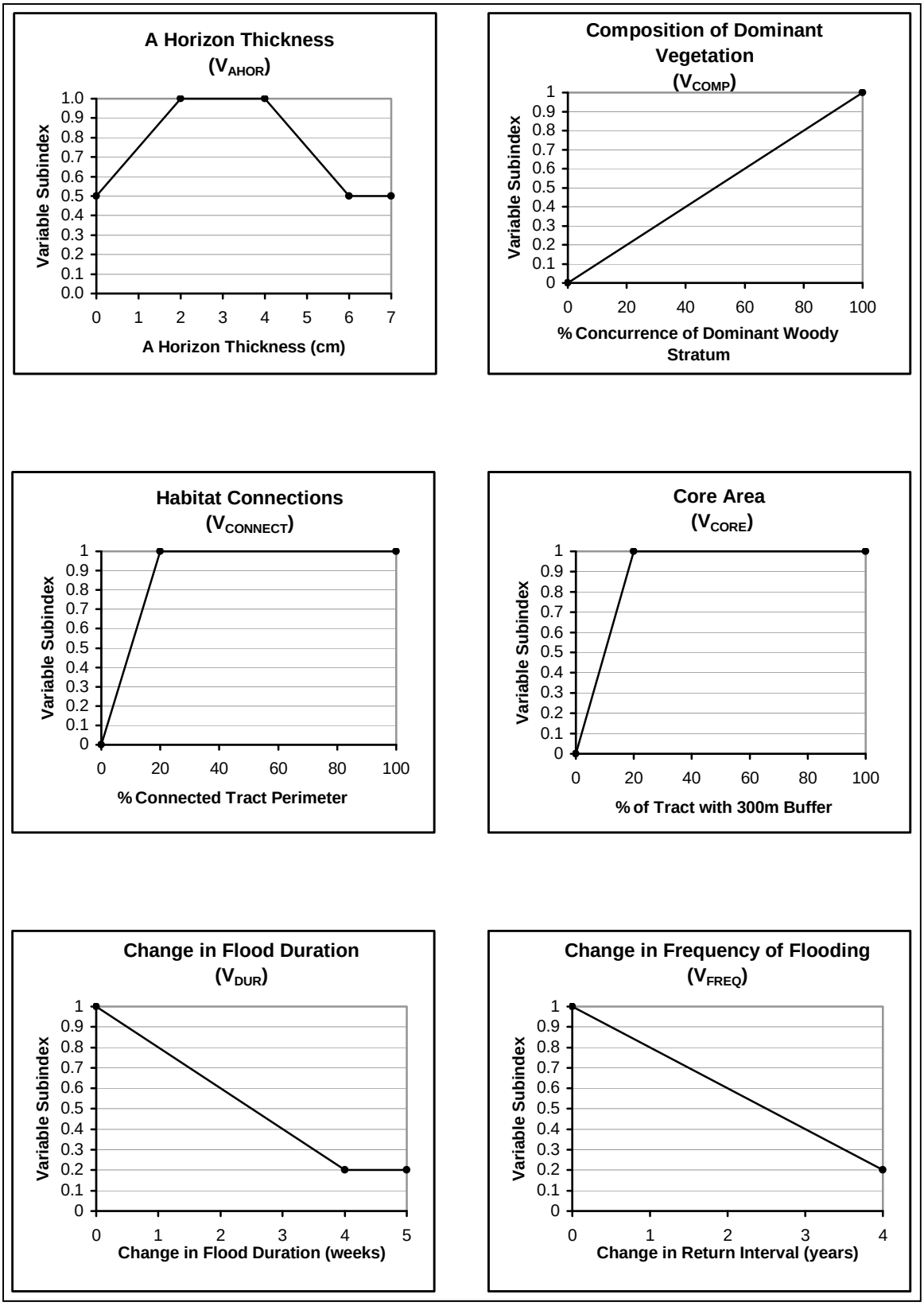


Figure 18. Subindex graphs for Low-Gradient Riverine Overbank wetlands (Sheet 1 of 4).

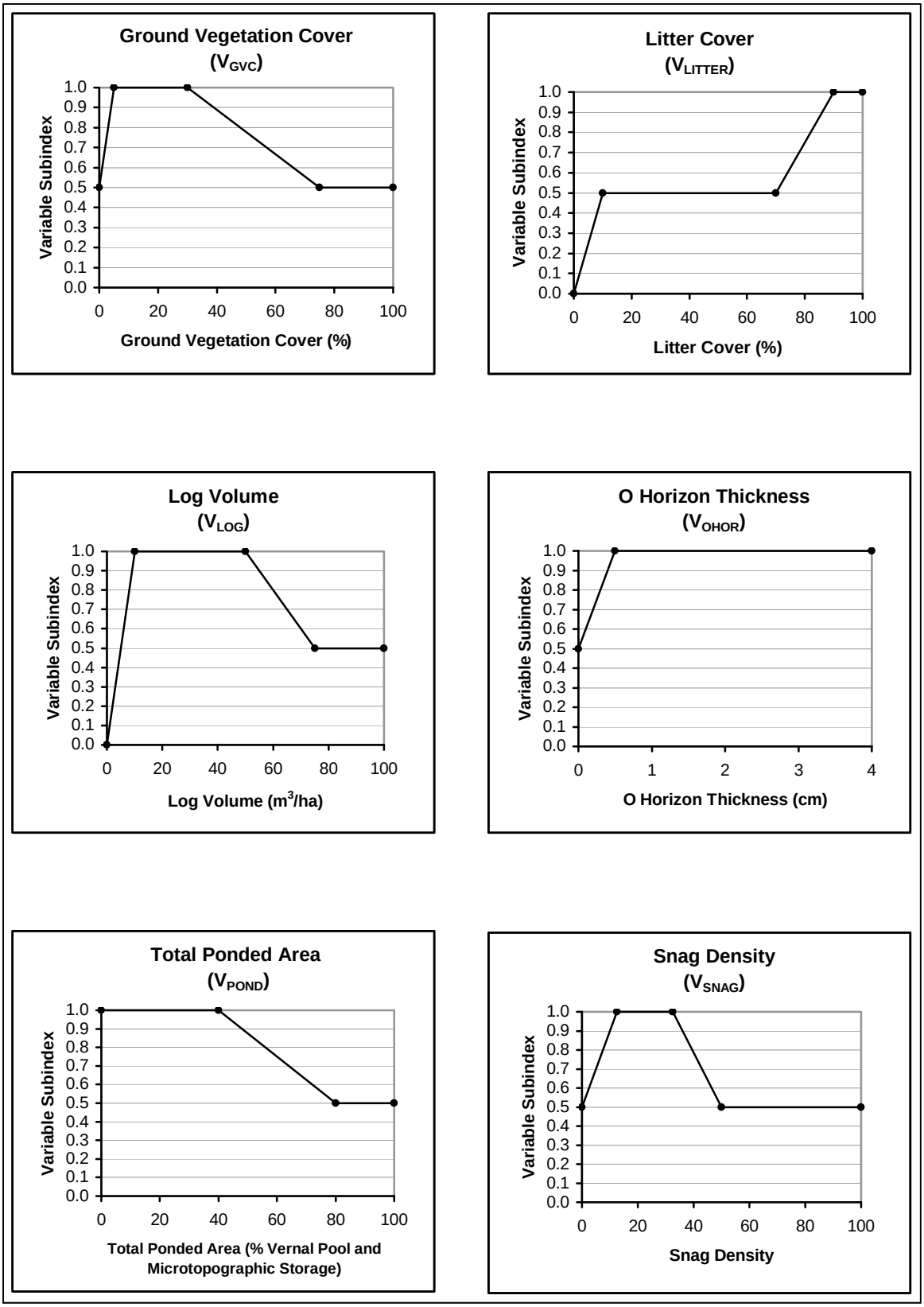


Figure 18. (Sheet 2 of 4).

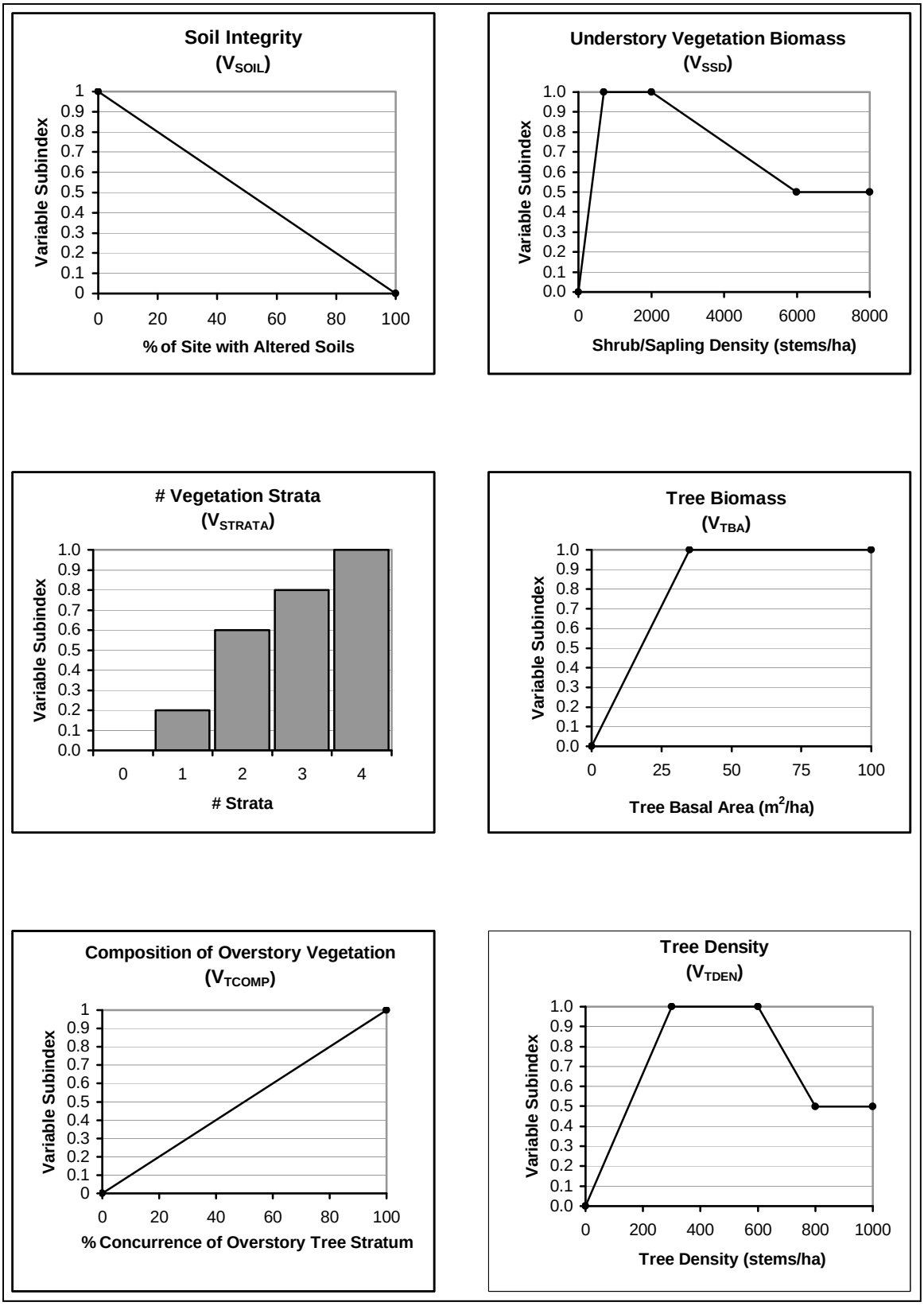


Figure 18. (Sheet 3 of 4).

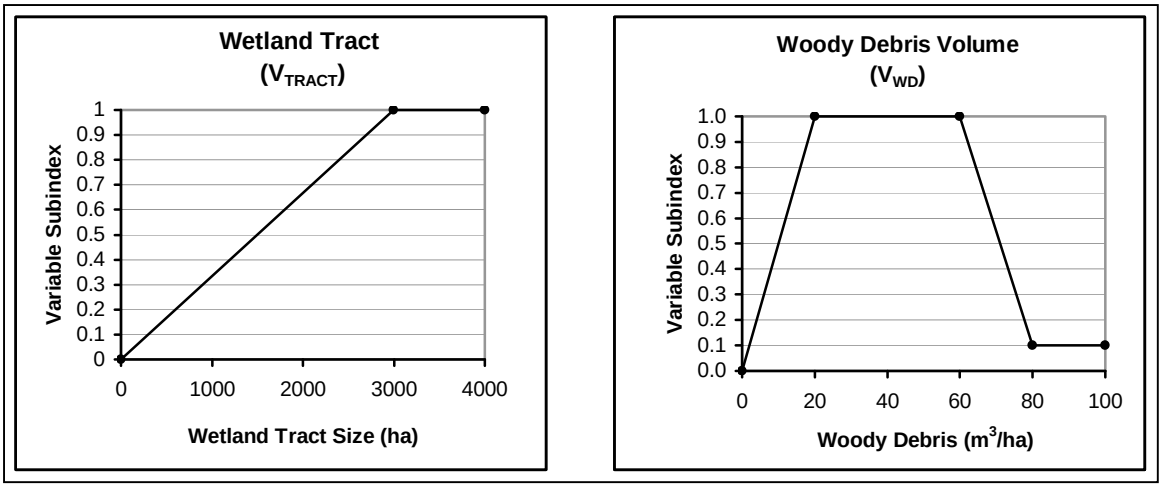


Figure 18. (Sheet 4 of 4).

b. Function 2: Detain Precipitation.

$$FCI = \frac{\left[V_{POND} + \frac{\left(V_{OHOR} + V_{LITTER}\right)}{2}\right]}{2} \tag{19}$$

c. Function 3: Cycle Nutrients.

$$FCI = \frac{\left[\frac{\left(V_{TBA} + V_{SSD} + V_{GVC}\right)}{3} + \frac{\left(V_{OHOR} + V_{AHOR} + V_{WD} + V_{SNAG}\right)}{4}\right]}{2} \tag{20}$$

d. Function 4: Export Organic Carbon.

$$FCI = V_{FREQ} \times \frac{\left[\frac{\left(V_{LITTER} + V_{OHOR} + V_{WD} + V_{SNAG}\right)}{4}\right] + \left[\frac{V_{TBA} + V_{SSD} + V_{GVC}}{3}\right]}{2} \tag{21}$$

e. Function 5: Maintain Plant Communities.

$$FCI = \left(\left\{\frac{\left[\frac{\left(V_{TBA} + V_{TDEN}\right)}{2} + V_{COMP}\right]}{2}\right\} \times \left[\frac{\left(V_{SOIL} + V_{DUR} + V_{POND}\right)}{3}\right]\right)^{1/2} \tag{22}$$

f. Function 6: Provide Wildlife Habitat.

$$FCI = \left\{ \begin{array}{c} \left[\frac{\left(V_{FREQ} + V_{DUR} + V_{POND}\right)}{3}\right] \times \left[\frac{\left(V_{TCOMP} + V_{STRATA} + V_{SNAG} + V_{TBA}\right)}{4}\right] \times \\ \left[\frac{\left(V_{LOG} + V_{OHOR}\right)}{2}\right] \times \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE}\right)}{3}\right] \end{array} \right\}^{1/4} \quad (23)$$

Subclass: Headwater Depression

Four functions are assessed for this subclass as shown in the following subparagraphs. All of the applicable models are modified from the general form presented in Chapter 4. In addition, alternate models are provided, which can be used in the event that ground-level observations cannot be made due to inundation. Figure 19 provides the relationship between the variable metrics and the subindex for each of the assessment variables based on the Headwater Depression reference data.

a. Function 1: Detain Floodwater. Not Assessed.
b. Function 2: Detain Precipitation. Not Assessed.
c. Function 3: Cycle Nutrients.

$$FCI = \frac{\left[\frac{\left(V_{TBA} + V_{SSD} + V_{GVC}\right)}{3} + \frac{\left(V_{OHOR} + V_{AHOR} + V_{WD} + V_{SNAG}\right)}{4}\right]}{2} \quad (24)$$

Applicable in the following alternate form when inundation prevents observation of ground-level features:

$$FCI = \frac{\left(V_{TBA} + V_{SSD} + V_{SNAG}\right)}{3} \quad (25)$$

d. Function 4: Export Organic Carbon.

$$FCI = V_{OUT} \times \frac{\left[\frac{\left(V_{LITTER} + V_{OHOR} + V_{WD} + V_{SNAG}\right)}{4}\right] + \left[\frac{\left(V_{TBA} + V_{SSD} + V_{GVC}\right)}{3}\right]}{2} \quad (26)$$

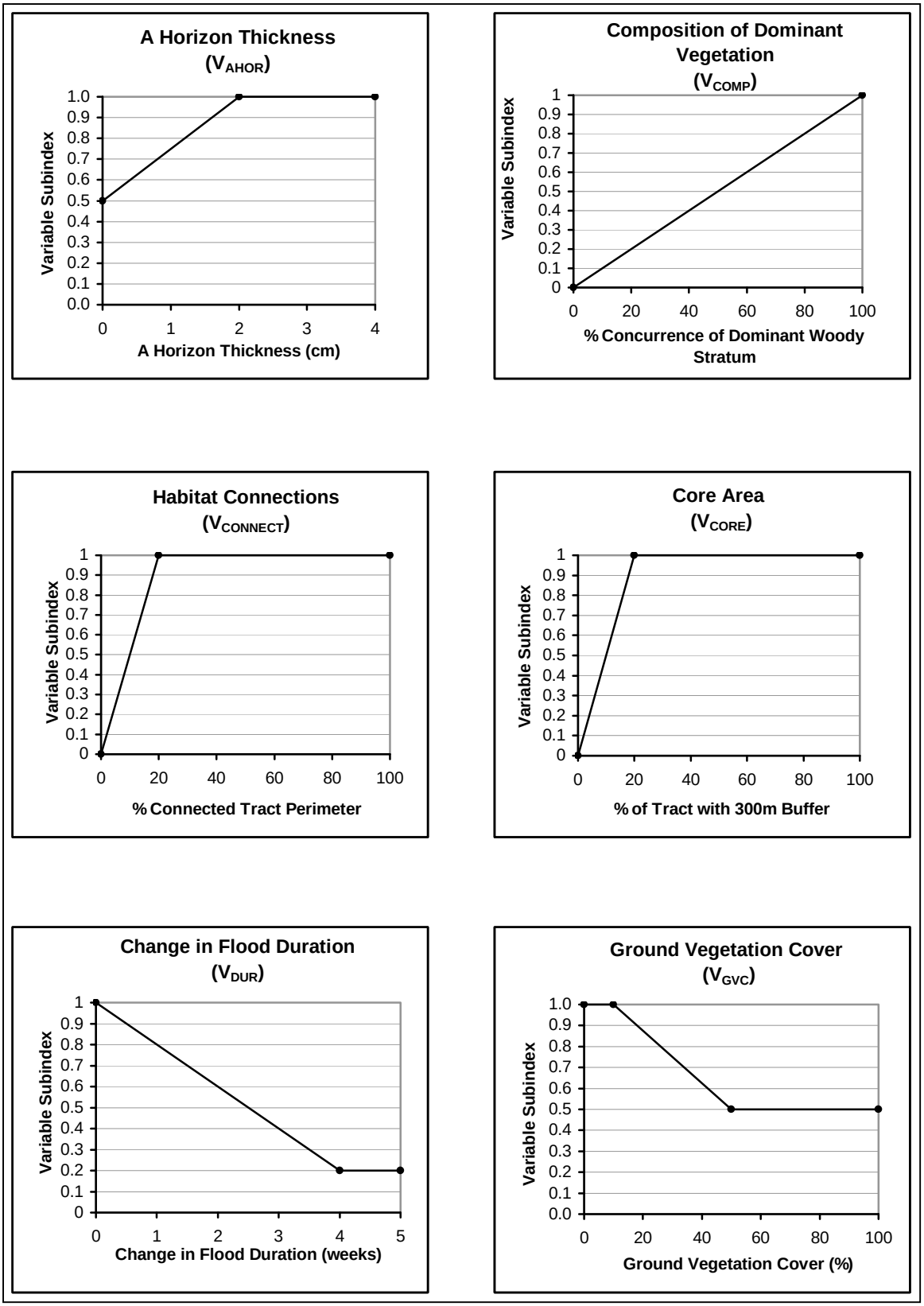
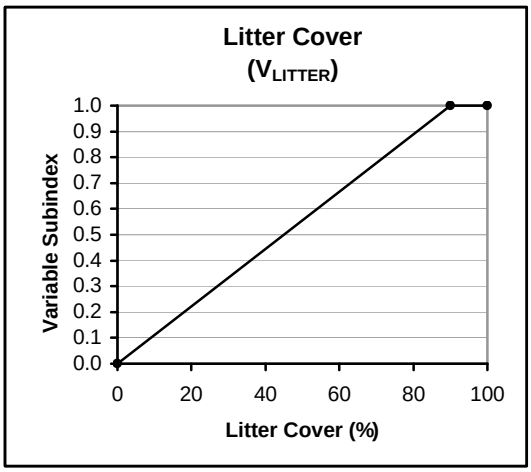
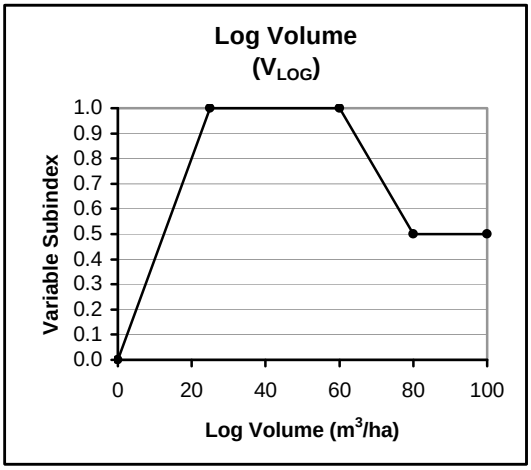
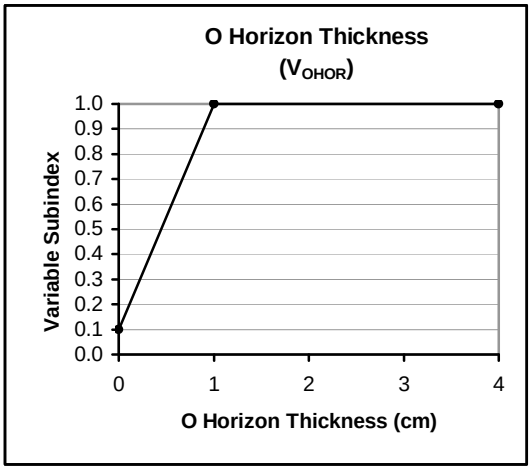


Figure 19. Subindex graphs for Headwater Depression wetlands (Sheet 1 of 4)

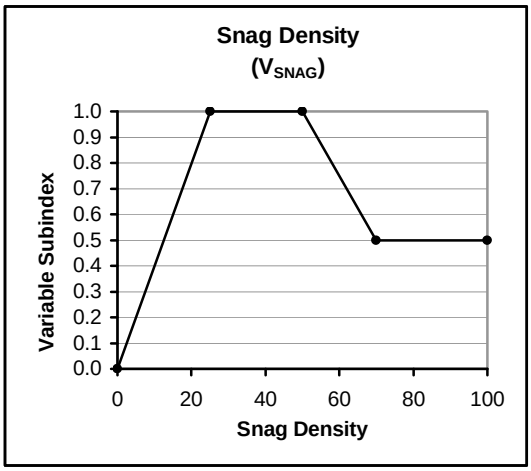






Change in Surface Water Outflow (V_{OUT})

	Before	
After	**Perennial**	**Seasonal**
Perennial	1.0	0.5
Seasonal	0.5	1.0
None	0	0



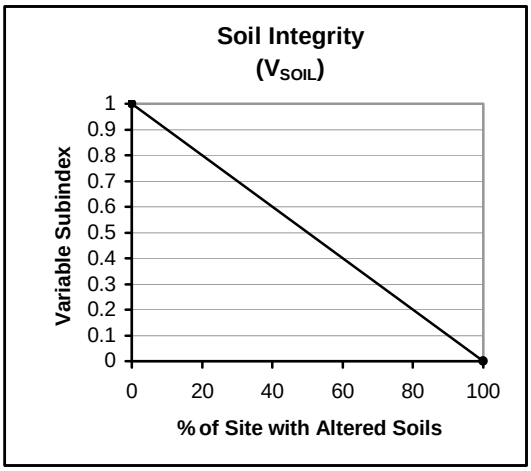


Figure 19. (Sheet 2 of 4).

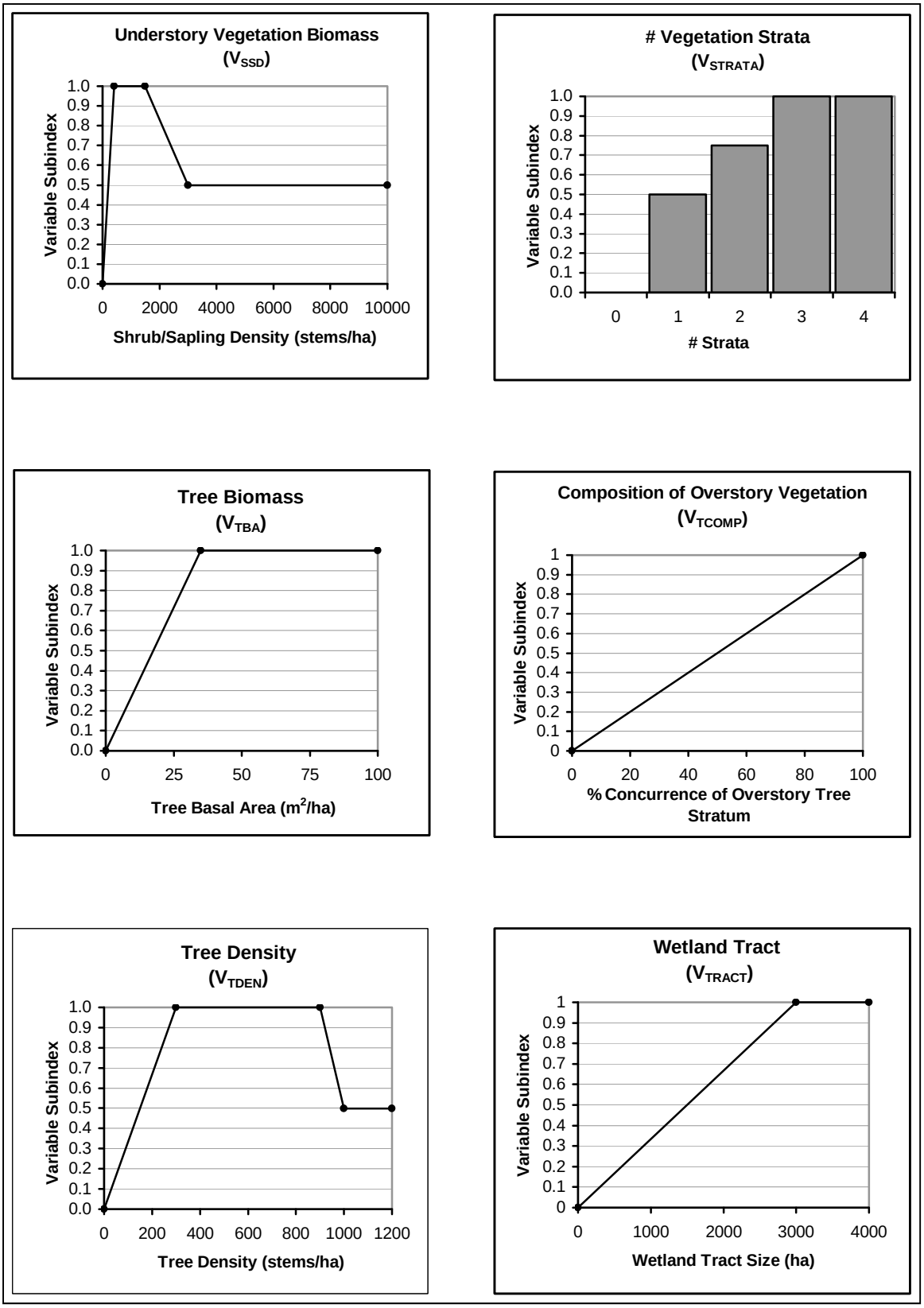


Figure 19. (Sheet 3 of 4).

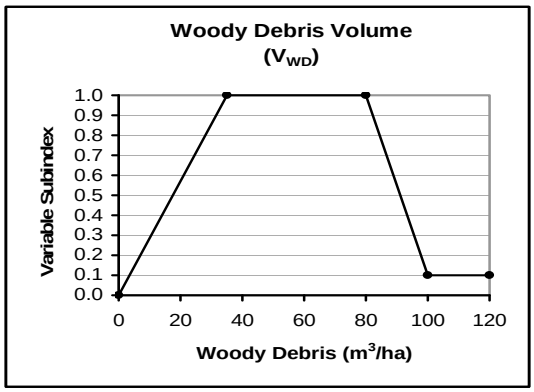


Figure 19. (Sheet 4 of 4).

Applicable in the following alternate form when inundation prevents observation of ground-level features:

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

e. *Function 5: Maintain Plant Communities. Applicable in the following modified form:*

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

Applicable in the following alternate form when inundation prevents observation of ground-level features:

$$FCI = \left(\left\{ \frac{\left[\frac{\left(V_{TBA} + V_{TDEN} \right)}{2} + V_{COMP} \right]}{2} \right\} \times V_{DUR} \right)^{1/2} \tag{29}$$

f. *Function 6: Provide Wildlife Habitat*. Applicable in the following modified form:

$$FCI = \left\{ \begin{array}{l} V_{DUR} \times \left[\frac{\left(V_{TCOMP} + V_{STRATA} + V_{SNAG} + V_{TBA} \right)}{4} \right] \times \\ \left[\frac{\left(V_{LOG} + V_{OHOR} \right)}{2} \right] \times \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE} \right)}{3} \right] \end{array} \right\}^{1/4} \tag{30}$$

Applicable in the following alternate form when inundation prevents observation of ground-level features:

$$FCI = \left\{ V_{DUR} \times \left[\frac{\left(V_{TCOMP} + V_{STRATA} + V_{SNAG} + V_{TBA} \right)}{4} \right] \times \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE} \right)}{3} \right] \right\}^{1/3} \tag{31}$$

Note that Headwater Depressions differ from other wetland types in that they are connected to the river system, not by river flooding, but by being a headwater source of river flows. As such, V_{FREQ}, the change in frequency of riverine flooding, is not used in these models. V_{OUT}, the change in outflow, is used in the Export Organic Carbon model. However, the Detain Floodwater model is not assessed for this subclass, because that function as defined refers specifically to capture of out-of-bank stream floodwaters. Because the Headwater Depression type evidently is groundwater-maintained, water is unlikely to be delivered to the system with the sudden hydrograph peak observed on stream systems; thus the contribution to floodwater detention is more similar to non-flooded systems and is not assessed here.

V_{OUT} is used in the Export Organic Carbon model, because organic material produced within the wetland is likely to move downstream with the outflow. Headwater Depressions having unaltered connections to their streams, whether it be a seasonal or perennial outflow, are assessed as having a subindex of 1.0 for V_{OUT}. If the Headwater Swamp is altered such that the outflow has changed from perennial to seasonal (e.g., if a boarded outflow has been installed to increase ponding within the depression part of the year) or from seasonal to perennial (e.g., if irrigation runoff is directed through the depression), then the subindex is assessed as a 0.5. Any change to any Headwater Swamp that cuts it off from its stream (e.g., a berm across the outlet) results in a V_{OUT} of 0 (Figure 19).

V_{OUT} is not used as a hydrology variable in the wildlife habitat model, where V_{FREQ} normally is intended to indicate primarily waterfowl and fish habitat availability. This is because flood timing may differ significantly from other wetland types, and because it is unlikely that these systems have fisheries functions similar to those of the Connected Depression or Low-Gradient Riverine subclasses. Unlike those river-inundated systems, Headwater Depression wetlands are not periodically overwhelmed by

floodwaters, but are connected to downstream systems by small and often intermittent channels. Although fish may or may not access these sites on a regular basis, too little is known about such use to support inclusion of this variable in the assessment process for habitat functions.

As for all of the depressional subclasses, the "percent ponding" variable is excluded from the models. Ponding (microdepressional storage) is difficult to estimate within an overall depressional system, as these systems generally drain to a central low point, then fill and overwhelm individual pond sites. The functional contribution of the micro-sites to precipitation storage, wildlife habitat, and similar functions is not evident in a system where a single, large pool is the dominant hydrologic feature. However, unlike other depressions, flood duration (V_{DUR}) is used in the vegetation and habitat functional models. This is because the outflow point of a headwater swamp serves as a place where flows can easily be detained and the depth and duration of flooding can be maximized, altering vegetation composition and structure, as well as habitat potential. Reference sites often showed this sort of alteration, sometimes in the form of a blocked culvert.

Subclass: Unconnected Depression

Three functions are assessed for this subclass as follows. Some of the applicable models are modified from the general form presented in Chapter 4. Alternate versions also are provided that can be used in the event that ground-level observations cannot be made due to inundation. Figure 20 provides the relationship between the variable metrics and the subindex for each of the assessment variables based on the Unconnected Depression reference data.

a. *Function 1: Detain Floodwater*. Not assessed.
b. *Function 2: Detain Precipitation*. Not assessed.
c. *Function 3: Cycle Nutrients.*

$$FCI = \frac{\left[\frac{\left(V_{TBA} + V_{SSD} + V_{GVC}\right)}{3} + \frac{\left(V_{OHOR} + V_{AHOR} + V_{WD} + V_{SNAG}\right)}{4}\right]}{2} \qquad (32)$$

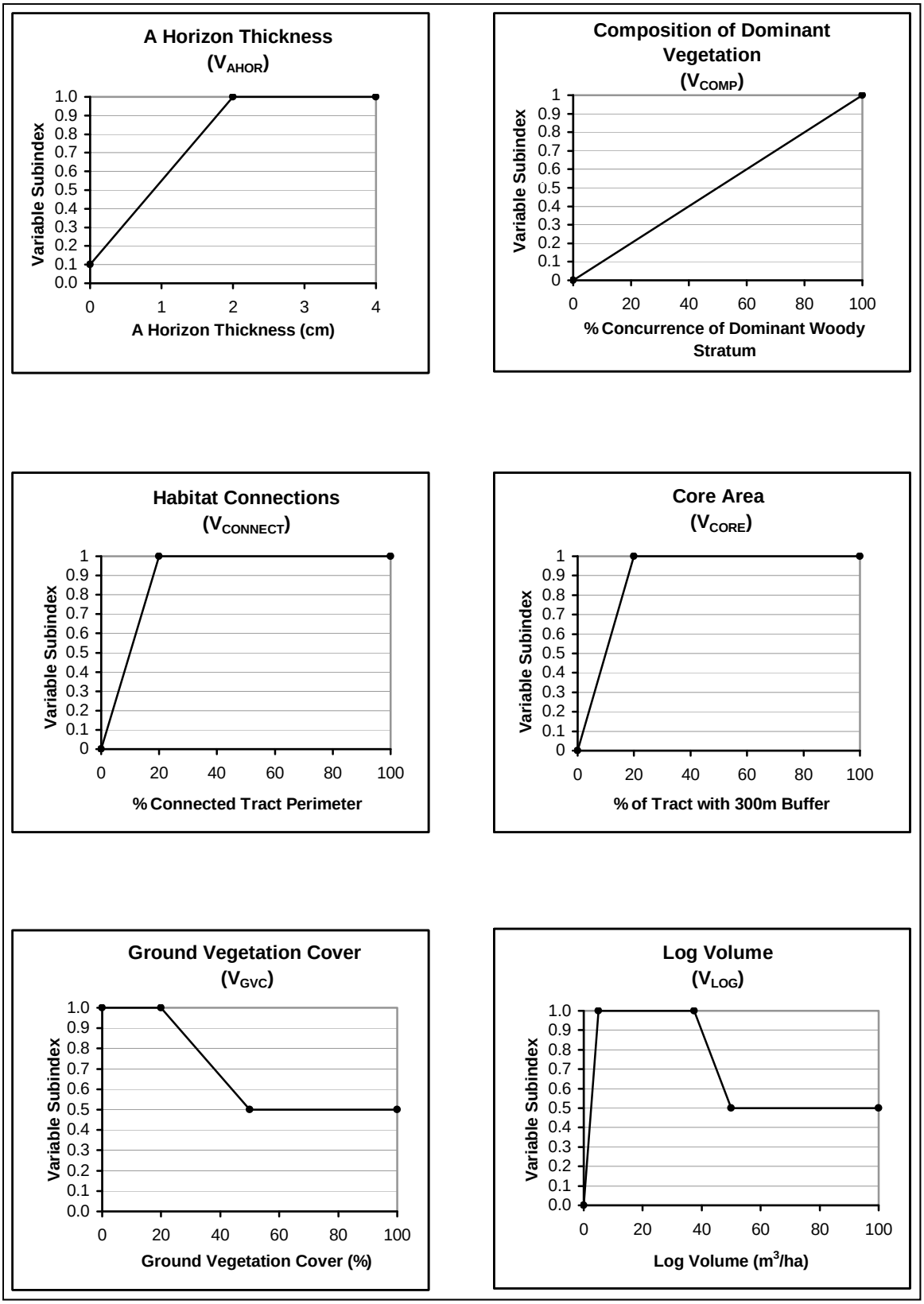


Figure 20. Subindex graphs for Unconnected Depression wetlands (Sheet 1 of 3).

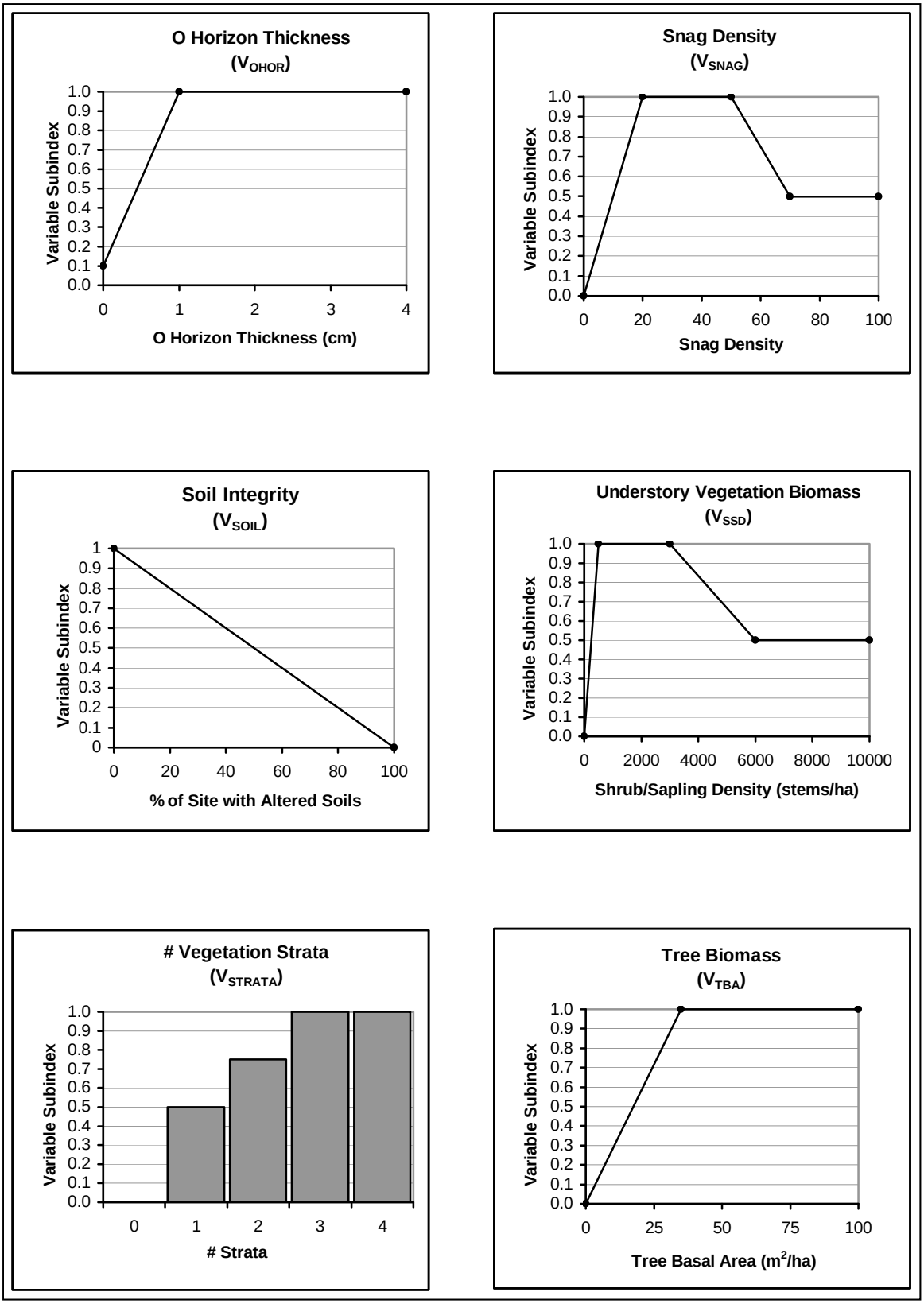


Figure 20. (Sheet 2 of 3).

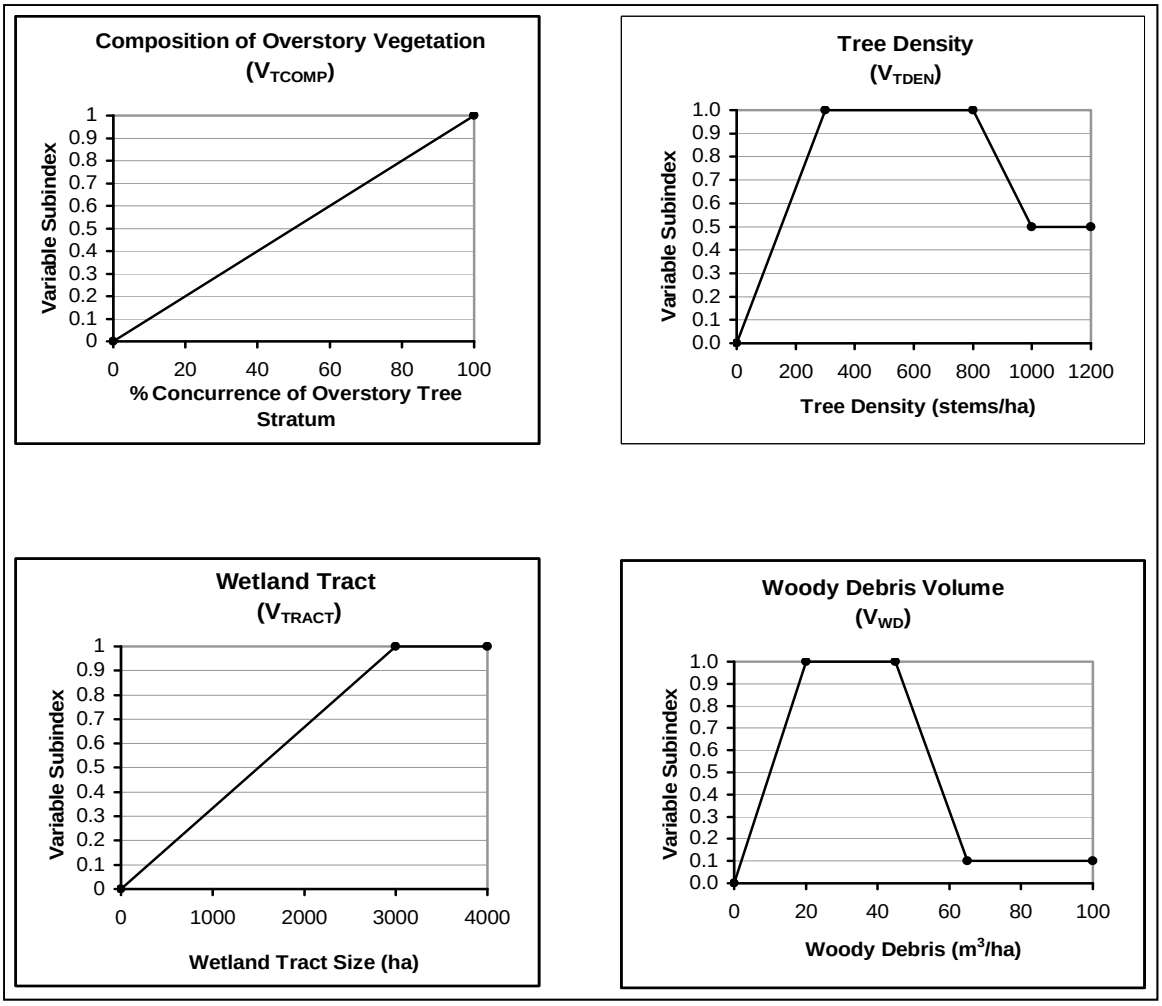


Figure 20. (Sheet 3 of 3).

Applicable in the following alternate form when inundation prevents observation of ground-level features:

$$FCI = \frac{\left(V_{TBA} + V_{SSD} + V_{SNAG}\right)}{3} \tag{33}$$

d. Function 4: Export Organic Carbon. Not assessed.

e. Function 5: Maintain Plant Communities. Applicable in the following modified form:

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

Applicable in the following alternate form when inundation prevents observation of ground-level features:

$$FCI = \frac{\left[\frac{\left(V_{TBA} + V_{TDEN}\right)}{2} + V_{COMP}\right]}{2} \tag{35}$$

f. Function 6: Provide *Wildlife Habitat*. Applicable in the following modified form:

$$FCI = \left\{ \begin{array}{c} \left[\frac{\left(V_{TCOMP} + V_{STRATA} + V_{SNAG} + V_{TBA}\right)}{4}\right] \times \\ \left[\frac{\left(V_{LOG} + V_{OHOR}\right)}{2}\right] \times \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE}\right)}{3}\right] \end{array} \right\}^{1/3} \tag{36}$$

Applicable in the following alternate form when inundation prevents observation of ground-level features:

$$FCI = \left\{ \left[\frac{\left(V_{TCOMP} + V_{STRATA} + V_{SNAG} + V_{TBA}\right)}{4}\right] \times \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE}\right)}{3}\right] \right\}^{1/2} \tag{37}$$

Subclass: Connected Depression

Six functions are assessed for this subclass as follows. Some of the models have been modified from the general model form presented in Chapter 4. Figure 21 provides the relationship between the variable metrics and the subindex for each of the assessment variables based on the Connected Depression reference data.

a. Function 1: Detain Floodwater.

$$FCI = V_{FREQ} \times \left[\frac{\left(V_{LOG} + V_{GVC} + V_{SSD} + V_{TDEN}\right)}{4}\right] \tag{38}$$

Applicable in the following alternate form when inundation prevents observation of ground-level features:

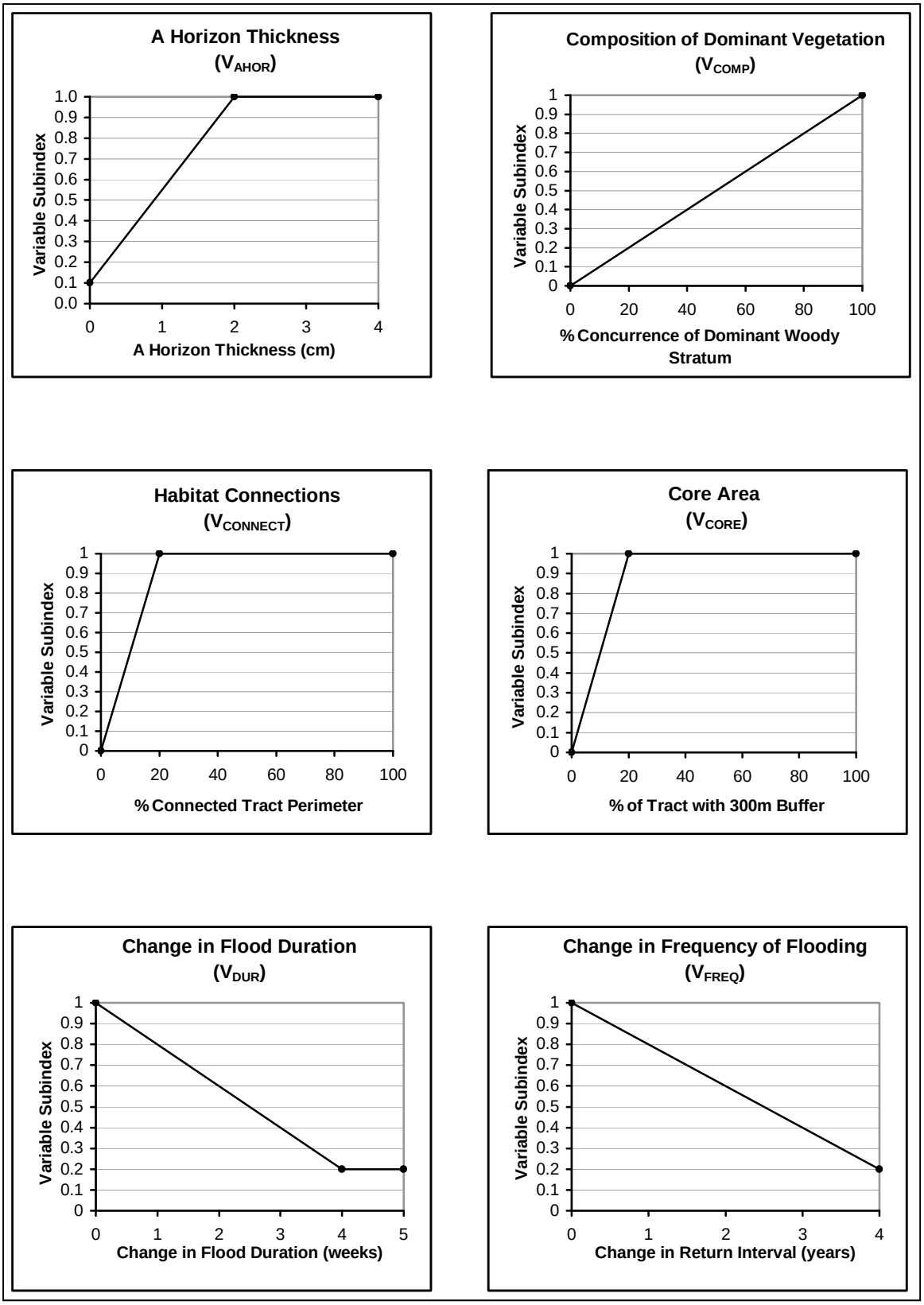


Figure 21. Subindex graphs for Connected Depression wetlands (Sheet 1 of 4).

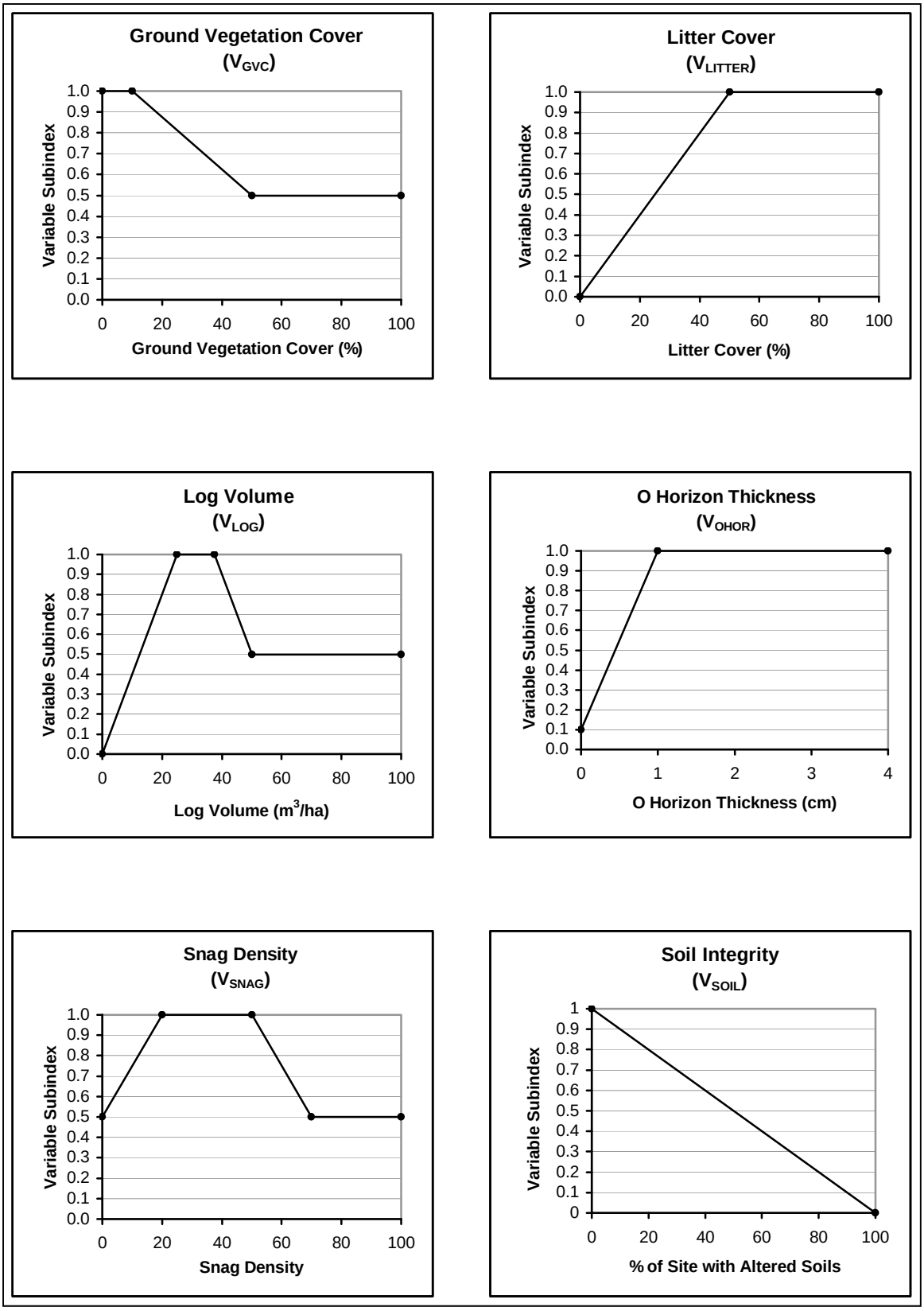


Figure 21. (Sheet 2 of 4).

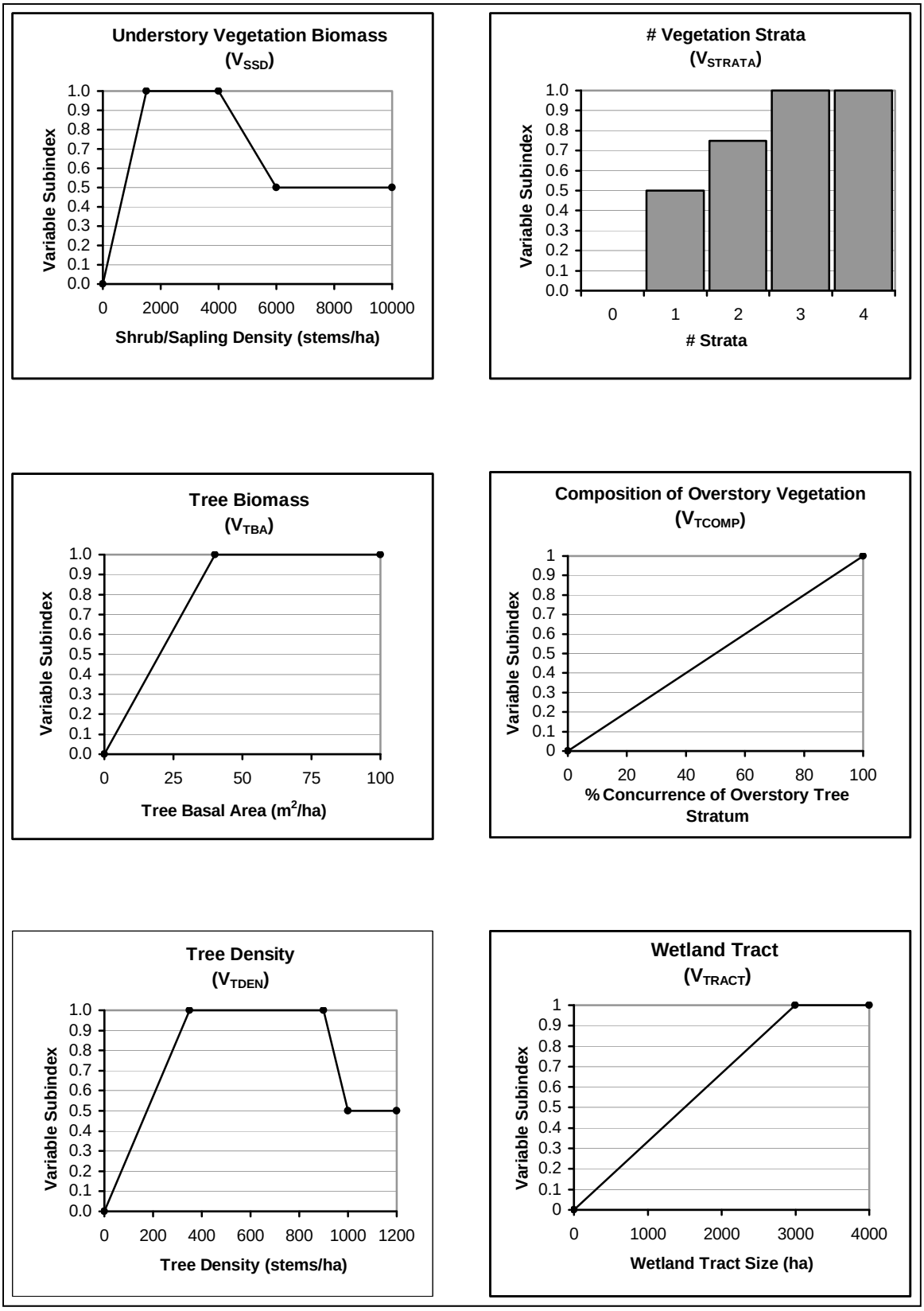


Figure 21. (Sheet 3 of 4).

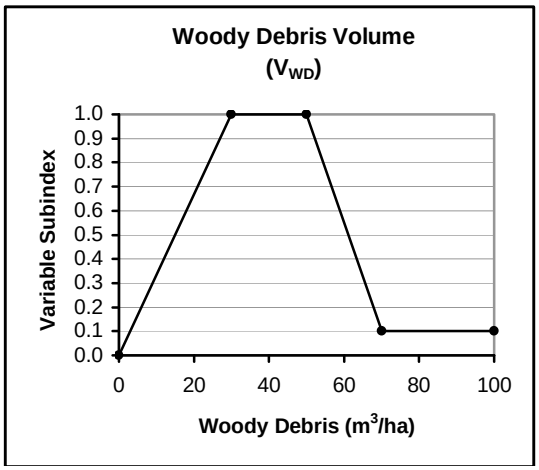


Figure 21. (Sheet 4 of 4).

$$FCI = V_{FREQ} \times \left[\frac{\left(V_{SSD} + V_{TDEN} \right)}{2} \right] \tag{39}$$

b. *Function 2: Detain Precipitation*. Not assessed.

c. *Function 3: Cycle Nutrients*. Applicable in the following modified form:

$$FCI = \frac{\left[\frac{\left(V_{TBA} + V_{SSD} + V_{GVC} \right)}{3} + \frac{\left(V_{OHOR} + V_{AHOR} + V_{WD} + V_{SNAG} \right)}{4} \right]}{2} \tag{40}$$

Applicable in the following alternate form when inundation prevents observation of ground-level features:

$$FCI = \frac{\left(V_{TBA} + V_{SSD} + V_{SNAG} \right)}{3} \tag{41}$$

d. *Function 4: Export Organic Carbon*. Applicable in the following modified form:

$$FCI = V_{FREQ} \times \left\{ \frac{\left[\frac{\left(V_{LITTER} + V_{OHOR} + V_{WD} + V_{SNAG} \right)}{4} \right] + \left[\frac{\left(V_{TBA} + V_{SSD} + V_{GVC} \right)}{3} \right]}{2} \right\} \tag{42}$$

Applicable in the following alternate form when inundation prevents observation of ground-level features:

$$FCI = V_{FREQ} \times \left[\frac{\left(V_{TBA} + V_{SSD} + V_{SNAG} \right)}{3} \right] \tag{43}$$

e. Function 5: Maintain Plant Communities. Applicable in the following modified form:

$$FCI = \left(\left\{ \frac{\left[\frac{\left(V_{TBA} + V_{TDEN} \right)}{2} + V_{COMP} \right]}{2} \right\} \times \left[\frac{\left(V_{SOIL} + V_{DUR} \right)}{2} \right] \right)^{1/2} \tag{44}$$

Applicable in the following alternate form when inundation prevents observation of ground-level features:

$$FCI = \left(\left\{ \frac{\left[\frac{\left(V_{TBA} + V_{TDEN} \right)}{2} + V_{COMP} \right]}{2} \right\} \times V_{DUR} \right)^{1/2} \tag{45}$$

f. Function 6: Provide *Wildlife Habitat*. Applicable in the following modified form:

$$FCI = \left\{ \begin{array}{c} \left[\frac{V_{FREQ} + V_{DUR}}{2} \right] \times \left[\frac{\left(V_{TCOMP} + V_{STRATA} + V_{SNAG} + V_{TBA} \right)}{4} \right] \times \\ \left[\frac{\left(V_{LOG} + V_{OHOR} \right)}{2} \right] \times \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE} \right)}{3} \right] \end{array} \right\}^{1/4} \tag{46}$$

Applicable in the following alternate form when inundation prevents observation of ground-level features:

$$FCI = \left\{ \begin{array}{c} \left[\frac{V_{FREQ} + V_{DUR}}{2} \right] \times \left[\frac{\left(V_{TCOMP} + V_{STRATA} + V_{SNAG} + V_{TBA} \right)}{4} \right] \times \\ \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE} \right)}{3} \right] \end{array} \right\}^{1/3} \tag{47}$$

6 Assessment Protocol

Introduction

Previous chapters of this Regional Guidebook have provided background information on the HGM Approach, characterized regional wetland subclasses, and have documented the variables, functional indices, and assessment models used to assess regional wetland subclasses in the Delta Region of Arkansas. This chapter outlines the procedures for collecting and analyzing the data required to conduct an assessment.

In most cases, permit review, restoration planning, and similar assessment applications require that pre- and post-project conditions of wetlands at the project site be compared to develop estimates of the loss or gain of function associated with the project. Both the pre- and post-project 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 post-project conditions used in making an assessment.

Where the proposed project involves wetland restoration or compensatory mitigation, this guidebook can also be used to assess the functional effectiveness of the proposed actions. The final section of this chapter provides recovery trajectory curves for selected variables that may be employed in that analysis.

A series of tasks are required to assess regional wetland subclasses in the Delta Region of Arkansas using the HGM Approach:

- Document the project purpose and characteristics.
- Screen for red flags.
- Define assessment objectives and identify regional wetland subclass(es) present, and assessment area boundaries.
- Collect field data.
- Analyze field data.
- Document assessment results.
- Apply assessment results.

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

Document the project purpose and characteristics

Data Sheet A1 (Site or Project Information and Assessment Documentation, Figure A1, Appendix A) provides a checklist of information needed to conduct a complete assessment, and serves as a cover sheet for all compiled assessment maps, drawings, data sheets, and other information. It requires the assignment of a project name, identification of personnel involved in the assessment, and attachment of supporting information and documentation. The first step in this process is to develop a narrative explanation of the project, with supporting maps and graphics. This should include a description of the project purpose and project area features, which can include information on location, 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 accompanying maps and drawings should indicate the locations of the project area boundaries, jurisdictional wetlands, wetland assessment areas (described later in this chapter), proposed impacts, roads, ditches, buildings, streams, soil types, plant communities, threatened or endangered species habitats, and other important features.

Many sources of information will be useful in characterizing a project area:

- Aerial photographs.
- Topographic maps.
- Geomorphic maps (Saucier 1994).
- County soil survey.
- National Wetland Inventory maps.
- Chapter 3 of this Regional Guidebook.

For large projects or complex landscapes, it is usually a good idea to use aerial photos and geomorphic information (from Appendix E) to develop a preliminary classification of wetlands for the project area and vicinity prior to going to the field. Figure 22 illustrates this process for a typical Delta lowland wetland complex. The rough wetland map can then be taken to the field to refine and revise the identification of wetland subclasses.

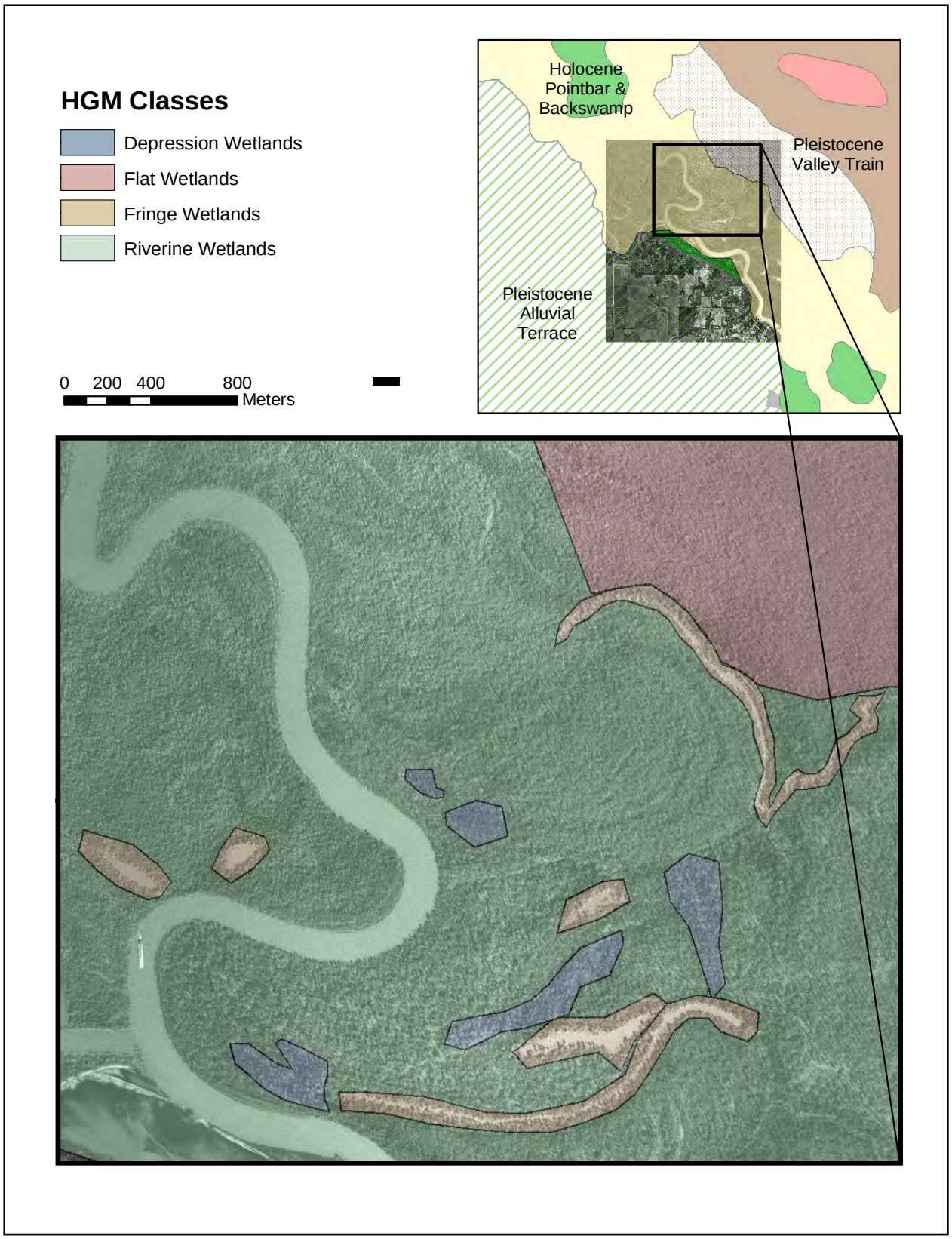


Figure 22. Example application of geomorphic mapping and aerial photography to develop a preliminary wetland classification for a proposed project area.

Attach the completed Project Description and supporting materials to Data Sheet A1.

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 8). 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 adversely affect threatened or endangered species, an assessment may be unnecessary since the project may be denied or modified based on the impacts to the protected species alone.

Define assessment objectives, identify regional wetland subclass(es) present, and identify assessment area boundaries

Begin the assessment process by unambiguously stating the objective of conducting the assessment. Most commonly, this will be simply to determine how a proposed project will impact wetland functions. However, there are other potential objectives:

- Compare several wetlands as part of an alternatives analysis.
- Identify specific actions that can be taken to minimize project impacts.
- Document baseline conditions at a wetland site.
- Determine mitigation requirements.
- Determine mitigation success.
- Evaluate the likely 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 among 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 vary depending on whether the project is a 404 individual permit review, an Advanced Identification (ADID) project, a Special Area Management Plan (SAMP), or some other assessment scenario.

Table 8. Red Flag Features and Respective Program/Agency Authority.

Red Flag Features	Authority[1]
Native Lands and areas protected under American Indian Religious Freedom Act	A
Hazardous waste sites identified under Comprehensive Environmental Response, Compensation, and Liability Act (Super Fund) (CERCLA) or Resource Conservation and Recovery Act (RCRA)	I
Areas providing critical habitat for species of special concern	C
Areas covered under the Farmland Protection Act	K
Floodplains, floodways, or floodprone areas	J
Areas with structures/artifacts of historic or archeological significance	G
Areas protected under the Land and Water Conservation Fund Act	K
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, M
Areas protected by the Safe Drinking Water Act	E, I, L
City, County, State, and National Parks	B, D, H, L
Areas supporting threatened or endangered species	C, F, H, I
Areas with unique geological features	H
Areas protected by the Wild and Scenic Rivers Act or Wilderness Act	D
State wetland mitigation banks	M

[1] Program Authority / Agency

A = Bureau of Indian Affairs

B = Arkansas State Parks

C = U.S. Fish and Wildlife Service

D = National Park Service (NPS)

E = Arkansas Department of Environmental Quality

F = Arkansas Game and Fish Commission

G = State Historic Preservation Officer (SHPO)

H = Arkansas Natural Heritage Commission

I = U.S. Environmental Protection Agency

J = Federal Emergency Management Administration

K = Natural Resource Conservation Service

L = Local Government Agencies

M = Arkansas Soil and Water Conservation Commission

Figures 23 through 26 present a simplified project scenario to illustrate the steps used to designate the boundaries of Wetland Assessment Areas (WAA), each of which will require a separate HGM assessment. Figure 23 illustrates a land cover map for a hypothetical project area. Figure 24

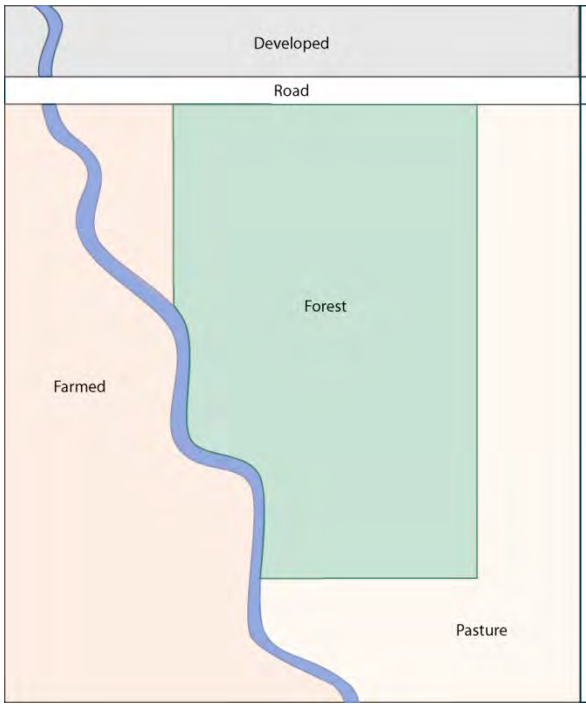


Figure 23. Land cover.

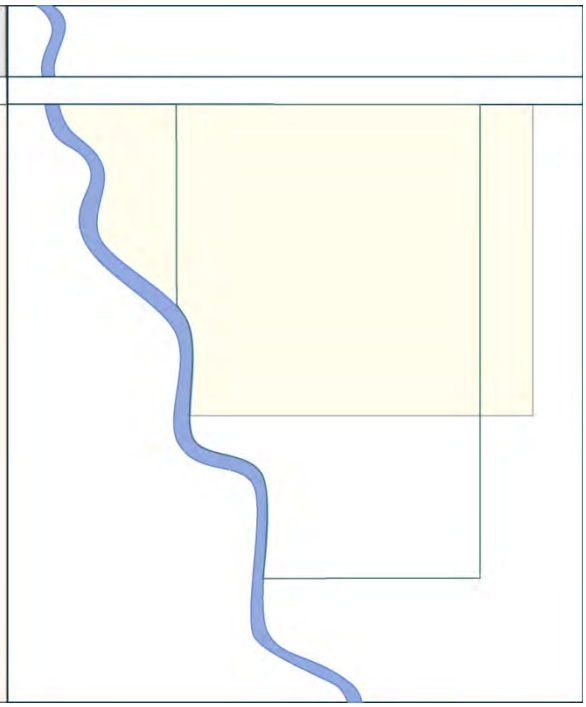


Figure 24. Project area (in yellow).

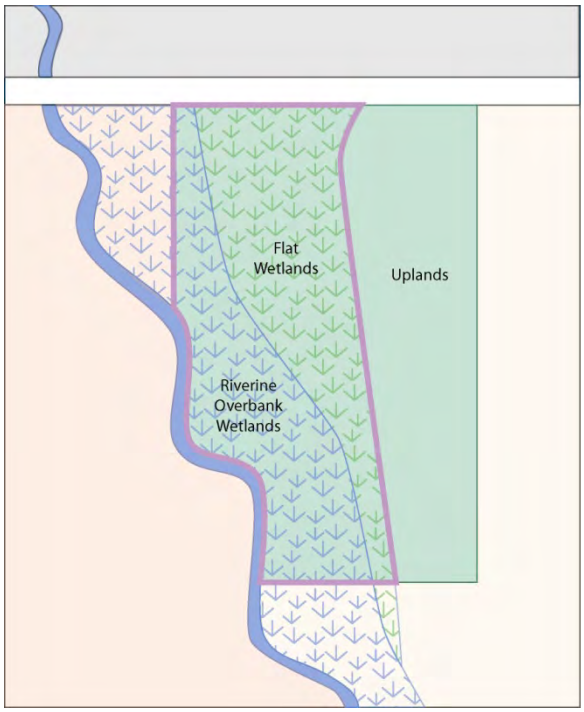


Figure 25. Wetland subclasses (purple line indicates extent of the "wetland tract").

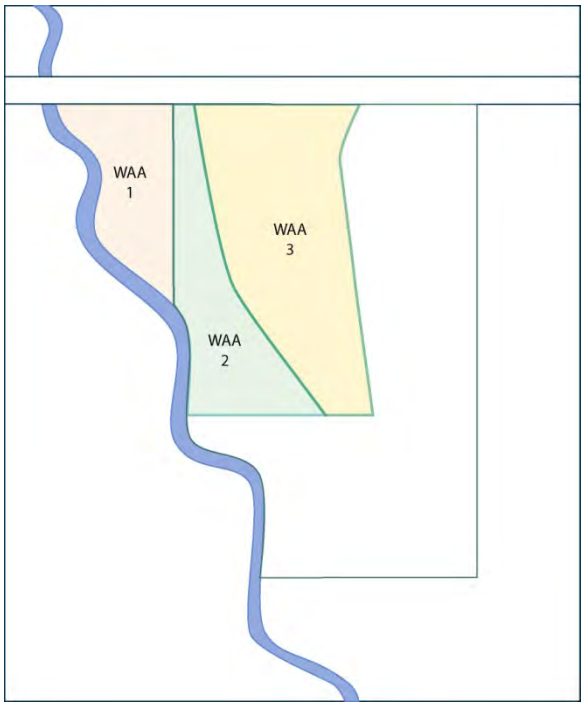


Figure 26. WAAs.

shows the project area (in yellow) superimposed on the land cover map. To determine the boundaries of the WAAs, first use the Keys to Wetland Classes and Subclasses (Figures 10 and 11) and identify the wetland subclasses within and contiguous to the project area (Figure 25). Overlay the project area boundary and the wetland subclass boundaries to identify the WAAs for which data will be collected (Figure 26). Attach these maps, photos, and drawings to Data Sheet A1 and complete the first three columns of the table on Data Sheet A1 by assigning an identifying number to each WAA, specifying the subclass it belongs to, and calculating the area in hectares.

Each WAA is a portion of the 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). However, as the size and heterogeneity of the project area increase, it is more likely that it will be necessary to define and assess multiple WAAs 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 wetlands belonging to the same regional subclass occur in the project area. Such noncontiguous wetlands must be designated as separate WAAs, because the assessment process includes consideration of the size and isolation of individual wetland units. The second situation occurs where more than one regional wetland subclass occurs within a project area, as illustrated in Figure 25, where both Flat and Low-gradient Riverine Overbank wetlands are present within the project area. These must be separated because they are assessed using different models and reference data systems. The third situation occurs where a contiguous wetland area of the same regional subclass exhibits spatial heterogeneity in terms of hydrology, vegetation, soils, or other assessment criteria. This is illustrated in Figure 26, where the area designated as Riverine Overbank Wetlands in Figure 25 is further subdivided into two WAAs based on land use and vegetation cover. The farmed area clearly will have different characteristics from those of the forested wetland, and they will be assessed separately (though using the same models and reference data).

In the Delta Region of Arkansas, the most common scenarios requiring designation of multiple WAAs involve tracts of land with interspersed

regional subclasses (such as depressions scattered within a matrix of flats or riverine wetlands) or tracts composed of a single regional subclass that includes areas with distinctly different land use influences that produce different land cover. For example, within a large riverine backwater unit, the following WAAs may be defined: cleared land, early successional sites, and mature forests. However, users should be cautious about splitting a project area into many WAAs based on relatively minor differences, such as local variation due to canopy gaps and edge effects. The reference curves used in this document (Chapter 5) incorporate such variation, and splitting areas into numerous WAAs based on subtle differences will not materially change the outcome of the assessment. It will, however, greatly increase the sampling and analysis requirements. Field experience in the region should provide a sense of the range of variability that typically occurs, and is sufficient to make reasonable decisions in defining multiple WAAs.

Collect field data

Information on the variables used to assess the functions of regional wetland subclasses in the Delta Region of Arkansas is collected at several different spatial scales, and requires several summarization steps. The checklists and data sheets in the appendices are designed to assist the assessment team in assembling the required materials and proceeding in an organized fashion. As noted, the Site or Project Information and Assessment Documentation Form (Appendix A1) is intended to be used as a cover sheet and for an overview of all documents and data sheets used in the assessment. Assembling the background information listed on this form should guide the assessment team in determining the number, types, and sizes of the separate WAAs likely to be designated within the project area. Based on that information, the field gear and data sheet checklists in Appendix A2 should be used to assemble the needed materials before heading to the field to conduct the assessment.

Note that different wetland subclasses require different field data sheets, because the assessment variables differ among subclasses (Table 9). Use the Data Sheet checklist in Appendix A2 to determine how many of each form are needed, then make copies of the required forms, which are provided in Appendix B.

Table 9. Applicability of variables by regional wetland subclass.

Variable Code	Flat	Riverine Backwater	Riverine Overbank	Headwater Depression	Unconnected Depression	Connected Depression
V_{AHOR}	+	+	+	*	*	*
V_{COMP}	+	+	+	+	+	+
$V_{CONNECT}$	+	+	+	+	+	+
V_{CORE}	+	+	+	+	+	+
V_{DUR}	not used	+	+	+	not used	+
V_{FREQ}	not used	+	+	not used	not used	+
V_{GVC}	+	+	+	*	*	*
V_{LITTER}	+	+	+	*	not used	*
V_{LOG}	+	+	+	*	*	*
V_{OHOR}	+	+	+	*	*	*
V_{OUT}	not used	not used	not used	+	not used	not used
V_{POND}	+	+	+	not used	not used	not used
V_{SNAG}	+	+	+	+	+	+
V_{SOIL}	+	+	+	*	*	*
V_{STRATA}	+	+	+	+	+	+
V_{SSD}	+	+	+	+	+	+
V_{TBA}	+	+	+	+	+	+
V_{TCOMP}	+	+	+	+	+	+
V_{TDEN}	+	+	+	+	+	+
V_{TRACT}	+	+	+	+	+	+
V_{WD}	+	+	+	*	*	*

Note: Variables not used in assessment of a particular subclass are identified. Variables always used in assessment of the subclass are indicated by +. Variables used unless site conditions preclude their observation are indicated by a shaded box marked with *.

The data sheets provided in Appendix B are organized to facilitate data collection at each of the several spatial scales of interest. For example, the first group of variables (Data Sheet 1) contains information about landscape scale or WAA-scale characteristics collected using aerial photographs, maps, and hydrologic information regarding each WAA and vicinity, or collected during a walking reconnaissance of the WAA. Data collected for these variables are entered directly on the Data Sheets, and do not require plot-based sampling. Information on the next group of variables is collected in sample plots placed in representative locations throughout the WAA. Data from a single plot are recorded on Data Sheet 2, which is made up of two

separate data sheets. Additional copies of Data Sheet 2 are completed for each plot sampled within the WAA.

All of the data sheets shown in Appendix B are printouts from the Arkansas Delta Data Sheets and FCI Calculator (Calculator), a single spreadsheet that allows raw data entry; the spreadsheet automatically calculates variable values, variable subindices and FCIs and FCUs. The Data Sheets from the spreadsheet should be printed out and taken in the field, and then the raw data may be entered in the same form in the Excel spreadsheet, so that automated calculations occur.

All data from each of the Data Sheets are compiled automatically by the Calculator in the Data Summary by Plot tab (Appendix D3). These summarized data are then used by the Calculator to automatically calculate the Functional Capacity of the wetland being assessed on the FCI/FCU Calculation Summary tab of the Arkansas Delta Data Sheets and FCI Calculator, once the Subclass is selected and raw data are entered.

The sampling procedures for conducting an assessment require few tools, but certain tapes, a shovel, specialized basal area estimation or measurement tools, reference materials, and an assortment of other items will be needed (Appendix A2). Generally, all measurements should be taken in metric units (although non-SI equivalents are indicated for most sampling criteria such as plot sizes). Collecting data in non-SI units will require conversion of sample data to metric <u>before</u> completing the necessary calculations of entering data into spreadsheets for summarization. There are two exceptions to this general rule: the recommended basal area prism is a non-SI 10-factor prism, which is an appropriate size for use in the forests of the Delta Region. A conversion factor is built into the data sheet to make the needed adjustments to the recorded field data. The second instance involves measurement of diameter-at-breast-height (dbh) using a special tape, and calculation of basal area, which is an alternative approach to the prism method. Because non-SI dbh tapes are more widely available than metric tapes, the summarization spreadsheets provided in Appendix D are able to accept either non-SI or metric units as input data.

A typical layout for the establishment of sample plots and transects in the hypothetical WAAs is shown in Figure 27. As in defining the WAA, there

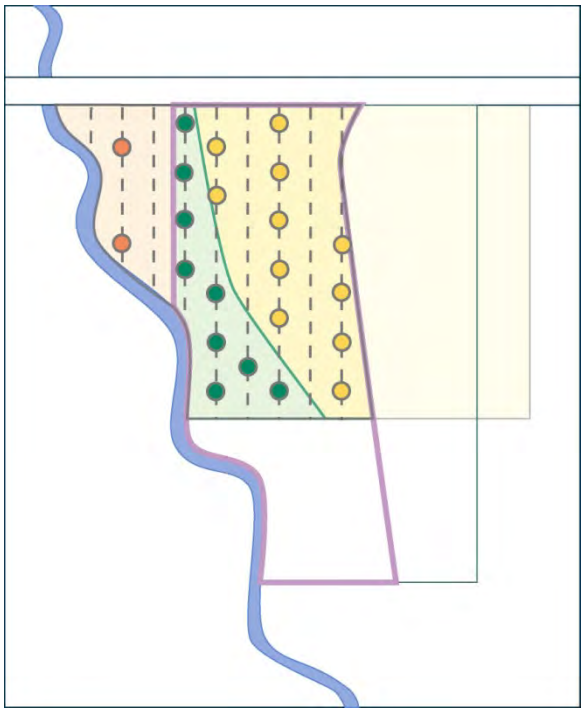


Figure 27. Example sample distribution (refer to Figure 26 for WAA designations).

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. If the WAA is relatively small (i.e., less than 2–3 acres, or about a hectare) and homogeneous with respect to the characteristics and processes that influence wetland function, then three or four 0.04-ha plots, with associated nested transects and subplots in representative locations, are probably adequate to characterize the WAA. Experience has shown that the time required to complete an assessment of an area of that size is 2–4 hours, depending primarily on the experience of the assessment team. However, as the size and heterogeneity of the WAA increase, more sample plots are required to represent the site accurately. Large forested wetland tracts usually include a mix of tree age classes, scattered small openings in the canopy that cause locally dense understory or ground cover conditions, and perhaps some very large individual trees or groups of old-growth trees. The sampling approach should not bias data collection to differentially emphasize or exclude any of these local conditions, but should represent the site as a whole. Therefore, on large sites the best approach often is a simple systematic plot layout, where evenly spaced parallel transects are established (using a compass and pacing) and sample plots are distributed at regular paced intervals along those transects. For example, a 12-ha tract, measuring about 345 m on each side, might be sampled using two transects spaced 100 m apart (and 50 m from the tract edge), with plots at 75-m intervals along each transect (starting 25 m from the tract edge). This would result in eight sampled plot locations, which should be adequate for a relatively diverse 12-ha forested wetland area. In Figure 27, WAA 2 illustrates this approach for establishing fairly high-density, uniformly distributed samples. Larger or more uniform sites can usually be sampled at a lower plot density. One approach is to establish a

series of transects, as described, and sample at intervals along alternate transects (see WAA 3 in Figure 27). Continue until the entire site has been sampled at a low plot density, then review the data and determine if the variability in overstory composition and basal area has been largely accounted for. That is, as the number of plots sampled has increased, are new dominant species no longer being encountered, and has the average basal area for the site changed markedly with the addition of recent samples? If not, there is probably no need to add further samples to the set. If overstory structure and composition variability remain high, then return to the alternate, unsampled transects and continue sampling until the data set is representative of the site as a whole, as indicated by a leveling off of the dominant species list and basal area values. Other variables may level off more quickly or slowly than tree composition and basal area, but these two factors are generally good indicators, and correspond well to the overall suite of characteristics of interest within a particular WAA. In some cases, such as sites where trees have been planted or composition and structure are highly uniform (e.g. sites dominated by a single tree species), it may be apparent that relatively few samples are adequate to reasonably characterize the wetland. In Figure 27, this is illustrated by the sample distribution in WAA 1, which is a farmed area where few variables are likely to be measurable, or at least will vary little from plot to plot. In this case, every other plot location is sampled along every other transect.

The information on Data Sheet 1 and on the multiple copies of Data Sheet 2 is compiled automatically by the Calculator in the Data Summary by Plot tab (Appendix D3). These summarized data are then used by the Calculator to automatically determine the Functional Capacity of the wetland being assessed on the FCI/FCU Calculation Summary tab of the Calculator for each WAA. All of the field and summary data sheets, as well as the printed output from the final spreadsheet calculations, should be attached to the Project Information and Assessment Documentation Form provided in Appendix A. Appendix C provides some alternate data sheets that may be needed in cases where alternative field methods are used, or where the user wishes to calculate summary data by hand, rather than using the spreadsheets. The use of these forms is explained on the forms themselves, and in the pertinent variable descriptions below. Appendix D contains the examples of the spreadsheets (in Excel format) that may be used to complete the data summary calculations, excluding those that make up the

Data Sheets in Appendix B. Appendix F is a listing of common and scientific names of tree and shrub species that are referenced on the field data sheets.

Detailed instructions on collecting the data for entry on Data Sheets 1 and 2 are provided in the following sections. Variables are listed in alphabetical order to facilitate locating them. Each set of directions results in an overall WAA value for the variable calculated on the Data Summary by Plot tab. Those numbers are then automatically used in FCI/FCU Calculation Summary tab (Appendix D4).

Not all variables are used to assess all subclasses, as described in Chapter 5 and Table 9, but the data sheets in Appendix B indicate which variables are pertinent to each subclass. The data sheets also provide brief summaries of the methods used to assess each variable, but the user should read through these more detailed descriptions and have them available in the field for reference as necessary.

V_{AHOR} - A Horizon Organic Accumulation

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, consisting of an accumulation of unrecognizable decomposed organic matter mixed with mineral soil (USDA SCS 1993). In practice, the HGM models using this variable are concerned with the storage of organic matter, so for these purposes the A horizon is identified in the field simply as a zone of darkened soil.

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

1. Establish sample points by selecting two or more locations within the 0.04-ha circular plot that are representative of the range of micro-topographic conditions in the plot, or select two or more of the four 1-m^2 subplots established for litter and ground cover estimation (see descriptions of those variables). Dig a hole (25 cm or 10 in. deep is usually adequate in the Delta Region) and measure the thickness of the A horizon. Record measurements in the yellow spaces on Data Sheet 2. The average value for the plot will be calculated automatically.
2. The average plot value will be automatically transferred to the Data Summary by Plot tab. An overall WAA value will be automatically

averaged on that form in the right-hand column. This WAA average value will then transfer automatically to the FCI/FCU Calculation Summary tab.

V_{COMP} / V_{TCOMP} - Composition of Tallest Woody Vegetation Stratum / Composition of Tree Stratum

These variables represent the species composition of the tallest woody stratum present in the assessment area. If the tree stratum is the tallest covering at least 20% of the area, V_{COMP} and V_{TCOMP} will be the same. The tallest stratum could be the tree, shrub-sapling, or seedling stratum. Percent concurrence with reference wetlands of the dominant species in the dominant vegetation stratum is used to quantify this variable. Measure it using the following procedure:

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 (living woody stems ≥ 10 cm or 4 in. at breast height), 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, check the box on Data Sheet 2 and go to Step 2. The tree stratum will be used to calculate concurrence for both V_{COMP} and V_{TCOMP}. If the percent cover of the tree stratum is estimated to be <20 percent, leave the box unchecked and go to Step 2. In this case, V_{TCOMP} will be zero, and the next tallest stratum covering at least 10% will be used to calculate concurrence for V_{COMP}.
2. Determine the stratum to be used for calculating concurrence. If the percent cover of the tree stratum was found to be at least 20% in Step 1 above, use that stratum and proceed to Step 3. If the tree stratum does not have at least 20 percent cover, determine the tallest woody stratum with at least 10 percent total cover. If there are no woody species present on the site, check the appropriate box at the bottom of the column for Group 3.
3. Determine concurrence. Within the selected stratum, identify the dominant species based on percent cover using the 50/20 rule: rank species in descending order of percent cover and 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. Check the boxes for these species on Data Sheet 2. 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, and dead or dormant plant parts. Users who do not feel confident in identifying trees and shrubs should get help.

4. Percent concurrence is automatically calculated and entered into V_{COMP} and V_{TCOMP} cells using the formula below, which weights dominant species based on their likelihood of being dominant in reference stands of varying condition. The result is intended to indicate the character of the developing forest.

$$\%Concurrence = \left[\frac{(\#Group1 \times 1.0) + (\#Group2 \times 0.66) + (\#Group3 \times 0.33)}{Total_\#Species_in_All_Groups}\right] \quad (48)$$

5. The plot value will be automatically transferred to the Data Summary by Plot tab. An overall WAA value will be automatically averaged on that form in the right-hand column. This WAA average value will then transfer automatically to the FCI/FCU Calculation Summary tab.

$V_{CONNECT}$ - Habitat Connectivity

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 vegetated with native species (Figure 28). Agricultural fields, orchards, clear cuts, pastures dominated by non-native species, mined areas, and developed areas are examples of unsuitable habitats, regardless of whether they meet the criteria for federally jurisdictional wetlands or not. Note that because this is a landscape-level variable, the "tract" is not limited to the WAA under consideration, but includes all contiguous forested wetlands (Figure 25).

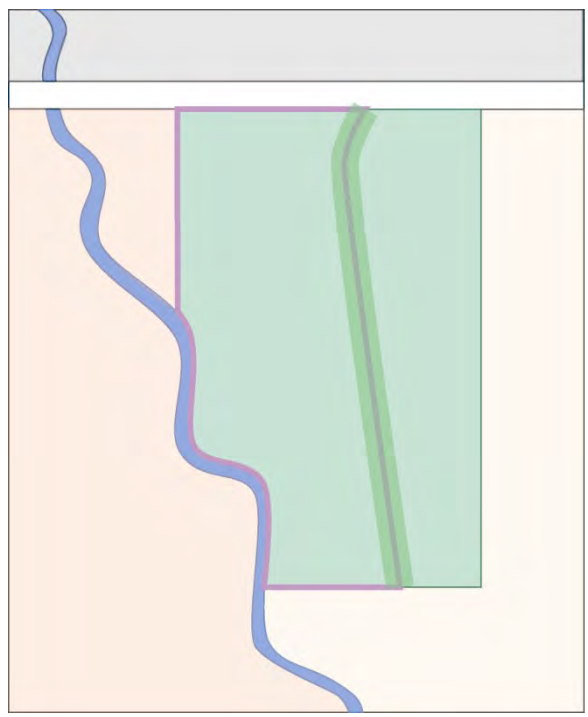


Figure 28. Identification of "connected perimeter" (green line). Refer to Figure 25 for subunit designations.

The percentage of the forested wetland tract boundary that is "connected" is used to quantify this variable. Note that the "tract" is not limited to the WAA under consideration, but includes all contiguous forested wetlands. An adja-

cent habitat is considered connected if it is within 0.5 km (0.31 mile) of the boundary of the forested wetland tract. Measure it as follows:

1. Calculate the length of the forested wetland tract boundary. Use field reconnaissance, topographic maps, aerial photography, Geographic Information System (GIS), or another suitable 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 previously.
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 Sheet 1 in the yellow box on the right-hand side of the $V_{CONNECT}$ row.
5. The WAA value will be automatically transferred to the Data Summary by Plot tab and to the FCI/FCU Calculation Summary tab.

V_{CORE} - Core Area

This variable is defined as the portion of a wetland tract that lies to the inside of a 100-m (330-ft) buffer interior of the boundary of the entire forested area (Figure 29). The percentage of a wetland tract that lies to the inside of this 100-m (330-ft) buffer zone is the metric used to quantify this variable. Note that the tract is not limited to the WAA under consideration, but includes all contiguous forested wetlands. Determine the value of this metric using the following procedure:

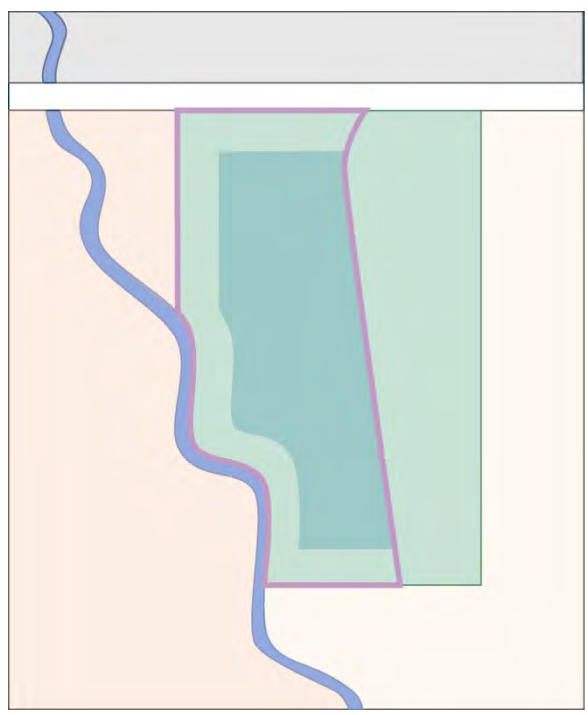


Figure 29. Identification of "core area." Refer to Figure 25 for subunit designations.

1. On a map or photo, draw a continuous line 100 m inside the boundary of the entire contiguous forested area.
2. Calculate the size of the wetland tract that lies inside this line. This is the core area.

3. Divide the size of the core area by the size of the wetland tract and then multiply by 100. The resulting number is the percent of the wetland tract that is the core area.
4. Record the percentage on Data Sheet 1 in the box on the right-hand side of the V_{CORE} row.
5. The WAA value will be automatically transferred to the Data Summary by Plot tab and to the FCI/FCU Calculation Summary tab.

V_{DUR} - Change in Growing Season Flood Duration

Growing season flood duration refers to the maximum number of continuous days in the growing season that overbank or backwater flooding from a stream inundates the WAA. Riverine and Connected Depression wetlands may flood as infrequently as one year in five (see the discussion of the V_{FREQ} variable in the following section). However, when flooding does occur, it usually extends for some days or weeks into the growing season, and strongly influences plant and animal communities. In some cases, where impoundments are constructed around existing wetlands (e.g., greentree reservoirs) or where stream engineering projects such as flood control projects are constructed, additional growing season flooding may occur in the spring or fall. The V_{DUR} variable is intended to reflect changes in function that result where changes in growing season hydrology have occurred or are expected to occur as a result of leveeing, drainage, impoundment, or other engineering projects. Either increases or decreases in growing season flood durations are assumed to cause reduced function relative to the pre-impact condition for both the Maintain Plant Communities and Provide Wildlife Habitat functions.

In order to account for this type of change, the V_{DUR} variable is incorporated in the relevant models. The V_{DUR} variable was developed for use primarily in the context of proposed Corps of Engineers water projects in the Delta Region, and is therefore structured specifically to accommodate the type of hydrologic information generated in the Corps project planning process. It was developed based on field studies on greentree reservoirs in the Bayou Meto basin (Heitmeyer and Ederington 2004), where changes in flood duration were expressed in terms of continuous days of flooding in the growing season. Changes in flood duration are presented as “zone changes,” where a single zone change corresponds to approximately one week of additional or reduced continuous flooding during the growing season. Because these data are usually generated to evaluate likely project-induced changes in the acreage of jurisdictional wetlands, the “period of continuous

flooding" may not correspond to the total days of flooding. At this time, no specific correlation has been established between this means of presenting flood duration data and the more common method of discussing flood durations that are based on total days of flooding in the entire annual cycle.

Estimates of growing-season flood durations are not typically readily available for any particular site, and in most cases the change in duration will be assumed to be zero unless specific information to the contrary is available from project planning or permit application documents. Whatever the case, the percent change should be calculated consistently for the before-project and after-project conditions as follows:

1. Determine the change in growing season flood duration by comparing the preproject and postproject flood durations.
2. Record the preproject and postproject growing season flood durations on Data Sheet 1 using drop-down menus in the V_{DUR} row.
3. The number of zone changes represented (where 1-week change in continuous growing-season flooding constitutes a zone change) will be automatically calculated.
4. The WAA value will be automatically transferred to the Data Summary by Plot tab and to the FCI/FCU Calculation Summary tab.

V_{FREQ} - Change in Frequency of Flooding

Frequency of flooding refers to the frequency (return interval in years) with which overbank or backwater flooding from a stream inundates the WAA. In the classification employed here, where the 5-year return interval distinguishes connected from unconnected wetlands, the frequencies of interest are the 1-, 2-, 3-, 4-, and 5-year return intervals. However, in the context of the assessment models where the V_{FREQ} variable is used, there is no implication that more frequent flooding translates to higher functionality. Rather, all connected wetlands are assumed to be fully functional with regard to the V_{FREQ} variable unless there has been a change in flood frequency, and any such change, whether more or less frequent, will have adverse effects on the wetland communities and processes currently in place. (Note: As with the classification system, flood frequencies established as a result of the major river engineering projects in the mid-twentieth century are considered to be the baseline condition in most assessment scenarios.) In practice, the change in flood frequency will be a consideration most often where the hydrology of a site has been recently modified, as through a levee, drainage, or pumping project, or where such a change is

proposed. In such situations the change in flood frequency can be used to indicate the magnitude of deviation from the preproject condition, calculated as follows:

1. Determine the change in recurrence interval by comparing the preproject and postproject flood frequencies. For the preproject condition, the recurrence interval can be determined or estimated using one of the following information sources:

    - Recurrence interval map.
    - Data from a nearby stream gage.
    - Regional flood frequency curves developed by local and State offices of USACE, U.S. Geological Survey (USGS) - Water Resources Division, State Geologic Surveys, or NRCS (Jennings et al. 1994).
    - Hydrologic models such as HEC-2 (U.S. Army Engineer Hydrologic Engineering Center (HEC) 1981, 1982), HEC-RAS (HEC 1997), or Hydrologic Simulation Program – Fortran (HSPF) (Bicknell et al. 1993).
    - Local knowledge.
    - A regional dimensionless rating curve.

    The same sources may be used to determine the postproject recurrence interval, or it may be specified in planning documents and applications.

2. Record the preproject and postproject recurrence intervals on Data Sheet 1 using the drop-down menus in the V_{FREQ} row.
3. The difference in return intervals will be automatically calculated.
4. The WAA value will be automatically transferred to the Data Summary by Plot tab and to the FCI/FCU Calculation Summary tab.

    Example: A Riverine Overbank site that normally floods every year (5 years out of 5) will be affected by a nearby channel-deepening project that reduces flood frequency to 2 years out of 5. The change in return interval is 3 years.

Note that the number of possible changes in return interval varies depending on the starting flood frequency. This is due in part to the classification of the flood frequencies: any area flooded more frequently than once a year is grouped with the 1-year return interval group, and

everything flooded less frequently than every 5 years is no longer classified as riverine, and therefore the frequency variable no longer applies. As Figure 30 illustrates, the maximum of four zone changes is possible only for wetlands starting in the 1- or 5-year return interval categories (blue and red). This maximum change leads to a 0.2 variable subindex. In contrast, if the starting return interval is 3 years, a maximum of two zone changes is possible in either direction (green line), leading to a potential subindex of 0.6. A subindex of 0.0 occurs only if the change in frequency extends beyond the 5-year return interval required in the definition of riverine wetlands.

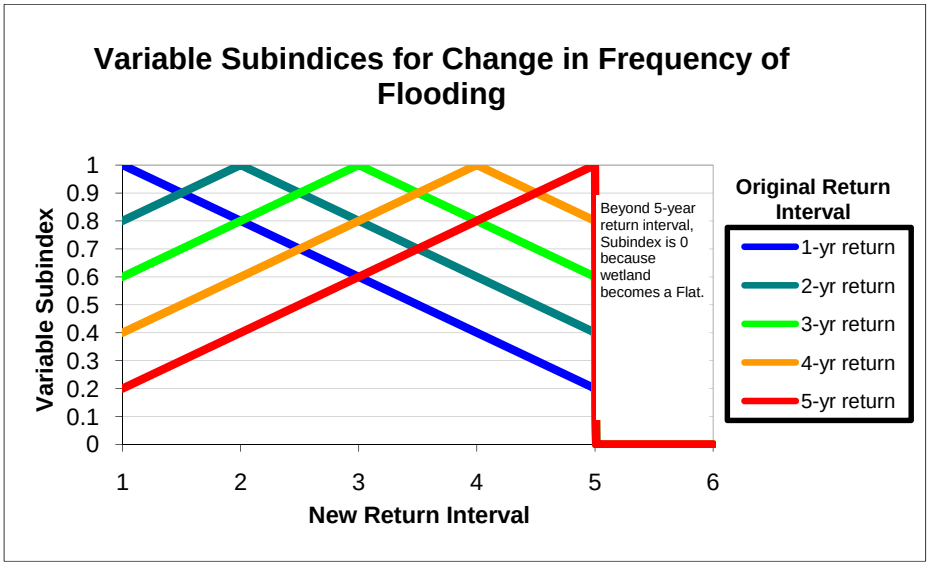


Figure 30. Potential variable subindices for different starting return interval frequencies.

V_{GVC} - Ground Vegetation Cover

Ground vegetation cover is defined as herbaceous and woody vegetation less than or equal to 1.4 m (4.5 ft) in height. The percent cover of ground vegetation is used to quantify this variable. Determine the value of this metric using the following procedure:

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-m² subplots placed 5 m (15 ft) from the plot center, one in each cardinal direction as illustrated in Figure 31. Record measurements for each subplot in the yellow cells in the V_{GVC} row on Data Sheet 2. The subplot values will automatically be averaged.

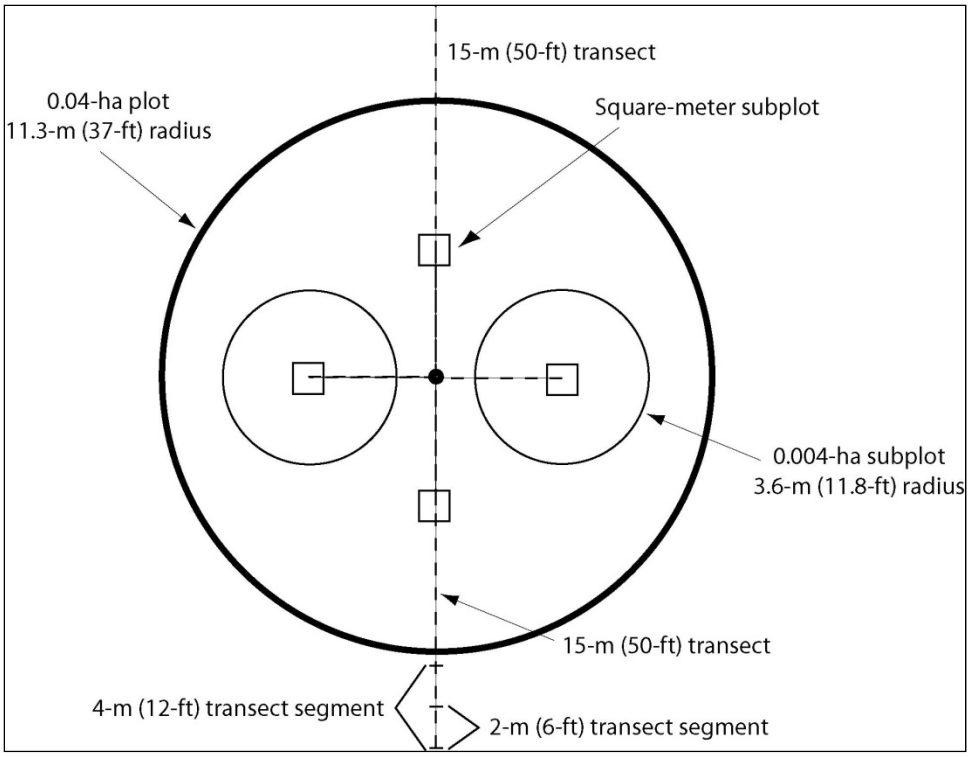


Figure 31. Layout of plots and transects for field sampling.

2. The average plot value will be automatically transferred to the Data Summary by Plot tab. An overall WAA value will be automatically averaged on that form in the right-hand column. This WAA average value will then transfer automatically to the FCI/FCU Calculation Summary tab.

V_{LITTER} - Litter Cover

Litter cover is estimated as the average percent of the ground surface covered by recognizable dead plant materials (primarily decomposing leaves and twigs). This estimate excludes undecomposed woody material large enough to be tallied in the woody debris transects (i.e., twigs larger than 0.6 cm (0.25 in.) in diameter — see V_{WD} discussion). It also excludes organic material sufficiently decayed to be included in the estimate of O horizon thickness (see V_{OHOR} discussion). Generally, litter cover is easily recognized and estimated except during autumn, during active leaf fall, when freshly fallen materials should be disregarded in making the estimate, because the volume of freshly fallen material will inflate cover estimates.

The percent cover of litter is used to quantify this variable. Determine the value of this metric using the following procedure:

1. Visually estimate the proportion of the ground surface that is covered by litter. Do this in each of the four 1-m² subplots (the same subplots established for estimating ground vegetation cover, Figure 30). Record measurements for each subplot in the yellow cells in the V_{LITTER} row on Data Sheet 2. The subplot values will automatically be averaged.
2. The average plot value will be automatically transferred to the Data Summary by Plot tab. An overall WAA value will be automatically averaged on that form in the right-hand column. This WAA average value will then transfer automatically to the FCI/FCU Calculation Summary tab.

V_{LOG} - Log Biomass

See discussions in the Woody Debris (V_{WD}) and Log Biomass (V_{LOG}) section later in this chapter.

V_{OHOR} - O Horizon Organic Accumulation

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 (USDA 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 following procedure:

1. Measure the thickness of the O horizon in the same holes dug to determine the thickness of the A horizon discussed previously. That will result in two or more measurements per plot, which are recorded as subplot values in the V_{OHOR} section of Data Sheet 2. The average value for the plot will be calculated automatically.
2. The average plot value will be automatically transferred to the Data Summary by Plot tab. An overall WAA value will be automatically averaged on that form in the right-hand column. This WAA average value will then transfer automatically to the FCI/FCU Calculation Summary tab.

V_{OUT} - Change in Surface Water Outflow

This variable represents the change in frequency at which water is discharged as surface flow from a headwater depression wetland to a

downslope stream. The variable is scored on the basis of field or map indicators that an alteration within the depression has affected surface water discharge.

The field procedure is as follows:

1. Inspect the lower perimeter of the headwater depression wetland and determine if there are indicators that surface water discharge has been altered. These may include a board structure to impede flow, a poorly designed or clogged culvert, a berm, or other impediment to flow across the lower end of the depression. Inspect the upper perimeter of the headwater depression for indications of additional water inputs such as irrigation pipe discharges or ditches flowing into the depression. Aerial photographs may also be useful for identifying these alterations.
2. If no alterations occur, or if the alterations do not appear to alter outflow (e.g., a well-functioning culvert), assume no change in the surface outflow of the wetland, and use the drop-down menus to indicate identical outflow regimes for pre- and post-project outflow. A subindex value of 1 will be automatically generated. If alterations have occurred (either additional inputs, or the impediment of outflow), but there is still some water making it through the lower end of the depression, make selections in the drop-down menus to reflect a change between perennial and seasonal outflow; a variable subindex of 0.5 will be generated. If a berm or other impediment has completely disconnected the depression from its stream, use the drop-down menu to indicate No Outflow, and a variable subindex of 0 will be generated.
3. The WAA value will be automatically transferred to the Data Summary by Plot tab and to the FCI/FCU Calculation Summary tab.

V_{POND} - Total Ponded Area

Total Ponded Area refers to the percent of the WAA ground surface likely to collect and hold precipitation for periods of days or weeks at a time. (Note: This is distinct from the area that is prone to flooding, where the surface of the WAA is inundated by overbank or backwater connections to stream channels). The smaller (microtopographic) depressions are usually a result of tree “tip ups” and the scouring effects of moving water, and typically they are between 1 and 10 m^2 in area. Larger vernal pools (usually at least 0.04 ha) occur in the broad swales typical of meander scroll topography, or in other areas where impeded drainage produces broad, shallow pools during rainy periods. The wetlands where these features are

important typically have a mix of both the small microdepressions and the larger vernal pools.

Estimate total ponded area using the following procedure:

1. During a reconnaissance walkover of the entire WAA, estimate the percentage of the assessment area surface having microtopographic depressions and vernal pool sites capable of ponding rainwater. Base the estimate on the actual presence of water immediately following an extended rainy period if possible, but during dry periods use indicators such as stained leaves or changes in ground vegetation cover. Generally, it is not difficult to visualize the approximate percentage of the area subject to ponding, but it is important to base the estimate on a walkover of the entire assessment area.
2. Report the percent of the assessment area subject to ponding on Data Sheet 1 in the yellow box on the right-hand side of the V_{POND} row, and transfer that value to the V_{POND} box on Data Sheet 3. Note that in the case of the Flats subclass, Data Sheet 2 also requires identification of the geomorphic surface on which the WAA is located, because percent ponding differs markedly among surfaces in the reference data set, which is reflected in the calibration curves and the summary spreadsheets. The geomorphic surface can be identified using the supplemental spatial data in Appendix E, or the map in Figure 6 may be adequate in many cases. Use the drop-down menu to assign the WAA to one of three possible surfaces:

    - Pleistocene Alluvial Terraces (formed by Pleistocene meander activity), identified as “alluvial (meandering stream) terraces” in the Pleistocene legend in Figure 6, and by map unit codes that begin with the following letters in Appendix E: Pt, Pd, Pi, Pp, and Qt.
    - Pleistocene Valley Train deposits (formed by glacial outwash events), identified as all Pleistocene surfaces other than terraces in Figure 6, and by map unit codes that begin with the letters Pv in Appendix E.
    - Holocene Alluvium (post-glacial meander belts), identified as all Holocene features in Figure 6, and by map unit codes that begin with the letter H in Appendix E.

3. The WAA value will be automatically transferred to the Data Summary by Plot tab and to the FCI/FCU Calculation Summary tab.

V_{SNAG} - Snag Density

Snags are standing dead woody stems at least 1.4 m (4.5 ft) tall with a dbh greater than or equal to 10 cm (4 in.). The density of snag stems per hectare is the metric used to quantify this variable. Measure it using the following procedure:

1. Count the number of snag stems within each 0.04-ha circular plot. Record the number of snag stems in the yellow box on the V_{SNAG} row on Data Sheet 2. The stems/ha will be automatically calculated.
2. The plot value will be automatically transferred to the Data Summary by Plot tab. An overall WAA value will be automatically averaged on that form in the right-hand column. This WAA average value will then transfer automatically to the FCI/FCU Calculation Summary tab.

V_{SOIL} - Soil Integrity

It is difficult in a rapid assessment context to assess soil integrity for two reasons. First, a variety of soil properties contribute to integrity that should be considered (i.e., structure, horizon development, texture, bulk density). Second, the spatial variability of soils within many wetlands makes it difficult to collect the number of samples necessary to characterize a site adequately. 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 the 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. As part of the reconnaissance walkover of the entire WAA, determine if any of the soils in the area being assessed have been altered. In particular, look for evidence of excavation or fill, severe compaction, or other types of impact that significantly alter soil properties. For the purposes of this assessment approach, the presence of a plow layer should not be considered 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. If altered soils exist, estimate the percentage of the assessment area that has soils that have been altered.

3. Report the percent of the assessment area with altered soils in the yellow box Data Sheet 1 in the V_{SOIL} row.
4. The WAA value will be automatically transferred to the Data Summary by Plot tab and to the FCI/FCU Calculation Summary tab.

V_{SSD} - Shrub-Sapling Density

Shrubs and saplings are woody stems less than 10 cm (4 in.) dbh and greater than 1.4 m (4.5 ft) in height. Density of shrub-sapling stems per hectare is the metric used to quantify this variable. Measure it using the following procedure:

1. Count woody stems less than 10 cm (4 in.) and greater than 1.4 m (4.5 ft) in height in two 0.004-ha circular subplots (radius 3.6 m or 11.8 ft) nested within the 0.04-ha plot (Figure 31). Record the number of stems in each 0.004-ha subplot in the yellow spaces provided in the V_{SSD} row on Data Sheet 2. The stems/ha will be automatically calculated.
2. The plot value will be automatically transferred to the Data Summary by Plot tab. An overall WAA value will be automatically averaged on that form in the right-hand column. This WAA average value will then transfer automatically to the FCI/FCU Calculation Summary tab.

V_{STRATA} - Number of Vegetation Strata

The number of vegetation layers (strata) present in a forested wetland reflects the diversity of food, cover, and nest sites available to wildlife, particularly birds, but also to many reptiles, invertebrates, and arboreal mammals. Estimate the vertical complexity of the WAA using the following procedure:

1. During a reconnaissance walkover of the entire WAA, identify which of the following vegetation layers are present and account for at least 10 percent cover, on average, throughout the site.

    - Canopy (trees in the canopy layer greater than or equal to 10 cm dbh).
    - Subcanopy (trees below the canopy layer greater than or equal to 10 cm dbh. Recognize this layer if it is distinctly different from a higher, more mature canopy).

- Understory (shrubs and saplings less than 10 cm dbh but at least 4.5 ft tall).
- Ground cover (woody plants less than 4.5 ft tall and herbaceous vegetation).

1. Use the drop-down menu in the V_{STRATA} row on Data Sheet 1 to select the number of vegetation strata (0 – 4) present in the WAA.
2. The WAA value will be automatically transferred to the Data Summary by Plot tab and to the FCI/FCU Calculation Summary tab.

V_{TBA} - Tree Basal Area

Trees are defined as living woody stems greater than or equal to 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 (Bonham 1989, Spurr and Barnes 1981, Tritton and Hornbeck 1982, Whittaker 1975, Whittaker et al. 1974). Tree basal area per hectare is the metric used to quantify this variable. Measure it using the following procedure:

1. Use a basal area wedge prism (or other basal area estimation tool) as directed to tally eligible tree stems, and enter the tally in the yellow space on the V_{TBA} line on Data Sheet 2. Basal area prisms are available in various Basal Area Factors, and in both SI (metric) and non-SI (English) versions. Some are inappropriate for use in collecting the data needed here, because they are intended to be used for large-diameter trees in areas with little understory. The non-SI 10-factor prism works well in forests of the Delta region, and it is readily available.
2. Basal area in m^2/ha will be automatically calculated.
3. The plot value will be automatically transferred to the Data Summary by Plot tab. An overall WAA value will be automatically averaged on that form in the right-hand column. This WAA average value will then transfer automatically to the FCI/FCU Calculation Summary tab.

An alternative method also is available to directly measure tree diameters in the 0.04-ha plot, rather than use a plotless (e.g., wedge prism) estimation method. The difference between the two methods is likely to be insignificant at the level of resolution employed in the HGM assessment. However, if a wedge prism or similar tool is not available, or if undergrowth is too thick to allow a prism to be used accurately, direct diameter measurement (using a dbh tape or tree caliper) may be the only option available. The direct

measurement approach can be used to facilitate more rigorous data collection, particularly if the relative dominance of each tree species is an important consideration. Therefore, an alternative field form is provided in Appendix C1 that can be used to record the species and diameter of every tree within the 0.04-ha plot. Basal area can be calculated by hand on that data sheet, or on the spreadsheet provided in Appendix D. The spreadsheet will also indicate the basal area of each tree so the individual tree values for each species can be summed to determine the total basal area by species if desired. This can be used simply to provide more detailed documentation of the assessment process, or to improve the rigor of estimates for the V_{TCOMP} variable. Tree counts directly from the basal area sheets can also be used.

In general, the recommended field methods are likely to be much faster than the diameter measurement approach, but the outcome of the assessment should not differ significantly regardless of which method is used. The automated Calculator only accepts Factor-10 tallies.

The procedure for using the alternative (direct diameter measurement) method is as follows:

1. Using a metric (cm) diameter tape, measure the diameter of all trees (living woody stems greater than or equal to 10 cm (4 in.) at breast height) (dbh) in a circular 0.04-ha plot with a radius of 11.3 m (37 ft). Record each diameter measurement in Column 2 of Data Sheet C1. Recording the species of each tree (Column 1) is optional, but may be helpful, as described previously.
2. A spreadsheet is available (Appendix D1) to complete the calculations in Steps 2–5, or they can be done by hand as follows:

    a. Square the dbh measurement for each woody stem and enter that number in Column 3.
    b. Convert the squared diameters to square meters per hectare by multiplying by 0.00196. Enter this number in Column 4.
    c. Sum all Column 4 numbers to get total basal area (m^2 / ha) for the plot. Use this value in any hand calculations.

V_{TCOMP} - Tree Composition

See V_{COMP}/V_{TCOMP} discussion.

V_{TDEN} - Tree Density

Tree density is the number of trees (i.e., living woody stems greater than or equal to 10 cm or 4 in.) per unit area. The density of tree stems per hectare is the metric used to quantify this variable. Measure it using the following procedure:

1. Count the number of tree stems within the 0.04-ha plot (note: this is not the same as the stem count taken with the basal area wedge prism to determine V_{TBA}). Care should be taken not to err in determining whether or not a tree should be counted. Measure the plot radius to all marginal trees, and include only trees having at least half the stem within the plot. If tree diameters were recorded to calculate basal area, then the number of stems can be counted directly from the supplemental basal area field sheet (Data Sheet C1, Appendix C).
2. Record the stem count in the yellow space in the V_{TDEN} row on Data Sheet 2. The density in stems/ha will be automatically calculated.
3. The plot value will be automatically transferred to the Data Summary by Plot tab. An overall WAA value will be automatically averaged on that form in the right-hand column. This WAA average value will then transfer automatically to the FCI/FCU Calculation Summary tab.

V_{TRACT} - Wetland Tract

This variable is defined as the area of contiguous forested wetland that includes the WAA (Figure 25). Adjacent wetlands need not be in the same regional subclass as the assessment area to be part of the wetland tract.

Determine the size of the wetland tract using the following procedure:

1. Determine the size of the forested wetland area in hectares that is contiguous and directly accessible to wildlife utilizing the WAA (including the WAA itself). Use topographic maps, aerial photography, GIS, field reconnaissance or another appropriate method.
2. Record the forested wetland area in hectares in the yellow box in the V_{TRACT} row on Data Sheet.
3. The WAA value will be automatically transferred to the Data Summary by Plot tab and to the FCI/FCU Calculation Summary tab.

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 are the metrics used to quantify these variables. Measure them with the following procedure (Brown 1974, Brown et al. 1982).

(Note: all stem diameter criteria and measurements for all size classes refer to diameter at the point of intersection with the transect line. Leaning dead stems that intersect the sampling plane are sampled. Dead trees and shrubs still supported by their roots are not sampled. Rooted stumps are not sampled, but uprooted stumps are sampled. Down stems that are decomposed to the point where they no longer maintain their shape but spread out on the ground are not sampled.)

1. Lay out two 15.24-m (50-ft) east-west transects, originating at the 0.04-ha plot center point (Figure 31).
2. Count the number of nonliving stems in Size Class 1 (small) (greater than or equal to 0.6 and less than 2.5 cm or greater than or equal to 0.25 and less than 1 in.) that intersect a vertical plane above a 2-m (6-ft) segment of each 15.24-m (50-ft) transect. This can be any 2-m (6-ft) segment, as long as it is consistently placed. Figure 31 illustrates it as placed at the end furthest from the plot center point. Record the number of Size Class 1 stems from each transect in the yellow spaces provided on the V_{WD} (Size Class 1) line on Data Sheet 2.
3. Count the number of nonliving stems in Size Class 2 (medium) (greater than or equal to 2.5 cm and less than 7.6 cm or greater than or equal to 1 in. and less than 3 in.) that intersect the plane above a 3.7-m (12-ft) segment of each 15.24-m (50-ft) transect. This can be any 3.7-m (12-ft) segment, as long as it is consistently placed. Figure 31 illustrates it as placed at the end furthest from the plot center point, overlapping with the 2-m (6-ft) transect segment. Record the number of Size Class 2 stems from each transect in the yellow spaces provided on the V_{WD} (Size Class 2) line on Data Sheet 2.
4. Measure and record the diameter of nonliving stems in Size Class 3 (large) (greater than or equal to 7.6 cm (≥3 in.)) that intersect the plane above the entire length of the 15.24-m (50-ft) transect. Record the diameter of individual stems (in centimeters) in Size Class 3 from each transect in the yellow spaces provided on the V_{LOG} and V_{WD} (Size Class 3) section on Data Sheet 2.

5. Volume of non-living fallen logs (V_{LOG}.) in m³/hectare and volume of woody debris (V_{WD}.) in m³/hectare will be automatically calculated.
6. The plot value will be automatically transferred to the Data Summary by Plot tab. An overall WAA value will be automatically averaged on that form in the right-hand column. This WAA average value will then transfer automatically to the FCI/FCU Calculation Summary tab.

   Alternative:

   Data Sheet C1 is an alternative field and calculation form that allows V_{LOG} and V_{WD} to be calculated by hand if the user does not wish to use the spreadsheet.

Analyze field data

The analysis of field data requires three steps. The first step is to transform the measure of each assessment variable into a variable subindex. This can be done manually by comparing the summary data (right-hand boxes) from the Data Summary By Plot tab to the graphs in Chapter 5. The second step is to insert the variable subindices into the appropriate assessment models in Chapter 5 and calculate the FCI for each assessed function. Finally, the FCI is multiplied by the area in hectares of the WAA to calculate FCUs for each assessed function.

However, all of these calculations are carried out automatically by entering the raw data into the Arkansas Delta Data Sheets and FCI Calculator. Note that the workbook creates appropriate data sheets and calculators for each subclass, and the subclass *must* be selected first, for proper variables, subindex curves, and formulae to be used. Starting at the FCI Calculator tab, enter the project name, general location, WAA number, WAA size (in hectares), and use the drop-down menu to select a subclass. If the analysis is going to include a simple mitigation sufficiency test using the Mitigation Sufficiency Calculator available at http://el.erdc.usace.army.mil/wetlands/datanal.html, use the drop-down menu for Project Site and Project Timing for instructions on where to enter the calculated FCIs.

Next go to the WAA & Tract Data Entry tab to enter data into Data Sheet 1. At the top of the page there is a place to enter Assessment Team and Sampling Date. Other relevant project data will be carried forward from the FCI Calculator tab. Note that there is a checkbox at the top of the page which, when assessing a Depression, asks if the site is inundated; ground-

level variables are not assessed in depressions with standing water. If desired, separate WAAs can be established for inundated and noninundated subsections of the depression.

When using the Arkansas Delta Data Sheets and FCI Calculator spreadsheet, note that in general yellow cells require data or information input. In many cases, drop-down menus are used. Green or white cells are generally values calculated by the spreadsheet based on data provided by the user. Only yellow cells and drop-down menus may be altered. Do not attempt to clear or enter data into any green or non-shaded boxes – the spreadsheet will not accept direct changes to those cells.

Enter all relevant data into Data Sheet 1. Then use the 11 Plot Data Entry tabs to enter Data Sheet 2 data for up to 11 plots. In the very unlikely case that more than 11 plots are necessary, divide the plots evenly into two WAAs and average the results. Additional plots cannot be added to the Arkansas Delta Data Sheets and FCI Calculator.

The Calculator checks the entered data against expected values, and identifies errors. For instance, if text is entered where a number is expected or a number greater than 100 is entered as a percent, an error message indicating “Invalid Entry” will appear. Likewise, if multiple plots are used, but not all of the variables are filled out for each plot, a “Check Data” message will appear. Address any error messages before continuing.

The last tab of the Calculator is the Data Summary By Plot tab. This may be printed out to show the values for all the variables across all plots within the WAA, as well as the average values. No data may be entered on this sheet.

After all data are entered, the FCI Calculator tab will have the summary of Average Variable Values, Variable Subindices, FCIs and FCUs in a single summary page with basic project and WAA information. This may be printed out or the values may be copied and pasted into Word or other programs.

The Calculator has been designed to be as automated as possible, while protecting the integrity of the numerous formulae necessary for the automated calculations. Hence, most cells cannot be altered, or even selected. This is to help in the speed and accuracy of data entry, but comes

at a cost. It is not possible to combine the use of the Calculator with the use of alternative methods (e.g., using dbh tape to calculate tree basal area rather than prisms). If these more manual sampling techniques are used, there is no easy way to incorporate the results into the Calculator.

Document assessment results

Once all of the data collection, summarization, and analysis steps have been completed, it is important to assemble all pertinent documentation. Appendix A2 is a cover sheet that, when completed, identifies the assembled maps, drawings, project descriptions, data sheets, and summary sheets (including spreadsheet printouts) that are attached to document the assessment. It is highly recommended that this documentation step be completed.

Apply assessment results

Once the assessment and analysis phases are complete, the results can be used to compare the same WAA at different points in time, compare different WAAs at the same point in time, or compare different alternatives to a project. The basic unit of comparison is the FCU, but it is often helpful to examine specific impacts and mitigation actions by examining their effects on the FCI independent of the area affected. The Calculator is a particularly useful tool for testing various scenarios and proposed actions — it allows experimentation with various alternative actions and areas affected to help isolate the project options with the least impact or the most effective restoration or mitigation approaches.

Note that the assessment procedure does not produce a single grand index of function — rather each function is separately assessed and scored, resulting in a set of functional index scores and functional units. How these are used in any particular analysis depends on the objectives of the analysis. In the case of an impact assessment, it may be reasonable to focus on the function that is most detrimentally affected. In cases where certain resources are particular regional priorities, the assessment may tend to focus on the functions most directly associated with those resources. For example, wildlife functions may be particularly important in an area that has been extensively converted to agriculture. Hydrologic functions may be of greatest interest if the project being assessed will alter water storage or flooding patterns. Conversely, this type of analysis can help to recognize when a particular function is being maximized to the

detriment of other functions, as might occur where a wetland is created as part of a stormwater facility; vegetation composition and structure, detritus accumulation, and other variables in such a setting would likely demonstrate that some functions are maintained at very low levels, while hydrologic functions are maximized.

Generally, comparisons can be made only between wetlands or alternatives that involve the same wetland subclass, although comparisons between subclasses can be made on the basis of functions performed rather than the magnitude of functional performance. For example, riverine subclasses have import and export functions that are not present in flats or unconnected depressions. Conversely, unconnected depressions are more likely to support endemic species than are river-connected systems. These types of comparisons may be particularly important where a proposed action will result in a change of subclass. When a levee, for example, will convert a riverine wetland to a flat, it is helpful to be able to recognize that certain import and export functions will no longer occur.

Users of this guidebook 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 the riverine and flats subclasses were dominated by a variety of oak species while the depressional subclasses were dominated by baldcypress and overcup oak. Sites that deviate from these reference conditions may 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 (e.g., cottonwood or willow dominating on new substrates 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 depression sites with near-permanent flooding are dominated by buttonbush. Where this occurs because of water control structures or impeded drainage due to roads, 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 component of

a larger wetland complex, and the V_{COMP} weighting system can be adjusted accordingly. Another potential way to deal with beaver in the modern landscape is to adopt the perspective that beaver complexes are fully functional but transient components of riverine wetland systems for all functions. At the same time, if beaver are not present (even in an area where they would normally be expected to occur), the resulting riverine wetland can be assessed using the models, but the overall WAA is not penalized either way. Other situations that require special consideration include areas affected by fire, sites damaged by ice storms, and similar occurrences. Note, however, that normal, noncatastrophic disturbances to wetlands (i.e., tree mortality causing small openings) are accounted for in the reference data used in this guidebook.

Because the HGM models are calibrated with reference to mature, complex plant communities, and the wildlife habitat models emphasize the requirements of species needing large, contiguous blocks of habitat, early successional wetlands in fragmented landscapes will receive very low assessment scores for the wildlife habitat function. In such situations, it may be useful to supplement the wildlife habitat assessment models with alternative methods such as the Habitat Evaluation Procedures (HEP) (U.S. Fish and Wildlife Service 1980). This approach can provide a more sensitive assessment of the early developmental period following wetland restoration or changes in management than the HGM models presented here.

Another potential consideration in the application of the assessment models presented here concerns the 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 32 represent general recovery trajectories for forested sites within the Delta Region of Arkansas 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 indicators for various time intervals, and calculate functional capacity indices for all assessed functions. These curves are specifically constructed to reflect wetland recovery following restoration of agricultural land, which is the most

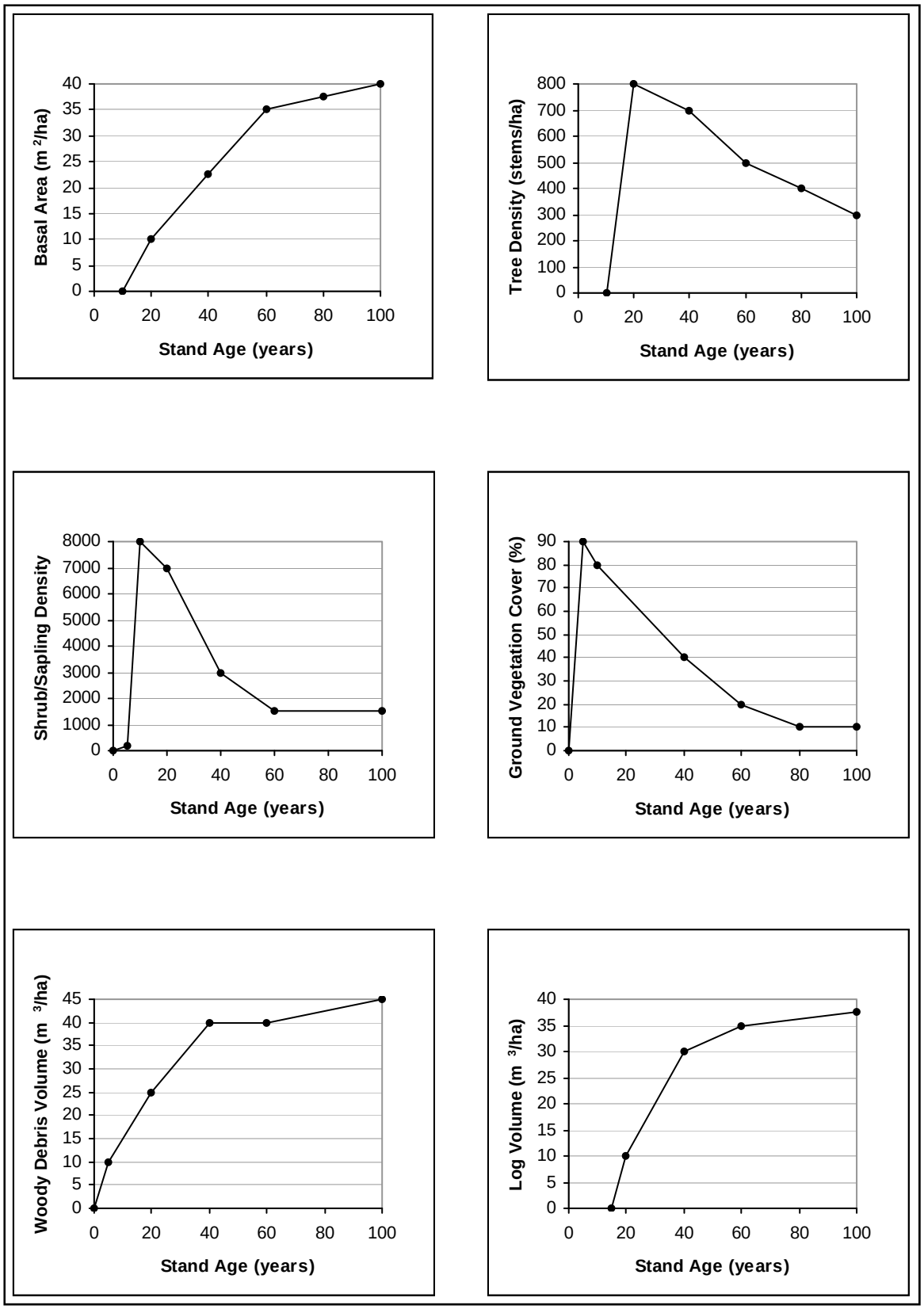


Figure 32. Projected recovery trajectories for selected assessment variables (Continued).

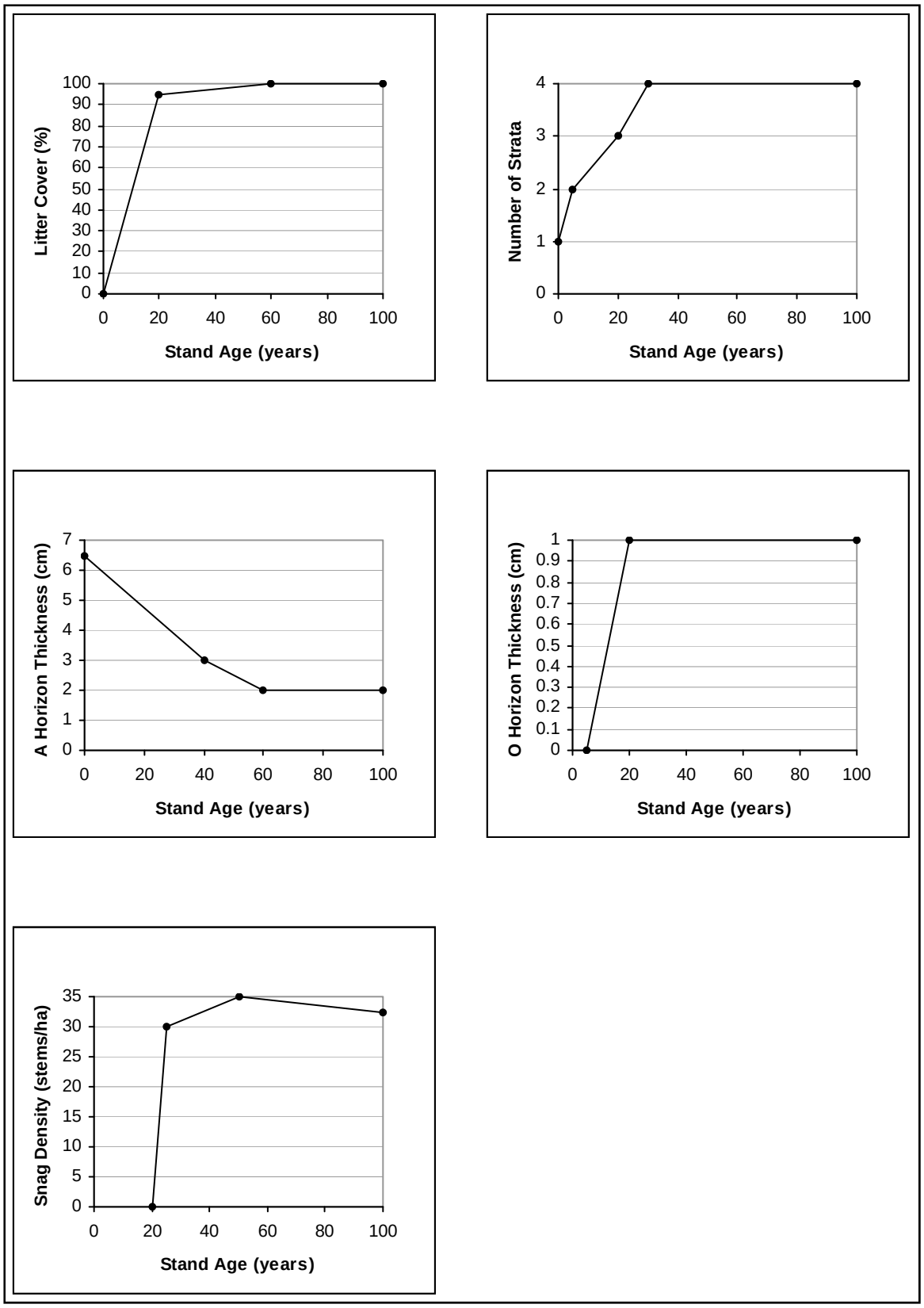


Figure 32. (Concluded).

common restoration scenario in the Delta Region of Arkansas. Therefore, they assume that the initial site condition includes bare ground that has been tilled (hence the deeper initial apparent A horizon). Note that landscape variables are not included here, because they require site-specific knowledge to project future conditions. However, it is also important to carefully consider the changing nature of the block size and connectivity variables used in the HGM models as the site matures. The spatial habitat variables (V_{TRACT}, V_{SCORE}, and V_{CONNECT}) are focused to a great extent on vegetation structure as it provides concealment and movement corridors. Thus, a wetland isolated from nearby forests at the initial assessment may be fully connected within a decade or two if the intervening fields have been allowed to grow into scrub and young forest habitats.

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 FCI score of 1.0 soon after planting for the compositional variable V_{COMP}, and maintain that fully functional status indefinitely as V_{TCOMP} becomes the applicable compositional variable. 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 32 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.

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Appendix A: Preliminary Project Documentation and Field Sampling Guidance

Contents

Appendix A1. Site or Project Information and Assessment Documentation

Appendix A2. Field Assessment Preparation Checklist including list of data sheets

Appendix A3. Layout of Plots and Transects for Field Sampling

Please reproduce these forms locally as needed.

SITE or PROJECT INFORMATION and ASSESSMENT DOCUMENTATION

(Complete one form for entire site or project area)

Date: _____
Project/Site Name: _____
Person(s) involved in assessment:

Field _____

_____

Computations/summarization/quality control_____

The following checked items are attached:

_____ A description of the project, including land ownership, baseline conditions, proposed actions, purpose, project proponent, regulatory or other context, and reviewing agencies.

_____ Maps, aerial photos, and /or drawings of the project area, showing boundaries and identifying labels of Wetland Assessment Areas and project features.

_____ Other pertinent documentation (describe): _____

_____

_____ Field Data Sheets and assessment summaries (listed in table below):

Wetland Assessment Area (WAA) ID Number	HGM Subclass	WAA Size (ha)	Number of plots sampled	Attached Data Sheets and Summary Forms		
				Data Sheets (number attached)		FCI/FCU Summaries (spreadsheet D3 printouts or hand calculations)
				Form 1	Form 2	

Alternative Field and Summarization Forms Attached:
_____ Basal Area (DATA SHEET C1)
_____ Log and Woody Debris (DATA SHEET C2)

FIELD ASSESSMENT PREPARATION CHECKLIST

Prior to conducting field studies, review the checklist below to determine what field gear will be required, and how many copies of each data sheet will be needed. It may be helpful to complete as much of the Project or Site Description Form (Appendix A1) as possible prior to going to the field, and for large or complex assessment areas, that form should be completed as part of a reconnaissance study to classify and map all of the Wetland Assessment Areas within the project area or site boundary.

FIELD GEAR REQUIRED	COMMENTS
DISTANCE TAPE (preferably metric, at least 50 ft or 20 m) AND ANCHOR PIN	Minimum of 1, but 2 will speed work if enough people are available to independently record different information. A survey pin is handy to mark the plot center and anchor the tape for woody debris transects and for determining plot boundaries.
FOLDING RULE	A folding rule, small tape, or dbh caliper suitable for measuring the diameter of logs is needed.
PLANT IDENTIFICATION MANUALS	At least one person on the assessment team must be able to readily and reliably identify woody species, but field guides are recommended as part of the assessment tool kit. If species of concern, threatened, or endangered species are potentially present, the assessment team should include a botanist who can recognize them.
PLOT LAYOUT DIAGRAM	A copy is attached to this checklist.
DATA SHEETS	See data sheet requirements table, below.
BASAL AREA PRISM OR DBH TAPE OR SUITABLE SUBSTITUTE	A 10-factor non-SI unit wedge prism (available from forestry equipment supply companies) is the recommended tool for quickly determining tree basal area. Other tools may be substituted if they provide comparable data. Guidelines for the use of the wedge prism are attached to this checklist. If using a dbh tape or caliper, note that you will need the supplemental field data sheet for recording diameter measurements (Data Sheet C1).
SOIL SURVEY	Optional, but may be helpful in evaluating soil-related variables.
HGM GUIDEBOOK (this document)	At minimum, Chapter 6 should be available in the field to consult regarding field methods. All assessment team members should be familiar with the entire document prior to fieldwork.
SHOVEL OR HEAVY-DUTY TROWEL	If heavy or hard soils are anticipated, a shovel will be necessary. You need to be able to dig at least 10 in. deep. A water bottle is recommended if conditions are dry, to help distinguish soil colors (organic-stained soils must be distinguished from mineral soil).
MISCELLANEOUS SUGGESTED GEAR	You'll need clipboards and pencils, and extra data sheets are highly recommended. Flagging may be helpful for establishing plot centers and boundaries, at least until the assessment team is comfortable with the field procedures. A camera and GPS unit will improve documentation of the assessment and are highly recommended. Record position and take a representative photo at each plot location. Field copies of aerial photos and topo maps may be important if multiple Wetland Assessment Areas must be established and recognized in the field.

DATA SHEETS

Print the following data sheets (Data Sheets 1 and 2, found in Appendix B) in the numbers indicated. (Extras are always a good idea.) Be sure to use the forms developed specifically for the wetland subclass(es) you are assessing.

DATA SHEET	Number of Copies Required
Project or Site Description and Assessment Documentation (1 page)	1
Data Sheet 1 - Tract and WAA-Level Variables (1 page) (Complete using maps, photos, hydrologic data, field reconnaissance, etc.)	1 per Wetland Assessment Area
Data Sheet 2 - Plot-Level Variables (2 pages per set) (Complete by sampling within nested circular plots and along transects)	Multiple sets, depending on size, variability, and number of Wetland Assessment Areas (see Chapter 6)
OPTIONAL: **Alternate Basal Area Field Form** (2 pages) Use if sampling with a dbh tape or caliper (rather than prism); you will also need Form C1 to calculate basal area. Both forms are located in Appendix C. Use of this alternate form does not allow automated calculation of FCIs and FCUs, since only raw prism data may be entered into the calculator.	Multiple copies (same number as Data Sheet 2 sets)

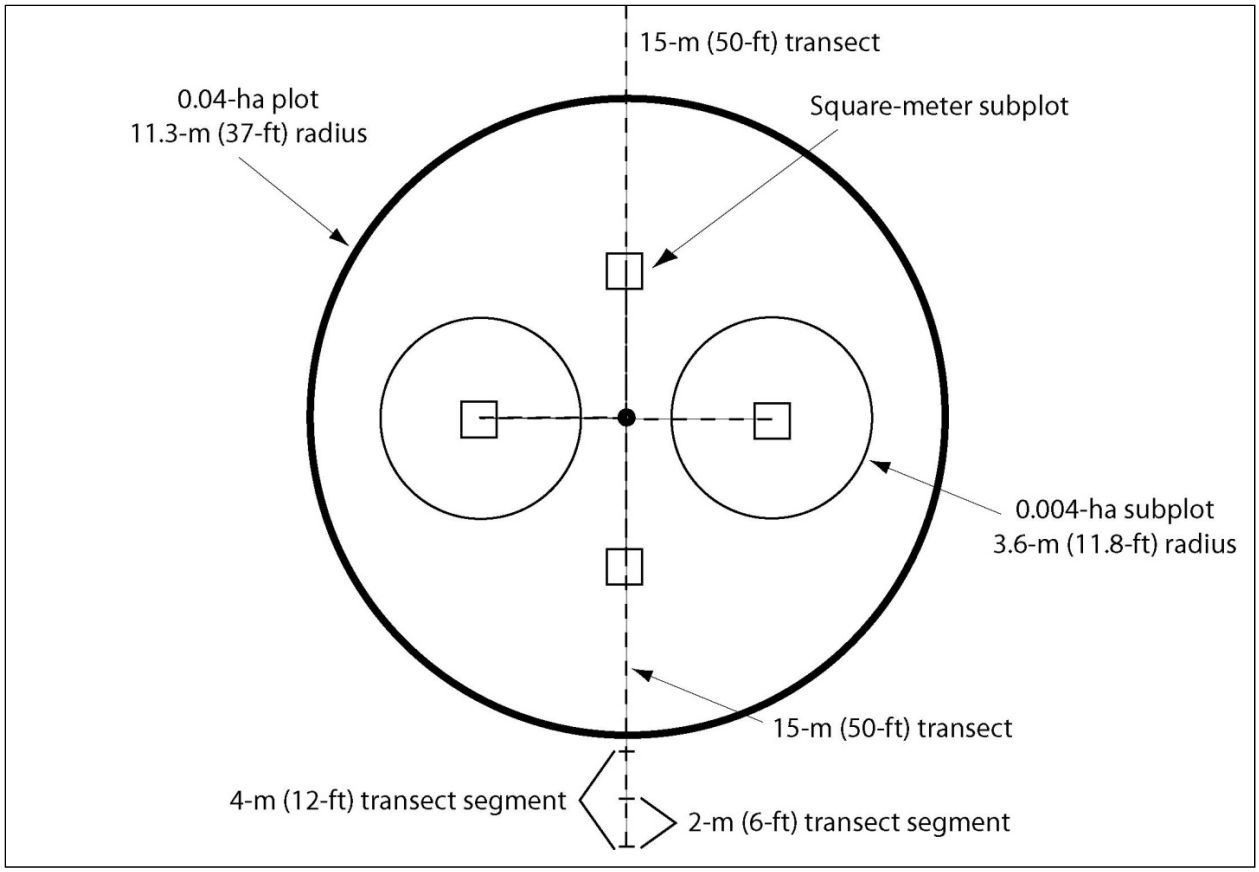

Figure A1. Layout of plots and transects for field sampling.

Appendix B: Field Data Sheets

All of the data sheets shown throughout this appendix are printouts from the Arkansas Delta Data Sheets and FCI Calculator, a single spreadsheet that allows raw data entry, calculates variable values, variable subindices and FCIs and FCUs. In this appendix, only those pages for which raw data are entered are presented. They may be printed out and taken in the field, and then the raw data may be entered in the same form in the Excel spreadsheet, so that automated calculations occur. Pages of the spreadsheet that are completed automatically are not included here, but examples of them are shown in Appendix D.

Contents

Appendix B1. Nonalkali Flat Wetlands

Appendix B2. Low-Gradient Riverine Backwater Wetlands

Appendix B3. Low-Gradient Riverine Overbank Wetlands

Appendix B4. Headwater Depression Wetlands

Appendix B5. Unconnected Depression Wetlands

Appendix B6. Connected Depression Wetlands

Note: This appendix contains printouts of the Arkansas Delta Data Sheets and FCI Calculator spreadsheet. A working copy is available for download at http://el.erdc.usace.army.mil/wetlands/datanal.html

Appendix B1: Field Data Sheets for Nonalkali Flat Wetlands

Data Sheet	Number of Pages	Title
1	1	Tract and Wetland Assessment Area Level Data Collection
2	2	Plot-Level Data Collection
Please reproduce forms for local use as needed.		

Appendix B1-1	Flat	Data Sheet 1 WAA/Tract Data	Sheet 1 of 1

These data sheets represent printouts of an electronic Excel data form that uses raw data to calculate variable indicator values, variable subindices, and ultimately functional capacity indices and units. Enter raw data in the yellow cells. When entering at the computer, use the drop down menus where provided. Green boxes are used by the calculator to run any necessary computations of the raw data before they are compared to subindex curves and translated to a variable subindex in the bottom of Data Sheet 2. Information that is relevant to the entire WAA will only be entered in the WAA/Tract data entry form, and will be carried to the plot data entry summaries and project summary tables.

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ WAA Number:

Project Name: _____

Location: _____ Sampling Date: _____

Subclass: Flat Project Type: _____ Timing: _____

☐ N/A, For Depressions Only

Sample Variables 1-5 using aerial photography, topographic maps, soil survey maps, etc.

1	V_{TRACT}	Forest tract size (ha). From aerial photos or field reconnaissance, estimate the size of the forested area that is contiguous to the WAA and accessible to wildlife (including the WAA itself, if it is forested). Include both upland and wetland forests. Record the area at right. If it exceeds 2,500 ha. (6,178 acres) enter "2500."	
2	V_{CORE}	Percent of wetland tract with at least a 100-m buffer from surrounding land uses. To do this, measure in 100 m from the perimeter of the entire forested area and draw a line. The portion of the wetland tract that lies inside this line is the core area. Percent of the Wetland Tract within the Core:	
3	$V_{CONNECT}$	Percent of wetland tract perimeter within 0.5 km of suitable habitats: upland forests, forested riparian areas, non-forested wetlands, and other natural communities. Excludes farm fields, pastures, heavily grazed or farmed wetlands, isolated clusters of trees, fencerows, clearcuts, wooded subdivisions. Lineal percentage of perimeter with suitable habitat within 0.5 km:	
4	V_{FREQ}	Change in flood frequency. Determine (or estimate) the frequency of flooding from streams for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter 0 if this is not an assessment involving hydrologic alteration. Pre-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5) Post-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5)	Not Used
5	V_{DUR}	Change in flood duration. Determine (or estimate) the duration of continuous flooding from streams (longest single event) during the growing season for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter average weeks of continuous growing season flooding. If greater than 10, enter 10. Pre-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10) Post-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10)	Not Used
6	V_{OUT}	Change in frequency of outflow in Headwater Depressions Only. Determine (or estimate) whether surface output is perennial, seasonal or zero both pre-project and post-project. Pre-project Outflow: Post-project Outflow:	Not Used

Sample Variables 7-9 during onsite field reconnaissance.

7	V_{POND}	Percentage of the site capable of ponding water. Estimate the area likely to pond following extended rainfall. This includes both large vernal pool sites (swales) and microdepressions such as those left by trees that have blown over and uprooted. For Flats, select geomorphic surface below. ONLY If Flat, Choose Geomorphic Surface: Percent ponding:	
8	V_{STRATA}	Number of vegetation strata present. Vegetation layers are considered present if they account for at least 10% cover. **Canopy** (trees ≥ 10 cm dbh that are in the canopy layer) **Subcanopy** (trees ≥ 10 cm dbh that are below the canopy layer) **Understory** (shrubs and saplings < 10 cm dbh but at least 1.4 m (4.5 ft) tall) **Ground cover** (woody plants < 1.4 m (4.5 ft) tall, and herbaceous vegetation) Choose:	
9	V_{SOIL}	Soil integrity. Estimate the percentage of the site that has significantly altered soils. Normal farm tillage is not considered a significant alteration in this case, but fill, land leveling that removes surface horizons, and compacted areas such as roads are counted.	

Appendix B1-2	Flat	Data Sheet 2 - Plot Data	Sheet 1 of 2

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ UTM Easting: _____
Project Name: _____ UTM Northing: _____
Location: _____ Sampling Date: _____
WAA Number: _____ Plot Number: _____ of _____ Plot Area (0.04 ha is standard): _____
Subclass: Flat Project Type: _____ Timing: _____

Sample Variables 10-21 within one or more representative 0.04-ha (0.1-acre) plot(s) within the WAA (separate data sheet each plot)

Observations from the Center Point

10	V_{TBA}	Basal area. Use a basal area wedge prism (English 10-factor) as directed, and tally eligible tree stems. The calculator automatically multiplies this tally by the conversion factor 2.3 to determine m^3/ha. Number of trees tallied	

Observations within a 0.04-ha plot

11	V_{TDEN}	Tree density. Count the number of trees (dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha. Number of trees tallied	
12	V_{SNAG}	Snag density. Count the number of snags (standing dead trees at least 1.4 m (4.5 ft) tall and dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha. Number of snags tallied	
13	V_{OHOR}	Thickness of the O horizon. Select two or more points within the plot that are representative of the range of microtopography within the plot as a whole. Dig a hole and measure the thickness of the O horizon (organic accumulation on the soil surface, excluding fresh litter, but including surface root mats if present). Subplot 1: Subplot 2: Subplot 3: Subplot 4:	
14	V_{AHOR}	Thickness of the A horizon. In the same holes as above, measure the thickness of the A horizon (mineral soil with incorporated organic matter, indicated by distinct darkening relative to lower horizons). Subplot 1: Subplot 2: Subplot 3: Subplot 4:	
15	V_{COMP}	Composition of tallest woody vegetation stratum, percent concurrence. If tree cover is ≥ 20%, use the 50/20 rule (see Chapter 6 for details) and check the dominant trees in Columns A, B, and C. If a dominant does not appear on the list, use local knowledge or literature to assign it to the appropriate column. If tree cover is < 20%, identify the next tallest woody stratum with at least 10% cover.	
16	V_{TCOMP}	Tree composition. ☐ Check box if tree cover is greater than or equal to 20%, and the composition concurrence below is for the tree stratum.	

Group 1 = 1.0	Group 2 = 0.66	Group 3 = 0.33
☐ *Carya ovata*	☐ *Acer negundo*	☐ *Carpinus caroliniana*
☐ *Pinus taeda*	☐ *Carya aquatica*	☐ *Cornus foemina*
☐ *Quercus lyrata*	☐ *Carya illinoensis*	☐ *Crataegus spp.*
☐ *Quercus michauxii*	☐ *Celtis laevigata*	☐ *Forestiera acuminata*
☐ *Quercus nigra*	☐ *Diospyros virginiana*	☐ *Gleditsia triacanthos*
☐ *Quercus nuttallii*	☐ *Fraxinus pennsylvanica*	☐ *Maclura pomifera*
☐ *Quercus pagoda*	☐ *Liquidambar styraciflua*	☐ *Morus rubra*
☐ *Quercus phellos*	☐ *Platanus occidentalis*	☐ *Ulmus crassifolia*
☐ *Quercus stellata*	☐ *Populus deltoides*	☐ *Ulmus alata*
☐ —	☐ *Quercus falcata*	☐ —
☐ —	☐ *Ulmus americana*	☐
☐	☐ —	☐
☐	☐	☐ **Check here if there are no woody species.**
☐	☐	
0 Species in Group 1	0 Species in Group 2	0 Species in Group 3

50/20 Rule: Rank species in descending order of percent cover, summing relative dominance in descending order until 50 percent is exceeded. This list of species, along with any additional species comprising at least 20 percent relative dominance, represent the dominant species in the plot.

Appendix B1-2	Flat	Data Sheet 2 - Plot Data	Sheet 2 of 2

Observations within two 0.004-ha plots. From the center point, measure north and south 5 m and establish two circular subplots with a radius of 3.6 m (11.8 ft). Within each subplot, measure the following:

17	V_{SSD}	Shrub/Sapling density. Count the number of woody stems that are at least 1.4 m (4.5 ft) tall, but less than 10 cm dbh in each subplot. The calculator multiplies the sum of both plots by 125 to determine understory stems/ha. Subplot 1: Subplot 2:	

Observations within 4 1-m × 1-m square subplots. From the center point, measure 5 m in each cardinal direction and establish a 1-m × 1-m square subplot. Within each subplot record the following:

18	V_{GVC}	Ground vegetation cover. Estimate the percent cover of all herbaceous plants and woody plants < 1.4 m (4.5 ft) tall. The calculator automatically averages the results of the four subplots. Subplot 1: Subplot 2: Subplot 3: Subplot 4:	
19	V_{LITTER}	Litter cover. Estimate the percent of the plot area covered by undecomposed litter. The calculator automatically averages the results of the four subplots. Subplot 1: Subplot 2: Subplot 3: Subplot 4:	

Observations along transects.

20	V_{LOG}	Log biomass. Volume per hectare of non-living fallen logs (m^3/ha).	
21	V_{WD}	Woody debris biomass. Volume per hectare of non-living fallen woody stems (m^3/ha).	

	Transect 1	Transect 2
Number of stems with diameters greater than or equal to 0.6 cm (0.25 in) and less than 2.5 cm (1 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Number of stems with diameters greater than or equal to 2.5 cm (1 in) and less than 7.6 cm (3 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Enter diameters (cm) of each fallen woody stem 7.6 cm (3 inches) or greater in diameter in each 50-foot transect. If there are no logs of this size, enter 0.		

Plot Summary

Variable	Value	VSI
V_{TRACT}		
V_{CORE}		
$V_{CONNECT}$		
V_{FREQ}		
V_{DUR}		
V_{OUT}		
V_{POND}		
V_{STRATA}		
V_{SOIL}		
V_{TBA}		
V_{TDEN}		
V_{SNAG}		
V_{OHOR}		
V_{AHOR}		
V_{COMP}		
V_{TCOMP}		
V_{SSD}		
V_{GVC}		
V_{LITTER}		
V_{LOG}		
V_{WD}		

Notes:

Appendix B2: Field Data Sheets for Low-Gradient Riverine Backwater Wetlands

Data Sheet	Number of Pages	Title
1	1	Tract and Wetland Assessment Area Level Data Collection
2	2	Plot-Level Data Collection
Please reproduce forms for local use as needed.		

Appendix B2-1	Low-Gradient Riverine Backwater	Data Sheet 1 WAA/Tract Data	Sheet 1 of 1

These data sheets represent printouts of an electronic Excel data form that uses raw data to calculate variable indicator values, variable subindices, and ultimately functional capacity indices and units. Enter raw data in the yellow cells. When entering at the computer, use the drop down menus where provided. Green boxes are used by the calculator to run any necessary computations of the raw data before they are compared to subindex curves and translated to a variable subindex in the bottom of Data Sheet 2. Information that is relevant to the entire WAA will only be entered in the WAA/Tract data entry form, and will be carried to the plot data entry summaries and project summary tables.

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ WAA Number:

Project Name: _____

Location: _____ Sampling Date: _____

Subclass: Low-Gradient Riverine Backwater Project Type: _____ Timing: _____

☐ N/A, For Depressions Only

Sample Variables 1-5 using aerial photography, topographic maps, soil survey maps, etc.

1	V_{TRACT}	Forest tract size (ha). From aerial photos or field reconnaissance, estimate the size of the forested area that is contiguous to the WAA and accessible to wildlife (including the WAA itself, if it is forested). Include both upland and wetland forests. Record the area at right. If it exceeds 2,500 ha, (6,178 acres) enter "2500."	
2	V_{CORE}	Percent of wetland tract with at least a 100-m buffer from surrounding land uses. To do this, measure in 100 m from the perimeter of the entire forested area and draw a line. The portion of the wetland tract that lies inside this line is the core area. Percent of the Wetland Tract within the Core:	
3	$V_{CONNECT}$	Percent of wetland tract perimeter within 0.5 km of suitable habitats: upland forests, forested riparian areas, non-forested wetlands, and other natural communities. Excludes farm fields, pastures, heavily grazed or farmed wetlands, isolated clusters of trees, fencerows, clearcuts, wooded subdivisions. Lineal percentage of perimeter with suitable habitat within 0.5 km:	
4	V_{FREQ}	Change in flood frequency. Determine (or estimate) the frequency of flooding from streams for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter 0 if this is not an assessment involving hydrologic alteration. Pre-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5) Post-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5)	
5	V_{DUR}	Change in flood duration. Determine (or estimate) the duration of continuous flooding from streams (longest single event) during the growing season for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter average weeks of continuous growing season flooding. If greater than 10, enter 10. Pre-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10) Post-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10)	
6	V_{OUT}	Change in frequency of outflow in Headwater Depressions Only. Determine (or estimate) whether surface output is perennial, seasonal or zero both pre-project and post-project. Pre-project Outflow: Post-project Outflow:	Not Used

Sample Variables 7-9 during onsite field reconnaissance.

7	V_{POND}	Percentage of the site capable of ponding water. Estimate the area likely to pond following extended rainfall. This includes both large vernal pool sites (swales) and microdepressions such as those left by trees that have blown over and uprooted. For Flats, select geomorphic surface below. ONLY If Flat, Choose Geomorphic Surface: Percent ponding:	
8	V_{STRATA}	Number of vegetation strata present. Vegetation layers are considered present if they account for at least 10% cover. **Canopy** (trees ≥ 10 cm dbh that are in the canopy layer) **Subcanopy** (trees ≥ 10 cm dbh that are below the canopy layer) **Understory** (shrubs and saplings < 10 cm dbh but at least 1.4 m (4.5 ft) tall) **Ground cover** (woody plants < 1.4 m (4.5 ft) tall, and herbaceous vegetation) Choose:	
9	V_{SOIL}	Soil integrity. Estimate the percentage of the site that has significantly altered soils. Normal farm tillage is not considered a significant alteration in this case, but fill, land leveling that removes surface horizons, and compacted areas such as roads are counted.	

Appendix B2-2 Low-Gradient Riverine Backwater Data Sheet 2 - Plot Data Sheet 1 of 2

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ UTM Easting: _____
Project Name: _____ UTM Northing: _____
Location: _____ Sampling Date: _____
WAA Number: _____ Plot Number: _____ of _____ Plot Area (0.04 ha is standard): _____
Subclass: Low-Gradient Riverine Backwater Project Type: _____ Timing: _____

Sample Variables 10-21 within one or more representative 0.04-ha (0.1-acre) plot(s) within the WAA (separate data sheet each plot)

Observations from the Center Point

10	V_{TBA}	Basal area. Use a basal area wedge prism (English 10-factor) as directed, and tally eligible tree stems. The calculator automatically multiplies this tally by the conversion factor 2.3 to determine m^3/ha.	
		Number of trees tallied	

Observations within a 0.04-ha plot

11	V_{TDEN}	Tree density. Count the number of trees (dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha.	
		Number of trees tallied	
12	V_{SNAG}	Snag density. Count the number of snags (standing dead trees at least 1.4 m (4.5 ft) tall and dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha.	
		Number of snags tallied	
13	V_{OHOR}	Thickness of the O horizon. Select two or more points within the plot that are representative of the range of microtopography within the plot as a whole. Dig a hole and measure the thickness of the O horizon (organic accumulation on the soil surface, excluding fresh litter, but including surface root mats if present). Subplot 1: Subplot 2: Subplot 3: Subplot 4:	
14	V_{AHOR}	Thickness of the A horizon. In the same holes as above, measure the thickness of the A horizon (mineral soil with incorporated organic matter, indicated by distinct darkening relative to lower horizons). Subplot 1: Subplot 2: Subplot 3: Subplot 4:	
15	V_{COMP}	Composition of tallest woody vegetation stratum, percent concurrence. If tree cover is ≥ 20%, use the 50/20 rule (see Chapter 6 for details) and check the dominant trees in Columns A, B, and C. If a dominant does not appear on the list, use local knowledge or literature to assign it to the appropriate column. If tree cover is < 20%, identify the next tallest woody stratum with at least 10% cover.	
16	V_{TCOMP}	Tree composition. ☐ Check box if tree cover is greater than or equal to 20%, and the composition concurrence below is for the tree stratum.	

Group 1 = 1.0	Group 2 = 0.66	Group 3 = 0.33
☐ *Carya aquatica*	☐ *Acer drummondii*	☐ *Carpinus caroliniana*
☐ *Quercus lyrata*	☐ *Acer negundo*	☐ *Cornus drummondii*
☐ *Quercus nuttallii*	☐ *Acer rubrum*	☐ *Cornus foemina*
☐ *Quercus phellos*	☐ *Carya illinoensis*	☐ *Crataegus spp.*
☐ —	☐ *Celtis laevigata*	☐ *Forestiera acuminata*
☐ —	☐ *Diospyros virginiana*	☐ *Ilex decidua*
☐ —	☐ *Fraxinus pennsylvanica*	☐ *Planera aquatica*
☐ —	☐ *Gleditsia aquatica*	☐ —
☐ —	☐ *Liquidambar styraciflua*	☐ —
☐ —	☐ *Salix nigra*	☐ —
☐ —	☐ *Ulmus americana*	☐
☐	☐ *Ulmus crassifolia*	☐
☐	☐	☐ **Check here if there are no woody species.**
☐	☐	
0 Species in Group 1	0 Species in Group 2	0 Species in Group 3

50/20 Rule: Rank species in descending order of percent cover, summing relative dominance in descending order until 50 percent is exceeded. This list of species, along with any additional species comprising at least 20 percent relative dominance, represent the dominant species in the plot.

Appendix B2-2 Low-Gradient Riverine Backwater Data Sheet 2 - Plot Data Sheet 2 of 2

Observations within two 0.004-ha plots. From the center point, measure north and south 5 m and establish two circular subplots with a radius of 3.6 m (11.8 ft). Within each subplot, measure the following:

17 V_{SSD} Shrub/Sapling density. Count the number of woody stems that are at least 1.4 m (4.5 ft) tall, but less than 10 cm dbh in each subplot. The calculator multiplies the sum of both plots by 125 to determine understory stems/ha.

Subplot 1: Subplot 2:

Observations within 4 1-m × 1-m square subplots. From the center point, measure 5 m in each cardinal direction and establish a 1-m × 1-m square subplot. Within each subplot record the following:

18 V_{GVC} Ground vegetation cover. Estimate the percent cover of all herbaceous plants and woody plants < 1.4 m (4.5 ft) tall. The calculator automatically averages the results of the four subplots.

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

19 V_{LITTER} Litter cover. Estimate the percent of the plot area covered by undecomposed litter. The calculator automatically averages the results of the four subplots.

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

Observations along transects.

20 V_{LOG} Log biomass. Volume per hectare of non-living fallen logs (m^3/ha).

21 V_{WD} Woody debris biomass. Volume per hectare of non-living fallen woody stems (m^3/ha).

	Transect 1	Transect 2
Number of stems with diameters greater than or equal to 0.6 cm (0.25 in) and less than 2.5 cm (1 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Number of stems with diameters greater than or equal to 2.5 cm (1 in) and less than 7.6 cm (3 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Enter diameters (cm) of each fallen woody stem 7.6 cm (3 inches) or greater in diameter in each 50-foot transect. If there are no logs of this size, enter 0.		

Plot Summary

Variable	Value	VSI
V_{TRACT}		
V_{CORE}		
$V_{CONNECT}$		
V_{FREQ}		
V_{DUR}		
V_{OUT}		
V_{POND}		
V_{STRATA}		
V_{SOIL}		
V_{TBA}		
V_{TDEN}		
V_{SNAG}		
V_{OHOR}		
V_{AHOR}		
V_{COMP}		
V_{TCOMP}		
V_{SSD}		
V_{GVC}		
V_{LITTER}		
V_{LOG}		
V_{WD}		

Notes:

Appendix B3: Field Data Sheets for Low-Gradient Riverine Overbank Wetlands

Data Sheet	Number of Pages	Title
1	1	Tract and Wetland Assessment Area Level Data Collection
2	2	Plot-Level Data Collection
Please reproduce forms for local use as needed.		

Appendix B3-1	Low-Gradient Riverine Overbank	Data Sheet 1 WAA/Tract Data	Sheet 1 of 1

These data sheets represent printouts of an electronic Excel data form that uses raw data to calculate variable indicator values, variable subindices, and ultimately functional capacity indices and units. Enter raw data in the yellow cells. When entering at the computer, use the drop down menus where provided. Green boxes are used by the calculator to run any necessary computations of the raw data before they are compared to subindex curves and translated to a variable subindex in the bottom of Data Sheet 2. Information that is relevant to the entire WAA will only be entered in the WAA/Tract data entry form, and will be carried to the plot data entry summaries and project summary tables.

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ WAA Number:

Project Name: _____

Location: _____ Sampling Date: _____

Subclass: Low-Gradient Riverine Overbank Project Type: _____ Timing: _____

☐ N/A, For Depressions Only

Sample Variables 1-5 using aerial photography, topographic maps, soil survey maps, etc.

1	V_{TRACT}	Forest tract size (ha). From aerial photos or field reconnaissance, estimate the size of the forested area that is contiguous to the WAA and accessible to wildlife (including the WAA itself, if it is forested). Include both upland and wetland forests. Record the area at right. If it exceeds 2,500 ha, (6,178 acres) enter "2500."	
2	V_{CORE}	Percent of wetland tract with at least a 100-m buffer from surrounding land uses. To do this, measure in 100 m from the perimeter of the entire forested area and draw a line. The portion of the wetland tract that lies inside this line is the core area.	
		Percent of the Wetland Tract within the Core:	
3	$V_{CONNECT}$	Percent of wetland tract perimeter within 0.5 km of suitable habitats: upland forests, forested riparian areas, non-forested wetlands, and other natural communities. Excludes farm fields, pastures, heavily grazed or farmed wetlands, isolated clusters of trees, fencerows, clearcuts, wooded subdivisions.	
		Lineal percentage of perimeter with suitable habitat within 0.5 km:	
4	V_{FREQ}	Change in flood frequency. Determine (or estimate) the frequency of flooding from streams for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter 0 if this is not an assessment involving hydrologic alteration.	
		Pre-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5)	
		Post-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5)	
5	V_{DUR}	Change in flood duration. Determine (or estimate) the duration of continuous flooding from streams (longest single event) during the growing season for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter average weeks of continuous growing season flooding. If greater than 10, enter 10.	
		Pre-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10)	
		Post-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10)	
6	V_{OUT}	Change in frequency of outflow in Headwater Depressions Only. Determine (or estimate) whether surface output is perennial, seasonal or zero both pre-project and post-project.	Not Used
		Pre-project Outflow:	
		Post-project Outflow:	

Sample Variables 7-9 during onsite field reconnaissance.

7	V_{POND}	Percentage of the site capable of ponding water. Estimate the area likely to pond following extended rainfall. This includes both large vernal pool sites (swales) and microdepressions such as those left by trees that have blown over and uprooted. For Flats, select geomorphic surface below.	
		ONLY If Flat, Choose Geomorphic Surface: Percent ponding:	
8	V_{STRATA}	Number of vegetation strata present. Vegetation layers are considered present if they account for at least 10% cover.	
		Canopy (trees ≥ 10 cm dbh that are in the canopy layer) **Subcanopy** (trees ≥ 10 cm dbh that are below the canopy layer) **Understory** (shrubs and saplings < 10 cm dbh but at least 1.4 m (4.5 ft) tall) **Ground cover** (woody plants < 1.4 m (4.5 ft) tall, and herbaceous vegetation)	Choose:
9	V_{SOIL}	Soil integrity. Estimate the percentage of the site that has significantly altered soils. Normal farm tillage is not considered a significant alteration in this case, but fill, land leveling that removes surface horizons, and compacted areas such as roads are counted.	

Appendix B3-2 Low-Gradient Riverine Overbank Data Sheet 2 - Plot Data Sheet 1 of 2

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ UTM Easting: _____
Project Name: _____ UTM Northing: _____
Location: _____ Sampling Date: _____
WAA Number: _____ Plot Number: _____ of _____ Plot Area (0.04 ha is standard): _____
Subclass: Low-Gradient Riverine Overbank Project Type: _____ Timing: _____

Sample Variables 10-21 within one or more representative 0.04-ha (0.1-acre) plot(s) within the WAA (separate data sheet each plot)

Observations from the Center Point

10	V_{TBA}	Basal area. Use a basal area wedge prism (English 10-factor) as directed, and tally eligible tree stems. The calculator automatically multiplies this tally by the conversion factor 2.3 to determine m^3/ha. Number of trees tallied	

Observations within a 0.04-ha plot

11	V_{TDEN}	Tree density. Count the number of trees (dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha. Number of trees tallied	
12	V_{SNAG}	Snag density. Count the number of snags (standing dead trees at least 1.4 m (4.5 ft) tall and dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha. Number of snags tallied	
13	V_{OHOR}	Thickness of the O horizon. Select two or more points within the plot that are representative of the range of microtopography within the plot as a whole. Dig a hole and measure the thickness of the O horizon (organic accumulation on the soil surface, excluding fresh litter, but including surface root mats if present). Subplot 1: Subplot 2: Subplot 3: Subplot 4:	
14	V_{AHOR}	Thickness of the A horizon. In the same holes as above, measure the thickness of the A horizon (mineral soil with incorporated organic matter, indicated by distinct darkening relative to lower horizons). Subplot 1: Subplot 2: Subplot 3: Subplot 4:	
15	V_{COMP}	Composition of tallest woody vegetation stratum, percent concurrence. If tree cover is ≥ 20%, use the 50/20 rule (see Chapter 6 for details) and check the dominant trees in Columns A, B, and C. If a dominant does not appear on the list, use local knowledge or literature to assign it to the appropriate column. If tree cover is < 20%, identify the next tallest woody stratum with at least 10% cover.	
16	V_{TCOMP}	Tree composition. ☐ Check box if tree cover is greater than or equal to 20%, and the composition concurrence below is for the tree stratum.	

Group 1 = 1.0	Group 2 = 0.66	Group 3 = 0.33
☐ *Carya aquatica*	☐ *Acer rubrum*	☐ *Acer negundo*
☐ *Carya illinoensis*	☐ *Acer saccharinum*	☐ *Carpinus caroliniana*
☐ *Gleditsia aquatica*	☐ *Celtis laevigata*	☐ *Crataegus spp.*
☐ *Platanus occidentalis*	☐ *Diospyros virginiana*	☐ *Forestiera acuminata*
☐ *Populus detoides*	☐ *Fraxinus pennsylvanica*	☐ *Morus rubra*
☐ *Quercus lyrata*	☐ *Liquidambar styraciflua*	☐ *Planera aquatica*
☐ *Quercus nuttallii*	☐ *Quercus nigra*	☐ *Ulmus crassifolia*
☐ *Quercus pagoda*	☐ *Ulmus americana*	☐ —
☐ *Quercus phellos*	☐ —	☐ —
☐ *Salix spp.*	☐ —	☐ —
☐ *Taxodium distichum*	☐ —	☐
☐	☐ —	☐
☐	☐	☐ **Check here if there are no woody species.**
☐	☐	
0 Species in Group 1	0 Species in Group 2	0 Species in Group 3

50/20 Rule: Rank species in descending order of percent cover, summing relative dominance in descending order until 50 percent is exceeded. This list of species, along with any additional species comprising at least 20 percent relative dominance, represent the dominant species in the plot.

Appendix B3-2	Low-Gradient Riverine Overbank	Data Sheet 2 - Plot Data	Sheet 2 of 2

Observations within two 0.004-ha plots. From the center point, measure north and south 5 m and establish two circular subplots with a radius of 3.6 m (11.8 ft). Within each subplot, measure the following:

17	V_{SSD}	Shrub/Sapling density. Count the number of woody stems that are at least 1.4 m (4.5 ft) tall, but less than 10 cm dbh in each subplot. The calculator multiplies the sum of both plots by 125 to determine understory stems/ha.	

Subplot 1: Subplot 2:

Observations within 4 1-m × 1-m square subplots. From the center point, measure 5 m in each cardinal direction and establish a 1-m × 1-m square subplot. Within each subplot record the following:

18	V_{GVC}	Ground vegetation cover. Estimate the percent cover of all herbaceous plants and woody plants < 1.4 m (4.5 ft) tall. The calculator automatically averages the results of the four subplots.	

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

19	V_{LITTER}	Litter cover. Estimate the percent of the plot area covered by undecomposed litter. The calculator automatically averages the results of the four subplots.	

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

Observations along transects.

20	V_{LOG}	Log biomass. Volume per hectare of non-living fallen logs (m^3/ha).	
21	V_{WD}	Woody debris biomass. Volume per hectare of non-living fallen woody stems (m^3/ha).	

	Transect 1	Transect 2
Number of stems with diameters greater than or equal to 0.6 cm (0.25 in) and less than 2.5 cm (1 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Number of stems with diameters greater than or equal to 2.5 cm (1 in) and less than 7.6 cm (3 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Enter diameters (cm) of each fallen woody stem 7.6 cm (3 inches) or greater in diameter in each 50-foot transect. If there are no logs of this size, enter 0.		

Plot Summary

Variable	Value	VSI
V_{TRACT}		
V_{CORE}		
$V_{CONNECT}$		
V_{FREQ}		
V_{DUR}		
V_{OUT}		
V_{POND}		
V_{STRATA}		
V_{SOIL}		
V_{TBA}		
V_{TDEN}		
V_{SNAG}		
V_{OHOR}		
V_{AHOR}		
V_{COMP}		
V_{TCOMP}		
V_{SSD}		
V_{GVC}		
V_{LITTER}		
V_{LOG}		
V_{WD}		

Notes:

Appendix B4: Field Data Sheets for Headwater Depression Wetlands

Data Sheet	Number of Pages	Title
1	1	Tract and Wetland Assessment Area Level Data Collection
2	2	Plot-Level Data Collection
Please reproduce forms for local use as needed.		

Appendix B4-1	Headwater Depression	Data Sheet 1 WAA/Tract Data	Sheet 1 of 1

These data sheets represent printouts of an electronic Excel data form that uses raw data to calculate variable indicator values, variable subindices, and ultimately functional capacity indices and units. Enter raw data in the yellow cells. When entering at the computer, use the drop down menus where provided. Green boxes are used by the calculator to run any necessary computations of the raw data before they are compared to subindex curves and translated to a variable subindex in the bottom of Data Sheet 2. Information that is relevant to the entire WAA will only be entered in the WAA/Tract data entry form, and will be carried to the plot data entry summaries and project summary tables.

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ WAA Number:

Project Name: _____

Location: _____ Sampling Date: _____

Subclass: Headwater Depression Project Type: _____ Timing: _____

☐ Check if Depression is Inundated

Sample Variables 1-5 using aerial photography, topographic maps, soil survey maps, etc.

1	V_{TRACT}	Forest tract size (ha). From aerial photos or field reconnaissance, estimate the size of the forested area that is contiguous to the WAA and accessible to wildlife (including the WAA itself, if it is forested). Include both upland and wetland forests. Record the area at right. If it exceeds 2,500 ha, (6,178 acres) enter "2500."	
2	V_{CORE}	Percent of wetland tract with at least a 100-m buffer from surrounding land uses. To do this, measure in 100 m from the perimeter of the entire forested area and draw a line. The portion of the wetland tract that lies inside this line is the core area. Percent of the Wetland Tract within the Core:	
3	$V_{CONNECT}$	Percent of wetland tract perimeter within 0.5 km of suitable habitats: upland forests, forested riparian areas, non-forested wetlands, and other natural communities. Excludes farm fields, pastures, heavily grazed or farmed wetlands, isolated clusters of trees, fencerows, clearcuts, wooded subdivisions. Lineal percentage of perimeter with suitable habitat within 0.5 km:	
4	V_{FREQ}	Change in flood frequency. Determine (or estimate) the frequency of flooding from streams for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter 0 if this is not an assessment involving hydrologic alteration. Pre-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5) Post-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5)	Not Used
5	V_{DUR}	Change in flood duration. Determine (or estimate) the duration of continuous flooding from streams (longest single event) during the growing season for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter average weeks of continuous growing season flooding. If greater than 10, enter 10. Pre-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10) Post-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10)	
6	V_{OUT}	Change in frequency of outflow in Headwater Depressions Only. Determine (or estimate) whether surface output is perennial, seasonal or zero both pre-project and post-project. Pre-project Outflow: Post-project Outflow:	

Sample Variables 7-9 during onsite field reconnaissance.

7	V_{POND}	Percentage of the site capable of ponding water. Estimate the area likely to pond following extended rainfall. This includes both large vernal pool sites (swales) and microdepressions such as those left by trees that have blown over and uprooted. For Flats, select geomorphic surface below. ONLY If Flat, Choose Geomorphic Surface: Percent ponding:	Not Used
8	V_{STRATA}	Number of vegetation strata present. Vegetation layers are considered present if they account for at least 10% cover. **Canopy** (trees ≥ 10 cm dbh that are in the canopy layer) **Subcanopy** (trees ≥ 10 cm dbh that are below the canopy layer) **Understory** (shrubs and saplings < 10 cm dbh but at least 1.4 m (4.5 ft) tall) **Ground cover** (woody plants < 1.4 m (4.5 ft) tall, and herbaceous vegetation) Choose:	
9	V_{SOIL}	Soil integrity. Estimate the percentage of the site that has significantly altered soils. Normal farm tillage is not considered a significant alteration in this case, but fill, land leveling that removes surface horizons, and compacted areas such as roads are counted. This variable not used if the depression is inundated.	

Appendix B4-2 **Headwater Depression** **Data Sheet 2 - Plot Data** **Sheet 1 of 2**

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ UTM Easting: _____
Project Name: _____ UTM Northing: _____
Location: _____ Sampling Date: _____
WAA Number: _____ Plot Number: _____ of _____ Plot Area (0.04 ha is standard): _____
Subclass: Headwater Depression _____ Project Type: _____ Timing: _____
Uninundated Depression

Sample Variables 10-21 within one or more representative 0.04-ha (0.1-acre) plot(s) within the WAA (separate data sheet each plot)

Observations from the Center Point

10	V_{TBA}	Basal area. Use a basal area wedge prism (English 10-factor) as directed, and tally eligible tree stems. The calculator automatically multiplies this tally by the conversion factor 2.3 to determine m^2/ha. Number of trees tallied	

Observations within a 0.04-ha plot

11	V_{TDEN}	Tree density. Count the number of trees (dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha. Number of trees tallied	
12	V_{SNAG}	Snag density. Count the number of snags (standing dead trees at least 1.4 m (4.5 ft) tall and dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha. Number of snags tallied	
13	V_{OHOR}	Thickness of the O horizon. Select two or more points within the plot that are representative of the range of microtopography within the plot as a whole. Dig a hole and measure the thickness of the O horizon (organic accumulation on the soil surface, excluding fresh litter, but including surface root mats if present). This variable is not used if depression is inundated. Subplot 1: _____ Subplot 2: _____ Subplot 3: _____ Subplot 4: _____	
14	V_{AHOR}	Thickness of the A horizon. In the same holes as above, measure the thickness of the A horizon (mineral soil with incorporated organic matter, indicated by distinct darkening relative to lower horizons). This variable is not used if depression is inundated. Subplot 1: _____ Subplot 2: _____ Subplot 3: _____ Subplot 4: _____	
15	V_{COMP}	Composition of tallest woody vegetation stratum, percent concurrence. If tree cover is ≥ 20%, use the 50/20 rule (see Chapter 6 for details) and check the dominant trees in Columns A, B, and C. If a dominant does not appear on the list, use local knowledge or literature to assign it to the appropriate column. If tree cover is < 20%, identify the next tallest woody stratum with at least 10% cover.	
16	V_{TCOMP}	Tree composition. ☐ Check box if tree cover is greater than or equal to 20%, and the composition concurrence below is for the tree stratum.	

Group 1 = 1.0	Group 2 = 0.66	Group 3 = 0.33
☐ *Acer drummondii*	☐ *Cephalanthus occidentalis*	☐ —
☐ *Acer rubrum*	☐ *Diospyros virginiana*	☐ —
☐ *Fraxinus pennsylvanica*	☐ *Forestiera acuminata*	☐ —
☐ *Nyssa aquatica*	☐ *Gleditsia aquatica*	☐ —
☐ *Populus heterophyla*	☐ *Planera aquatica*	☐ —
☐ *Quercus lyrata*	☐ *Ulmus americana*	☐ —
☐ *Taxodium distichum*	☐ —	☐ —
☐ —	☐ —	☐ —
☐ —	☐ —	☐ —
☐ —	☐ —	☐ —
☐	☐ —	☐
☐	☐	☐
☐	☐	☐ **Check here if there are no woody species.**
0 Species in Group 1	0 Species in Group 2	0 Species in Group 3

50/20 Rule: Rank species in descending order of percent cover, summing relative dominance in descending order until 50 percent is exceeded. This list of species, along with any additional species comprising at least 20 percent relative dominance, represent the dominant species in the plot.

Appendix B4-2	Headwater Depression	Data Sheet 2 - Plot Data	Sheet 2 of 2

Observations within two 0.004-ha plots. From the center point, measure north and south 5 m and establish two circular subplots with a radius of 3.6 m (11.8 ft). Within each subplot, measure the following:

17	V_{SSD}	Shrub/Sapling density. Count the number of woody stems that are at least 1.4 m (4.5 ft) tall, but less than 10 cm dbh in each subplot. The calculator multiplies the sum of both plots by 125 to determine understory stems/ha. Subplot 1: Subplot 2:	

Observations within 4 1-m × 1-m square subplots. From the center point, measure 5 m in each cardinal direction and establish a 1-m × 1-m square subplot. Within each subplot record the following:

18	V_{GVC}	Ground vegetation cover. Estimate the percent cover of all herbaceous plants and woody plants < 1.4 m (4.5 ft) tall. The calculator automatically averages the results of the four subplots. This variable is not used if depression is inundated. Subplot 1: Subplot 2: Subplot 3: Subplot 4:	
19	V_{LITTER}	Litter cover. Estimate the percent of the plot area covered by undecomposed litter. The calculator automatically averages the results of the four subplots. This variable is not used if depression is inundated. Subplot 1: Subplot 2: Subplot 3: Subplot 4:	

Observations along transects.

20	V_{LOG}	Log biomass. Volume per hectare of non-living fallen logs (m^3/ha).	
21	V_{WD}	Woody debris biomass. Volume per hectare of non-living fallen woody stems (m^3/ha).	

These variables are not used if depression is inundated.

	Transect 1	Transect 2
Number of stems with diameters greater than or equal to 0.6 cm (0.25 in) and less than 2.5 cm (1 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Number of stems with diameters greater than or equal to 2.5 cm (1 in) and less than 7.6 cm (3 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Enter diameters (cm) of each fallen woody stem 7.6 cm (3 inches) or greater in diameter in each 50-foot transect. If there are no logs of this size, enter 0.		

Plot Summary

Variable	Value	VSI
V_{TRACT}		
V_{CORE}		
$V_{CONNECT}$		
V_{FREQ}		
V_{DUR}		
V_{OUT}		
V_{POND}		
V_{STRATA}		
V_{SOIL}		
V_{TBA}		
V_{TDEN}		
V_{SNAG}		
V_{OHOR}		
V_{AHOR}		
V_{COMP}		
V_{TCOMP}		
V_{SSD}		
V_{GVC}		
V_{LITTER}		
V_{LOG}		
V_{WD}		

Notes:

Appendix B5: Field Data Sheets for Unconnected Depression Wetlands

Data Sheet	Number of Pages	Title
1	1	Tract and Wetland Assessment Area Level Data Collection
2	2	Plot-Level Data Collection
Please reproduce forms for local use as needed.		

Appendix B5-1	Unconnected Depression	Data Sheet 1 WAA/Tract Data	Sheet 1 of 1

These data sheets represent printouts of an electronic Excel data form that uses raw data to calculate variable indicator values, variable subindices, and ultimately functional capacity indices and units. Enter raw data in the yellow cells. When entering at the computer, use the drop down menus where provided. Green boxes are used by the calculator to run any necessary computations of the raw data before they are compared to subindex curves and translated to a variable subindex in the bottom of Data Sheet 2. Information that is relevant to the entire WAA will only be entered in the WAA/Tract data entry form, and will be carried to the plot data entry summaries and project summary tables.

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ WAA Number:

Project Name: _____

Location: _____ Sampling Date: _____

Subclass: Unconnected Depression Project Type: _____ Timing: _____

☐ Check if Depression is Inundated

Sample Variables 1-5 using aerial photography, topographic maps, soil survey maps, etc.

1	V_{TRACT}	Forest tract size (ha). From aerial photos or field reconnaissance, estimate the size of the forested area that is contiguous to the WAA and accessible to wildlife (including the WAA itself, if it is forested). Include both upland and wetland forests. Record the area at right. If it exceeds 2,500 ha, (6,178 acres) enter "2500."	
2	V_{CORE}	Percent of wetland tract with at least a 100-m buffer from surrounding land uses. To do this, measure in 100 m from the perimeter of the entire forested area and draw a line. The portion of the wetland tract that lies inside this line is the core area. Percent of the Wetland Tract within the Core:	
3	$V_{CONNECT}$	Percent of wetland tract perimeter within 0.5 km of suitable habitats: upland forests, forested riparian areas, non-forested wetlands, and other natural communities. Excludes farm fields, pastures, heavily grazed or farmed wetlands, isolated clusters of trees, fencerows, clearcuts, wooded subdivisions. Lineal percentage of perimeter with suitable habitat within 0.5 km:	
4	V_{FREQ}	Change in flood frequency. Determine (or estimate) the frequency of flooding from streams for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter 0 if this is not an assessment involving hydrologic alteration. Pre-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5) Post-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5)	Not Used
5	V_{DUR}	Change in flood duration. Determine (or estimate) the duration of continuous flooding from streams (longest single event) during the growing season for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter average weeks of continuous growing season flooding. If greater than 10, enter 10. Pre-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10) Post-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10)	Not Used
6	V_{OUT}	Change in frequency of outflow in Headwater Depressions Only. Determine (or estimate) whether surface output is perennial, seasonal or zero both pre-project and post-project. Pre-project Outflow: Post-project Outflow:	Not Used

Sample Variables 7-9 during onsite field reconnaissance.

7	V_{POND}	Percentage of the site capable of ponding water. Estimate the area likely to pond following extended rainfall. This includes both large vernal pool sites (swales) and microdepressions such as those left by trees that have blown over and uprooted. For Flats, select geomorphic surface below. ONLY If Flat, Choose Geomorphic Surface: Percent ponding:	Not Used
8	V_{STRATA}	Number of vegetation strata present. Vegetation layers are considered present if they account for at least 10% cover. **Canopy** (trees ≥ 10 cm dbh that are in the canopy layer) **Subcanopy** (trees ≥ 10 cm dbh that are below the canopy layer) **Understory** (shrubs and saplings < 10 cm dbh but at least 1.4 m (4.5 ft) tall) **Ground cover** (woody plants < 1.4 m (4.5 ft) tall, and herbaceous vegetation) Choose:	
9	V_{SOIL}	Soil integrity. Estimate the percentage of the site that has significantly altered soils. Normal farm tillage is not considered a significant alteration in this case, but fill, land leveling that removes surface horizons, and compacted areas such as roads are counted. This variable not used if the depression is inundated.	

Appendix B5-2 Unconnected Depression Data Sheet 2 - Plot Data Sheet 1 of 2

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ UTM Easting: _____
Project Name: _____ UTM Northing: _____
Location: _____ Sampling Date: _____
WAA Number: _____ Plot Number: _____ of _____ Plot Area (0.04 ha is standard): _____
Subclass: Unconnected Depression Project Type: _____ Timing: _____
Uninundated Depression

Sample Variables 10-21 within one or more representative 0.04-ha (0.1-acre) plot(s) within the WAA (separate data sheet each plot)

Observations from the Center Point

10	V_{TBA}	Basal area. Use a basal area wedge prism (English 10-factor) as directed, and tally eligible tree stems. The calculator automatically multiplies this tally by the conversion factor 2.3 to determine m^3/ha.	
		Number of trees tallied	

Observations within a 0.04-ha plot

11	V_{TDEN}	Tree density. Count the number of trees (dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha.	
		Number of trees tallied	
12	V_{SNAG}	Snag density. Count the number of snags (standing dead trees at least 1.4 m (4.5 ft) tall and dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha.	
		Number of snags tallied	
13	V_{OHOR}	Thickness of the O horizon. Select two or more points within the plot that are representative of the range of microtopography within the plot as a whole. Dig a hole and measure the thickness of the O horizon (organic accumulation on the soil surface, excluding fresh litter, but including surface root mats if present). This variable is not used if depression is inundated. Subplot 1: Subplot 2: Subplot 3: Subplot 4:	
14	V_{AHOR}	Thickness of the A horizon. In the same holes as above, measure the thickness of the A horizon (mineral soil with incorporated organic matter, indicated by distinct darkening relative to lower horizons). This variable is not used if depression is inundated. Subplot 1: Subplot 2: Subplot 3: Subplot 4:	
15	V_{COMP}	Composition of tallest woody vegetation stratum, percent concurrence. If tree cover is ≥ 20%, use the 50/20 rule (see Chapter 6 for details) and check the dominant trees in Columns A, B, and C. If a dominant does not appear on the list, use local knowledge or literature to assign it to the appropriate column. If tree cover is < 20%, identify the next tallest woody stratum with at least 10% cover.	
16	V_{TCOMP}	Tree composition. ☐ Check box if tree cover is greater than or equal to 20%, and the composition concurrence below is for the tree stratum.	

Group 1 = 1.0	Group 2 = 0.66	Group 3 = 0.33
☐ *Acer rubrum*	☐ *Acer negundo*	☐ —
☐ *Carya aquatica*	☐ *Celtis laevigata*	☐ —
☐ *Fraxinus tomentosa*	☐ *Cephalanthus occidentails*	☐ —
☐ *Nyssa aquatica*	☐ *Diospyros virginiana*	☐ —
☐ *Populus heterophyla*	☐ *Forestiera acuminata*	☐ —
☐ *Quercus lyrata*	☐ *Liquidambar styraciflua*	☐ —
☐ *Quercus palustris*	☐ *Planera aquatica*	☐ —
☐ *Taxodium distichum*	☐ *Ulmus americana*	☐ —
☐ —	☐ —	☐ —
☐ —	☐ —	☐ —
☐ —	☐ —	☐
☐	☐ —	☐
☐	☐	☐ **Check here if there are no woody species.**
☐	☐	
0 Species in Group 1	0 Species in Group 2	0 Species in Group 3

50/20 Rule: Rank species in descending order of percent cover, summing relative dominance in descending order until 50 percent is exceeded. This list of species, along with any additional species comprising at least 20 percent relative dominance, represent the dominant species in the plot.

Appendix B5-2	Unconnected Depression	Data Sheet 2 - Plot Data	Sheet 2 of 2

Observations within two 0.004-ha plots. From the center point, measure north and south 5 m and establish two circular subplots with a radius of 3.6 m (11.8 ft). Within each subplot, measure the following:

17 V_{SSD} Shrub/Sapling density. Count the number of woody stems that are at least 1.4 m (4.5 ft) tall, but less than 10 cm dbh in each subplot. The calculator multiplies the sum of both plots by 125 to determine understory stems/ha.

Subplot 1: Subplot 2:

Observations within 4 1-m × 1-m square subplots. From the center point, measure 5 m in each cardinal direction and establish a 1-m × 1-m square subplot. Within each subplot record the following:

18 V_{GVC} Ground vegetation cover. Estimate the percent cover of all herbaceous plants and woody plants < 1.4 m (4.5 ft) tall. The calculator automatically averages the results of the four subplots.

This variable is not used if depression is inundated.

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

19 V_{LITTER} Litter cover. Estimate the percent of the plot area covered by undecomposed litter. The calculator automatically averages the results of the four subplots.

This variable is not used if depression is inundated.

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

Observations along transects.

20 V_{LOG} Log biomass. Volume per hectare of non-living fallen logs (m^3/ha).

21 V_{WD} Woody debris biomass. Volume per hectare of non-living fallen woody stems (m^3/ha).

These variables are not used if depression is inundated.

	Transect 1	Transect 2
Number of stems with diameters greater than or equal to 0.6 cm (0.25 in) and less than 2.5 cm (1 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Number of stems with diameters greater than or equal to 2.5 cm (1 in) and less than 7.6 cm (3 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Enter diameters (cm) of each fallen woody stem 7.6 cm (3 inches) or greater in diameter in each 50-foot transect. If there are no logs of this size, enter 0.		

Plot Summary

Variable	Value	VSI
V_{TRACT}		
V_{CORE}		
$V_{CONNECT}$		
V_{FREQ}		
V_{DUR}		
V_{OUT}		
V_{POND}		
V_{STRATA}		
V_{SOIL}		
V_{TBA}		
V_{TDEN}		
V_{SNAG}		
V_{OHOR}		
V_{AHOR}		
V_{COMP}		
V_{TCOMP}		
V_{SSD}		
V_{GVC}		
V_{LITTER}		
V_{LOG}		
V_{WD}		

Notes:

Appendix B6: Field Data Sheets for Connected Depression Wetlands

Data Sheet	Number of Pages	Title
1	1	Tract and Wetland Assessment Area Level Data Collection
2	2	Plot-Level Data Collection
Please reproduce forms for local use as needed.		

Appendix B6-1	Connected Depression	Data Sheet 1 WAA/Tract Data	Sheet 1 of 1

These data sheets represent printouts of an electronic Excel data form that uses raw data to calculate variable indicator values, variable subindices, and ultimately functional capacity indices and units. Enter raw data in the yellow cells. When entering at the computer, use the drop down menus where provided. Green boxes are used by the calculator to run any necessary computations of the raw data before they are compared to subindex curves and translated to a variable subindex in the bottom of Data Sheet 2. Information that is relevant to the entire WAA will only be entered in the WAA/Tract data entry form, and will be carried to the plot data entry summaries and project summary tables.

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ WAA Number:

Project Name: _____

Location: _____ Sampling Date: _____

Subclass: Connected Depression Project Type: _____ Timing: _____

☐ Check if Depression is Inundated

Sample Variables 1-5 using aerial photography, topographic maps, soil survey maps, etc.

1	V_{TRACT}	Forest tract size (ha). From aerial photos or field reconnaissance, estimate the size of the forested area that is contiguous to the WAA and accessible to wildlife (including the WAA itself, if it is forested). Include both upland and wetland forests. Record the area at right. If it exceeds 2,500 ha, (6,178 acres) enter "2500."	
2	V_{CORE}	Percent of wetland tract with at least a 100-m buffer from surrounding land uses. To do this, measure in 100 m from the perimeter of the entire forested area and draw a line. The portion of the wetland tract that lies inside this line is the core area. Percent of the Wetland Tract within the Core:	
3	$V_{CONNECT}$	Percent of wetland tract perimeter within 0.5 km of suitable habitats: upland forests, forested riparian areas, non-forested wetlands, and other natural communities. Excludes farm fields, pastures, heavily grazed or farmed wetlands, isolated clusters of trees, fencerows, clearcuts, wooded subdivisions. Lineal percentage of perimeter with suitable habitat within 0.5 km:	
4	V_{FREQ}	Change in flood frequency. Determine (or estimate) the frequency of flooding from streams for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter 0 if this is not an assessment involving hydrologic alteration. Pre-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5) Post-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5)	
5	V_{DUR}	Change in flood duration. Determine (or estimate) the duration of continuous flooding from streams (longest single event) during the growing season for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter average weeks of continuous growing season flooding. If greater than 10, enter 10. Pre-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10) Post-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10)	
6	V_{OUT}	Change in frequency of outflow in Headwater Depressions Only. Determine (or estimate) whether surface output is perennial, seasonal or zero both pre-project and post-project. Pre-project Outflow: Post-project Outflow:	Not Used

Sample Variables 7-9 during onsite field reconnaissance.

7	V_{POND}	Percentage of the site capable of ponding water. Estimate the area likely to pond following extended rainfall. This includes both large vernal pool sites (swales) and microdepressions such as those left by trees that have blown over and uprooted. For Flats, select geomorphic surface below. ONLY If Flat, Choose Geomorphic Surface: Percent ponding:	Not Used
8	V_{STRATA}	Number of vegetation strata present. Vegetation layers are considered present if they account for at least 10% cover. **Canopy** (trees ≥ 10 cm dbh that are in the canopy layer) **Subcanopy** (trees ≥ 10 cm dbh that are below the canopy layer) **Understory** (shrubs and saplings < 10 cm dbh but at least 1.4 m (4.5 ft) tall) **Ground cover** (woody plants < 1.4 m (4.5 ft) tall, and herbaceous vegetation) Choose:	
9	V_{SOIL}	Soil integrity. Estimate the percentage of the site that has significantly altered soils. Normal farm tillage is not considered a significant alteration in this case, but fill, land leveling that removes surface horizons, and compacted areas such as roads are counted. This variable not used if the depression is inundated.	

Appendix B6-2	Connected Depression	Data Sheet 2 - Plot Data	Sheet 1 of 2

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ UTM Easting: _____
Project Name: _____ UTM Northing: _____
Location: _____ Sampling Date: _____
WAA Number: _____ Plot Number: _____ of _____ Plot Area (0.04 ha is standard): _____
Subclass: Connected Depression _____ Project Type: _____ Timing: _____
Uninundated Depression

Sample Variables 10-21 within one or more representative 0.04-ha (0.1-acre) plot(s) within the WAA (separate data sheet each plot)

Observations from the Center Point

10	V_{TBA}	Basal area. Use a basal area wedge prism (English 10-factor) as directed, and tally eligible tree stems. The calculator automatically multiplies this tally by the conversion factor 2.3 to determine m^3/ha. Number of trees tallied	

Observations within a 0.04-ha plot

11	V_{TDEN}	Tree density. Count the number of trees (dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha. Number of trees tallied	
12	V_{SNAG}	Snag density. Count the number of snags (standing dead trees at least 1.4 m (4.5 ft) tall and dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha. Number of snags tallied	
13	V_{OHOR}	Thickness of the O horizon. Select two or more points within the plot that are representative of the range of microtopography within the plot as a whole. Dig a hole and measure the thickness of the O horizon (organic accumulation on the soil surface, excluding fresh litter, but including surface root mats if present). This variable is not used if depression is inundated. Subplot 1: Subplot 2: Subplot 3: Subplot 4:	
14	V_{AHOR}	Thickness of the A horizon. In the same holes as above, measure the thickness of the A horizon (mineral soil with incorporated organic matter, indicated by distinct darkening relative to lower horizons). This variable is not used if depression is inundated. Subplot 1: Subplot 2: Subplot 3: Subplot 4:	
15	V_{COMP}	Composition of tallest woody vegetation stratum, percent concurrence. If tree cover is ≥ 20%, use the 50/20 rule (see Chapter 6 for details) and check the dominant trees in Columns A, B, and C. If a dominant does not appear on the list, use local knowledge or literature to assign it to the appropriate column. If tree cover is < 20%, identify the next tallest woody stratum with at least 10% cover.	
16	V_{TCOMP}	Tree composition. ☐ Check box if tree cover is greater than or equal to 20%, and the composition concurrence below is for the tree stratum.	

Group 1 = 1.0	Group 2 = 0.66	Group 3 = 0.33
☐ *Acer rubrum*	☐ *Celtis laevigata*	☐ —
☐ *Carya aquatica*	☐ *Forestiera acuminata*	☐ —
☐ *Fraxinus pennsylvanica*	☐ *Gleditsia aquatica*	☐ —
☐ *Nyssa aquatica*	☐ *Planera aquatica*	☐ —
☐ *Quercus lyrata*	☐ *Salix nigra*	☐ —
☐ *Taxodium distichum*	☐ *Ulmus americana*	☐ —
☐ —	☐ —	☐ —
☐ —	☐ —	☐ —
☐ —	☐ —	☐ —
☐ —	☐ —	☐ —
☐ —	☐ —	☐
☐	☐ —	☐
☐	☐	☐ **Check here if there are no woody species.**
☐	☐	
0 Species in Group 1	0 Species in Group 2	0 Species in Group 3

50/20 Rule: Rank species in descending order of percent cover, summing relative dominance in descending order until 50 percent is exceeded. This list of species, along with any additional species comprising at least 20 percent relative dominance, represent the dominant species in the plot.

Appendix B6-2	Connected Depression	Data Sheet 2 - Plot Data	Sheet 2 of 2

Observations within two 0.004-ha plots. From the center point, measure north and south 5 m and establish two circular subplots with a radius of 3.6 m (11.8 ft). Within each subplot, measure the following:

17	V_{SSD}	Shrub/Sapling density. Count the number of woody stems that are at least 1.4 m (4.5 ft) tall, but less than 10 cm dbh in each subplot. The calculator multiplies the sum of both plots by 125 to determine understory stems/ha. Subplot 1: Subplot 2:	

Observations within 4 1-m × 1-m square subplots. From the center point, measure 5 m in each cardinal direction and establish a 1-m × 1-m square subplot. Within each subplot record the following:

18	V_{GVC}	Ground vegetation cover. Estimate the percent cover of all herbaceous plants and woody plants < 1.4 m (4.5 ft) tall. The calculator automatically averages the results of the four subplots. This variable is not used if depression is inundated. Subplot 1: Subplot 2: Subplot 3: Subplot 4:	
19	V_{LITTER}	Litter cover. Estimate the percent of the plot area covered by undecomposed litter. The calculator automatically averages the results of the four subplots. This variable is not used if depression is inundated. Subplot 1: Subplot 2: Subplot 3: Subplot 4:	

Observations along transects.

20	V_{LOG}	Log biomass. Volume per hectare of non-living fallen logs (m^3/ha).	
21	V_{WD}	Woody debris biomass. Volume per hectare of non-living fallen woody stems (m^3/ha).	

These variables are not used if depression is inundated.

	Transect 1	Transect 2
Number of stems with diameters greater than or equal to 0.6 cm (0.25 in) and less than 2.5 cm (1 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Number of stems with diameters greater than or equal to 2.5 cm (1 in) and less than 7.6 cm (3 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Enter diameters (cm) of each fallen woody stem 7.6 cm (3 inches) or greater in diameter in each 50-foot transect. If there are no logs of this size, enter 0.		

Plot Summary

Variable	Value	VSI
V_{TRACT}		
V_{CORE}		
$V_{CONNECT}$		
V_{FREQ}		
V_{DUR}		
V_{OUT}		
V_{POND}		
V_{STRATA}		
V_{SOIL}		
V_{TBA}		
V_{TDEN}		
V_{SNAG}		
V_{OHOR}		
V_{AHOR}		
V_{COMP}		
V_{TCOMP}		
V_{SSD}		
V_{GVC}		
V_{LITTER}		
V_{LOG}		
V_{WD}		

Notes:

Appendix C: Alternate Field Forms

Contents

Alternate Data Sheet C1. Basal Area Determination using Diameter Measurements

Alternate Data Sheet C2. Procedures for Manually Calculating Woody Debris and Log Volume

Please reproduce these forms locally as needed.

ALTERNATIVE DATA SHEET C1 (1 page) – BASAL AREA DETERMINTATION USING DIAMETER MEASUREMENTS

SUBCLASS: _____

WAA # _____

PLOT # _____

If you are not using a basal area prism or similar tool to estimate tree basal area for the V_{TBA} variable, but instead are measuring individual tree diameters, use the form below to record tree diameters within each 0.04-ha plot. Follow the directions to summarize these data in terms of m²/ha at the plot level, or use the spreadsheet provided in Appendix D. Note that species need not be associated with each diameter measure, but that option is included in case you wish to sum individual basal areas of each species to develop a more accurate estimate of V_{TCOMP} than the reconnaissance-level sample provides. You can also count the trees in the table below to get tree density (V_{TDEN}) rather than using the plot count specified on Data Sheet 2.

Record the species (optional) and dbh (cm) of all trees (i.e., woody stems ≥ 10 cm or 4 in dbh) in the 0.04-ha plot in Columns 1 and 2 in the table below. Complete the calculations (or use spreadsheet) to derive basal area per tree, and sum to get total plot basal area (m²/ha).

1	2	3	4	1	2	3	4
Species Code (optional)	dbh (cm)	Square the value in column 2 (dbh x dbh)	Multiply the value in column 3 by 0.00196 to get m²/ha per tree	Species Code (optional)	dbh (cm)	Square the value in column 2 (dbh x dbh)	Multiply the value in column 3 by 0.00196 to get m²/ha per tree

SUM ALL COLUMN 4 VALUES TO GET TOTAL PLOT BASAL AREA = _____ (m² / ha)

Record Total Basal Area on Data Sheet 2 in the V_{TBA} row as a plot value

ALTERNATIVE DATA SHEET C2 (2 pages) – PROCEDURES FOR MANUALLY CALCULATING WOODY DEBRIS AND LOG VOLUME

SUBCLASS: _____

WAA # _____

PLOT # _____

If you do not wish to use the spreadsheet provided in Appendix D to calculate woody debris and log volume for use in generating the V_{WD} and V_{LOG} variables, you can calculate the same summary data manually. Transfer the transect data recorded on Data Sheet 2 (Plot-Level Data Collection, Observations along Transects) to the data sheet below, and make the indicated calculations.

From Data Sheet 2, transfer the small woody debris stem counts (Size Class 1 - stems between 0.6 and 2.54 cm in diameter) for Transects 1 and 2, sum them, and multiply by 0.722 to convert to volume per hectare:

Stem Count, Transect 1 ____

Stem Count, Transect 2 ____

total number of stems = _____ × 0.722 = _____ m³/ha, Size Class 1

From Data Sheet 2, transfer the medium woody debris stem counts (Size Class 2 - stems between 2.54 and 7.6 cm in diameter) for Transects 1 and 2, sum them, and multiply by 3.449 to convert to volume per hectare:

Stem Count, Transect 1 ____

Stem Count, Transect 2 ____

total number of stems = _____ × 3.449 = _____ m³/ha, Size Class 2

From Data Sheet 2, transfer the diameter (cm) of each stem of Size Class 3 (large stems, > 7.6 cm, or >3 in.) measured along Transect 1 and Transect 2 into the table below. Multiply each diameter measurement by 0.3937, and then square the result. Sum all results, then multiply that sum by 0.2657 to get large woody debris volume (m³/ha).

Transect 1			Transect 2		
1	2	3	1	2	3
Stem Diameter (cm)	Multiply stem diameter by 0.3937	Square the result in column 2	Stem Diameter (cm)	Multiply stem diameter by 0.3937	Square the result in column 2
		SUM=			**SUM=**

ALTERNATIVE DATA SHEET C2 (2 pages) – PROCEDURES FOR MANUALLY CALCULATING WOODY DEBRIS AND LOG VOLUME

SUBCLASS: _____

WAA # _____

PLOT # _____

V_{LOG} Sum of Size Class 3 Transect 1 + Sum of Size Class 3 Transect 2 = _____ × 0.2657 = _____ m^3/ha, Size Class 3
V_{WD} Sum of Size Class 1 _____m^3/ha + Size Class 2 _____m^3/ha + Size Class 3 _____m^2/ha = _____ m^3/ha (total woody debris volume/ha)

Appendix D: Spreadsheets

Contents

Appendix D1. Alternate Basal Area Calculation Spreadsheet (Figure D1).

Appendix D2. Log and Woody Debris Calculation Spreadsheet (Figures D2 and D3).

Appendix D3. Example of Data Summary By Plot tab of the Arkansas Delta Data Sheets and FCI Calculator. This Summary is automatically generated by the spreadsheet once the Subclass is selected and raw data are entered.

Appendix D4. Example of FCI/FCU Calculation Summary tab of the Arkansas Delta Data Sheets and FCI Calculator. This Summary is automatically generated by the spreadsheet once the Subclass is selected and raw data are entered.

Note: This appendix contains demonstration printouts of these spreadsheets. Working copies are available for download at: http://el.erdc.usace.army.mil/wetlands/datanal.html

Basal Area (V_{TBA}) Calculator
(Version of 12/2001)

Use one of the forms below (depending on whether tree diameters were measured in centimeters or inches) to calculate total basal area (m^2/ha) for a plot. Transfer the Total Plot Basal Area value (located in red cell) to the V_{TBA} line on Data Form 3 (Wetland Assessment Area Data Summary). Delete values from all green input cells and repeat data entry as needed for additional plots. (Note: Recording of species codes is optional. Users may want to include species associated with individual tree diameters to assist in determining dominance for V_{TCOMP} calcuations, but the spreadsheets below will work without entering species codes.)

Enter individual tree species code in cells A6-A35 (optional)	Enter individual tree diameters (cm) in cells B6-B35	Converts to cm^2/0.04 ha 3.14*(tree diameter/2)^2=cm^2	Converts to m^2/ha - Column C*0.0001*25=m^2/ha
		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
		Total Plot Basal Area in m^2/ha :	**0.00**

Figure D1. Example of the input form used in the basal area calculator spreadsheet.

Fill in Size Class 1 (stem count), Size Class 2 (stem count), and Size Class 3 (stem diameters in centimeters) in appropriate light green shaded areas below. Find resulting plot values for V_{LOG} and V_{WD} subindices in yellow shaded areas at the bottom of the sheet.

	Size Class 1 No. of Stems/ 1.83 m Transect		Size Class 1 Total Stem Count	Size Class 1 tons/acre	Size Class 2 No. of Stems/ 3.65 m Transect		Size Class 2 Total Stem Count	Size Class 2 tons/acre
	Transect 1	Transect 2			Transect 1	Transect 2		
Plot 1			0	0.0			0	0.0
Plot 2			0	0.0			0	0.0
Plot 3			0	0.0			0	0.0
Plot 4			0	0.0			0	0.0
Plot 5			0	0.0			0	0.0

Size Class 3 Stem Diameters (cm) 15.25 m Transect		Size Class 3 Stem Diameter^2 (in)		Size Class 3 Stem Diameters (cm) 15.25 m Transect		Size Class 3 Stem Diameter^2 (in)		Size Class 3 Stem Diameters (cm) 15.25 m Transect		Size Class 3 Stem Diameter^2 (in)	
Plot 1		Plot 1		Plot 2		Plot 2		Plot 3		Plot 3	
Transect 1	Transect 2	Transect 1	Transect 2	Transect 1	Transect 2	Transect 1	Transect 2	Transect 1	Transect 2	Transect 1	Transect 2
		0.0	0.0			0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0			0.0	0.0

Size Class 3 Stem Diameters (cm) 15.25 m Transect		Size Class 3 Stem Diameter^2 (in)		Size Class 3 Stem Diameters (cm) 15.25 m Transect		Size Class 3 Stem Diameter^2 (in)	
Plot 4		Plot 4		Plot 5		Plot 5	
Transect 1	Transect 2	Transect 1	Transect 2	Transect 1	Transect 2	Transect 1	Transect 2
		0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0

Figure D2. Example of the input form used in the woody debris calculation spreadsheet (Continued).

	Size Class 3 Sum of Stem Diameter^2 (in)		Size Class 3 Total Diameter^2 (in)	Size Class 3 tons/acre	Size Class 3 ft^3/acre	Size Classes 1, 2, 3 tons/acre	Size Classes 1, 2, 3 ft^3/acre
	Transect 1	Transect 2					
Plot 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plot 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plot 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plot 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plot 5	0.0	0.0	0.0	0.0	0.0	0.0	0.0

V_{LOG} and V_{WD} plot values can be found below:

Plot Number	(V_{LOG}) Size Class 3 m^3/ha
Plot 1	0.0
Plot 2	0.0
Plot 3	0.0
Plot 4	0.0
Plot 5	0.0

Plot Number	(V_{WD}) Size Classes 1, 2, 3 m^3/ha
Plot 1	0.0
Plot 2	0.0
Plot 3	0.0
Plot 4	0.0
Plot 5	0.0

Figure D2. (Concluded).

WAA Data Summary	WAA Number :	Low-Gradient Riverine Backwater

Variable	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10	Plot 11	Number of Plots Used	Average Measure
1 V_{TRACT}													
2 V_{CORE}													
3 $V_{CONNECT}$													
4 V_{FREQ}													
5 V_{DUR}													
6 V_{OUT}													
7 V_{POND}													
8 V_{STRATA}													
9 V_{SOIL}													
10 V_{TBA}													
11 V_{TDEN}													
12 V_{SNAG}													
13 V_{OHOR}													
14 V_{AHOR}													
15 V_{COMP}													
16 V_{TCOMP}													
17 V_{SSD}													
18 V_{GVC}													
19 V_{LITTER}													
20 V_{LOG}													
21 V_{WD}													

Ver. 6-27-11

FCI/FCU Calculator for the Arkansas Delta HGM Guidebook

To create appropriate plot data entry forms and ensure accurate calculations, select the HGM Subclass present on the site in the drop list below. Enter in the yellow cells the number and size of the Wetland Assessment Area (WAA) being sampled, the project name, and location. Use the drop down menus to indicate whether this WAA represents the Project Site or Mitigation Site, before project or after project. Then go to the Data Entry tabs to enter individual field measurements for each plot. Information that is relevant to the entire WAA will only be entered in Plot 1, and will be carried to the other plots and summary sheet. For information on determining how to split a project into WAAs, see A Revised Regional Guidebook for Applying the Hydrogeomorphic Approach to the Functional Assessment of Forested Wetlands in the Delta Region of Arkansas, Lower Mississippi Valley (Klimas *et al.* 2011). The Mitigation Sufficiency Carlucaltor is available for download at the ERDC website.

Enter information in yellow cells, and select HGM Subclass and Site information from dropdown menus. A Subclass must be selected prior to printing out data sheets.

Project Name:
Location:
Sampling Date(s): Enter dates on Plot Sheets

Select HGM Subclass present at this WAA: Low-Gradient Riverine Backwater

WAA number:
WAA size (ha): 1

Project Site:

Project Timing:

All summaries of results are automatically calculated based on data entered into the individual plot entry data sheets.

Functional Results Summary:

Please Fill Out Site and Project Information Above

Function	Functional Capacity Index	Functional Capacity Units
Detain Floodwater		
Detain Precipitation		
Cycle Nutrients		
Export Organic Carbon		
Maintain Plant Communities		
Provide Habitat for Fish and Wildlife		

Variable Measure and Subindex Summary:

Variable	Name	Average Measure	Subindex
V_{TRACT}	Forested Tract Size (ha)		
V_{CORE}	Percent of wetland tract with at least a 100-m buffer		
$V_{CONNECT}$	Percent of wetland tract perimeter within 0.5 km of suitable habitats		
V_{FREQ}	Change in flood frequency (years change)		
V_{DUR}	Change in growing season flood duration (weeks change)		
V_{OUT}	Change in frequency of surface outflow in Headwater Depressions only		Not Used
V_{POND}	Total Ponded Area (%)		
V_{STRATA}	Number of Vegetation Strata		
V_{SOIL}	Soil Integrity (%)		
V_{TBA}	Tree Basal Area (m^3/ha)		
V_{TDEN}	Tree Density (stems/ha)		
V_{SNAG}	Snag Density (stems/ha)		
V_{OHOR}	O Horizon Organic Accumulation (cm)		
V_{AHOR}	A Horizon Organic Accumulation (cm)		
V_{COMP}	Composition of Tallest Woody Vegetation Stratum (%)		
V_{TCOMP}	Tree Composition (%)		
V_{SSD}	Shrub-Sapling Density (stems/ha)		
V_{GVC}	Ground Vegetation Cover (%)		
V_{LITTER}	Litter Cover (%)		
V_{LOG}	Log Biomass (m^3/ha)		
V_{WD}	Woody debris biomass (m^3/ha)		

Appendix E: Spatial Data

The following digital spatial data pertinent to the Delta Region of Arkansas are available for downloading to assist in orienting field work, assembling project area descriptions, and identifying geomorphic surfaces and soils. Unless otherwise indicated, the files are in ArcView format, and a copy of ArcExplorer is included in the download folder to allow access to the files. Some familiarity with ArcView is required to load and manipulate the digital information.

- ArcExplorer (program file: ae2setup – includes user manual)
- Roads
- Cities and Towns
- Counties
- Geomorphology (Saucier 1994)
- Hydrology
- STATSGO soils
- Wetland Planning Regions and Wetland Planning Areas

All of this information can be downloaded from the ERDC website at http://el.erdc.usace.army.mil/publications.cfm?Topic=techreport&Code=emrrp

Appendix F: Common and Scientific Names of Plant Species Referenced in Text and Data Sheets

Scientific Name	Common Name
Acer drummondii	Swamp red maple
Acer negundo	Box elder
Acer saccharinum	Silver maple
Amorpha fruticosa	Leadplant
Asimina triloba	Paw-paw
Betula nigra	River birch
Callicarpa americana	Beautyberry
Carpinus caroliniana	Ironwood
Carya aquatica	Water hickory
Carya cordiformis	Bitternut hickory
Carya illinoensis	Pecan
Carya laciniosa	Shellbark hickory
Carya ovata	Shagbark hickory
Carya tomentosa	Mockernut hickory
Catalpa speciosa	Catalpa
Celtis laevigata	Sugarberry
Cephalanthus occidentalis	Buttonbush
Cornus drummondii	Smooth dogwood
Cornus florida	Flowering dogwood
Cornus foemina	Swamp dogwood
Crataegus spp.	Hawthorn
Diospyros virginiana	Persimmon
Forestiera acuminata	Swamp privet
Fraxinus americana	White ash
Fraxinus pennsylvanica	Green ash
Gleditsia aquatica	Water locust
Gleditsia triacanthos	Honey locust
Hibiscus spp.	Hibiscus
Ilex decidua	Deciduous holly
Itea virginica	Virginia willow
Leitneria floridana	Corkwood
Ligustrum spp.	Common privet
Lindera melissifolia	Pondberry

Scientific Name	Common Name
Liquidambar styraciflua	Sweetgum
Morus rubra	Red mulberry
Nyssa aquatica	Water tupelo
Nyssa sylvatica	Blackgum
Pinus taeda	Loblolly pine
Planera aquatica	Water elm
Platanus occidentalis	Sycamore
Populus deltoides	Eastern cottonwood
Populus heterophylla	Swamp cottonwood
Prunus angustifolia	Chickasaw plum
Prunus serotina	Black cherry
Quercus falcata	Southern red oak
Quercus lyrata	Overcup oak
Quercus michauxii	Cow oak
Quercus nigra	Water oak
Quercus nuttallii	Nuttall oak
Quercus pagoda	Cherrybark oak
Quercus palustris	Pin oak
Quercus phellos	Willow oak
Quercus shumardii	Shumard oak
Quercus similis	Delta post oak
Quercus stellata	Post oak
Quercus velutina	Black oak
Rubus spp.	Blackberry
Salix nigra	Black willow
Sambucus canadensis	Elderberry
Styrax americana	Storax
Taxodium distichum	Baldcypress
Ulmus alata	Winged elm
Ulmus americana	American elm
Ulmus crassifolia	Cedar elm
Vaccinium spp.	blueberry
	(concluded)

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14. ABSTRACT

The Hydrogeomorphic (HGM) Approach is a method for developing and applying indices for the site-specific assessment of wetland functions. The HGM Approach was initially designed to be used in the context of the Clean Water Act Section 404 Regulatory Program permit review process 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 design of wetland restoration projects, and management of wetlands.

This is Version 2.0 of a Regional Guidebook that presents the HGM Approach for assessing the functions of most of the wetlands that occur in the Delta Region of Arkansas, which is part of the Lower Mississippi River Alluvial Valley. The report begins with an overview of the HGM Approach and then classifies and characterizes the principal wetlands that have been identified within the Delta Region of Arkansas. Detailed HGM assessment models and protocols are presented for six of those wetland types, or subclasses, representing all of the forested wetlands in the region other than those associated with lakes and impoundments. The following wetland subclasses are treated in detail: Flat, Mid-gradient Riverine, Low-gradient Riverine Backwater, Low-gradient Riverine Overbank, Headwater Depression, Isolated Depression, and Connected Depression. For each wetland subclass, the guidebook presents (a) the rationale used to select the wetland

(see reverse)

15. SUBJECT TERMS

404 Regulatory Program
Arkansas Delta
Clean Water Act
Functional assessment
Geomorphology
Hydrogeomorphic (HGM) Approach
Hydrology
Impact Assessment

(see reverse)

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Arkansas State Highway and Transportation Department
P.O. Box 2261, Little Rock, AR 72203;

Arkansas Natural Heritage Commission
323 Center Street, Little Rock, AR 72201

14. ABSTRACT

functions considered in the assessment process, (b) the rationale used to select assessment model variables, (c) the rationale used to develop assessment models, and (d) the functional index calibration curves developed from reference wetlands that are used in the assessment models. The guidebook outlines an assessment protocol for using the model variables and functional indices to assess each of the wetland subclasses. The appendices provide field data collection forms, spreadsheets for making calculations, and a variety of supporting spatial data intended for use in the context of a Geographic Information System.

15. SUBJECT TERMS

Lower Mississippi River
Mississippi Alluvial Valley
Mississippi Valley
Mitigation
National Action Plan
Reference wetlands
Wetland
Wetland assessment
Wetland classification
Wetland function
Wetland restoration

Appendix E
Part 4

Hydrogeomorphic (HGM) Assessment of Alternatives for the St. Johns Bayou Basin and New Madrid Floodway Project

U.S. Army Corps of Engineers
Memphis District

WORKING DRAFT AS OF 6-17-12

HYDROGEOMORPHIC (HGM) ASSESSMENT OF ALTERNATIVES FOR THE ST. JOHNS/NEW MADRID FLOOD ABATEMENT PROJECT

A Hydrogeomorphic (HGM) wetland assessment was requested by Memphis District on impacts associated with the St. Johns/New Madrid flood abatement project. The Arkansas Delta Regional Guidebook (Klimas et al. 2011, Appendix E, Part 5 of the EIS) was developed by the Arkansas Multi-Agency Planning Team and ERDC personnel in cooperation with EPA Region 6, which provided much of the funding. This Guidebook was originally developed for the Mississippi Alluvial Plain within Arkansas, which is located just south of the project area and comprises very similar geomorphology, soils and vegetation, so much so that the Reference Domain, that area for which the Guidebook is deemed applicable, has been officially extended to all areas within the lower Mississippi Alluvial Valley north of Arkansas. The Guidebook and its models were certified for use on this project, provided that changes were made to the HGM Functional Capacity Index (FCI) calculator that afforded fewer opportunities for data entry and hand calculation errors. The calculator was retooled to address these requirements, and was thoroughly tested during the data entry and FCI calculation portion of the analysis.

BACKGROUND: THE HGM ASSESSMENT APPROACH

The HGM assessment approach is described in detail in various documents (e.g. Smith et al. 1995) and the Arkansas Delta Regional Guidebook (Klimas et al. 2011) provides specifics relevant to the models and reference data that are used in this report. However, the brief overview below, taken from Klimas (2006), may be helpful for anyone unfamiliar with the terminology and process of the HGM approach.

The HGM approach incorporates several components. Wetlands are first grouped into regional subclasses based on functional similarities, as represented by hydrogeomorphic setting. Thus, wetlands in isolated depressions function differently than wetlands on river floodplains in various respects. For example, a functional riverine wetland exports organic materials to downstream aquatic systems during floods, whereas a depression that lacks a surface connection to a stream does not perform that function. Therefore, a group of functions can be identified for each regional subclass, and other regional subclasses may not perform those functions, or may perform them to different degrees.

In order to estimate the degree to which a wetland performs a particular function, HGM represents each function in terms of a simple logic model made up of variables that can be measured in the field or derived from existing information sources. In order to run the models, the variable values must be determined or estimated. The flood frequency and duration components for this project were supplied by the District. Information on living and dead vegetation is obtained using standard forest sampling methods. Models used to assess all of the other functions use similarly obtained information as model variables.

The FCI value generated by the assessment model is an index between zero and 1.0, where a value of 1.0 represents a fully functional condition. Under HGM methodology, the FCI is multiplied by a measure of the area of the wetland (e.g., acreage) to calculate the Functional Capacity Units (FCU) present for each function. This is essentially the same process used in the Habitat Evaluation Procedures (HEP) (U.S. Fish and Wildlife Service 1980), where indicators of habitat quality are

combined into simple models to calculate a Habitat Suitability Index (HSI) and multiplied by a measure of area to produce Habitat Units (HU). There is one fundamental difference between the ways these two assessment approaches are developed, however. Whereas the indicators employed in HEP models are calibrated based on literature and expert opinion, the calibration curves for HGM indicators are derived from extensive field sampling of reference wetlands.

The model variables employed in the assessment models are calibrated based on field data collected in the applicable wetland subclass. The calibration curve (also called the "subindex curve") for each variable in each subclass relates the variable value to an index between zero and 1.0, where the maximum value is that found in wetlands that represent the least-disturbed examples of the wetland subclass within the region. The shape of the calibration curve is established by sampling a set of wetlands that represent a range of condition classes between the least-disturbed, and severely disturbed. Sets of curves for each variable and wetland subclass in the region are included in the Guidebook (Klimas et al. 2011), based on sampling of more than 100 field sites. Because each variable is calibrated separately for each subclass, functional comparisons across subclasses cannot be made quantitatively, though they can be addressed qualitatively.

As with all of the HGM guidebook development efforts, the Delta Region models, calibration curves, and application tools such as sampling methods and data summary spreadsheets were developed by a team of regional experts. Users of the guidebooks apply this information to specific assessment tasks, and can use the same models and reference data on various projects throughout the region. The models and calibration curves are applied in an assessment scenario by following detailed guidance presented in the Delta HGM Guidebook. The user collects field data from the assessment area, and compares that data to the calibration curve to derive a subindex. The subindex values are inserted into the model, generating an FCI for the function being assessed. Multiplying the FCI by acreage generates FCUs, which represent the functional units associated with the assessment area, and which can be compared among assessment areas of the same regional subclass. Pre- and post-project FCUs can be compared to determine impacts, and project alternatives can be compared to help identify the preferred alternative. However, in order to take into account the time required to recover functions following an impact or restoration actions an additional set of curves representing recovery trajectories is required. Recovery trajectories were developed and published as part of the Delta Region Guidebook (Klimas et al. 2011) and their use is discussed in detail in Klimas 2006.

The HGM guidebook used for this project (Klimas et al. 2011) is a modified version of the original 2004 document. It was changed in 2011 to address a defect in the hydrology variables, and the revised version was reviewed and certified for use on this project. The reviewers agreed that the reference data developed for the Delta Regional Guidebook is appropriate for application to the SJNM project area. The geomorphic processes and hydrology that formed the landscape of southeastern Missouri are the same as those that shaped adjacent areas in Arkansas, where the reference data set was collected. The project area supports the same wetland subclasses, on the same geomorphic surfaces and soil types, as the guidebook reference sites, and it has been subject to similar agricultural development and hydrologic changes. Field studies indicated some shift s in the relative dominance of certain tree species, as would be expected in an area at a higher latitude than the reference area, but the guidebook allows for modification of the species composition variables to accommodate just such an eventuality. Therefore, some minor changes were made to those variables based on field observations and professional experience in the region. Otherwise, the Delta regional guidebook was used without modification to its certified version.

DATA COLLECTION METHODS AND ASSUMPTIONS FOR THIS ASSESSMENT

This assessment is limited to all areas with direct impacts (e.g., clearing, widening of ditches, re-contouring, etc.), and all wetland areas within the 5-year floodplain that are by definition river-connected, and subject to changes in inundation regimes due to the project. Wetlands outside the 5-year floodplain are primarily precipitation driven, and are not affected by changes in river hydrology in a way that the HGM approach can ascertain; thus, they are not included in the analysis unless they are subject to direct impacts. This HGM analysis reports all results by basin.

Functional Capacity Indices (FCIs) were calculated based on data from field locations within the two basins, using the models and variable subindex curves found in Klimas et al. 2011. Sixty-one plots within twenty wetland assessment areas were used in the calculations, and an additional thirty locations were visually inspected from the road to ensure that the data already collected had captured the variation identified within the project area. Field data collection was conducted in September 2010 by Elizabeth Murray and Jody Pagan, following the field methods described in the Arkansas Delta Regional Guidebook (Klimas et al. 2011, Appendix E, Part 5). All data forms for all subclasses can be found in that report. Candidate sample sites were identified on GIS based on apparent subclass, condition class, and category of impact. The subclass of each wetland assessment area was verified in the field. Landscape level variables were assessed in the office after field sampling using GIS. Hydrologic variables for each plot (change in flood frequency and change in flood duration) were provided by Memphis District using their hydraulic modeling for project alternatives.

The sample plots were distributed throughout the 5-year floodplain within the project area. Three HGM subclasses were sampled: Low Gradient Riverine Backwater (LGRB), Low Gradient Riverine Overbank (LGRO), and Connected Depressions (CD). Project impacts are expected to occur in three basic forms: direct clearing of forests and site alteration, leading to a reduction of wetland functions to zero; modest indirect hydrologic impacts due to drainage improvements and pumping, resulting in changes to hydrologic variables only, which reduce but do not eliminate river-connected wetland functions; and finally major hydrologic impacts which result in a change in wetland subclass from a river-connected subclass to a non-river connected subclass. In these cases, LGRB and LGRO become Flats, a precipitation driven bottomland hardwood type, and CD wetlands become Unconnected Depressions (UCD), which are primarily maintained by direct precipitation and local runoff. Upon completion of field sampling in all subclasses and condition classes known to exist in the study area, an additional 30 wetland sites were identified and examined from the road to ensure that they were within the range of compositional and structural variation already represented in the sample database. These visual inspections verified that no further sampling was necessary.

Wetland jurisdictional determinations were not made as part of this assessment. Acreages of jurisdictional wetlands for the wetland assessment were provided by the Memphis District, CE. The acreage of agricultural areas deemed as jurisdictional “Farmed Wetlands” was provided to Memphis District by the Natural Resources Conservation Service (NRCS). Memphis District divided this total acreage by basin, and the resulting “Farmed Wetland” acreages for each basin were supplied to ERDC by Memphis District. It is assumed for the purposes of this analysis, that all of these “Farmed Wetlands” are within the 5-year floodplain and subject to the HGM analysis. All Farmed Wetlands are assumed to be LGRB under Existing Conditions for the purposes of this assessment.

Acreages of “Forested Wetlands” were developed for each basin by Memphis District and provided to ERDC. Geographic Information System (GIS) and sampling ratios were then employed to divide these Forested Wetland acreages into subtotals by HGM subclass.

All alternatives were assessed over a 50-year life of project. It is assumed here that the prevailing management and land use patterns will continue and result in no change in the average condition of existing resources (other than WRP) over the life of the project under the proposed project alternatives, including the No Action alternative. This is consistent with the approach used in the HEP analysis. Because it is assumed that there will be no variable changes for areas other than WRP, only the WRP results are annualized in the assessment of project impacts.

For the Authorized Project and alternatives, all impacts are assumed to be immediate upon project approval, and no mitigation is included in the analysis. However, annualized results for mitigation scenarios have been include to help guide the mitigation process, both in determining the amount necessary and the advantages of siting mitigation in some areas over others. All areas that will be cleared are assumed to remain cleared, and all changes to hydrology are assumed to remain constant. As with the No Action Alternative, all forest conditions are assumed constant over the life of the project in all alternatives. Because the impacts are assumed to take place immediately upon project decision and then remain constant over the 50-year life of the project, these results are also not annualized. The alternate approach, utilized in the HEP analysis, of having impacts occur over the course of the first year and then annualizing results in a mere 0.6% decrease in impacts associated with the alternative. Considering the multiple subclasses, and multiple functional models, each of which would have to be annualized separately, and the uncertainty regarding the implementation schedule for specific project components, annualization of year-one impacts implies a level of sensitivity in the HGM analysis that cannot be justified. Any other alternatives that include areas with expected forest maturation over the life of the project (i.e., WRP, mitigation areas, etc.) include annualized results for those portions of the assessment.

RESULTS

Alternative 1 - No Action

1.1. Existing Conditions

St. Johns Basin

Existing Conditions in the St. Johns Basin are documented in Tables 1a and 1b. Approximately 5233 acres of forested wetlands occur within the St. Johns Basin. Of these, approximately 76% (3848 acres) are LGRB HGM subclass, and 24% (1385 acres) are LGRO wetlands. There are also approximately 142 acres of “Farmed Wetlands” that fall into the LGRB HGM subclass. No CD wetlands were identified within the basin. The FCIs associated with forested LGRB wetlands ranged from 0.47 for the Provide Habitat for Fish and Wildlife function, to 0.90 for the Detain Precipitation function. Similarly, FCIs for “Farmed” LGRB wetlands in the basin ranged from 0.0 for Plant Communities and Habitat functions, to 0.54 for the Detain Precipitation function (Table 1a).

Table 1a and 1b: St. Johns Basin Existing Conditions FCIs and FCUs

HGM Assessment of Potential Wetlands: Existing Conditions By Basin below the 5-year floodplain FCIs

Basin	St. Johns Basin					
Vegetation Class	Ag Fields	Forested Area: 5233 ac				
HGM Subclass	LGRB	LGRB	LGRO	Flat	CD[2]	UCD
Acreage[1]	792	3848	1385	0	0	0
Function	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**
Detain Floodwater	0.25	0.65	0.97	0.00	0.00	0.00
Detain Precipitation	0.54	0.90	0.75	0.00	0.00	0.00
Cycle Nutrients	0.24	0.68	0.84	0.00	0.00	0.00
Export Organic Carbon	0.19	0.68	0.78	0.00	0.00	0.00
Maintain Plant Communities	0.00	0.79	0.82	0.00	0.00	0.00
Provide Habitat for Fish and Wildlife	0.00	0.47	0.49	0.00	0.00	0.00

1 Forested acreage were provided by Memphis District. Agricultural Acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 No connected depressions were located or sampled within St. Johns Basin.

HGM Assessment of Potential Wetlands: Existing Conditions By Basins below the 5-year floodplain, FCUs

Basin	St. Johns Basin					
Vegetation Class	Ag Fields	Forested Area: 5233 ac				
HGM Subclass	LGRB	LGRB	LGRO	Flat	CD[2]	UCD
Acreage[1]	792	3848	1385	0	0	0
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**
Detain Floodwater	198	2501	1343	0	0	0
Detain Precipitation	428	3463	1039	0	0	0
Cycle Nutrients	190	2617	1163	0	0	0
Export Organic Carbon	150	2617	1080	0	0	0
Maintain Plant Communities	0	3040	1136	0	0	0
Provide Habitat for Fish and Wildlife	0	1809	679	0	0	0

1 Forested acreage were provided by Memphis District. Agricultural Acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 No connected depressions were located or sampled within St. Johns Basin.

The FCIs for LGRO forested wetlands ranged between 0.49 for the Habitat function to 0.97 for the Detain Floodwater function (Table 1a). When these FCIs are multiplied through by the representative acreages for each subclass, the highest FCUs for each subclass are 428 FCUs for “Farmed” LGRB wetlands for the Detain Precipitation function, 3463 FCUs for forested LGRB wetlands for the Detain Precipitation function, and 1343 FCUs for forested LGRO wetlands for the Detain Floodwater function (Table 1b). Under the current assumptions these FCUs remain constant over the 50-year life of project for the No Action alternative, and there are no functional losses or gains.

New Madrid Floodway.

Existing Conditions in the New Madrid Floodway are documented in Tables 2a and 2b. Approximately 8807 acres of forested wetlands occur within the New Madrid Floodway. Of these, approximately 83% (7344 acres) are LGRB HGM subclass, 13% (1163 acres) are LGRO wetlands, and 3.4% (300 acres) are Connected Depression (CD) wetlands. There are also approximately 375 acres of "Farmed Wetlands" that fall into the LGRB HGM subclass. The FCIs associated with forested LGRB wetlands ranged from 0.77 for the Provide Habitat for Fish and Wildlife function, to 0.97 for the Detain Precipitation function. Similarly, FCIs for "Farmed" LGRB wetlands in the basin ranged from 0.0 for Plant Communities and Habitat functions, to 0.54 for the Detain Precipitation function (Table 2a).

Table 2a and 2b: New Madrid Floodway Existing Conditions FCIs and FCUs

HGM Assessment of Potential Wetlands: Existing Conditions By Basin below the 5-year floodplain FCIs

Basin	New Madrid					
Vegetation Class	Ag Fields	Forested Area: 8807 ac				
HGM Subclass	LGRB	LGRB	LGRO	Flat	CD	UCD
Acreage[1]	306	7344	1163	0	300	0
Function	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**
Detain Floodwater	0.25	0.88	0.82	NA	0.53	0.00
Detain Precipitation	0.54	0.97	0.58	0.00	NA	0.00
Cycle Nutrients	0.24	0.85	0.85	0.00	0.61	0.00
Export Organic Carbon	0.19	0.85	0.79	NA	0.57	0.00
Maintain Plant Communities	0.00	0.93	0.84	0.00	0.67	0.00
Provide Habitat for Fish and Wildlife	0.00	0.77	0.63	0.00	0.57	0.00

1 Forested acreage were provided by Memphis District. Agricultural Acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

HGM Assessment of Potential Wetlands: Existing Conditions By Basin below the 5-year floodplain FCUs

Basin	New Madrid					
Vegetation Class	Ag Fields	Forested Area: 8807 ac				
HGM Subclass	LGRB	LGRB	LGRO	Flat	CD	UCD
Acreage[1]	306	7344	1163	0	300	0
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**
Detain Floodwater	77	6463	954	NA	159	0
Detain Precipitation	165	7124	675	0	NA	0
Cycle Nutrients	73	6242	989	0	183	0
Export Organic Carbon	58	6242	919	NA	171	0
Maintain Plant Communities	0	6830	977	0	201	0
Provide Habitat for Fish and Wildlife	0	5655	733	0	171	0

1 Forested acreage were provided by Memphis District. Agricultural Acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

The FCIs for LGRO forested wetlands ranged between 0.58 for the Detain Precipitation function to 0.85 for the Cycle Nutrients function (Table 2a). The FCIs for CD forested wetlands ranged between 0.53 for the Detain Floodwater function to 0.67 for the Maintain Plant Communities function (Table 2a).

When these FCIs are multiplied through by the representative acreages for each subclass, the highest FCUs for each subclass are 165 FCUs for “Farmed” LGRB wetlands for the Detain Precipitation function, 7124 FCUs for forested LGRB wetlands for the Detain Precipitation function, 989 FCUs for forested LGRO wetlands for the Cycle Nutrients function, and 201 FCUs for forested CD wetlands for the Maintain Plant Communities function (Table 2b). Under the current assumptions these FCUs remain constant over the 50-year life of project for the No Action alternative, and there are no functional losses or gains.

1.2. Future enrollment of WRP without (w/o) the project

St. Johns Basin

The Memphis District has requested that No Action Alternative includes expected additional WRP acreage over the life of the project. According to figures provided by the District, this will add approximately 1445 acres of WRP wetlands within the 5-year floodplain to the St. Johns Basin, of which 1127 acres are Forested wetlands, assumed to be LGRB, and 318 acres are herbaceous wetlands, assumed to be CD wetlands. All these acres are assumed to come from current Prior Converted areas, and will not affect the Farmed Wetland totals. This is a conservative assumption.

The No Action Alternative varies from Existing Conditions only in the annualized gains in WRP (last two columns of Tables 3a and b). There are no gains or losses in the Ag Fields that qualify as wetlands, nor in the forested wetlands.

Based on information provided by the District, WRP was assumed to occur in small blocks, averaging 200 ha (roughly 500 acres) that are a mix of forest and herbaceous wetlands, and not connected to existing blocks of forest. The FCIs shown above for WRP assume that all WRP is planted in the first year of the project, and are annualized over the 50-year life of the project based on variable projects provided in the Guidebook. Time increments used included years 0, 1, 5, 15, 25, and 50, consistent with other assessment models for the project. Forested WRP was allowed to have all variables project to their Year-50 value, whereas herbaceous WRP had all vegetation-related variables stall at approximately a Year-5 value. It is assumed that these areas are managed for waterfowl, and woody vegetation would be suppressed.

The only difference between this Alternative 1.2 (Existing Conditions Plus Annualized Projected WRP Without Project) and Alternative 1.1 (Existing Conditions) is the annualized gain of the WRP. The highest FCUs for the LGRB wetlands are 1042 for the Detain Precipitation function. The highest FCUs for the CD wetlands are 135 for the Cycle Nutrients Function. Alternative 1.2 serves as the baseline against which the losses associated with the other alternatives are measured.

HGM Assessment of Potential Wetlands: No Action Alternative By Basin below the 5-year floodplain FCIs

Basin	St. Johns Basin							
EPA Vegetation Class	Ag Fields	Forested Area: 5233 ac					WRP[3] : 1445 ac	
HGM Subclass	LGRB	LGRB	LGRO	Flat	CD[2]	UCD	LGRB	CD[4]
Acreage[1]	792	3848	1385	0	0	0	1127	318
Function	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**
Detain Floodwater	0.25	0.65	0.97	0.00	0.00	0.00	0.60	0.21
Detain Precipitation	0.54	0.90	0.75	0.00	0.00	0.00	0.93	NA
Cycle Nutrients	0.24	0.68	0.84	0.00	0.00	0.00	0.72	0.42
Export Organic Carbon	0.19	0.68	0.78	0.00	0.00	0.00	0.72	0.41
Maintain Plant Communities	0.00	0.79	0.82	0.00	0.00	0.00	0.76	0.16
Provide Habitat for Fish and Wildlife	0.00	0.47	0.49	0.00	0.00	0.00	0.27	0.15

1 Forested acreage were provided by Memphis District. Agricultural Acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 No connected depressions were located or sampled within St. Johns Basin.

3 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2011. Only the WRP acreage within the 5-year floodplain is assessed.

4 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

HGM Assessment of Potential Wetlands: No Action Alternative By Basins below the 5-year floodplain, FCUs

Basin	St. Johns Basin							
EPA Vegetation Class	Ag Fields	Forested Area: 5233 ac					WRP3 : 1445 ac	
HGM Subclass	LGRB	LGRB	LGRO	Flat	CD[2]	UCD	LGRB	CD[4]
Acreage	792	3848	1385	0	0	0	1127	318
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**
Detain Floodwater	198	2501	1343	0	0	0	674	67
Detain Precipitation	428	3463	1039	0	0	0	1042	NA
Cycle Nutrients	190	2617	1163	0	0	0	814	135
Export Organic Carbon	150	2617	1080	0	0	0	814	129
Maintain Plant Communities	0	3040	1136	0	0	0	855	51
Provide Habitat for Fish and Wildlife	0	1809	679	0	0	0	299	48

1 Forested acreage were provided by Memphis District. Agricultural Acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 No connected depressions were located or sampled within St. Johns Basin.

3 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2011. Only the WRP acreage within the 5-year floodplain is assessed.

4 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

Table 3a and 3b: St. Johns Basin No Action Alternative FCIs and FCUs

New Madrid Floodway

The Memphis District has requested that No Action Alternative includes expected additional WRP acreage over the life of the project. According to figures provided by the District, this will add approximately 765 acres of WRP wetlands within the 5-year floodplain to the New Madrid Floodway, divided into 595 acres of Forested wetlands, assumed to be LGRB, and 170 acres of herbaceous wetlands, assumed to be CD wetlands. All these acres are assumed to come from current Prior Converted areas, and will not affect the Farmed Wetland totals. This is a conservative assumption.

The No Action Alternative varies from Existing Conditions only in the annualized gains in WRP (last two columns of Tables 4a and b). There are no gains or losses in the Ag Fields that qualify as wetlands, nor in the forested wetlands.

WRP was assumed to occur in small blocks, averaging 200 ha (roughly 500 acres) that are a mix of forest and herbaceous wetlands, and not connected to existing blocks of forest. The FCIs shown above for WRP assume that all WRP is planted in the first year of the project, and are annualized over the 50-year life of the project based on variable projects provided in the Guidebook. Time increments used included years 0, 1, 5, 15, 25, and 50, consistent with other assessment models for the project. Forested WRP was allowed to have all variables project to their Year-50 value, whereas herbaceous WRP had all vegetation-related variables stall at approximately a Year-5 value. It is assumed that these areas are managed for waterfowl, and woody vegetation would be suppressed.

Table 4a and 4b: New Madrid Floodway No Action Alternative FCIs and FCUs

HGM Assessment of Potential Wetlands: No Action Alternative By Basin below the 5-year floodplain FCIs

Basin	New Madrid							
Vegetation Class	Ag Fields	Forested Area: 8807 ac					WRP[2] : 765 ac	
HGM Subclass	LGRB	LGRB	LGRO	Flat	CD	UCD	LGRB	CD[3]
Acreage[1]	306	7344	1163	0	300	0	595	170
Function	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**
Detain Floodwater	0.25	0.88	0.82	NA	0.53	NA	0.60	0.21
Detain Precipitation	0.54	0.97	0.58	0.00	NA	NA	0.93	NA
Cycle Nutrients	0.24	0.85	0.85	0.00	0.61	0.00	0.72	0.42
Export Organic Carbon	0.19	0.85	0.79	NA	0.57	NA	0.72	0.41
Maintain Plant Communities	0.00	0.93	0.84	0.00	0.67	0.00	0.76	0.16
Provide Habitat for Fish and Wildlife	0.00	0.77	0.63	0.00	0.57	0.00	0.27	0.15

1 Forested acreage were provided by Memphis District. Agricultural Acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2011. Only the WRP acreage within the 5-year floodplain is assessed.

3 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

HGM Assessment of Potential Wetlands: No Action Alternative By Basin below the 5-year floodplain FCUs

Basin	New Madrid							
EPA Vegetation Class	Ag Fields	Forested Area: 8807 ac					WRP2 : 765 ac	
HGM Subclass	LGRB	LGRB	LGRO	Flat	CD	UCD	LGRB	CD[3]
Acreage[1]	306	7344	1163	0	300	0	595	170
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**
Detain Floodwater	77	6463	954	NA	159	NA	356	36
Detain Precipitation	165	7124	675	0	NA	NA	550	NA
Cycle Nutrients	73	6242	989	0	183	0	430	72
Export Organic Carbon	58	6242	919	NA	171	NA	430	69
Maintain Plant Communities	0	6830	977	0	201	0	452	27
Provide Habitat for Fish and Wildlife	0	5655	733	0	171	0	158	26

1 Forested acreage were provided by Memphis District. Agricultural Acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2011. Only the WRP acreage within the 5-year floodplain is assessed.

3 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

The only difference between this Alternative 1.2 (Existing Conditions Plus Annualized Projected WRP Without Project) and Alternative 1.1 (Existing Conditions) is the annualized gain of the WRP. The highest FCUs for the LGRB wetlands are 550 FCUs for the Detain Precipitation function. The highest FCUs for the CD wetlands are 72 FCUs for the Cycle Nutrients Function. Alternative 1.2 serves as the baseline against which the losses associated with the other alternatives are measured.

Alternative 2.1 – Authorized Project - St. Johns Basin

Details for the Authorized Project within St. Johns Basin can be found in the Alternatives Section of the EIS. Using the assumptions and data sources identified in the Methods, the conditions and impacts associated with the Authorized Project are identified in Tables 5 and 6 below. Acreages for all Direct Impacts, as well as hydrology variables for all indirect impacts, were supplied by Memphis District.

The conditions forecast after the authorized project is implemented in St. Johns basin are documented in Tables 5a and 5b. A total of 673 acres of LGRO forested wetlands are completely cleared, dredged, or filled, and lose all wetland function. The remaining acres of forested LGRO, all acres "Farmed" and forested LGRB wetlands, and all WRP areas suffer modest decreases in function due to hydrologic changes associated with the project. Total changes of FCIs and FCUs comparing the Authorized Project (Alternative 2.1), with the No Action alternative (Alternative 1.2) are shown in Tables 6a and 6b.

Tables 5a and 5b: Authorized Project Conditions – St. Johns Basin:

HGM Assessment of Potential Wetlands: Authorized Project Conditions By Basins below the 5-year floodplain: FCIs

Basin	St. Johns								
Vegetation Class	Ag Fields	Forested Area						WRP[3] : 1445 ac	
HGM Subclass	LGRB	LGRB	LGRO		Flat	CD[2]	UCD	LGRB	CD[4]
Impacts	Indirect Hydro	Indirect Hydro	Direct Clearing	Indirect Hydro				Indirect Hydro	Indirect Hydro
Acreage[1]	792	3848	673	712	0	0	0	1127	318
Function	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**
Detain Floodwater	0.23	0.63	0.00	0.97	NA	NA	NA	0.58	0.19
Detain Precipitation	0.54	0.90	0.00	0.75	NA	NA	NA	0.93	NA
Cycle Nutrients	0.24	0.68	0.00	0.84	NA	NA	NA	0.72	0.42
Export Organic Carbon	0.17	0.66	0.00	0.78	NA	NA	NA	0.70	0.39
Maintain Plant Communities	0.00	0.78	0.00	0.78	NA	NA	NA	0.75	0.15
Provide Habitat for Fish and Wildlife	0.00	0.47	0.00	0.48	NA	NA	NA	0.27	0.15

1 Forested acreage were provided by Memphis District. Agricultural acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 No connected depressions were located or sampled within St. Johns Basin.

3 WRP FCI are annualized over a 50-year lif3 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2011. Only the WRP acreage within the 5-year floodplain is assessed.

4 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

HGM Assessment of Potential Wetlands: Authorized Project Conditions By Basin below the 5-year floodplain: FCUs

Basin	St. Johns								
EPA Vegetation Class	Ag Fields	Forested Area						WRP[3] : 1445 ac	
HGM Subclass	LGRB	LGRB	LGRO		Flat	CD[2]	UCD	LGRB	CD[4]
Impacts	Indirect Hydro	Indirect Hydro	Direct Clearing	Indirect Hydro				Indirect Hydro	Indirect Hydro
Acreage[1]	792	3848	673	712	0	0	0	1127	318
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**
Detain Floodwater	182	2424	0	691	NA	NA	NA	651	61
Detain Precipitation	428	3463	0	534	NA	NA	NA	1042	NA
Cycle Nutrients	190	2617	0	598	NA	NA	NA	814	135
Export Organic Carbon	135	2540	0	555	NA	NA	NA	791	123
Maintain Plant Communities	0	3001	0	555	NA	NA	NA	844	48
Provide Habitat for Fish and Wildlife	0	1809	0	342	NA	NA	NA	299	48

1 Forested acreage were provided by Memphis District. Agricultural acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 No connected depressions were located or sampled within St. Johns Basin.

3 WRP FCI are annualized over a 50-year lif3 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2011. Only the WRP acreage within the 5-year floodplain is assessed.

4 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

Tables 6a and 6b: Losses Associated with the Authorized Project as compared with No Action Alternative – St. Johns Basin

HGM Assessment of Potential Wetlands:Difference between Authorized Project Conditions and No Action Alternative By Basin below the 5-year floodplain: FCIs

Basin	St. Johns								
Vegetation Class	Ag Fields	Forested Area						WRP[3] : 1445 ac	
HGM Subclass	LGRB	LGRB	LGRO		Flat	CD[2]	UCD	LGRB	CD[4]
Impacts	Indirect Hydro	Indirect Hydro	Direct Clearing	Indirect Hydro				Indirect Hydro	Indirect Hydro
Acreage[1]	792	3848	673	712	0	0	0	1127	318
Function	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**
Detain Floodwater	-0.02	-0.02	-0.97	0.00	NA	NA	NA	-0.02	-0.02
Detain Precipitation	0.00	0.00	-0.75	0.00	NA	NA	NA	0.00	NA
Cycle Nutrients	0.00	0.00	-0.84	0.00	NA	NA	NA	0.00	0.00
Export Organic Carbon	-0.02	-0.02	-0.78	0.00	NA	NA	NA	-0.02	-0.02
Maintain Plant Communities	0.00	-0.01	-0.82	-0.04	NA	NA	NA	-0.01	-0.01
Provide Habitat for Fish and Wildlife	0.00	0.00	-0.49	-0.01	NA	NA	NA	0.00	0.00

1 Forested acreage were provided by Memphis District. Agricultural acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 No connected depressions were located or sampled within St. Johns Basin.

3 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2009. Only the WRP acreage within the 5-year floodplain is assessed.

4 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

HGM Assessment of Potential Wetlands:Difference between Authorized Project Conditions and No Action Alternative By Basin below the 5-year floodplain: FCUs

Basin	St. Johns								
Vegetation Class	Ag Fields	Forested Area						WRP[3] : 1445 ac	
HGM Subclass	LGRB	LGRB	LGRO		Flat	CD[2]	UCD	LGRB	CD[4]
Impacts	Indirect Hydro	Indirect Hydro	Direct Clearing	Indirect Hydro				Indirect Hydro	Indirect Hydro
Acreage[1]	792	3848	673	712	0	0	0	1127	318
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**
Detain Floodwater	-16	-77	-653	0	NA	NA	NA	-23	-6
Detain Precipitation	0	0	-505	0	NA	NA	NA	0	NA
Cycle Nutrients	0	0	-565	0	NA	NA	NA	0	0
Export Organic Carbon	-16	-77	-525	0	NA	NA	NA	-23	-6
Maintain Plant Communities	0	-38	-552	-28	NA	NA	NA	-11	-3
Provide Habitat for Fish and Wildlife	0	0	-330	-7	NA	NA	NA	0	0

1 Forested acreage were provided by Memphis District. Agricultural acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 No connected depressions were located or sampled within St. Johns Basin.

3 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2009. Only the WRP acreage within the 5-year floodplain is assessed.

4 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

Table 6c: Summary of FCU losses for the Authorized Alternative (2.1) in St. John's Basin.

	Losses in FCUs		
Function	**LGRB**	**LGRO**	**CD[1]**
Detain Floodwater	-116.0	-653.0	0.0
Detain Precipitation	0.0	-505.0	NA
Cycle Nutrients	0.0	-565.0	0.0
Export Organic Carbon	-116.0	-525.0	0.0
Maintain Plant Communities	-49.0	-580.0	0.0
Provide Habitat for Fish and Wildlife	0.0	-337.0	0.0

1 No connected depressions were located or sampled within St. Johns Basin.

Changes in FCIs and FCUs associated with the Authorized Project within the St. Johns basin are shown by category in Tables 6a and 6b, above. The majority of impacts are associated with the clearing and widening of ditches in the LGRO subclass (Direct Clearing, above). Much more modest impacts are associated with the changes in hydrology. Slight changes in both flood frequency and flood duration affected the Detain Floodwater, Export Organic Carbon and Maintain Plant Communities functions in the LGRB subclass, although this change does not show up in the Maintain Plant Communities function of the agricultural areas, since the function was already at an FCI of 0.0. Low Gradient Riverine Overbank wetlands only suffered a change in flood duration in this alternative, not flood frequency. Hence only the Maintain Plant Communities and the Provide Habitat for Fish and Wildlife Functions were affected. While these slight changes in hydrology affected the models in modest ways (changes in FCIs ranged between 0 and 0.04 where only indirect hydrological impacts were felt), nonetheless when multiplied across the relatively large acreages of the LGRB subclass, meaningful losses of FCUs result

The largest functional losses in the St. Johns Basin under the Authorized Project represent a loss of 653 LGRO FCUs in the Detail Floodwater subclass, resulting from direct clearing. The highest losses resulting from indirect hydrological changes were to the LGRB vegetated subclass, where 77 FCUs were lost to both the Detain Floodwater and Maintain Plant Communities functions.

Total losses of FCUs for this alternative are summarized by subclass in Table 6c. It should be noted that this mitigation debt is summarized in FCUs. The acreage required will depend on the rate of functional gain realized by the mitigation scenarios, which are subject to post-project hydrology.

Alternative 2.2 – Authorized Project - New Madrid Floodway

Details of the Authorized Project within the New Madrid Floodway may be found in the Alternatives Section of the EIS. Using the assumptions and data sources identified in the Methods, the conditions and impacts associated with the Authorized Project are identified in Tables 7 and 8 below. Acreages for all Direct Impacts, as well as hydrology variables for all indirect impacts, were supplied by Memphis District.

The conditions forecast after the authorized project is implemented in New Madrid Floodway are documented in Tables 7a and 7b. The vast majority of impacts are associated with indirect hydrologic changes; only 7 acres of LGRB are subjected direct clearing. Of the losses resulting from indirect hydrologic changes, the vast majority of those are from changes in frequency so severe that a fundamental shift from a river connected subclass to an unconnected subclass occurs. Hence, of the 7344 acres of naturally vegetated LGRB existing in the New Madrid Floodway currently, 6829 acres are cut off from the river sufficiently to qualify as Flats (Table 7). All functions associated with these areas as LGRB wetlands are lost, and though they still exist on the landscape as Flats, they no longer perform the functions of Detain Floodwater or Export Organic Compounds to the aquatic ecosystem in a measureable way.

Tables 7a and 7b: Authorized Project Conditions – New Madrid Floodway:

HGM Assessment of Potential Wetlands: Authorized Project Conditions By Basin below the 5-year floodplain: FCIs

Basin	New Madrid											
Vegetation Class	Ag Fields		Forested Areas = 8807						WRP[2] : 765 ac			
HGM Subclass	LGRB	Flat	LGRB		LGRO	Flat	CD	UCD	LGRB	Flat	CD[3]	UCD
Impacts	Indirect Hydro	Indirect Hydro	Direct Clearing	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro
Acreage[1]	21	285	7	508	1163	6829	27	273	42	553	12	158
Function	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**
Detain Floodwater	0.20	NA	0.00	0.84	0.66	NA	0.54	NA	0.48	NA	0.17	NA
Detain Precipitation	0.54	0.35	0.00	0.90	0.58	0.77	NA	NA	0.93	0.71	NA	NA
Cycle Nutrients	0.24	0.19	0.00	0.84	0.85	0.79	0.63	0.64	0.72	0.67	0.42	0.53
Export Organic Carbon	0.15	NA	0.00	0.78	0.64	NA	0.63	NA	0.58	NA	0.33	NA
Maintain Plant Communities	0.00	0.00	0.00	0.81	0.73	0.89	0.63	0.75	0.68	0.68	0.09	0.39
Provide Habitat for Fish and Wildlife	0.00	0.00	0.00	0.59	0.58	0.72	0.77	0.51	0.25	0.24	0.13	0.09

1 Forested acreage were provided by Memphis District. Agricultural Acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.
2 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2011. Only the WRP acreage within the 5-year floodplain is assessed.
3 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

HGM Assessment of Potential Wetlands: Authorized Project Conditions By Basin below the 5-year floodplain: FCUs

Basin	New Madrid											
Vegetation Class	Ag Fields		Forested Areas						WRP[2] : 765 ac			
HGM Subclass	LGRB	Flat	LGRB		LGRO	Flat	CD	UCD	LGRB	Flat	CD[3]	UCD
Impacts	Indirect Hydro	Indirect Hydro	Direct Clearing	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro
Acreage[1]	21	285	7	508	1163	6829	27	273	42	553	12	158
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**
Detain Floodwater	4	NA	0	427	768	NA	15	NA	20	NA	2	NA
Detain Precipitation	11	100	0	457	675	5258	NA	NA	39	393	NA	NA
Cycle Nutrients	5	54	0	427	989	5395	17	175	30	371	5	84
Export Organic Carbon	3	NA	0	396	744	NA	17	NA	24	NA	4	NA
Maintain Plant Communities	0	0	0	412	849	6078	17	205	29	376	1	61
Provide Habitat for Fish and Wildlife	0	0	0	300	675	4917	21	139	11	133	2	14

1 Forested acreage were provided by Memphis District. Agricultural Acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.
2 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2011. Only the WRP acreage within the 5-year floodplain is assessed.
3 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

Tables 8a and 8b: Gains and Losses Associated with the Authorized Project as compared with No Action Alternative – New Madrid Floodway.

HGM Assessment of Potential Wetlands: Gains and Losses between No Action Alternative and Authorized Project Conditions By Basins below the 5-year floodplain: FCUs

Losses due to wholesale conversion to non-river connected Subclass, or due to direct clearing

Basin	New Madrid										
Vegetation Class	Ag Fields		Forested Area					WRP			
HGM Subclass	LGRB	Flat	LGRB		Flat	CD	UCD	LGRB	Flat	CD	UCD
Impacts	Indirect Hydro	Indirect Hydro	Direct Clearing	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro
Acreage	-285	285	-7	-6829	6829	-273	273	-553	553	-158	158
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**
Detain Floodwater	-71	NA	-6	-6010	NA	-145	NA	-336	NA	-34	NA
Detain Precipitation	-154	100	-7	-6624	5258	NA	NA	-512	393	NA	NA
Cycle Nutrients	-68	54	-6	-5805	5395	-167	175	-399	371	-67	84
Export Organic Carbon	-54	NA	-6	-5805	NA	-156	NA	-405	NA	-65	NA
Maintain Plant Communities	0	0	-7	-6351	6078	-183	205	-423	376	-26	61
Provide Habitat for Fish and Wildlife	0	0	-5	-5258	4917	-156	139	-147	133	-24	14

Losses due to incremental decreases in function within remaining river-connected subclasses

Basin	New Madrid					
Vegetation Class	Ag Fields	Forested Area			WRP	
HGM Subclass	LGRB	LGRB	LGRO	CD	LGRB	CD
Impacts	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro
Acreage	21	508	1163	27	42	12
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**
Detain Floodwater	-1	-20	-186	0	-5	0
Detain Precipitation	0	-36	0	NA	0	NA
Cycle Nutrients	0	-5	0	-1	0	0
Export Organic Carbon	-1	-36	-174	-2	-6	-1
Maintain Plant Communities	0	-61	-128	-1	-3	-1
Provide Habitat for Fish and Wildlife	0	-91	-58	-1	-1	0

Table 8c. Summary of FCU losses for the Authorized Alternative (2.2) in New Madrid Floodway..

	Losses in FCUs		
Function	**LGRB**	**LGRO**	**CD**
Detain Floodwater	-6449	-186	-179
Detain Precipitation	-7332	0	NA
Cycle Nutrients	-6283	0	-234
Export Organic Carbon	-6312	-174	-223
Maintain Plant Communities	-6845	-128	-211
Provide Habitat for Fish and Wildlife	-5503	-58	-181

Table 8a illustrates the functional losses due to wholesale conversion of wetland acres to a subclass unconnected to the river, or due to direct clearing. The 6829 acres converted from LGRB to flats results in a loss of 6010 FCUs in the Detain Floodwater function and 5805 FCUs in the Export Organic Carbon function that are in no way offset by the fact that some gains occurred in the Flats subclass. Even in the functions that both LGRB and Flat wetlands both perform, the fact that the indices are calibrated only within each subclass means that the FCUs cannot be added or subtracted across subclasses (e.g., Detain Precipitation), or represent fundamentally different conditions (i.e., the plants and habitat provided by different subclasses are different, and therefore cannot fully substitute for each other). As a result, although these acres are still considered to be jurisdictional wetlands and still occur within the landscape of the project area, they are treated as though they were cleared, because from a functional standpoint, they are no longer provided the same functions that they were before the project.

Those wetland areas not subject to a full scale removal from the 5-year floodplain and resultant subclass shift are still subject to an incremental decrease in function, summarized in Table 8b. For instance, the 508 acres of LGRB remaining after the Flats are removed are subject to decreases in FCIs ranging from 0.01 to 0.18, and the resulting losses of FCUs when multiplied by the acreages are provided in Table 8b. If the acreages are also small, in some cases these functional losses are negligible as compared with the losses due to subclass conversion. However, in order to be consistent with other alternatives, in which the changes to the 5-year floodplain are much less severe, we have added these areas to the overall mitigation debt for the alternative. LGRO wetlands were not converted to other subclasses, and so their incremental functional loss reported in Table 8b were relatively larger, the 186 FCUs lost in Detain floodwater function being the most severe impact.

Alternative 2.3 – Authorized Project - St. Johns Basin and New Madrid Floodway

This alternative is simply the sum of the losses to both basins under the Authorized Project (Tables 6c and 8c). The largest combined impact to LGRB was still to Detain Precipitation, which lost 7332 FCUs over the two basins. Detain Floodwater was the most impact function for LGRO wetlands, with a loss of 839 FCUs lost. Since no CD wetlands were found in the St Johns Basin, the losses for both basins is the same as that for New Madrid Floodway, with the largest impact to Cycle Nutrients, 234 FCUs lost.

Alternative 3 – Authorized Project with Avoid and Minimize Measures

St. Johns Basin

The Authorized Project with Avoid and Minimize Measures within the St. Johns Basin consists of smaller a smaller footprint for the direct clearing and the bottom width of the ditches (Alternatives Section, EIS). Acreages for all Direct Impacts, as well as hydrology variables for all indirect impacts, were supplied by Memphis District. This alternative varies from the Authorized Project within the St. Johns Basin by having only 409 acres of the LGRO forest type subject to Direct Clearing, 264 acres fewer than in the Authorized Project. These acres are instead subject to the Indirect Hydrology impacts. The hydrology variables that affect indirect impacts are identical to those in the Authorized Project.

The conditions forecast after the Authorized Project with Avoid and Minimize Measures is implemented in St. Johns basin are documented in Tables 9a and 9b. A total of 409 acres of LGRO forested wetlands are completely cleared, dredged, or filled, and lose all wetland function. The remaining acres of forested LGRO, all acres “Farmed” and forested LGRB wetlands, and all WRP areas suffer modest decreases in function due to hydrologic changes associated with the project.

Total changes of FCIs and FCUs comparing the Authorized Project with Avoid and Minimize Measures with the No Action alternative are shown in Tables 10a and 10b, and are summarized by subclass in Table 10c. The majority of impacts are associated with the clearing and widening of ditches in the LGRO subclass. Much more modest impacts are associated with the changes in hydrology. Changes in both flood frequency and flood duration effected the Detain Floodwater, Export Organic Carbon and Maintain Plant Communities functions in the LGRB subclass, although this change does not show up in the Maintain Plant Communities function of the agricultural areas, since the function was already at an FCI of 0.0. Low Gradient Riverine Overbank wetlands only suffered a change in flood duration in this alternative, not flood frequency. Hence only the Maintain Plant Communities and the Provide Habitat for Fish and Wildlife Functions were affected.

The largest functional impacts within the St. Johns Basin include a loss of 397 LGRO FCUs in the Detain Floodwater function, and a total 116 LGRB FCUs, also in the Detain Floodwater function (Tables 10 b and 10c). This constitutes a decrease in impacts of approximately 256 LGRO FCUs as compared to the Authorized Project impacts.

Tables 9a and 9b: Authorized Project With Avoid and Minimize Measures Alternative Conditions – St. Johns Basin:

HGM Assessment of Potential Wetlands: Avoid and Minimize Alternative Conditions By Basins below the 5-year floodplain: FCIs

Basin	St. Johns								
Vegetation Class	Ag Fields	Forested Area						WRP[3] : 1445 ac	
HGM Subclass	LGRB	LGRB	LGRO		Flat	CD[2]	UCD	LGRB	CD[4]
Impacts	Indirect Hydro	Indirect Hydro	Direct Clearing	Indirect Hydro				Indirect Hydro	Indirect Hydro
Acreage[1]	792	3848	409	976	0	0	0	1127	318
Function	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**
Detain Floodwater	0.23	0.63	0.00	0.97	NA	NA	NA	0.58	0.19
Detain Precipitation	0.54	0.90	0.00	0.75	NA	NA	NA	0.93	N/A
Cycle Nutrients	0.24	0.68	0.00	0.84	NA	NA	NA	0.72	0.42
Export Organic Carbon	0.17	0.66	0.00	0.78	NA	NA	NA	0.70	0.39
Maintain Plant Communities	0.00	0.78	0.00	0.78	NA	NA	NA	0.75	0.15
Provide Habitat for Fish and Wildlife	0.00	0.47	0.00	0.48	NA	NA	NA	0.27	0.15

1 Forested acreage were provided by Memphis District. Agricultural acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 No connected depressions were located or sampled within St. Johns Basin.

3 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2011. Only the WRP acreage within the 5-year floodplain is assessed.

4 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

HGM Assessment of Potential Wetlands: Avoid and Minimize Alternative Conditions By Basin below the 5-year floodplain: FCUs

Basin	St. Johns								
Vegetation Class	Ag Fields	Forested Area						WRP[3] : 1445 ac	
HGM Subclass	LGRB	LGRB	LGRO		Flat	CD[2]	UCD	LGRB	CD[4]
Impacts	Indirect Hydro	Indirect Hydro	Direct Clearing	Indirect Hydro				Indirect Hydro	Indirect Hydro
Acreage[1]	792	3848	409	976	0	0	0	1127	318
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**
Detain Floodwater	182	2424	0	947	NA	NA	NA	651	61
Detain Precipitation	428	3463	0	732	NA	NA	NA	1042	N/A
Cycle Nutrients	190	2617	0	820	NA	NA	NA	814	135
Export Organic Carbon	135	2540	0	761	NA	NA	NA	791	123
Maintain Plant Communities	0	3001	0	761	NA	NA	NA	844	48
Provide Habitat for Fish and Wildlife	0	1809	0	468	NA	NA	NA	299	48

1 Forested acreage were provided by Memphis District. Agricultural acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 No connected depressions were located or sampled within St. Johns Basin.

3 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2011. Only the WRP acreage within the 5-year floodplain is assessed.

4 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

Tables 10a and 10b: Gains and Losses Associated with the Authorized Project With Avoid and Minimize Measures Alternative as compared with No Action Alternative – St. Johns Basin

HGM Assessment of Potential Wetlands:Difference between Avoid & Minimize Alternative and No Action Alternative below the 5-year floodplain: FCIs

Basin	St. Johns								
Vegetation Class	Ag Fields	Forested Area						WRP[3] : 1445 ac	
HGM Subclass	LGRB	LGRB	LGRO		Flat	CD[2]	UCD	LGRB	CD[4]
Impacts	Indirect Hydro	Indirect Hydro	Direct Clearing	Indirect Hydro				Indirect Hydro	Indirect Hydro
Acreage[1]	792	3848	409	976	0	0	0	1127	318
Function	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**
Detain Floodwater	-0.02	-0.02	-0.97	0.00	NA	NA	NA	-0.02	-0.02
Detain Precipitation	0.00	0.00	-0.75	0.00	NA	NA	NA	0.00	N/A
Cycle Nutrients	0.00	0.00	-0.84	0.00	NA	NA	NA	0.00	0.00
Export Organic Carbon	-0.02	-0.02	-0.78	0.00	NA	NA	NA	-0.02	-0.02
Maintain Plant Communities	0.00	-0.01	-0.82	-0.04	NA	NA	NA	-0.01	-0.01
Provide Habitat for Fish and Wildlife	0.00	0.00	-0.49	-0.01	NA	NA	NA	0.00	0.00

1 Forested acreage were provided by Memphis District. Agricultural acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 No connected depressions were located or sampled within St. Johns Basin.

3 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2011. Only the WRP acreage within the 5-year floodplain is assessed.

4 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

HGM Assessment of Potential Wetlands:Difference between Avoid & Minimize Alternative and No Action Alternative below the 5-year floodplain: FCUs

Basin	St. Johns								
Vegetation Class	Ag Fields	Forested Area						WRP[3] : 1445 ac	
HGM Subclass	LGRB	LGRB	LGRO		Flat	CD[2]	UCD	LGRB	CD[4]
Impacts	Indirect Hydro	Indirect Hydro	Direct Clearing	Indirect Hydro				Indirect Hydro	Indirect Hydro
Acreage[1]	792	3848	409	976	0	0	0	1127	318
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**
Detain Floodwater	-16	-77	-397	0	NA	NA	NA	-23	-6
Detain Precipitation	0	0	-307	0	NA	NA	NA	0	N/A
Cycle Nutrients	0	0	-344	0	NA	NA	NA	0	0
Export Organic Carbon	-15	-77	-319	0	NA	NA	NA	-23	-6
Maintain Plant Communities	0	-39	-335	-39	NA	NA	NA	-11	-3
Provide Habitat for Fish and Wildlife	0	0	-200	-10	NA	NA	NA	0	0

1 Forested acreage were provided by Memphis District. Agricultural acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 No connected depressions were located or sampled within St. Johns Basin.

3 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2011. Only the WRP acreage within the 5-year floodplain is assessed.

4 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

Table 10c. Summary of FCU losses for the Avoid and Minimize Alternative (3.1) in St. Johns Basin.

	Losses in FCUs		
Function	**LGRB**	**LGRO**	**CD[1]**
Detain Floodwater	-116	-397	0
Detain Precipitation	0	-307	NA
Cycle Nutrients	0	-344	0
Export Organic Carbon	-115	-319	0
Maintain Plant Communities	-50	-374	0
Provide Habitat for Fish and Wildlife	0	-210	0

1 No connected depressions were located or sampled within St. Johns Basin.

3.1. Management Scenario 1 New Madrid Floodway

Details of the Management Scenario 1 for the Authorized Project With Avoid and Minimize Measures Alternative within the New Madrid Floodway may be found in the Alternatives Section of the EIS. Using the assumptions and data sources identified in the Methods, the conditions and impacts associated with the Authorized Project are identified in Tables 11 and 12 below. Acreages for all Direct Impacts, as well as hydrology variables for all indirect impacts, were supplied by Memphis District.

The conditions forecast after the Authorized Project With Avoid and Minimize Measures Management Scenario 1 is implemented in New Madrid Floodway are documented in Tables 11a and 11b. The vast majority of impacts are associated with indirect hydrologic changes. Total changes of FCIs and FCUs comparing the Authorized Project With Avoid and Minimize Measures Management Scenario 1 (Alternative 3.1), with the No Action alternative (Alternative 1.2) are shown in Tables 12a and 12b.

Changes in FCIs and FCUs associated with the Authorized Project With Avoid and Minimize Measures Management Scenario 1 within the New Madrid Floodway are shown in Tables 12a and 12b, and summarized by subclass in Table 12c. The vast majority of impacts are associated with indirect hydrologic changes; only 7 acres of LGRB are subjected direct clearing. Of the losses resulting from indirect hydrologic changes, more than half of those are from changes in frequency severe enough that a fundamental shift from a river connected subclass to an unconnected subclass occurs. Hence, of the 7344 acres of naturally vegetated LGRB existing in the New Madrid Floodway currently, 2216 acres are cut off from the river sufficiently to be outside the 5-year floodplain, and therefore to qualify as Flats (Table 11). All functions associated with these areas as LGRB wetlands are lost, and though they still exist on the landscape as Flats, they no longer perform the functions of Detain Floodwater or Export Organic Compounds to the aquatic ecosystem in a measureable way.

Table 12a illustrates the functional losses due to wholesale conversion of wetland acres to a subclass unconnected to the river, or due to direct clearing. The 2216 acres converted from LGRB to flats results in a loss of 1950 FCUs in the Detain Floodwater function and 1884 FCUs in the Export Organic Carbon function that are in no way offset by the fact that some gains occurred in the Flats subclass. Even in the functions that both LGRB and Flat wetlands perform, the fact that the indices are calibrated only within each subclass means that the FCUs cannot be added or subtracted across subclasses (e.g., Detain Precipitation), or that they represent fundamentally different conditions (i.e., the plants and habitat provided by different subclasses are different, and therefore cannot fully substitute for each other). As a result, although these acres are still considered to be jurisdictional wetlands and still occur within the landscape of the project area, they are treated as though they were cleared, because from a functional standpoint, they are no longer provided the same functions that they were before the project.

Those wetland areas not subject to a full scale removal from the 5-year floodplain and the resultant subclass shift are still subject to an incremental decrease in function, summarized in Table 12b. For instance, the 5121 acres of forested LGRB remaining after the Flats are removed are subject to decreases in FCIs ranging from 0.01 to 0.27, and the resulting losses of FCUs when multiplied by the acreages are provided in Table 12b. The largest of these impacts are the loss of 1280 FCUs for the Detain Floodwater function, and a loss of 1383 FCUs in the Export Carbon function (Table 12b)

Tables 11a and 11b: Authorized Project With Avoid and Minimize Measures Management Scenario 1 Conditions – New Madrid Floodway:

HGM Assessment of Potential Wetlands: Alternative 3.1 Conditions By Basin below the 5-year floodplain: FCIs

Basin	New Madrid											
Vegetation Class	Ag Fields		Forested Areas						WRP[2] : 765 ac			
HGM Subclass	LGRB	Flat	LGRB		LGRO	Flat	CD	UCD	LGRB	Flat	CD[3]	UCD
Impacts	Indirect Hydro	Incirect Hydro	Direct Clearing	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro
Acreage[1]	214	92	7	5121	1163	2216	191	109	416	179	119	51
Function	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**
Detain Floodwater	0.15	NA	0.00	0.63	0.79	NA	0.44	NA	0.36	NA	0.12	NA
Detain Precipitation	0.54	0.35	0.00	0.96	0.58	0.79	NA	NA	0.93	0.71	NA	NA
Cycle Nutrients	0.24	0.19	0.00	0.84	0.85	0.88	0.58	0.76	0.72	0.67	0.42	0.53
Export Organic Carbon	0.11	NA	0.00	0.58	0.76	0.00	0.49	NA	0.43	NA	0.24	NA
Maintain Plant Communities	0.00	0.00	0.00	0.86	0.81	0.93	0.47	0.86	0.71	0.68	0.12	0.39
Provide Habitat for Fish and Wildlife	0.00	0.00	0.00	0.73	0.62	0.71	0.48	0.61	0.25	0.24	0.13	0.09

1 Forested acreage were provided by Memphis District. Agricultural Acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2011. Only the WRP acreage within the 5-year floodplain is assessed.

3 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

HGM Assessment of Potential Wetlands: Alternative 3.1 Conditions By Basin below the 5-year floodplain: FCUs

Basin	New Madrid											
Vegetation Class	Ag Fields		Forested Areas						WRP2 : 765 ac			
HGM Subclass	LGRB	Flat	LGRB		LGRO	Flat	CD	UCD	LGRB	Flat	CD[3]	UCD
Impacts	Indirect Hydro	Incirect Hydro	Direct Clearing	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro
Acreage[1]	214	92	7	5121	1163	2216	191	109	416	179	119	51
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**
Detain Floodwater	32	NA	0	3226	919	NA	84	NA	150	NA	14	NA
Detain Precipitation	116	32	0	4916	675	1751	NA	NA	385	127	NA	NA
Cycle Nutrients	51	18	0	4302	989	1950	111	83	300	120	50	27
Export Organic Carbon	24	NA	0	2970	884	0	94	NA	179	NA	29	NA
Maintain Plant Communities	0	0	0	4404	942	2061	90	94	295	122	14	20
Provide Habitat for Fish and Wildlife	0	0	0	3738	721	1573	92	67	104	43	16	5

1 Forested acreage were provided by Memphis District. Agricultural Acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2011. Only the WRP acreage within the 5-year floodplain is assessed.

3 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

Tables 12a and 12b: Gains and Losses Associated with the Authorized Project With Avoid and Minimize Measures Management Scenario 1 as compared with No Action Alternative – New Madrid Floodway.

HGM Assessment of Potential Wetlands: Gains and Losses between No Action Alternative and Alternative 3.1 Conditions By Basins below the 5-year floodplain: FCUs

Losses due to wholesale conversion to non-river connected Subclass, or due to direct clearing

Basin	New Madrid										
Vegetation Class	Ag Fields		Forested Area					WRP			
HGM Subclass	LGRB	Flat	LGRB		Flat	CD	UCD	LGRB	Flat	CD	UCD
Impacts	Indirect Hydro	Indirect Hydro	Direct Clearing	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro
Acreage	-92	92	0	-2216	2216	-109	109	-179	179	-51	51
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**
Detain Floodwater	-23	NA	0	-1950	NA	-58	NA	-107	NA	-11	NA
Detain Precipitation	-50	32	0	-2150	1751	NA	NA	-166	127	NA	NA
Cycle Nutrients	-22	18	0	-1884	1950	-66	83	-129	120	-22	27
Export Organic Carbon	-17	NA	0	-1884	NA	-62	NA	-129	NA	-21	NA
Maintain Plant Communities	0	0	0	-2061	2061	-73	94	-136	122	-8	20
Provide Habitat for Fish and Wildlife	0	0	0	-1706	1573	-62	67	-47	43	-8	5

Losses due to incremental decreases in function within remaining river-connected subclasses

Basin	New Madrid					
Vegetation Class	Ag Fields	Forested Area			WRP	
HGM Subclass	LGRB	LGRB	LGRO	CD	LGRB	CD
Impacts	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro
Acreage	214	5121	1163	191	416	119
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**
Detain Floodwater	-21	-1280	-35	-17	-99	-11
Detain Precipitation	0	-51	0	NA	0	NA
Cycle Nutrients	0	-51	0	-6	0	0
Export Organic Carbon	-17	-1383	-35	-15	-121	-20
Maintain Plant Communities	0	-358	-35	-38	-20	-5
Provide Habitat for Fish and Wildlife	0	-205	-12	-17	-6	-2

Table 12c. Summary of FCU losses for the Avoid and Minimize Alternative (3.1) in New Madrid Floodway.

	Losses in FCUs		
Function	**LGRB**	**LGRO**	**CD**
Detain Floodwater	-3487	-35	-97
Detain Precipitation	-2423	0	0
Cycle Nutrients	-2092	0	-94
Export Organic Carbon	-3558	-35	-118
Maintain Plant Communities	-2582	-35	-124
Provide Habitat for Fish and Wildlife	-1970	-12	-89

Total losses of FCUs for this alternative are summarized by subclass in Table 12c. The largest impacts are to the Detain Floodwater and Export Organic Carbon functions for both LGRB and LGRO wetlands. It should be noted that this mitigation debt is summarized in FCUs. The acreage required will depend on the rate of functional gain realized by the mitigation scenarios, which are subject to post-project hydrology.

3.2. Management Scenario 2 New Madrid Floodway

Details of the Management Scenario 2 for the Authorized Project With Avoid and Minimize Measures Alternative within the New Madrid Floodway may be found in the Alternatives Section of the EIS. Using the assumptions and data sources identified in the Methods, the conditions and impacts associated with the Authorized Project are identified in Tables 13 and 14 below. Acreages for all Direct Impacts, as well as hydrology variables for all indirect impacts, were supplied by Memphis District.

The conditions forecast after the Authorized Project With Avoid and Minimize Measures Management Scenario 2 is implemented in New Madrid Floodway are documented in Tables 13a and 13b. The vast majority of impacts are associated with indirect hydrologic changes. Total changes of FCIs and FCUs comparing the Authorized Project With Avoid and Minimize Measures Management Scenario 2 (Alternative 3.2), with the No Action alternative (Alternative 1.2) are shown in Tables 14a and 14b.

Changes in FCIs and FCUs associated with the Authorized Project With Avoid and Minimize Measures Management Scenario 2 within the New Madrid Floodway are shown in Tables 14a and 14b, and summarized by subclass in Table 14c. The vast majority of impacts are associated with indirect hydrologic changes; only 7 acres of LGRB are subjected direct clearing. Of the losses resulting from indirect hydrologic changes, the majority of those are from changes in frequency severe enough that a fundamental shift from a river connected subclass to an unconnected subclass occurs. Hence, of the 7344 acres of naturally vegetated LGRB existing in the New Madrid Floodway currently, 3253 acres are cut off from the river sufficiently to be outside the 5-year floodplain, and therefore to qualify as Flats (Table 13). All functions associated with these areas as LGRB wetlands

are lost, and though they still exist on the landscape as Flats, they no longer perform the functions of Detain Floodwater or Export Organic Compounds to the aquatic ecosystem in a measureable way.

Table 14a illustrates the functional losses due to wholesale conversion of wetland acres to a subclass unconnected to the river, or due to direct clearing. The 3253 acres converted from LGRB to flats results in a loss of 2863 FCUs in the Detain Floodwater function and 2765 FCUs in the Export Organic Carbon function that are in no way offset by the fact that some gains occurred in the Flats subclass. Even in the functions that both LGRB and Flat wetlands perform, the fact that the indices are calibrated only within each subclass means that the FCUs cannot be added or subtracted across subclasses (e.g., Detain Precipitation), or that they represent fundamentally different conditions (i.e., the plants and habitat provided by different subclasses are different, and therefore cannot fully substitute for each other). As a result, although these acres are still considered to be jurisdictional wetlands and still occur within the landscape of the project area, they are treated as though they were cleared, because from a functional standpoint, they are no longer provided the same functions that they were before the project.

Those wetland areas not subject to a full scale removal from the 5-year floodplain and the resultant subclass shift are still subject to an incremental decrease in function, summarized in Table 14b. For instance, the 4084 acres of forested LGRB remaining after the Flats are removed are subject to decreases in FCIs ranging from 0.01 to 0.26, and the resulting losses of FCUs when multiplied by the acreages are provided in Table 14b. The largest of these impacts are the loss of 1062 FCUs for the Export Organic Carbon function, and a loss of 939 FCUs in the Detain Floodwater function (Table 14b)

Total losses of FCUs for this alternative are summarized by subclass in Table 14c. The largest impacts are to the Detain Floodwater (a loss of 4046 FCUs) and Export Organic Carbon (4102 FCUs) functions for LGRB wetlands. The Maintain Plant Communities function for LGRO (a loss of 70 FCUs) and CD wetlands (a loss of 138 FCUs), LGRO wetlands, products of changes to flood duration seen in this alternative. Although the gains of Flat and UCD are reported, they are not meant to be seen as offsetting the losses. It should also be noted that this mitigation debt is summarized in FCUs. The acreage required will depend on the rate of functional gain realized by the mitigation scenarios, which are subject to post-project hydrology.

Tables 13a and 13b: Authorized Project With Avoid and Minimize Measures Management Scenario 2 Conditions – New Madrid Floodway:

HGM Assessment of Potential Wetlands: Alternative 3.2 Conditions By Basin below the 5-year floodplain: FCIs

Basin	New Madrid											
Vegetation Class	Ag Fields		Forested Areas						WRP[2] : 765 ac			
HGM Subclass	LGRB	Flat	LGRB		LGRO	Flat	CD	UCD	LGRB	Flat	CD[3]	UCD
Impacts	Indirect Hydro	Indirect Hydro	Direct Clearing	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro
Acreage[1]	171	135	7	4084	1163	3253	191	109	333	262	95	75
Function	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**
Detain Floodwater	0.20	NA	0.00	0.65	0.79	NA	0.44	NA	0.48	NA	0.17	NA
Detain Precipitation	0.54	0.35	0.00	0.96	0.58	0.81	NA	NA	0.93	0.71	NA	NA
Cycle Nutrients	0.24	0.19	0.00	0.82	0.85	0.85	0.58	0.76	0.72	0.67	0.42	0.53
Export Organic Carbon	0.15	NA	0.00	0.59	0.76	NA	0.49	NA	0.58	NA	0.33	NA
Maintain Plant Communities	0.00	0.00	0.00	0.85	0.78	0.91	0.41	0.86	0.71	0.68	0.12	0.39
Provide Habitat for Fish and Wildlife	0.00	0.00	0.00	0.71	0.60	0.73	0.47	0.61	0.25	0.24	0.13	0.09

1 Forested acreage were provided by Memphis District. Agricultural Acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2011. Only the WRP acreage within the 5-year floodplain is assessed.

3 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

HGM Assessment of Potential Wetlands: Alternative 3.2 Conditions By Basin below the 5-year floodplain: FCUs

Basin	New Madrid											
Vegetation Class	Ag Fields		Forested Areas						WRP[2] : 765 ac			
HGM Subclass	LGRB	Flat	LGRB		LGRO	Flat	CD	UCD	LGRB	Flat	CD[3]	UCD
Impacts	Indirect Hydro	Indirect Hydro	Direct Clearing	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro
Acreage[1]	171	135	7	4084	1163	3253	191	109	333	262	95	75
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**
Detain Floodwater	34	NA	0	2655	919	NA	84	NA	160	NA	16	NA
Detain Precipitation	92	47	0	3921	675	2635	NA	NA	310	186	NA	NA
Cycle Nutrients	41	26	0	3349	989	2765	111	83	240	176	40	40
Export Organic Carbon	26	NA	0	2410	884	NA	94	NA	193	NA	31	NA
Maintain Plant Communities	0	0	0	3471	907	2960	78	94	236	178	11	29
Provide Habitat for Fish and Wildlife	0	0	0	2900	698	2375	90	66	83	63	12	7

1 Forested acreage were provided by Memphis District. Agricultural Acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2011. Only the WRP acreage within the 5-year floodplain is assessed.

3 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

Tables 14a and 14b: Gains and Losses Associated with the Authorized Project With Avoid and Minimize Measures Management Scenario 2 as compared with No Action Alternative – New Madrid Floodway.

HGM Assessment of Potential Wetlands: Gains and Losses between No Action Alternative and Alternative 3.2 Conditions By Basins below the 5-year floodplain: FCUs
Losses due to wholesale conversion to non-river connected Subclass, or due to direct clearing

Basin	New Madrid										
Vegetation Class	Ag Fields		Forested Area					WRP			
HGM Subclass	LGRB	Flat	LGRB		Flat	CD	UCD	LGRB	Flat	CD	UCD
Impacts	Indirect Hydro	Indirect Hydro	Direct Clearing	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro
Acreage	-135	135	7	-3253	3253	-109	109	-262	262	-75	75
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**
Detain Floodwater	-34	NA	-6	-2863	NA	-58	NA	-157	NA	-16	NA
Detain Precipitation	-73	47	-7	-3155	2635	NA	NA	-242	186	NA	NA
Cycle Nutrients	-32	26	-6	-2765	2765	-66	83	-189	176	-32	40
Export Organic Carbon	-26	NA	-6	-2765	NA	-62	NA	-189	NA	-30	NA
Maintain Plant Communities	0	0	-7	-3025	2960	-73	94	-199	178	-12	29
Provide Habitat for Fish and Wildlife	0	0	-5	-2505	2375	-62	67	-69	63	-11	7

Losses due to incremental decreases in function within remaining river-connected subclasses

Basin	New Madrid					
Vegetation Class	Ag Fields	Forested Area			WRP	
HGM Subclass	LGRB	LGRB	LGRO	CD	LGRB	CD
Impacts	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro
Acreage	171	4084	1163	191	333	95
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**
Detain Floodwater	-9	-939	-35	-17	-39	-4
Detain Precipitation	0	-41	0	NA	-2	NA
Cycle Nutrients	0	-123	0	-6	-1	0
Export Organic Carbon	-7	-1062	-35	-15	-47	-7
Maintain Plant Communities	0	-327	-70	-50	-16	-4
Provide Habitat for Fish and Wildlife	0	-245	-35	-19	-5	-2

Table 14c. Summary of FCU losses for the Avoid and Minimize Alternative (3.2) in New Madrid Floodway.

	Losses in FCUs			Gains in FCUs	
Function	**LGRB**	**LGRO**	**CD**	**Flats**	**UCD**
Detain Floodwater	-4046	-35	-95	NA	NA
Detain Precipitation	-3520	0	0	2868	NA
Cycle Nutrients	-3116	0	-104	2966	123
Export Organic Carbon	-4102	-35	-115	NA	NA
Maintain Plant Communities	-3574	-70	-138	3138	123
Provide Habitat for Fish and Wildlife	-2830	-35	-94	2438	73

4.1. Limited Management Scenario New Madrid Floodway

Details of the Alternative 4.1 within the New Madrid Floodway may be found in the Alternatives Section of the EIS. Using the assumptions and data sources identified in the Methods, the conditions and impacts associated with the alternative are identified in Tables 15 and 16, below. Acreages for all Direct Impacts, as well as hydrology variables for all indirect impacts, were supplied by Memphis District.

The conditions forecast after Alternative 4.1 is implemented in New Madrid Floodway are documented in Tables 15a and 15b. The vast majority of impacts are associated with indirect hydrologic changes.

Total changes of FCIs and FCUs comparing Alternative 4.1 with the No Action alternative (Alternative 1.2) are shown in Tables 16a and 16b, and summarized by subclass in Table 16c. The vast majority of impacts are associated with indirect hydrologic changes; only 7 acres of LGRB are subjected direct clearing. Of the losses resulting from indirect hydrologic changes, the majority of those are from changes in frequency severe enough that a fundamental shift from a river connected subclass to an unconnected subclass occurs. Hence, of the 7344 acres of naturally vegetated LGRB existing in the New Madrid Floodway currently, 2150 acres are cut off from the river sufficiently to be outside the 5-year floodplain, and therefore to qualify as Flats (Table 15). All functions associated with these areas as LGRB wetlands are lost, and though they still exist on the landscape as Flats, they no longer perform the functions of Detain Floodwater or Export Organic Compounds to the aquatic ecosystem in a measureable way.

Table 16a illustrates the functional losses due to wholesale conversion of wetland acres to a subclass unconnected to the river, or due to direct clearing. The 2150 acres converted from LGRB to flats results in a loss of 1892 FCUs in the Detain Floodwater function and 1828 FCUs in the Export Organic Carbon function that are in no way offset by the fact that some gains occurred in the Flats subclass. Even in the functions that both LGRB and Flat wetlands perform, the fact that the indices are calibrated only within each subclass means that the FCUs cannot be added or subtracted across

Tables 15a and 15b: Alternative 4.1 Conditions – New Madrid Floodway:

HGM Assessment of Potential Wetlands: Alternative 4.1 Conditions By Basin below the 5-year floodplain: FCIs

Basin	New Madrid											
Vegetation Class	Ag Fields		Forested Areas						WRP[2] : 765 ac			
HGM Subclass	LGRB	Flat	LGRB		LGRO	Flat	CD	UCD	LGRB	Flat	CD[3]	UCD
Impacts	Indirect Hydro	Indirect Hydro	Direct Clearing	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro
Acreage[1]	217	89	7	5187	1163	2150	191	109	422	173	121	49
Function	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**
Detain Floodwater	0.15	NA	0.00	0.72	0.66	NA	0.41	NA	0.48	NA	0.17	NA
Detain Precipitation	0.54	0.35	0.00	0.96	0.58	0.78	NA	NA	0.93	0.71	NA	NA
Cycle Nutrients	0.24	0.19	0.00	0.84	0.85	0.87	0.58	0.76	0.72	0.67	0.42	0.53
Export Organic Carbon	0.11	NA	0.00	0.67	0.64	NA	0.46	NA	0.58	NA	0.32	NA
Maintain Plant Communities	0.00	0.00	0.00	0.92	0.84	0.91	0.53	0.86	0.76	0.68	0.16	0.39
Provide Habitat for Fish and Wildlife	0.00	0.00	0.00	0.77	0.62	0.70	0.49	0.61	0.26	0.24	0.14	0.09

1 Forested acreage were provided by Memphis District. Agricultural Acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2011. Only the WRP acreage within the 5-year floodplain is assessed.

3 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

HGM Assessment of Potential Wetlands: Alternative 4.1 Conditions By Basin below the 5-year floodplain: FCUs

Basin	New Madrid											
Vegetation Class	Ag Fields		Forested Areas						WRP2 : 765 ac			
HGM Subclass	LGRB	Flat	LGRB		LGRO	Flat	CD	UCD	LGRB	Flat	CD[3]	UCD
Impacts	Indirect Hydro	Indirect Hydro	Direct Clearing	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro
Acreage[1]	217	89	7	5187	1163	2150	191	109	422	173	121	49
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**
Detain Floodwater	33	NA	0	3735	768	NA	78	NA	203	NA	21	NA
Detain Precipitation	117	31	0	4980	675	1677	NA	NA	393	123	NA	NA
Cycle Nutrients	52	17	0	4357	989	1871	111	83	304	116	51	26
Export Organic Carbon	24	NA	0	3475	744	NA	88	NA	245	NA	39	NA
Maintain Plant Communities	0	0	0	4772	977	1957	101	94	321	118	19	19
Provide Habitat for Fish and Wildlife	0	0	0	3994	721	1505	94	67	110	42	17	4

1 Forested acreage were provided by Memphis District. Agricultural Acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2011. Only the WRP acreage within the 5-year floodplain is assessed.

3 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

Tables 16a and 16b: Gains and Losses Associated with Alternative 4.1 as compared with No Action Alternative – New Madrid Floodway.

HGM Assessment of Potential Wetlands: Gains and Losses between No Action Alternative and Alternative 4.1 Conditions By Basins below the 5-year floodplain: FCUs
Losses due to wholesale conversion to non-river connected Subclass, or due to direct clearing

Basin	New Madrid										
Vegetation Class	Ag Fields		Forested Area					WRP			
HGM Subclass	LGRB	Flat	LGRB		Flat	CD	UCD	LGRB	Flat	CD	UCD
Impacts	Indirect Hydro	Indirect Hydro	Direct Clearing	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro
Acreage	-89	89	7	-2150	2150	-109	109	-173	173	-49	49
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**
Detain Floodwater	-22	NA	-6	-1892	NA	-58	NA	-103	NA	-10	NA
Detain Precipitation	-48	31	-7	-2086	1677	NA	NA	-160	123	NA	NA
Cycle Nutrients	-21	17	-6	-1828	1871	-66	83	-125	116	-21	26
Export Organic Carbon	-17	NA	-6	-1828	NA	-62	NA	-125	NA	-20	NA
Maintain Plant Communities	0	0	-7	-2000	1957	-73	94	-131	118	-8	19
Provide Habitat for Fish and Wildlife	0	0	-5	-1656	1505	-62	67	-46	42	-7	4

Losses due to incremental decreases in function within remaining river-connected subclasses

Basin	New Madrid					
Vegetation Class	Ag Fields	Forested Area			WRP	
HGM Subclass	LGRB	LGRB	LGRO	CD	LGRB	CD
Impacts	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro
Acreage	214	5121	1163	191	416	119
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**
Detain Floodwater	-21	-819	-186	-23	-49	-5
Detain Precipitation	0	-51	0	NA	2	NA
Cycle Nutrients	0	-51	0	-6	-1	0
Export Organic Carbon	-17	-922	-174	-21	-59	-10
Maintain Plant Communities	0	-51	0	-27	0	0
Provide Habitat for Fish and Wildlife	0	0	-12	-15	-2	-1

Table 16c. Summary of FCU losses for Alternative 4.1 in New Madrid Floodway.

	Losses in FCUs			Gains in FCUs	
Function	**LGRB**	**LGRO**	**CD**	**Flats**	**UCD**
Detain Floodwater	-2914	-186	-96	NA	NA
Detain Precipitation	-2350	0	NA	1831	NA
Cycle Nutrients	-2032	0	-93	2003	109
Export Organic Carbon	-2973	-174	-113	NA	NA
Maintain Plant Communities	-2188	0	-108	2074	113
Provide Habitat for Fish and Wildlife	-1709	-12	-86	1547	71

subclasses (e.g., Detain Precipitation), or that they represent fundamentally different conditions (i.e., the plants and habitat provided by different subclasses are different, and therefore cannot fully substitute for each other). As a result, although these acres are still considered to be jurisdictional wetlands and still occur within the landscape of the project area, they are treated as though they were cleared, because from a functional standpoint, they are no longer provided the same functions that they were before the project.

Those wetland areas not subject to a full scale removal from the 5-year floodplain and the resultant subclass shift are still subject to an incremental decrease in function, summarized in Table 16b. For instance, the 5121 acres of forested LGRB remaining after the Flats are removed are subject to decreases in FCIs ranging from 0.01 to 0.18, and the resulting losses of FCUs when multiplied by the acreages are provided in Table 16b. The largest of these impacts are the loss of 922 FCUs for the Export Organic Carbon function, and a loss of 819 FCUs in the Detain Floodwater function (Table 16b).

Total losses of FCUs for this alternative are summarized by subclass in Table 16c. The largest impacts are to the Detain Floodwater (a loss of 2914 FCUs) and Export Organic Carbon (2973 FCUs) functions for LGRB wetlands. Although the gains of Flat and UCD are reported, they are not meant to be seen as offsetting the losses of river-connected subclass. It should also be noted that this mitigation debt is summarized in FCUs. The acreage required will depend on the rate of functional gain realized by the mitigation scenarios, which are subject to post-project hydrology.

4.2. Limited Management with Reforestation Scenario New Madrid Floodway

Details of the Alternative 4.2 within the New Madrid Floodway may be found in the Alternatives Section of the EIS. It is identical to Alternative 4.1, except that it also calls for the reforestation of 13,340 acres of current agricultural lands to wet forests. Using the assumptions and data sources identified in the Methods, the conditions and impacts associated with the alternative are identified in Tables 17 and 18, below. Acreages for all Direct Impacts, as well as hydrology variables for all indirect impacts, were supplied by Memphis District.

The conditions forecast after Alternative 4.2 is implemented in New Madrid Floodway are documented in Tables 17a and 17b. The vast majority of impacts are associated with indirect hydrologic changes.

Total changes of FCIs and FCUs comparing Alternative 4.2 with the No Action alternative (Alternative 1.2) are shown in Tables 18a and 18b, and summarized by subclass in Table 18c. These impacts are identical to those in Alternative 4.1, with the exception of the last two columns, the Newly Restored Forest. Annualized FCIs were calculated for these areas over the 50-year life of the project. The ratio of LGRB to CD wetlands was based on the typical ratio used in WRP restorations, but it was assumed that these areas would be allowed to mature fully, unlike CD in WRP which are typically arrested at an herbaceous stage.
As a result of the 13,340 acres of restoration, this alternative actually results in gains for most subclasses of river-connected wetlands, as summarized in Table 18c. The restoration of 12,820 acres of forested LGRB results in a gain of function ranging from 6154 FCUs for the Detain Floodwater function to 11,923 FCUs for the Detain Precipitation function (Table 17b, Table 18b). The function Detain Floodwater was the one least influenced by the restoration, and even that function shows a gain in FCUs (35) for LGRB wetlands for this alternative. Other functions have much larger surpluses for the LGRB subclass, from 2021 FCUs for the Export Organic Carbon function, to 7555 FCUs for the Maintain Plant Communities function. Likewise, CD wetlands experienced no functional losses for this alternative. Only LGRO wetlands were subject to functional losses, since it was assumed that the restoration would all be existing agricultural land, which is assumed to be appropriate for LGRB and CD restoration. Those losses were focused on the Detain Floodwater function, with a loss of 186 FCUs, and Export Organic Carbon, with a loss of 174 FCUs.

It should be noted that this mitigation debt is summarized in FCUs. The acreage required will depend on the rate of functional gain realized by the mitigation scenarios, which are subject to post-project hydrology.

Tables 17a and 17b: Alternative 4.2 Conditions – New Madrid Floodway:

HGM Assessment of Potential Wetlands: Alternative 4.2 Conditions By Basin below the 5-year floodplain: FCIs

Basin	New Madrid													
Vegetation Class	Ag Fields		Forested Areas						WRP[2] : 765 ac				Newly Restored Forest	
HGM Subclass	LGRB	Flat	LGRB		LGRO	Flat	CD	UCD	LGRB	Flat	CD[3]	UCD	LGRB	CD[3]
Impacts	Indirect Hydro	Indirect Hydro	Direct Clearing	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro
Acreage[1]	217	89	7	5187	1163	2150	191	109	422	173	121	49	12820	1900
Function	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**	**FCI**
Detain Floodwater	0.15	NA	0.00	0.72	0.66	NA	0.41	NA	0.48	NA	0.17	NA	0.48	0.17
Detain Precipitation	0.54	0.35	0.00	0.96	0.58	0.78	NA	NA	0.93	0.71	NA	NA	0.93	NA
Cycle Nutrients	0.24	0.19	0.00	0.84	0.85	0.87	0.58	0.76	0.72	0.67	0.42	0.53	0.72	0.42
Export Organic Carbon	0.11	NA	0.00	0.67	0.64	NA	0.46	NA	0.58	NA	0.32	NA	0.58	0.32
Maintain Plant Communities	0.00	0.00	0.00	0.92	0.84	0.91	0.53	0.86	0.76	0.68	0.16	0.39	0.76	0.16
Provide Habitat for Fish and Wildlife	0.00	0.00	0.00	0.77	0.62	0.70	0.49	0.61	0.26	0.24	0.14	0.09	0.59	0.14

1 Forested acreage were provided by Memphis District. Agricultural Acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2011. Only the WRP acreage within the 5-year floodplain is assessed.

3 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

HGM Assessment of Potential Wetlands: Alternative 4.2 Conditions By Basin below the 5-year floodplain: FCUs

Basin	New Madrid													
Vegetation Class	Ag Fields		Forested Areas						WRP2 : 765 ac				Newly Restored Forest	
HGM Subclass	LGRB	Flat	LGRB		LGRO	Flat	CD	UCD	LGRB	Flat	CD[3]	UCD	LGRB	CD[3]
Impacts	Indirect Hydro	Indirect Hydro	Direct Clearing	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro
Acreage[1]	217	89	7	5187	1163	2150	191	109	422	173	121	49	12820	1900
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCI**	**FCI**
Detain Floodwater	33	NA	0	3735	768	NA	78	NA	203	NA	21	NA	6154	323
Detain Precipitation	117	31	0	4980	675	1677	NA	NA	393	123	NA	NA	11923	NA
Cycle Nutrients	52	17	0	4357	989	1871	111	83	304	116	51	26	9230	798
Export Organic Carbon	24	NA	0	3475	744	NA	88	NA	245	NA	39	NA	7436	608
Maintain Plant Communities	0	0	0	4772	977	1957	101	94	321	118	19	19	9743	304
Provide Habitat for Fish and Wildlife	0	0	0	3994	721	1505	94	67	110	42	17	4	7564	266

1 Forested acreage were provided by Memphis District. Agricultural Acreage from NRCS, and assigned to basins by Memphis District. Vegetation Class acreages were subdivided into HGM subclasses based in GIS and field sample data.

2 WRP FCI are annualized over a 50-year life of project, based on projections in Klimas et al. 2011. Only the WRP acreage within the 5-year floodplain is assessed.

3 Forest WRP is assumed to be LGRB, herbaceous WRP is assumed to be CD; both are assumed to be restored from PC agricultural lands.

Tables 18a and 18b: Gains and Losses Associated with Alternative 4.2 as compared with No Action Alternative – New Madrid Floodway.

HGM Assessment of Potential Wetlands: Gains and Losses between No Action Alternative and Alternative 4.2 Conditions By Basins below the 5-year floodplain: FCUs
Losses due to wholesale conversion to non-river connected Subclass, or due to direct clearing

Basin	New Madrid										
Vegetation Class	Ag Fields		Forested Area					WRP			
HGM Subclass	LGRB	Flat	LGRB		Flat	CD	UCD	LGRB	Flat	CD	UCD
Impacts	Indirect Hydro	Indirect Hydro	Direct Clearing	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro
Acreage	-89	89	7	-2150	2150	-109	109	-173	173	-49	49
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**
Detain Floodwater	-22	NA	-6	-1892	NA	-58	NA	-103	NA	-10	NA
Detain Precipitation	-48	31	-7	-2086	1677	NA	NA	-160	123	NA	NA
Cycle Nutrients	-21	17	-6	-1828	1871	-66	83	-125	116	-21	26
Export Organic Carbon	-17	NA	-6	-1828	NA	-62	NA	-125	NA	-20	NA
Maintain Plant Communities	0	0	-7	-2000	1957	-73	94	-131	118	-8	19
Provide Habitat for Fish and Wildlife	0	0	-5	-1656	1505	-62	67	-46	42	-7	4

Losses and gains due to incremental decreases or increases in function within remaining river-connected subclasses (increases only in restoration areas)

Basin	New Madrid							
Vegetation Class	Ag Fields	Forested Area			WRP		Newly Restored Forest	
HGM Subclass	LGRB	LGRB	LGRO	CD	LGRB	CD	LGRB	CD
Impacts	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro	Indirect Hydro
Acreage	214	5121	1163	191	416	119	12820	1900
Function	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCU**	**FCI**	**FCI**
Detain Floodwater	-21	-819	-186	-23	-49	-5	2949	228
Detain Precipitation	0	-51	0	NA	2	NA	5000	NA
Cycle Nutrients	0	-51	0	-6	-1	0	6154	589
Export Organic Carbon	-17	-922	-174	-21	-59	-10	5000	513
Maintain Plant Communities	0	-51	0	-27	0	0	9743	304
Provide Habitat for Fish and Wildlife	0	0	-12	-15	-2	-1	7564	266

Table 18c. Summary of FCU gains and losses for Alternative 4.2 in New Madrid Floodway.

	Losses/Gains in FCUs			Gains in FCUs	
Function	**LGRB**	**LGRO**	**CD**	**Flats**	**UCD**
Detain Floodwater	35	-186	132	NA	NA
Detain Precipitation	2650	0	0	1831	NA
Cycle Nutrients	4122	0	496	2003	109
Export Organic Carbon	2027	-174	400	NA	NA
Maintain Plant Communities	7555	0	196	2074	113
Provide Habitat for Fish and Wildlife	5855	-12	180	1547	71

1 Negative mitigation debt indicates a surplus based on forest restoration that is part of the project.

Mitigation Scenarios

Annualized FCIs were calculated for potential mitigation. For each alternative, the post-project hydrology was used for the FCI projects. Hence, there are different tables for annualized functional gain for each alternative, within each basin. In addition, for each alternative, two Tract Size scenarios were used for Low Gradient Riverine Backwater wetland mitigation, one reflecting mitigation accomplished in large 500 ha (1200 ac) tracts connected to similarly sized blocks of existing habitat, and another reflecting mitigation accomplished in smaller (~500 ac), more isolated tracts. In all cases, it is assumed that wetland mitigation will be planted in the first year of the project, will be allowed to grow to forest, and will not be arrested at an herbaceous stage. As with the WRP projections, FCIs were annualized using the following year intervals: 0, 1, 5, 15, 25, and 50. It is assumed that any planting mortality is immediately rectified, and does not affect the projections for vegetation variables. These two Tract Size scenarios only differ in results for the Provide Wildlife Habitat function, but because this function has the lowest functional gain, it may well be a determining factor in mitigation requirements. The difference in the two scenarios show a clear advantage of linking mitigation to existing blocks of forested wetland.

Low Gradient Overbank wetlands occur in narrow strips along riparian corridors. While it is possible that they can occur in large tracts consisting of both Low Gradient Riverine Overbank and Backwater wetlands, given the condition of the basin, it seems more likely that mitigation of this subclass would occur in smaller, relatively unconnected tracts. It is assumed that LGRO mitigation will occur in 100 ha (250 acre) tracts that are approximately 10 percent connected, reflecting that they are likely filling gaps in a riparian corridor, but not linked or near large blocks of forest. Results for all mitigation projections are shown in Table 7. These are to help guide the siting and amount of mitigation in a general sense. Once actual mitigation locations are identified, the projections can be rerun with actual tract size, core and connectivity amounts, which will lead to more accurate calculations of mitigation debt.

Mitigation Annualized FCIs are offered for each alternative. In addition, the acreage required for mitigating a single lost FCU is also tabularized for each alternative. Then, a summary table offers the impacts associated with each alternative for each function, and these FCUs are multiplied through by

the acres required to mitigate a single FCU, resulting in an estimate of required acreage based on all the assumptions used in this analysis. In each case, the acreage required assumes that the basin is subject to the post-project hydrology.

The mitigation proposal includes creation of a structure that would restore more natural flooding to Big Oak Tree State Park (BOTSP) and some of its surrounding area. For each alternative, an additional table indicates how this structure would change the mitigation debt. At the time of this initial analysis, final design of the structure had yet to be finalized, and therefore certain assumptions were made. It is assumed that the design will optimize the hydrologic gain within the park itself. So first, the impacts associated with the BOTSP are removed from the mitigation debt, and second, the BOTSP is assumed to receive an improvement to its flood frequency (V_{FREQ}) and flood duration (V_{DUR}) resulting in a 0.2 increase to the variable subindex of both of these variables. The functional gains associated with the increased indices for these variables are also calculated.

Finally, some of the farmland around the BOTSP will be subject to improved hydrology, and would accrue mitigation functional lift at a higher rate than the parts of the basin subject to post-project hydrology unaffected by the structure. Where the rest of the basin might be subject to a loss in frequency or duration of flooding, post project, it is assumed that the structure counteracts these projects impacts within a limited area near the park. It is assumed for the purposes of this analysis that these areas would instead be subject to the No Action Annualized FCIs, which are subject to existing hydrology. It is not known how extensive this area would be, so this is reported as a difference in FCIs, not FCUs or acres.

Alternative 1 - No Action

1.1. Existing Conditions

No Annualized FCIs need to be calculated to represent Existing Conditions.

1.2 . Future enrollment of WRP without (w/o) the project

Table 19: Annualized gains per acre of for Forested WRP Subject to Existing Hydrologic Conditions

Mitigation Scenario	Wetland Functions					
	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Provide Wildlife Habitat
LGRB	Annualized Functional Capacity Indices					
Small (500ac) Tracts	0.598	0.925	0.722	0.722	0.759	0.265
Large (1200ac) Tracts	0.598	0.925	0.722	0.722	0.759	0.599
LGRO	Annualized Functional Capacity Indices					
Small (250ac) Tracts	0.636	0.902	0.622	0.614	0.693	0.452

Alternative 2 - Authorized Project

2.1. St. John's Bayou Basin Improvements Only

Mitigation associated with the Authorized Project within St Johns Basin would be subject to annualized FCIs reflecting the post-project hydrology as shown in Tables 20a and 20b.

Tables 20a and 20b: Annualized FCIs and Acres Needed to offset 1 Lost FCU by Subclass, Function and Mitigation Scenario Associated The Authorized Project in St. Johns Bayou.

Mitigation FCIs below the 5-year floodplain For Authorized Project Within St Johns Basin. All restored wetlands are forested.

Mitigation Scenario	Wetland Functions					
	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Provide Wildlife Habitat
LGRB	Annualized Functional Capacity Indices					
Small (500ac) Tracts	0.578	0.925	0.722	0.702	0.749	0.265
Large (1200ac) Tracts	0.578	0.925	0.722	0.702	0.749	0.599
LGRO	Annualized Functional Capacity Indices					
Small (250ac) Tracts	0.636	0.902	0.622	0.614	0.653	0.442
CD	Annualized Functional Capacity Indices					
Inclusions in Large (1200ac) Tracts	0.581	NA	0.668	0.629	0.635	0.602

Mitigation Acres needed to offset 1 lost FCU: below the 5-year floodplain for Authorized Project Within St Johns Basin. All restored wetlands are forested.

Mitigation Scenario	Wetland Functions					
	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Provide Wildlife Habitat
LGRB	Acres Needed to Offset 1 Lost FCU					
Small (500ac) Tracts	1.729	1.081	1.386	1.425	1.335	3.781
Large (1200ac) Tracts	1.729	1.081	1.386	1.425	1.335	1.671
LGRO	Acres Needed to Offset 1 Lost FCU					
Small (250ac) Tracts	1.572	1.109	1.607	1.628	1.530	2.265
CD	Acres Needed to Offset 1 Lost FCU					
Inclusions in Large (1200ac) Tracts	1.723	NA	1.498	1.589	1.574	1.663

Using these mitigation functional gains, and the FCU losses associated with the Authorized Project in the St. Johns Basin, mitigation debt can be calculated in acres (Table 21).

Table 21. Functional Losses in FCUs Associated with the Authorized Project within St. Johns Basin, and a Calculation of Mitigation Acres Based on Mitigation Annualized FCIs from Table 20.

Mitigation Required for Authorized Project in St. Johns Basin, Assuming that Mitigation is accomplished in large connected tracts, and post-project hydrology.

	Losses in FCUs			Mitigation for Losses in Acres Using Mitigation Rates for Large Tracts & Post Authorized Project Hydrology		
Function	**LGRB**	**LGRO**	**CD[1]**	**LGRB**	**LGRO**	**CD**
Detain Floodwater	-116.0	-653.0	0.0	200.6	1026.2	0.0
Detain Precipitation	0.0	-505.0	NA	0.0	559.8	NA
Cycle Nutrients	0.0	-565.0	0.0	0.0	908.1	0.0
Export Organic Carbon	-116.0	-525.0	0.0	165.3	854.9	0.0
Maintain Plant Communities	-49.0	-580.0	0.0	65.4	887.7	0.0
Provide Habitat for Fish and Wildlife	0.0	-337.0	0.0	0.0	763.3	0.0

1 No connected depressions were located or sampled within St. Johns Basin.

Table 21 shows the losses associated with the Authorized Project in St. Johns Basin summarized by subclass. Mitigation requirements for each subclass are then calculated by multiplying the FCUs lost by the Mitigation Acres Needed to Offset 1 FCU, as calculated in Table 20. It is assumed that mitigation is taking place within the 5-year floodplain, subject to the post-project hydrology. Cells highlighted in yellow indicate the maximum mitigation required for each subclass. If this acreage is mitigated, losses to the maximally impacted function will be mitigated, and all other functional losses will be more than fully offset. For both the LGRB and LGRO subclasses, the largest acreage requirements are associated with the Detain Floodwater Function, 200.6 acres for LGRB wetlands, and 1026.2 acres for LGRO wetlands.

2.2. New Madrid Floodway Levee Closure Only

Mitigation associated with the Authorized Project within the New Madrid Floodway would be subject to annualized FCIs reflecting the post-project hydrology as shown in Tables 22a and 22b.

Tables 22a and 22b: Annualized FCIs and Acres Needed to offset 1 Lost FCU by Subclass, Function and Mitigation Scenario Associated with the Authorized Project in the New Madrid Floodway.

Mitigation FCIs below the 5-year floodplain For Authorized Project Within New Madrid Floodway. All restored wetlands are forested.

Mitigation Scenario	Wetland Functions					
	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Provide Wildlife Habitat
LGRB	**Annualized Functional Capacity Indices**					
Small (500ac) Tracts	0.477	0.925	0.722	0.577	0.682	0.246
Large (1200ac) Tracts	0.477	0.925	0.722	0.577	0.682	0.555
LGRO	**Annualized Functional Capacity Indices**					
Small (250ac) Tracts	0.507	0.902	0.622	0.489	0.601	0.422
CD	**Annualized Functional Capacity Indices**					
Inclusions in Large (1200ac) Tracts	0.481	NA	0.668	0.518	0.410	0.530

Mitigation Acres needed to offset 1 lost FCU: below the 5-year floodplain for Authorized Project Within New Madrid Floodway. All restored wetlands are forested.

Mitigation Scenario	Wetland Functions					
	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Provide Wildlife Habitat
LGRB	**Acres Needed to Offset 1 Lost FCU**					
Small (500ac) Tracts	2.098	1.081	1.386	1.735	1.466	4.065
Large (1200ac) Tracts	2.098	1.081	1.386	1.735	1.466	1.803
LGRO	**Acres Needed to Offset 1 Lost FCU**					
Small (250ac) Tracts	1.972	1.109	1.607	2.046	1.664	2.372
CD	**Acres Needed to Offset 1 Lost FCU**					
Inclusions in Large (1200ac) Tracts	2.078	NA	1.498	1.930	2.437	1.889

Using these mitigation functional gains, and the FCU losses associated with the Authorized Project in the New Madrid Floodway, mitigation debt can be calculated in acres (Table 23).

Table 23. Functional Losses in FCUs Associated with the Authorized Project within the New Madrid Floodway, and a Calculation of Mitigation Acres Based on Mitigation Annualized FCIs from Table 22.

Mitigation Required for Authrized Project New Madrid Floodway, Assuming that Mitigation is accomplished in large connected tracts around Big Oak State Park

	Losses in FCUs			Gains in FCUs		Mitigation for Losses in Acres Using Mitigation Rates for Large Tracts & Post Authorized Project Hydrology		
Function	**LGRB**	**LGRO**	**CD**	**Flats**	**UCD**	**LGRB**	**LGRO**	**CD**
Detain Floodwater	-6449	-186	-179	NA	NA	13531	367	372
Detain Precipitation	-7332	0	NA	5651	NA	7925	0	NA
Cycle Nutrients	-6283	0	-234	5765	258	8706	0	351
Export Organic Carbon	-6312	-174	-223	NA	NA	10949	357	431
Maintain Plant Communities	-6845	-128	-211	6454	266	10038	213	514
Provide Habitat for Fish and Wildlife	-5503	-58	-181	5050	153	9924	138	341

Table 23 shows the losses associated with the Authorized Project in New Madrid Floodway summarized by subclass. Mitigation requirements for each subclass are then calculated by multiplying the FCUs lost by the Mitigation Acres Needed to Offset 1 FCU, as calculated in Table 22. It is assumed that mitigation is taking place within the 5-year floodplain, in large (1200 acre) well-connected tracts, but that no structure has been installed to restore flooding. Thus, the mitigation is maturing while subject to the altered hydrology associated with the Authorized Project. This leads to a much smaller functional lift per acre (or Annualized FCI), and larger acreage requirements for mitigation to offset the losses associated with the project. Cells highlighted in yellow indicate the maximum mitigation required for each subclass. If this acreage is mitigated, losses to the most impacted function will be mitigated, and all other functions will be more than fully offset. For both the LGRB and LGRO subclasses, the largest acreage requirements are associated with the Detain Floodwater Function, 13,531 acres for LGRB wetlands, and 367 acres for LGRO wetlands. For CD wetlands, the largest mitigation acreage requirement is associated with the Export Organic Carbon Function, resulting in 431 acres of CD wetlands.

If the structure is built to restore more natural flooding to Big Oak Tree State Park (BOTSP), then the FCUs lost shown in Table 23 would be decreased. Table 24 shows that the impacts associated with the BOTSP are removed from the mitigation debt as No Longer Impacted. In addition, hydrology is planned to be improved beyond existing conditions. This analysis assumes that the design will optimize the hydrologic gain within the park itself. The BOTSP is assumed to receive an improvement to its flood frequency (V_{FREQ}) and flood duration (V_{DUR}) resulting in a 0.2 increase to the variable subindex of both of these variables. The functional gains associated with the increased indices for these variables are also calculated and shown in Table 24. The resulting benefit is 1615.1 LGRB mitigation acres saved, and 83 CD mitigation acres saved.

Table 24. Analysis of Benefits of a Flood Structure Restoring Flood Frequency and Duration to BOTSP, in terms of FCUs no longer impacted, FCUs Gained Due to Hydrologic Improvement beyond Existing Conditions, and Acreages Associated with the FCUs

Subclass	LGRB			CD			Mitigation Acres Saved	
Acres	976			49				
FCUs	No Longer Impacted	Hydrologic Improvement	Total	No Longer Impacted	Hydrologic Improvement	Total	LGRB	CD
Detain Floodwater	810.1	156.2	966.3	33.8	6.86	40.66	-1615.1	-67.7
Detain Precipitation	976	0	976	NA	NA	NA	-1054.9	NA
Cycle Nutrients	868.6	0	868.6	33.3	0	33.3	-1203.5	-49.9
Export Organic Carbon	868.6	175.7	1044.3	34.3	6.86	41.16	-1446.8	-63.4
Maintain Plant Communities	927.2	29.3	956.5	44.1	3.92	48.02	-1300.5	-83.0
Provide Habitat for Fish and Wildlife	732	29.3	761.3	33.3	1.47	34.77	-1296.9	-59.2

In addition, some of the farmland around the BOTSP will be subject to improved hydrology, and would accrue mitigation functional lifts at a higher rate than the portions of the basin subject to post-Authorized Project hydrology. It is assumed for the purposes of this analysis that these areas would instead on average have hydrology similar to existing conditions, and be subject to the No Action Annualized FCIs. It is not known how extensive this area would be, so this benefit is reported FCIs, not FCUs or acres. Tables 25a and 25b show the FCIs that should be used to calculated mitigation acres required when mitigation is accomplished within this hydrologically improved area, rather than elsewhere in the basin. They supplant the FCIs shown in Tables 22a and 22b within this area. Mitigation accomplished outside the area influenced by the Structure would still be subject to FCIs offered in Tables 22a and 22b.

Tables 25a and 25b: Annualized FCIs and Acres Needed to offset 1 Lost FCU by Subclass and Function within Areas Around Big Oak Tree State Park Hydrologically Improved by the Structure and Available for Mitigation, New Madrid Floodway.

Mitigation FCIs below the 5-year floodplain within the area around BOTSP that is subject to hydrologic improvement due to the structure. All restored wetlands are forested.

Mitigation Scenario	Wetland Functions					
	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Provide Wildlife Habitat
LGRB	Annualized Functional Capacity Indices					
Small (500ac) Tracts	0.598	0.925	0.722	0.722	0.759	0.265
Large (1200ac) Tracts	0.598	0.925	0.722	0.722	0.759	0.599
LGRO	Annualized Functional Capacity Indices					
Small (250ac) Tracts	0.636	0.902	0.622	0.614	0.693	0.452
CD	Annualized Functional Capacity Indices					
Inclusions in Large (1200ac) Tracts	0.601	N/A	0.668	0.649	0.645	0.602

Mitigation Acres needed to offset 1 lost FCU: below the 5-year floodplain within the area around BOTSP that is subject to hydrologic improvement due to the structure. All restored wetlands are forested.

Mitigation Scenario	Wetland Functions					
	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Provide Wildlife Habitat
LGRB	Acres Needed to Offset 1 Lost FCU					
Small (500ac) Tracts	1.671	1.081	1.386	1.385	1.318	3.781
Large (1200ac) Tracts	1.671	1.081	1.386	1.385	1.318	1.671
LGRO	Acres Needed to Offset 1 Lost FCU					
Small (250ac) Tracts	1.572	1.109	1.607	1.628	1.442	2.215
CD	Acres Needed to Offset 1 Lost FCU					
Inclusions in Large (1200ac) Tracts	1.665	NA	1.498	1.540	1.550	1.663

2.3. Combined 2.1 and 2.2 Projects

If the Authorized Project is completed within both basins, the combined acreage totals given in Tables 21 and 23 will be required. The combined acreages are as follows: 13,732 acres of LGRB wetlands, 1393 acres of LGRO wetlands, and 431 acres of CD wetlands.

These totals could be decreased by at least 1615 LGRB mitigation acres saved, and 83 CD mitigation acres saved if the structure restoring hydrology to BOTSP is built. Additional benefits could be gained, depending on how much mitigation could be accomplished within the improved hydrology zone around BOTSP. The difference in FCIs between Tables 22 and 25 reflect this gain.

Alternative 3 - Authorized Project with Avoid and Minimize Measures

St. Johns Basin

Mitigation associated with the Authorized Project within St Johns Basin would be subject to annualized FCIs reflecting the post-project hydrology as shown in Tables 26a and 26b.

Tables 26a and 26b: Annualized FCIs and Acres Needed to offset 1 Lost FCU by Subclass, Function and Mitigation Scenario Associated The Authorized Project in St. Johns Bayou.

Mitigation FCIs below the 5-year floodplain For Authorized Project Within St Johns Basin. All restored wetlands are forested.

Mitigation Scenario	Wetland Functions					
	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Provide Wildlife Habitat
LGRB	**Annualized Functional Capacity Indices**					
Small (500ac) Tracts	0.578	0.925	0.722	0.702	0.749	0.265
Large (1200ac) Tracts	0.578	0.925	0.722	0.702	0.749	0.599
LGRO	**Annualized Functional Capacity Indices**					
Small (250ac) Tracts	0.636	0.902	0.622	0.614	0.653	0.442
CD	**Annualized Functional Capacity Indices**					
Inclusions in Large (1200ac) Tracts	0.581	NA	0.668	0.629	0.635	0.602

Mitigation Acres needed to offset 1 lost FCU: below the 5-year floodplain for Authorized Project Within St Johns Basin. All restored wetlands are forested.

Mitigation Scenario	Wetland Functions					
	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Provide Wildlife Habitat
LGRB	**Acres Needed to Offset 1 Lost FCU**					
Small (500ac) Tracts	1.729	1.081	1.386	1.425	1.335	3.781
Large (1200ac) Tracts	1.729	1.081	1.386	1.425	1.335	1.671
LGRO	**Acres Needed to Offset 1 Lost FCU**					
Small (250ac) Tracts	1.572	1.109	1.607	1.628	1.530	2.265
CD	**Acres Needed to Offset 1 Lost FCU**					
Inclusions in Large (1200ac) Tracts	1.723	NA	1.498	1.589	1.574	1.663

Using these mitigation functional gains, and the FCU losses associated with the Authorized Project in the St. Johns Basin, mitigation debt can be calculated in acres (Table 27).

Table 27. Functional Losses in FCUs Associated with the Authorized Project with Avoid and Minimize Measures within St. Johns Basin, and a Calculation of Mitigation Acres Based on Mitigation Annualized FCIs from Table 26.

Mitigation Required for Avoid and Minimize Alternative Assuming that Mitigation is accomplished in large connected tracts, and post-project hydrology.

	Losses in FCUs			Mitigation for Losses in Acres Using Mitigation Rates for Large Tracts & Post Project Hydrology		
Function	**LGRB**	**LGRO**	**CD[1]**	**LGRB**	**LGRO**	**CD**
Detain Floodwater	-116	-397	0	201	623	0
Detain Precipitation	0	-307	NA	0	340	NA
Cycle Nutrients	0	-344	0	0	552	0
Export Organic Carbon	-115	-319	0	164	519	0
Maintain Plant Communities	-50	-374	0	67	573	0
Provide Habitat for Fish and Wildlife	0	-210	0	0	476	0

1 No connected depressions were located or sampled within St. Johns Basin.

Table 27 shows the losses associated with the Authorized Project with Avoid and Minimize Measures in St. Johns Basin summarized by subclass. Mitigation requirements for each subclass are then calculated by multiplying the FCUs lost by the Mitigation Acres Needed to Offset 1 FCU, as calculated in Table 26. It is assumed that mitigation is taking place within the 5-year floodplain, subject to the post-project hydrology. Cells highlighted in yellow indicate the maximum mitigation required for each subclass. If this acreage is mitigated, losses to the maximally impacted function will be mitigated, and all other functions will be more than mitigated. For both the LGRB and LGRO subclasses, the largest acreage requirements are associated with the Detain Floodwater Function, 201 acres for LGRB wetlands, and 623 acres of LGRO wetlands.

3.1. New Madrid Floodway Management Scenario 1

Mitigation associated with the Authorized Project with Avoid and Minimize Measures Management Scenario 1 within the New Madrid Floodway would be subject to annualized FCIs reflecting the post-project hydrology as shown in Tables 28a and 28b.

Tables 28a and 28b: Annualized FCIs and Acres Needed to offset 1 Lost FCU by Subclass, Function and Mitigation Scenario Associated with the Authorized Project with Avoid and Minimize Measures Management Scenario 1 in the New Madrid Floodway.

Mitigation FCIs below the 5-year floodplain For Authorized Project With Avoid & Minimize Measures Management Scenario 1 Within New Madrid Floodway. All restored wetlands are forested.

Mitigation Scenario	Wetland Functions					
	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Provide Wildlife Habitat
LGRB	Annualized Functional Capacity Indices					
Small (500ac) Tracts	0.598	0.925	0.722	0.722	0.736	0.246
Large (1200ac) Tracts	0.598	0.925	0.722	0.722	0.736	0.587
LGRO	Annualized Functional Capacity Indices					
Small (250ac) Tracts	0.636	0.902	0.622	0.614	0.667	0.444
CD	Annualized Functional Capacity Indices					
Inclusions in Large (1200ac) Tracts	0.601	NA	0.668	0.649	0.579	0.588

Mitigation Acres needed to offset 1 lost FCU: below the 5-year floodplain For Authorized Project With Avoid & Minimize Measures Management Scenario 1 Within New Madrid Floodway. All restored wetlands are forested.

Mitigation Scenario	Wetland Functions					
	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Provide Wildlife Habitat
LGRB	Acres Needed to Offset 1 Lost FCU					
Small (500ac) Tracts	1.671	1.081	1.386	1.385	1.360	4.065
Large (1200ac) Tracts	1.671	1.081	1.386	1.385	1.360	1.704
LGRO	Acres Needed to Offset 1 Lost FCU					
Small (250ac) Tracts	1.572	1.109	1.607	1.628	1.500	2.255
CD	Acres Needed to Offset 1 Lost FCU					
Inclusions in Large (1200ac) Tracts	1.665	NA	1.498	1.540	1.729	1.702

Using these mitigation functional gains, and the FCU losses associated with the Authorized Project with Avoid and Minimize Measures Management Scenario 1 in the New Madrid Floodway, mitigation debt can be calculated in acres (Table 29). Table 25 shows the losses associated with the Authorized Project with Avoid and Minimize Measures Management Scenario 1 in New Madrid Floodway summarized by subclass. Mitigation requirements for each subclass are then calculated by multiplying the FCUs lost by the Mitigation Acres Needed to Offset 1 FCU, as calculated in Table 28.

Table 29. Functional Losses in FCUs Associated with the Authorized Project with Avoid and Minimize Measures Management Scenario 1 within the New Madrid Floodway, and a Calculation of Mitigation Acres Based on Mitigation Annualized FCIs from Table 28.

Mitigation Required for Alternative 3.1 New Madrid Floodway, Assuming that Mitigation is accomplished in large connected tracts around Big Oak State Park.

	Losses in FCUs			Gains in FCUs		Mitigation for Losses in Acres Using Mitigation Rates for Large Tracts & Post Project Hydrology		
Function	**LGRB**	**LGRO**	**CD**	**Flats**	**UCD**	**LGRB**	**LGRO**	**CD**
Detain Floodwater	-3487	-35	-97	NA	NA	5828	55	161
Detain Precipitation	-2423	0	0	1910	NA	2619	0	NA
Cycle Nutrients	-2092	0	-94	2088	110	2899	0	141
Export Organic Carbon	-3558	-35	-118	NA	NA	4929	57	182
Maintain Plant Communities	-2582	-35	-124	2183	113	3511	52	215
Provide Habitat for Fish and Wildlife	-1970	-12	-89	1616	71	3356	26	152

It is assumed that mitigation is taking place within the 5-year floodplain, in large (1200 acre) well-connected tracts, but that no structure has been installed to restore flooding. Thus, the mitigation is maturing while subject to the altered hydrology associated with the Authorized Project with Avoid and Minimize Measures Management Scenario 1. This leads to a smaller functional lift per acre (or Annualized FCI), and larger acreage requirements for mitigation to offset the losses associated with the project. Cells highlighted in yellow indicate the maximum mitigation required for each subclass. If this acreage is mitigated, losses to the maximally impacted function will be mitigated, and all other functions will be more than mitigated. For the LGRB subclass, the largest acreage requirements are associated with the Detain Floodwater Function: 5828 acres for LGRB wetlands. For the LGRO subclass, the Export Organic Carbon Function required the greatest acreage at 57 acres. For CD wetlands, the largest mitigation acreage requirement is associated with the Maintain Plant Communities Function, resulting in 215 acres of CD wetlands.

If the structure is built to restore more natural flooding to Big Oak Tree State Park (BOTSP), then the FCUs lost shown in Table 29 would be decreased. Table 30 shows that the impacts associated with the BOTSP are removed from the mitigation debt as No Longer Impacted. In addition, hydrology is planned to be improved beyond existing conditions. This analysis assumes that the design will optimize the hydrologic gain within the park itself. The BOTSP is assumed to receive an improvement to its flood frequency (V_{FREQ}) and flood duration (V_{DUR}) resulting in a 0.2 increase to the variable subindex of both of these variables. The functional gains associated with the increased indices for these variables are also calculated and shown in Table 26. The resulting benefit is 1615.1 LGRB mitigation acres saved, and 83 CD mitigation acres saved.

Table 30. Analysis of Benefits of a Flood Structure Restoring Flood Frequency and Duration to BOTSP, in terms of FCUs no longer impacted, FCUs Gained Due to Hydrologic Improvement beyond Existing Conditions, and Acreages Associated with the FCUs

Subclass	LGRB			CD			Mitigation Acres Saved	
Acres	976			49				
FCUs	No Longer Impacted	Hydrologic Improvement	Total	No Longer Impacted	Hydrologic Improvement	Total	LGRB	CD
Detain Floodwater	810.1	156.2	966.3	33.8	6.86	40.66	-1615.1	-67.7
Detain Precipitation	976	0	976	NA	NA	NA	-1054.9	NA
Cycle Nutrients	868.6	0	868.6	33.3	0	33.3	-1203.5	-49.9
Export Organic Carbon	868.6	175.7	1044.3	34.3	6.86	41.16	-1446.8	-63.4
Maintain Plant Communities	927.2	29.3	956.5	44.1	3.92	48.02	-1300.5	-83.0
Provide Habitat for Fish and Wildlife	732	29.3	761.3	33.3	1.47	34.77	-1296.9	-59.2

In addition, some of the farmland around the BOTSP will be subject to improved hydrology, and would accrue mitigation functional lifts at a higher rate than the portions of the basin subject to post-Authorized Project hydrology. It is assumed for the purposes of this analysis that these areas would instead on average have hydrology similar to existing conditions, and be subject to the No Action Annualized FCIs. It is not known how extensive this area would be, so this benefit is reported FCIs, not FCUs or acres. Tables 31a and 31b show the FCIs that should be used to calculated mitigation acres required when mitigation is accomplished within this hydrologically improved area, rather than elsewhere in the basin. They supplant the FCIs shown in Tables 28a and 28b within this area. Mitigation accomplished outside the area influenced by the Structure would still be subject to FCIs offered in Tables 28a and 28b.

Tables 31a and 31b: Annualized FCIs and Acres Needed to offset 1 Lost FCU by Subclass and Function within Areas Around Big Oak Tree State Park Hydrologically Improved by the Structure and Available for Mitigation, New Madrid Floodway.

Mitigation FCIs below the 5-year floodplain within the area around BOTSP that is subject to hydrologic improvement due to the structure. All restored wetlands are forested.

Mitigation Scenario	Wetland Functions					
	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Provide Wildlife Habitat
LGRB	Annualized Functional Capacity Indices					
Small (500ac) Tracts	0.598	0.925	0.722	0.722	0.759	0.265
Large (1200ac) Tracts	0.598	0.925	0.722	0.722	0.759	0.599
LGRO	Annualized Functional Capacity Indices					
Small (250ac) Tracts	0.636	0.902	0.622	0.614	0.693	0.452
CD	Annualized Functional Capacity Indices					
Inclusions in Large (1200ac) Tracts	0.601	N/A	0.668	0.649	0.645	0.602

Mitigation Acres needed to offset 1 lost FCU: below the 5-year floodplain within the area around BOTSP that is subject to hydrologic improvement due to the structure. All restored wetlands are forested.

Mitigation Scenario	Wetland Functions					
	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Provide Wildlife Habitat
LGRB	Acres Needed to Offset 1 Lost FCU					
Small (500ac) Tracts	1.671	1.081	1.386	1.385	1.318	3.781
Large (1200ac) Tracts	1.671	1.081	1.386	1.385	1.318	1.671
LGRO	Acres Needed to Offset 1 Lost FCU					
Small (250ac) Tracts	1.572	1.109	1.607	1.628	1.442	2.215
CD	Acres Needed to Offset 1 Lost FCU					
Inclusions in Large (1200ac) Tracts	1.665	NA	1.498	1.540	1.550	1.663

3.2. New Madrid Floodway Management Scenario 2

Mitigation associated with the Authorized Project with Avoid and Minimize Measures Management Scenario 2 within the New Madrid Floodway would be subject to annualized FCIs reflecting the post-project hydrology as shown in Tables 32a and 32b.

Tables 32a and 32b: Annualized FCIs and Acres Needed to offset 1 Lost FCU by Subclass, Function and Mitigation Scenario Associated with the Authorized Project with Avoid and Minimize Measures Management Scenario 2 in the New Madrid Floodway.

Mitigation FCIs below the 5-year floodplain For Authorized Project With Avoid & Minimize Measures Management Scenario 2 Within New Madrid Floodway. All restored wetlands are forested.

Mitigation Scenario	Wetland Functions					
	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Provide Wildlife Habitat
LGRB	**Annualized Functional Capacity Indices**					
Small (500ac) Tracts	0.477	0.925	0.722	0.577	0.709	0.249
Large (1200ac) Tracts	0.477	0.925	0.722	0.577	0.709	0.565
LGRO	**Annualized Functional Capacity Indices**					
Small (250ac) Tracts	0.507	0.902	0.622	0.489	0.632	0.430
CD	**Annualized Functional Capacity Indices**					
Inclusions in Large (1200ac) Tracts	0.483	NA	0.668	0.520	0.500	0.552

Mitigation Acres needed to offset 1 lost FCU: below the 5-year floodplain For Authorized Project With Avoid & Minimize Measures Management Scenario 2 Within New Madrid Floodway. All restored wetlands are forested.

Mitigation Scenario	Wetland Functions					
	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Provide Wildlife Habitat
LGRB	**Acres Needed to Offset 1 Lost FCU**					
Small (500ac) Tracts	2.098	1.081	1.386	1.735	1.411	4.024
Large (1200ac) Tracts	2.098	1.081	1.386	1.735	1.411	1.770
LGRO	**Acres Needed to Offset 1 Lost FCU**					
Small (250ac) Tracts	1.972	1.109	1.607	2.046	1.583	2.328
CD	**Acres Needed to Offset 1 Lost FCU**					
Inclusions in Large (1200ac) Tracts	2.070	NA	1.498	1.923	1.998	1.813

Using these mitigation functional gains, and the FCU losses associated with the Authorized Project with Avoid and Minimize Measures Management Scenario 2 in the New Madrid Floodway, mitigation debt can be calculated in acres (Table 33). Table 33 shows the losses associated with the Authorized Project with Avoid and Minimize Measures Management Scenario 2 in New Madrid Floodway summarized by subclass. Mitigation requirements for each subclass are then calculated by multiplying the FCUs lost by the Mitigation Acres Needed to Offset 1 FCU, as calculated in Table 32.

Table 33. Functional Losses in FCUs Associated with the Authorized Project with Avoid and Minimize Measures Management Scenario 2 within the New Madrid Floodway, and a Calculation of Mitigation Acres Based on Mitigation Annualized FCIs from Table 28.

Mitigation Required for Alternative 3.2 New Madrid Floodway, Assuming that Mitigation is accomplished in large connected tracts around Big Oak State Park.

	Losses in FCUs			Gains in FCUs		Mitigation for Losses in Acres Using Mitigation Rates for Large Tracts & Post Project Hydrology		
Function	**LGRB**	**LGRO**	**CD**	**Flats**	**UCD**	**LGRB**	**LGRO**	**CD**
Detain Floodwater	-4046	-35	-95	NA	NA	8490	69	196
Detain Precipitation	-3520	0	0	2868	NA	3805	0	NA
Cycle Nutrients	-3116	0	-104	2966	123	4317	0	156
Export Organic Carbon	-4102	-35	-115	NA	NA	7115	71	221
Maintain Plant Communities	-3574	-70	-138	3138	123	5043	110	277
Provide Habitat for Fish and Wildlife	-2830	-35	-94	2438	73	5008	81	171

It is assumed that mitigation is taking place within the 5-year floodplain, in large (1200 acre) well-connected tracts, but that no structure has been installed to restore flooding. Thus, the mitigation is maturing while subject to the altered hydrology associated with the Authorized Project with Avoid and Minimize Measures Management Scenario 2. This leads to a smaller functional lift per acre (or Annualized FCI), and larger acreage requirements for mitigation to offset the losses associated with the project. Cells highlighted in yellow indicate the maximum mitigation required for each subclass. If this acreage is mitigated, losses to the maximally impacted function will be mitigated, and all other functions will be more than mitigated. For the LGRB subclass, the largest acreage requirements are associated with the Detain Floodwater Function: 8490 acres for LGRB wetlands. For the LGRO subclass, the Maintain Plant Communities Function required the greatest acreage at 110 acres. For CD wetlands, the largest mitigation acreage requirement is associated with the Export Organic Carbon Function, resulting in 221 acres of CD wetlands.

If the structure were built to restore more natural flooding to Big Oak Tree State Park (BOTSP), then the FCUs lost shown in Table 29 would be decreased. Table 34 shows that the impacts associated with the BOTSP are removed from the mitigation debt as No Longer Impacted. In addition, hydrology is planned to be improved beyond existing conditions. There are currently few details about how this structure would deliver water to BOTSP. This analysis assumes that the design will optimize the hydrologic gain within the park itself. The BOTSP is assumed to receive an improvement to its flood frequency (V_{FREQ}) and flood duration (V_{DUR}) resulting in a 0.2 increase to the variable subindex of both of these variables. The functional gains associated with the increased indices for these variables are also calculated and shown in Table 30. The resulting benefit is 1615.1 LGRB mitigation acres saved, and 83 CD mitigation acres saved.

Table 34. Analysis of Benefits of a Flood Structure Restoring Flood Frequency and Duration to BOTSP, in terms of FCUs no longer impacted, FCUs Gained Due to Hydrologic Improvement beyond Existing Conditions, and Acreages Associated with the FCUs

Subclass	LGRB			CD			Mitigation Acres Saved	
Acres	976			49				
FCUs	No Longer Impacted	Hydrologic Improvement	Total	No Longer Impacted	Hydrologic Improvement	Total	LGRB	CD
Detain Floodwater	810.1	156.2	966.3	33.8	6.86	40.66	-1615.1	-67.7
Detain Precipitation	976	0	976	NA	NA	NA	-1054.9	NA
Cycle Nutrients	868.6	0	868.6	33.3	0	33.3	-1203.5	-49.9
Export Organic Carbon	868.6	175.7	1044.3	34.3	6.86	41.16	-1446.8	-63.4
Maintain Plant Communities	927.2	29.3	956.5	44.1	3.92	48.02	-1300.5	-83.0
Provide Habitat for Fish and Wildlife	732	29.3	761.3	33.3	1.47	34.77	-1296.9	-59.2

In addition, some of the farmland around the BOTSP will be subject to improved hydrology, and would accrue mitigation functional lifts at a higher rate than the portions of the basin subject to post-Authorized Project hydrology. It is assumed for the purposes of this analysis that these areas would instead on average have hydrology similar to existing conditions, and would be subject to the No Action Annualized FCIs. It is not known how extensive this area would be, so this benefit is reported FCIs, not FCUs or acres. Tables 35a and 35b show the FCIs that should be used to calculated mitigation acres required when mitigation is accomplished within this hydrologically improved area, rather than elsewhere in the basin. They supplant the FCIs shown in Tables 32a and 32b within this area. Mitigation accomplished outside the area influenced by the Structure would still be subject to FCIs offered in Tables 32a and 32b.

Tables 35a and 35b: Annualized FCIs and Acres Needed to offset 1 Lost FCU by Subclass and Function within Areas Around Big Oak Tree State Park Hydrologically Improved by the Structure and Available for Mitigation, New Madrid Floodway.

Mitigation FCIs below the 5-year floodplain within the area around BOTSP that is subject to hydrologic improvement due to the structure. All restored wetlands are forested.

Mitigation Scenario	Wetland Functions					
	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Provide Wildlife Habitat
LGRB	Annualized Functional Capacity Indices					
Small (500ac) Tracts	0.598	0.925	0.722	0.722	0.759	0.265
Large (1200ac) Tracts	0.598	0.925	0.722	0.722	0.759	0.599
LGRO	Annualized Functional Capacity Indices					
Small (250ac) Tracts	0.636	0.902	0.622	0.614	0.693	0.452
CD	Annualized Functional Capacity Indices					
Inclusions in Large (1200ac) Tracts	0.601	N/A	0.668	0.649	0.645	0.602

Mitigation Acres needed to offset 1 lost FCU: below the 5-year floodplain within the area around BOTSP that is subject to hydrologic improvement due to the structure. All restored wetlands are forested.

Mitigation Scenario	Wetland Functions					
	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Provide Wildlife Habitat
LGRB	Acres Needed to Offset 1 Lost FCU					
Small (500ac) Tracts	1.671	1.081	1.386	1.385	1.318	3.781
Large (1200ac) Tracts	1.671	1.081	1.386	1.385	1.318	1.671
LGRO	Acres Needed to Offset 1 Lost FCU					
Small (250ac) Tracts	1.572	1.109	1.607	1.628	1.442	2.215
CD	Acres Needed to Offset 1 Lost FCU					
Inclusions in Large (1200ac) Tracts	1.665	NA	1.498	1.540	1.550	1.663

4.1 & 4.2. New Madrid Floodway Limited Management Scenarios

Mitigation associated with the Alternatives 4.1 and 4.2 within the New Madrid Floodway would be subject to annualized FCIs reflecting the post-project hydrology as shown in Tables 36a and 36b. Using these mitigation functional gains, and the FCU losses associated with the Alternatives 4.1 and 4.2 in the New Madrid Floodway, mitigation debt can be calculated in acres (Tables 37 and 38).

Tables 36a and 36b: Annualized FCIs and Acres Needed to offset 1 Lost FCU by Subclass, Function and Mitigation Scenario Associated with the Authorized Project with Avoid and Minimize Measures Management Scenario 1 in the New Madrid Floodway.

Mitigation FCIs below the 5-year floodplain For Alternatives 4.1 and 4.2 Within New Madrid Floodway. All restored wetlands are forested.

Mitigation Scenario	Wetland Functions					
	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Provide Wildlife Habitat
LGRB	Annualized Functional Capacity Indices					
Small (500ac) Tracts	0.598	0.925	0.722	0.722	0.736	0.246
Large (1200ac) Tracts	0.598	0.925	0.722	0.722	0.736	0.587
LGRO	Annualized Functional Capacity Indices					
Small (250ac) Tracts	0.636	0.902	0.622	0.614	0.667	0.444
CD	Annualized Functional Capacity Indices					
Inclusions in Large (1200ac) Tracts	0.601	NA	0.668	0.649	0.579	0.588

Mitigation Acres needed to offset 1 lost FCU: below the 5-year floodplain For Alternatives 4.2 and 4.2 Within New Madrid Floodway. All restored wetlands are forested.

Mitigation Scenario	Wetland Functions					
	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Provide Wildlife Habitat
LGRB	Acres Needed to Offset 1 Lost FCU					
Small (500ac) Tracts	1.671	1.081	1.386	1.385	1.360	4.065
Large (1200ac) Tracts	1.671	1.081	1.386	1.385	1.360	1.704
LGRO	Acres Needed to Offset 1 Lost FCU					
Small (250ac) Tracts	1.572	1.109	1.607	1.628	1.500	2.255
CD	Acres Needed to Offset 1 Lost FCU					
Inclusions in Large (1200ac) Tracts	1.665	NA	1.498	1.540	1.729	1.702

Tables 37 and 38 shows the losses associated with Alternatives 4.1 and 4.2 in New Madrid Floodway summarized by subclass. Mitigation requirements for each subclass are then calculated by multiplying the FCUs lost by the Mitigation Acres Needed to Offset 1 FCU, as calculated in Table 36.

Table 37. Functional Losses in FCUs Associated with Alternative 4.1 within the New Madrid Floodway, and a Calculation of Mitigation Acres Based on Mitigation Annualized FCIs from Table 36.

Mitigation Required for Alternative 4.1 New Madrid Floodway, Assuming that Mitigation is accomplished in large connected tracts around Big Oak State Park.

	Losses in FCUs			Gains in FCUs		Mitigation for Losses in Acres Using Mitigation Rates for Large Tracts & Post Project Hydrology		
Function	**LGRB**	**LGRO**	**CD**	**Flats**	**UCD**	**LGRB**	**LGRO**	**CD**
Detain Floodwater	-2914	-186	-96	NA	NA	4870	292	160
Detain Precipitation	-2350	0	NA	1831	NA	2539	0	NA
Cycle Nutrients	-2032	0	-93	2003	109	2815	0	140
Export Organic Carbon	-2973	-174	-113	NA	NA	4119	284	174
Maintain Plant Communities	-2188	0	-108	2074	113	2975	0	186
Provide Habitat for Fish and Wildlife	-1709	-12	-86	1547	71	2911	26	146

It is assumed that mitigation is taking place within the 5-year floodplain, in large (1200 acre) well-connected tracts, but that no structure has been installed to restore flooding. Thus, the mitigation is maturing while subject to the altered hydrology associated with the Alternative 4 hydrology. This leads to a smaller functional lift per acre (or Annualized FCI), and larger acreage requirements for mitigation to offset the losses associated with the project. Cells highlighted in yellow indicate the maximum mitigation required for each subclass. If this acreage is mitigated, losses to the maximally impacted function will be mitigated, and all other functions will be more than mitigated. For the LGRB subclass, the largest acreage requirements are associated with the Detain Floodwater Function: 4870 acres for LGRB wetlands. For the LGRO subclass, the Detain Floodwater Function required the greatest acreage at 292 acres. For CD wetlands, the largest mitigation acreage requirement is associated with the Maintain Plant Communities Function, resulting in 186 acres of CD wetlands.

Alternative 4.2 results in identical post-project hydrology, and hence identical mitigation FCIs, but involves extensive forest restoration as part of the project. Thus, the mitigation debt is much lower, and in most cases a surplus of wetland function with respect to a future without project is forecast. Table 38 summarizes these mitigation requirements.

Table 38. Functional Losses in FCUs Associated with Alternative 4.2 within the New Madrid Floodway, and a Calculation of Mitigation Acres Based on Mitigation Annualized FCIs from Table 36.

Mitigation Required for Alternative 4.2 New Madrid Floodway, Assuming that Mitigation is accomplished in large connected tracts around Big Oak State Park.

	Losses/Gains in FCUs			Gains in FCUs		Mitigation for Losses in Acres Using Mitigation Rates for Large Tracts & Post Project Hydrology[1]		
Function	**LGRB**	**LGRO**	**CD**	**Flats**	**UCD**	**LGRB**	**LGRO**	**CD**
Detain Floodwater	35	-186	132	NA	NA	-58	292	-220
Detain Precipitation	2650	0	0	1831	NA	-2865	0	NA
Cycle Nutrients	4122	0	496	2003	109	-5711	0	-742
Export Organic Carbon	2027	-174	400	NA	NA	-2808	284	-616
Maintain Plant Communities	7555	0	196	2074	113	-10272	0	-339
Provide Habitat for Fish and Wildlife	5855	-12	180	1547	71	-9974	26	-306

1 Negative mitigation debt indicates a surplus based on forest restoration that is part of the project.

It is assumed that mitigation is taking place within the 5-year floodplain, in large (1200 acre) well-connected tracts, but that no structure has been installed to restore flooding. Thus, the mitigation is maturing while subject to the altered hydrology associated with the Alternative 4 hydrology. This leads to a smaller functional lift per acre (or Annualized FCI), and larger acreage requirements for mitigation to offset the losses associated with the project. Cells highlighted in yellow indicate the maximum mitigation required for each subclass. If this acreage is mitigated, losses to the maximally impacted function will be mitigated, and all other functions will be more than mitigated. Mitigation is actually only required for the LGRO wetland subclass. The largest acreage requirement is associated with the Detain Floodwater function: 292 acres.

If the structure is built to restore more natural flooding to Big Oak Tree State Park (BOTSP), then the FCUs lost shown in Tables 37 and 38 would be decreased. Table 39 shows that the impacts associated with the BOTSP are removed from the mitigation debt as No Longer Impacted. In addition, hydrology is planned to be improved beyond existing conditions. This analysis assumes that the design will optimize the hydrologic gain within the park itself. The BOTSP is assumed to receive an improvement to its flood frequency (V_{FREQ}) and flood duration (V_{DUR}) resulting in a 0.2 increase to the variable subindex of both of these variables. The functional gains associated with the increased indices for these variables are also calculated and shown in Table 39. The resulting benefit is 1615.1 LGRB mitigation acres saved, and 83 CD mitigation acres saved.

Table 39. Analysis of Benefits of a Flood Structure Restoring Flood Frequency and Duration to BOTSP, in terms of FCUs no longer impacted, FCUs Gained Due to Hydrologic Improvement beyond Existing Conditions, and Acreages Associated with the FCUs

Subclass	LGRB			CD			Mitigation Acres Saved	
Acres	976			49				
FCUs	No Longer Impacted	Hydrologic Improvement	Total	No Longer Impacted	Hydrologic Improvement	Total	LGRB	CD
Detain Floodwater	810.1	156.2	966.3	33.8	6.86	40.66	-1615.1	-67.7
Detain Precipitation	976	0	976	NA	NA	NA	-1054.9	NA
Cycle Nutrients	868.6	0	868.6	33.3	0	33.3	-1203.5	-49.9
Export Organic Carbon	868.6	175.7	1044.3	34.3	6.86	41.16	-1446.8	-63.4
Maintain Plant Communities	927.2	29.3	956.5	44.1	3.92	48.02	-1300.5	-83.0
Provide Habitat for Fish and Wildlife	732	29.3	761.3	33.3	1.47	34.77	-1296.9	-59.2

In addition, some of the farmland around the BOTSP will be subject to improved hydrology, and would accrue mitigation functional lifts at a higher rate than the portions of the basin subject to post-Authorized Project hydrology. It is assumed for the purposes of this analysis that these areas would instead on average have hydrology similar to existing conditions, and be subject to the No Action Annualized FCIs. It is not known how extensive this area would be, so this benefit is reported FCIs, not FCUs or acres. Tables 40a and 40b show the FCIs that should be used to calculated mitigation acres required when mitigation is accomplished within this hydrologically improved area, rather than elsewhere in the basin. They supplant the FCIs shown in Tables 36a and 36b within this area. Mitigation accomplished outside the area influenced by the Structure would still be subject to FCIs offered in Tables 36a and 36b.

Tables 40a and 40b: Annualized FCIs and Acres Needed to offset 1 Lost FCU by Subclass and Function within Areas Around Big Oak Tree State Park Hydrologically Improved by the Structure and Available for Mitigation, New Madrid Floodway.

Mitigation FCIs below the 5-year floodplain within the area around BOTSP that is subject to hydrologic improvement due to the structure. All restored wetlands are forested.

Mitigation Scenario	Wetland Functions					
	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Provide Wildlife Habitat
LGRB	Annualized Functional Capacity Indices					
Small (500ac) Tracts	0.598	0.925	0.722	0.722	0.759	0.265
Large (1200ac) Tracts	0.598	0.925	0.722	0.722	0.759	0.599
LGRO	Annualized Functional Capacity Indices					
Small (250ac) Tracts	0.636	0.902	0.622	0.614	0.693	0.452
CD	Annualized Functional Capacity Indices					
Inclusions in Large (1200ac) Tracts	0.601	N/A	0.668	0.649	0.645	0.602

Mitigation Acres needed to offset 1 lost FCU: below the 5-year floodplain within the area around BOTSP that is subject to hydrologic improvement due to the structure. All restored wetlands are forested.

Mitigation Scenario	Wetland Functions					
	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Provide Wildlife Habitat
LGRB	Acres Needed to Offset 1 Lost FCU					
Small (500ac) Tracts	1.671	1.081	1.386	1.385	1.318	3.781
Large (1200ac) Tracts	1.671	1.081	1.386	1.385	1.318	1.671
LGRO	Acres Needed to Offset 1 Lost FCU					
Small (250ac) Tracts	1.572	1.109	1.607	1.628	1.442	2.215
CD	Acres Needed to Offset 1 Lost FCU					
Inclusions in Large (1200ac) Tracts	1.665	NA	1.498	1.540	1.550	1.663

CONCLUSIONS

Within the St Johns Basin, the Avoid And Minimize Alternative, 3.1, has the fewest impacts to wetlands. Mitigation required within St. Johns basin includes 201 acres of LGRB and 623 acres of LGRO wetlands. Both requirements are driven by losses to the Detain Floodwater function.

Within the New Madrid Floodway, Alternative 4.2 has the fewest impacts to wetlands, and in fact the restoration associated with that alternative creates a surplus of wetland functions for most subclasses. Only 292 acres of LGRO wetlands are estimated to be needed for mitigation under this alternative.

If Alternative 4.2 is deemed unfeasible, Alternative 4.1 is the next least impacting alternative. Estimated mitigation requirements for Alternative 4.1 include 4870 acres of LGRB wetlands, 292 acres of LGRO wetlands, and 186 acres of CD wetlands.

Alternative 3.1, The Authorized Project with Avoid and Minimize Measures with Management Scenario 1 within the New Madrid Floodway had the next fewest impacts to wetlands. For the LGRB subclass, the largest acreage requirements are associated with the Detain Floodwater Function: 5828 acres for LGRB wetlands. For the LGRO subclass, the Export Organic Carbon Function required the greatest acreage at 57 acres. For CD wetlands, the largest mitigation acreage requirement is associated with the Maintain Plant Communities Function, resulting in 215 acres of CD wetlands.

These mitigation acreages may be further reduced by the construction of the structure that would restore improved hydrology to the Big Oak Tree State Park and some portion of the surrounding farmland. At the very least, the improved hydrology to the park itself results in 1615 LGRB mitigation acres saved, and 83 CD mitigation acres saved. Additional reductions could be possible by completing mitigation in the surrounding farmland subject to the improved hydrology, but since the expanse of the area under the influence of the structure is not determined, actual saved acreages cannot be calculated at this point.

Actual mitigation requirements will need to be calculated once the final design of any structure and the final layout of mitigation are determined. However, the estimates in this report serve to illustrate the difference between the alternatives, and the potential advantages of different strategies regarding siting of the mitigation.

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Appendix E
Part 5

Section 404(b)(1) Evaluation Report

U.S. Army Corps of Engineers
Memphis District

Appendix E
Part 5

Section 404(b)(1) Evaluation Report

U.S. Army Corps of Engineers
Memphis District

DRAFT

SECTION 404(B)(1) EVALUATION REPORT

ST. JOHNS BAYOU - NEW MADRID FLOODWAY PROJECT
NEW MADRID, MISSISSIPPI, AND SCOTT COUNTIES, MISSOURI

I. Introduction

This evaluation of compliance with the Clean Water Act, 40 CFR Part 230 – Section 404(b)(1) Guidelines (Guidelines) relies on the detailed information in the draft environmental impact statement (EIS) to which it is attached and is not intended to be a "stand alone" document.

The purpose of these Guidelines is to restore and maintain the chemical, physical, and biological integrity of waters of the United States through the control of discharges of dredged or fill material. Generally, dredged or fill material should not be discharged into aquatic ecosystems, unless it can be demonstrated that such a discharge will not have an unacceptable adverse impact either individually or in combination with known and/or probable impacts of other activities affecting the ecosystems of concern.

The procedures for documenting compliance with the Guidelines include the following:

- Examining practicable alternatives to the proposed discharge that might have fewer adverse environmental impacts, including not discharging into a water of the U.S. or discharging into an alternative aquatic site.
- Evaluating the potential short- and long-term effects, including cumulative effects, of a proposed discharge of dredged or fill material on the physical, chemical and biological components of aquatic environments.
- Identifying appropriate and practicable measures to mitigate the unavoidable adverse environmental impacts of the proposed discharge.
- Making and documenting the Finding of Compliance required by §230.12 of the Guidelines.

The Tentatively Selected Plan (TSP), Alternative 3.1, construct and operate flood control improvements in both the St. Johns Bayou Basin and New Madrid Floodway, with seasonal flood pulse management and measures to avoid and minimize environmental impact, will be evaluated for compliance. Alternative 3.1 is the least environmentally damaging practicable alternative (LEDPA).[1]

II. Project Description

a. Location. The St. Johns Bayou Basin and New Madrid Floodway are located in Mississippi, New Madrid, and Scott Counties in southeast Missouri (Figure 1). The New Madrid Floodway setback levee separates the two basins and prevents Mississippi River water from

[1] As this is a draft document, USACE invites public comment on the analyses and conclusions. Should the selected alternative change in the final environmental impact statement, this 404(b)(1) analysis will be revised to evaluate that alternative for compliance under the Guidelines.

flooding the St. Johns Bayou Basin. The frontline levee forms the eastern boundary of the New Madrid Floodway, but a 1,500-foot gap between the setback levee and the frontline levee allows Mississippi River water to back up into the floodway, causing backwater flooding.

The St. Johns Bayou Basin is approximately 324,170 acres (507 square miles) in size, extending north to Commerce, Missouri, east to East Prairie, Missouri, and south to New Madrid, Missouri. Major streams and ditches include St. Johns Bayou, Setback Levee Ditch, St. James Ditch, St. Johns Ditch, Lee Rowe Ditch, and Maple Slough Ditch. All of these ditches flow into St. Johns Bayou, and, via the St. Johns Bayou outlet structure, empty into the Mississippi River.

The New Madrid Floodway is approximately 132,600 acres (207 square miles) in size, beginning just south of Cairo, Illinois, and extending south to New Madrid. Major streams and ditches include Mud Ditch, Wilkerson Ditch, St. Johns Diversion Ditch, Tenmile Pond, and St. James Bayou. St. James Bayou and the other ditches flow into Mud Ditch, which passes through the 1,500-foot gap, converges with St. Johns Bayou, and empties into the Mississippi River about one-half mile east of New Madrid. Additional information can be found in Section 3 of the draft EIS.

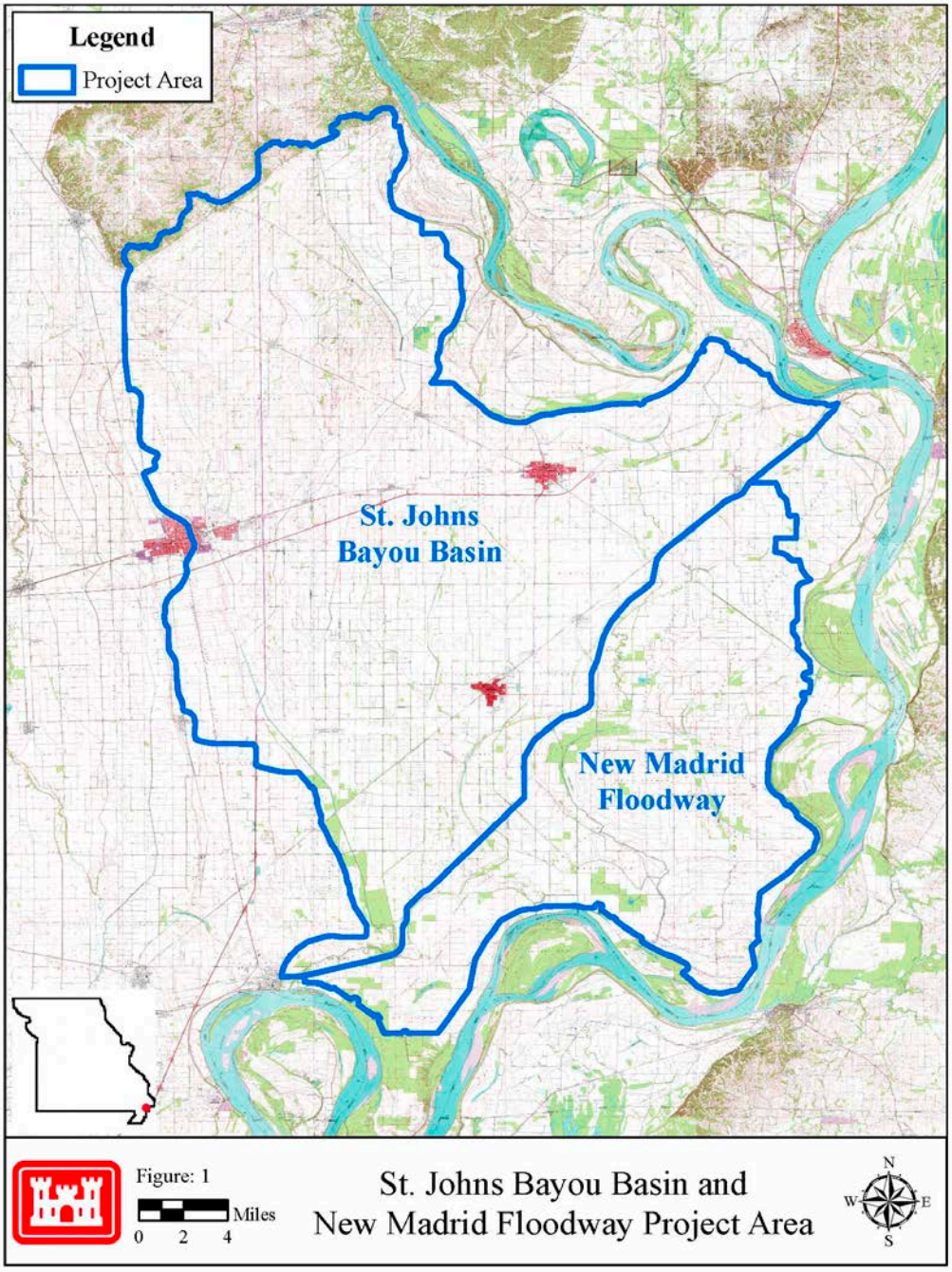
The purpose and need of this project as directed by Congressional mandate is for USACE to reduce the likelihood and adverse effects—on agricultural and urban lands—of backwater and headwater flooding in the New Madrid Floodway and in the St. Johns Bayou Basin. The endstate authorized by Congress in both the Flood Control Act of 1954 and in the Water Resources Development Act of 1986 was closure of the 1,500 foot gap in New Madrid Floodway as well as channel clearing, enlargement, and modifications in the two basins as well as a floodwater pumping plant in both basins, as well as other environmental and recreational features. Through various studies described in Section 1 of the draft EIS, the authorized project has been further refined and modified to incorporate avoid and minimize measures, but the overall project purpose to improve the means and methods of preventing and controlling destructive floodwaters has remained the same.

b. General Description.

1) Existing Conditions. In the St. Johns Bayou Basin, the existing gravity outlet structure at the lower end of St. Johns Bayou prevents Mississippi River backwater flooding. Floodgates in the six 10-foot by 10-foot concrete box culverts remain open under normal conditions to provide drainage through the New Madrid Floodway setback levee; the conveyance has a maximum capacity of 10,000 cubic feet per second (cfs). The floodgates are manually closed during periods of high water in the river. When the river level is lower, in elevation, than the level of St. Johns Bayou, the floodgates remain open and St. Johns Bayou flows naturally into the Mississippi. During periods of high water in the Mississippi River, the floodgates are closed, which impounds St. Johns Bayou and causes it to back-up in the basin, inundating lower-lying areas. This kind of flooding, though less severe than backwater flooding from the Mississippi, can be extensive and is exacerbated by rainfall. The 2-year flood floodplain in the St. Johns Bayou Basin reaches an elevation of 291 feet[2], flooding approximately 11,904 acres, of which approximately 60 percent are devoted to agricultural production. Flooding in the New Madrid

[2] Elevation is expressed in terms of number of feet above sea level, as calculated using a recognized datum.

Floodway most frequently occurs when the Mississippi River rises in the spring. As the Mississippi River rises, it backs up into the New Madrid Floodway through the 1,500-foot gap, inundating low-lying areas until the river recedes. The 2-year floodplain in the New Madrid Floodway reaches an elevation of 292.1 feet, inundating approximately 33,391 acres, of which approximately 74 percent are devoted to agricultural production.



Over time, and especially as the result of levee construction, the project area has undergone dramatic anthropogenic modification. What once was an expansive bottomland hardwood forest (BLH) ecosystem has been converted into a mostly homogenous landscape of agricultural fields. Conversion of wetlands to cropland is well documented as a leading cause of wetlands loss in the United States (Dahl and Allord, 1997).

The U.S. Army Corps of Engineers (USACE) estimates that 86 percent of the wetlands historically present in the project area have been lost due to conversion to cropland. Further, natural drainage systems have been replaced by a vast network of ditches and drainage structures designed to drain low-lying areas to make them agriculturally productive. While some reaches of larger ditches have some riparian buffer, most project area ditches have little to no buffer and are farmed to top bank. Intensive soybean and corn farming operations, coupled with a lack of protective buffers capable of retaining sediments and nutrients, result in the project area being a large contributor to nutrients in the Mississippi River. Robertson, et al (2009) determined with ≥90 percent certainty that the area was ranked in the top 15 watersheds (out of 818) for nitrogen and phosphorous contribution to the Gulf of Mexico, and concluded that the highest total nitrogen (TN) yields closely coincide with areas of intense agricultural production.

To ensure that the number of acres of wetlands would not be underestimated, USACE assumed that vegetated areas, of all types listed in the National Land Cover Database (NLCD), that lie within the existing 5-year floodplain are wetlands. Using this assumption, 5,233 acres of wetlands exist within the St. Johns Bayou Basin and 8,807 acres of wetlands exist within the New Madrid Floodway. Adding wetlands forecasted to be enrolled in the Wetlands Reserve program (WRP), the total in the St. Johns Bayou Basin rises to 6,678 acres and the total in the New Madrid Floodway rises to 9,572 acres.

The acreage of farmland falling under Clean Water Act jurisdiction was established from Natural Resource Conservation Service (NRCS) estimates of farmed wetlands (lands that are wetlands) and prior converted cropland (lands that are not wetlands). NRCS calculated that 1,098 acres of farmed wetlands are located within the project area (792 acres in the St. Johns Bayou Basin and 306 acres in the New Madrid Floodway, respectively). Additional information can be found in Section 3 of the draft EIS and Appendix E, Part 1.

2) Recommended Plan. The tentatively selected plan (TSP), alternative 3.1, combines the congressionally-authorized project (alternative 2.3) with measures to lessen environmental impacts, including smaller channel enlargements in the St. Johns Bayou Basin and modifying operation of the proposed-to-be-constructed outlet structure in the New Madrid Floodway closure levee, to permit backwater flooding in the New Madrid Floodway to an elevation of 289.5 feet. A full description of alterative 3.1 can be found in Section 2 of the draft EIS.

The measures to lessen environmental impacts were formulated from the findings and recommendations of an Independent External Peer Review (IEPR) panel, public scoping, inter-agency coordination, and previous environmental impact assessments. Tables 1 and 2 provide preliminary flood control alternatives and project objectives considered. Section 2 of the draft EIS describes the process by which alternatives were formulated, screened, and the range of alternatives subsequently established.

Table 1. St. Johns Bayou Basin preliminary alternatives and project objectives.

Measure	Reduce Community Isolation	Reduce Agricultural Flood Damages	Reduce Street and Road Flood Damages	Retain for Screening
St. Johns Bayou Pumping Station	X	X	X	Y
St. Johns Bayou Ditch Modifications	X	X	X	Y
East Prairie Ring Levee			X	Y
St. Johns Bayou Fish and Wildlife Refuge		X		N
St. Johns Bayou Expanded Fish and Wildlife Refuge		X		Y
St. Johns Bayou Agriculture to Silviculture		X		Y
St. Johns Bayou Crop Conversion		X		Y
St. Johns Bayou Nutrient Trading				N
St. Johns Bayou Relocations	X			Y
St. Johns Bayou Raise Roads	X			Y

Table 2. New Madrid Floodway preliminary alternatives and project objectives.

Measure	Reduce Community Isolation	Reduce Agricultural Flood Damages	Reduce Street and Road Flood Damages	Retain for Screening
New Madrid Floodway Authorized Closure Levee	X	X	X	Y
New Madrid Floodway Alternate Levee Locations	X	X	X	Y
New Madrid Floodway Pumping Station	X	X	X	Y
New Madrid Floodway Fish and Wildlife Refuge		X		N
New Madrid Floodway Expanded Fish and Wildlife Refuge		X		Y
New Madrid Floodway Agriculture to Silviculture		X		Y
New Madrid Floodway Crop Conversion		X		Y
New Madrid Floodway Nutrient Trading				N
New Madrid Floodway Relocations	X			Y
New Madrid Floodway Raise Roads	X			Y

Eight alternatives were carried forward for detailed analysis. They include:

• Alternative 1: no action;

• Alternative 2.1: construct and operate flood control improvements in the St. Johns Bayou Basin only;

• Alternative 2.2: construct and operate flood control improvements in the New Madrid Floodway only;

• Alternative 2.3: construct and operate flood control improvements in both the St. Johns Bayou Basin and New Madrid Floodway;

• Alternative 3.1: construct and operate flood control improvements in both the St. Johns Bayou Basin and New Madrid Floodway, with seasonal flood pulse management and measures to avoid and minimize environmental impact;

• Alternative 3.2: construct and operate flood control improvements in both the St. Johns Bayou Basin and New Madrid Floodway, with seasonal flood pulse management affording greater springtime flood protection and measures to avoid and minimize environmental impact;

• Alternative 4.1: construct and operate flood control improvements in both the St. Johns Bayou Basin and New Madrid Floodway, with floodplain connectivity maintained up to an elevation of 289.5 feet in the New Madrid Floodway and measures to avoid and minimize environmental impact; and

• Alternative 4.2: construct and operate flood control improvements in both the St. Johns Bayou Basin and New Madrid Floodway, with floodplain connectivity in the New Madrid Floodway maintained up to an elevation of 289.5 feet, reforestation of agricultural lands below an elevation of 289.5 feet, and measures to avoid and minimize environmental impact.

As noted, alternative 3.1 has been identified as the TSP. It would provide the greatest net excess economic benefit[3] while reducing environmental impacts compared to the congressionally-authorized project (alternative 2.3). In addition, alternative 3.1 contributes to social well-being by reducing flooding that inundates roads and isolates residential communities.

The elements of alternative 3.1 are:

- Close the 1,500-foot gap in the New Madrid Floodway by constructing a levee. The levee would be constructed of 233,000 cubic yards of earth and have a crown-height elevation of 317.0 feet, a top width of 16 feet, a base width of approximately 302 feet, and side slopes of 4.5:1.
- Construct in the closure levee four gated, 10-foot by 10-foot box culverts as an outlet for Mud Ditch. The gates would be closed only to prevent backwater flooding and to maintain sufficient impounded water in winter to inundate lands for waterfowl habitat.
- Raise the lower section of the New Madrid Floodway frontline levee to an equivalent crown-height elevation of 317.0 feet. This would require approximately 127,000 cubic yards of material. The levee would be substantially similar in dimension as the closure levee.
- Raise the crown-height elevation along 14.1 miles of the New Madrid Floodway setback levee. It is anticipated that 2.4 million cubic yards of material would be required. No changes to base width are proposed. Therefore, construction would be entirely confined to the existing levee footprint.
- Construct a 1,500-cfs pump in the New Madrid Floodway at or near the location of the Mud Ditch outlet structure.
- Modify St. Johns Bayou Basin streams and ditches as follows:
    - 3.7 miles of the lower St. Johns Bayou would be enlarged from one side to a bottom width of 120 feet. Approximately 856,770 cubic yards of material would be deposited along the bank and would re-vegetate naturally. Conservation easements would be purchased to ensure this benefit.

[3] Excess benefits are calculated as the total annualized dollars in expected benefit minus the cost of the investment, which is distinguished from return on investment or benefit to cost ratio.

- The lower 8.1 miles of Setback Levee Ditch would be enlarged from 40 feet to 50 feet along the left descending bank. Approximately 675,000 cubic yards of material would be placed in a 120-foot wide embankment and allowed to re-vegetate naturally as part of a conservation easement.
- The lower 3.5 miles of St. James Ditch would be enlarged along the left descending bank by increasing the bottom width from 35 feet to 45 feet. The remaining 7.8 miles of channel work would increase the top bank width to 80 feet. Approximately 630,000 cubic yards of excavated material would be placed in a 100-foot wide buffer along the left descending bank.

- Construct a 1,000 cfs pumping station in the St. Johns Bayou Basin.
- Maintain the current scheme of operations for the St. Johns Bayou gravity outlet structure (*i.e.,* close gates to prevent backwater flooding).
- Impound water in the St. Johns Bayou Basin to an elevation of 285.0 feet, for the benefit of waterfowl, by closing the St. Johns Bayou outlet structure from 1 December to 31 January.

c. Authority and Purpose. Authority to build and operate the St. Johns Bayou and New Madrid Floodway Project is granted by section 203 of the Flood Control Act of 1954 and section 401(a) of the Water Resources Development Act of 1986. As prescribed by Congress, the purpose of the proposed project is to reduce the likelihood and effects of flood-related damage, disruption, and dislocation in the project area by improving the means and methods of preventing and controlling destructive floodwaters. Additional information can be found in Section 1 of the draft EIS.

d. General Description of Dredged or Fill Material

(1) General Characteristics of Material. Dredged and fill material consists of sediment and other matter to be removed from streams and ditches; four gated, 10-foot by 10-foot concrete box culverts to be placed in the New Madrid Floodway closure levee as an outlet for Mud Ditch; material used to construct transverse dikes and hard points at selected ditch confluence areas; and, earthen material used to construct the New Madrid Floodway closure levee. Soils within the drainage ditches in St. Johns Bayou Basin consist primarily of silts, clays, and sands deposited by the Mississippi River.

(2) Quantity of Material. A combined total of approximately 3.79 million cubic yards of material would be removed from St. Johns Bayou Basin ditches and placed along the banks of St. Johns Bayou, Setback Levee Ditch, and St. James Ditch. Approximately 233,000 cubic yards of material would be utilized for the New Madrid Floodway closure levee, to be located between the New Madrid Floodway setback levee mile 35 and 37.

(3) Source of Material. Approximately 447 acres of borrow pits, located in prior converted cropland in the lower portions of the St. Johns Bayou Basin and New Madrid Floodway, would be used as sources of material for the New Madrid Floodway closure levee and for raising the lower portion of the New Madrid Floodway frontline levee.

e. Description of the Proposed Discharge Site(s)

(1) Location. The project area is located in New Madrid, Mississippi, and Scott Counties in southeast Missouri (Figure 1). Additional information can be found in Section 1 of the draft EIS.

(2) Size. The New Madrid Floodway closure levee would occupy an area of approximately 9 acres. The placement of fill material along ditch banks in the St. Johns Bayou Basin would cover an area of approximately 84.9 acres along St. Johns Bayou, of 222 acres along Setback Levee Ditch, and of 102.3 acres along St. James Ditch.

(3) Type of Site/Habitat. A typical ditch in the project area consists of a straight, trapezoidal channel with a relatively flat, uniform bed devoid of substantial bar structures. Additional information can be found in Section 3.0 of the draft EIS. Other sites and habitats likely to be affected by the proposed fill activities are a mix of vegetated wetlands, agricultural areas (prior converted cropland and farmed wetlands), and WRP areas. Prior converted cropland constitutes a significant portion of the affected acreage. The remaining areas may experience modest decreases in function due to projected hydrologic changes in the project area.

(4) Timing and Duration. The timing and duration of construction is subject to the appropriation and availability of funds.

f. Description of Disposal Method. Various types of mechanical equipment (e.g., bulldozers and excavators) would be utilized to excavate, transport, and place material at the locations described.

II. Factual Determinations

a. Physical Substrate Determinations

(1) Substrate Elevation and Slope. The proposed box culvert in Mud Ditch would not impact ditch substrate elevation or slope. Channel enlargement reaches would result in channel deepening. Additional information regarding channel enlargement can be found in Section 4 of the draft EIS.

(2) Sediment Type. Sediments are comprised of a mixture of sand, silt, and clay.

(3) Dredged/Fill Material Movement. No foreseeable movement of dredge/fill material would be expected. Best management practices, such as silt fences, would be utilized during construction. In addition, the establishment of woody and grass riparian buffer strips would provide excellent erosion control.

(4) Physical Effects on Benthos. The effects on benthos are described in Section 4 of the draft EIS. Dredge/fill operations would physically remove much of the benthos within the

construction footprint. Re-colonization of the benthic zone would be expected to take place within a limited period of time.

(5) Other Effects. Additional effects, including indirect impacts associated with changes to flood frequency and duration are described in Section 4.0 of the draft EIS.

(6) Actions Taken to Minimize Impacts. Alternative 3.1 incorporates several avoid and minimize measures which reduce environmental impacts compared to the authorized project. The lower 3.7 miles of St. Johns Bayou would be excavated from the right descending bank only (channel enlargement typically involves excavation of both banks) and the proposed bottom width increase would be reduced from 200 feet to 120 feet. Excavated material would be placed in the project right-of-way along the right descending bank and would be allowed to re-vegetate naturally.

Setback Levee Ditch would be enlarged from one side (left descending bank) only. Therefore, existing riparian vegetation on the right descending bank would be preserved. Setback Levee Ditch previously had a high concentration of mussels along the right descending bank. However, based on recent surveys, this is no longer the case. Regardless, the right descending bank would be avoided. Therefore, this area would remain intact in case mussels re-colonize.

Rights-of-way along St. James Ditch would alternate sides to protect areas of riparian vegetation (*i.e.*, spoil material would be side-cast, where practical, into prior converted cropland (as opposed to vegetated areas)).

In addition to reducing direct impacts by enlarging channels from one side only, USACE proposes to implement a 40-foot grass buffer strip on one bank as an environmental design feature. Although grass buffers do not provide shade to the level of woody vegetation, in agricultural regions, grassy areas may be more effective in reducing bank erosion and trapping suspended sediments than wooded areas (Lyons 2000). In fact, Castle et al. (1994) reported that grass buffer strips as narrow as 15 feet trapped approximately 90 percent of NH_4-N, NO_3-N and PO_4-P, and that trapping efficiencies increased to between 96 percent and 99.9 percent when the buffer width was increased to 30 feet. Wolf (2009) also noted that switchgrass provides excellent erosion control when used as filter strips, grass hedges, or cover on levee banks.

The approximately 447 acres of borrow pits needed for fill material would be ecologically designed to benefit floodplain fisheries, as well as provide wetlands habitat.

In order to minimize impacts associated with closing the New Madrid Floodway, backwater flooding would be allowed up to prescribed elevations by leaving the to-be-constructed Mud Ditch outlet structure gates open, thereby maintaining a degree of connectivity with the Mississippi River that otherwise would be lost. Additional information can be found in Section 2 of the draft EIS.

b. Water Circulation, Fluctuation, and Salinity Determinations

(1) Water. The effects of material export vary considerably among the constituents of interest and between the two project areas, compared to what would likely occur were the authorized project not constructed and operated. Within the New Madrid Floodway, net average export of total phosphorus (TP) would be reduced by about 15-20 percent by alternative 3.1. However, in the St. Johns Bayou Basin, alternative 3.1 would cause little effect on TP export compared to what likely would occur were the authorized project not constructed and operated. Likewise, total nitrogen (TN) export associated with alternative 3.1 showed no discernible influence compared to alternative 2.1 in the St. Johns Bayou Basin, but in the New Madrid Floodway, alternative 3.1 would reduce average nitrogen export by about 15 percent compared to existing conditions. Likewise, implementation of alternative 3.1 in the St. Johns Bayou Basin would have little influence on organic carbon export, but in the New Madrid Floodway, alternative 3.1 reduces organic carbon export by about 40 percent compared to existing conditions. The pattern of sediment is similar to carbon. Alternative 3.1 has little influence on sediment export from the St. Johns Bayou Basin, but reduces sediment export from the New Madrid Floodway by about half.

(a) Salinity. Due to the location of the project area, salinity issues are not applicable.

(b) Water Chemistry. Water quality analysis conducted concludes that no expected change in water chemistry would result from project implementation.

(c) Clarity. No change in water clarity would be expected by implementation of the TSP.

(d) Color. No change in water color would be expected by implementation of the TSP.

(e) Odor. No change in water odor would be expected by implementation of the TSP.

(f) Taste. The ditches and bayou are not currently used as a municipal water supply, nor are they expected to be used as such. Therefore, the effect of project implementation on water taste is not applicable.

(g) Dissolved Gas Levels. No change would be expected in dissolved gas levels by implementation of the TSP.

(h) Nutrients. Aside from the water quality benefits described above, no change is expected in water nutrients by implementation of the TSP.

(i) Eutrophication. No change would be expected in eutrophication by implementation of the TSP.

(j) Others as Appropriate. Existing ditches undergo routine maintenance consisting of vegetation and sediment removal. Therefore, there is a limited amount of shade found in the ditches. Enlarging ditches would further remove the limited amount of stream bank vegetation and shade provided, which would increase water surface area. Both of these will cause some elevation of water temperature in the waterways. This effect is being minimized by working from one bank and leaving the vegetative cover on the other. In addition, material deposited along the banks of streams would be allowed to re-vegetate and remain as a conservation easement. Furthermore, the proposed vegetative riparian buffers would be expected to reduce sediment and nutrient loads from adjacent agricultural fields.

(2) Current Patterns and Circulation

(a) Current Patterns and Flow. It is anticipated that enlargement of ditches would increase flow capacity.

Although construction of the closure levee and box culverts would not alter flow during most of the year during non-flood stages, closure of the 1,500-foot gap in the Frontline Levee would limit the amount of flooding in the New Madrid Floodway. Additional information regarding project impacts can be found in Section 4 of the draft EIS.

(b) Velocity. Enlarging ditches would be expected to reduce channel roughness. Therefore, water velocity would be increased. However, mitigation features such as transverse dikes would be expected to provide a sinuous low flow channel and reduce velocity.

(c) Stratification. No stratification would occur in ditches beyond that which may normally take place under existing conditions.

(d) Hydrologic Regime. The hydrologic regime would be modified in the New Madrid Floodway. Additional information regarding project impacts to hydrological regimes can be found in Section 4 of the draft EIS.

(3) Normal Water Level Fluctuations. No changes to water fluctuation patterns are anticipated during non-flood periods. Closure of the levee and pumping stations would modify water level fluctuations. Further information is found in Section 4 of the draft EIS.

(4) Salinity Gradients. Due to the location of the project area, salinity issues are not applicable.

(5) Actions That Would Be Taken to Minimize Impacts. To minimize impacts associated with closing the New Madrid Floodway gap, a level of connectivity between the floodway and the Mississippi River would remain by allowing backwater flooding to reach prescribed elevations prior to closing the gates in the proposed Mud Ditch outlet structure,

operating the proposed pumping station, or both. Additional information can be found in Section 2 of the draft EIS.

c. Suspended Particulate/Turbidity Determinations

(1) Expected Changes in Suspended Particulates and Turbidity Levels in Vicinity of Disposal Site. No long term significant increase in suspended particulate levels or extended periods of turbidity would be expected. Discharge activities would increase turbidity during construction but return shortly thereafter to preconstruction levels.

(2) Effects on Chemical and Physical Properties of the Water Column.

(a) Light penetration. Excavation activities within ditches would temporarily increase turbidity within these waterways, thereby temporarily reducing light penetration. Conditions would return to preconstruction levels after completion of the proposed project. Construction activities to close the 1,500-foot gap in the Frontline Levee would be conducted during low water or dry periods, thus would have no effect on light penetration.

(b) Dissolved oxygen (DO). Deposition of excavated material into the wetlands or the waterways would not significantly affect DO levels. The re-suspension of reduced sediments may temporarily lower dissolved oxygen concentrations, but no long-term adverse effects would be anticipated.

(c) Toxic metals and organics. No significant long term impacts would be anticipated.

(d) Pathogens. There are no known pathogen problems in any of the waterways, thus no effect on pathogens would be expected.

(e) Aesthetics. No appreciable changes in aesthetics of the water column would be expected.

(f) Others as Appropriate. None expected.

(3) Effects on Biota.

(a) Primary production, photosynthesis. Excavation of the fill material would remove biota within the excavated areas, and placement of the material would cover any existing biota within the disposal sites. A minor setback in primary production would take place until vegetation reestablishes.

(b) Suspension/filter feeders. Excavation of the fill material would remove biota within the excavated areas. Based on the number and diversity of mussels reported in a 2010 survey for this project, it is expected that re-colonization would eventually take place, provided channel cleanouts are not frequent.

(c) Sight feeders. Noise and disturbance of project-related equipment would displace most fisheries and avian sight-feeders during construction. Habitat suitability would be temporarily reduced in the excavated reaches. After construction, fish and avian species would return to the areas and invertebrates would re-colonize the substrate.

(4) Actions Taken To Minimize Impacts. Alternative 3.1 incorporates actions to avoid and minimize impacts. Among these are reducing channel work in streams and ditches, reducing wooded wetlands impacts, and maintaining a level of connectivity between the Mississippi River and the New Madrid Floodway. Additional information can be found in Section 4 of the draft EIS.

d. Contaminant Determinations. The discharge of excavated material is not expected to introduce, translocate, or increase any contaminant.

e. Aquatic Ecosystem and Organism Determinations

(1) Effects on Plankton. Due to the location of the project area, impacts to plankton are not applicable.

(2) Effects on Benthos. Excavation for channel enlargement would remove biota within the excavated areas. No long term changes to benthos are anticipated. Additional information can be found in Section 4 of the draft EIS.

(3) Effects on Nekton. The nekton community of the project area consists primarily of fishes. Project impacts have been assessed based on various ecological models. In summary the project (without compensatory mitigation) would impact fish spawning and rearing habitat. Impacts to project area fishes can be found in Section 4 of the draft EIS.

(4) Effects on the Aquatic Food Web. Project impacts have been assessed based on various ecological models. In summary the project (without compensatory mitigation) would impact fish spawning and rearing habitat, winter waterfowl habitat, and spring/fall shorebird habitat. These effects are detailed in Section 4 of the draft EIS.

(5) Effects on Special Aquatic Sites.

(a) Sanctuaries and Refuges. There are no known sanctuaries or refuges within the project area.

(b) Wetlands. A combined total of approximately 418 acres of vegetated wetlands in the St. Johns Bayou Basin and New Madrid Floodway would be directly impacted by the project. Closing the New Madrid Floodway gap and operating pumping stations would indirectly impact wetlands. These impacts are discussed in Section 4 of the draft EIS. With mitigation, post-project vegetated wetland acres are expected to increase by roughly 2,351 acres in the St. Johns Bayou Basin, by 4,160 acres in the New Madrid Floodway, and 3,050 acres in the batture area.

(c) Mud Flats. Mud flats are not known to exist within the project area.

(d) Vegetated Shallows. Vegetated shallows are permanently inundated areas that under normal circumstances support communities of rooted aquatic vegetation, such as turtle grass and eelgrass in estuarine or marine systems, as well as a number of freshwater species in rivers and lakes. There are no known vegetative shallows in the project area.

(e) Coral Reefs. There are no coral reefs in the project area.

(f) Riffle and Pool Complexes. Riffle and pool complexes have not been identified within the project area. The typical agricultural ditch within the project area consists of a straight, trapezoidal channel with a relatively flat, uniform bed devoid of substantial bar structures.

(6) Threatened and Endangered Species. Consultation with the U.S. Fish and Wildlife Service (USFWS) is on-going.

(7) Other Wildlife. Impacts to terrestrial wildlife, including qualitative assessments to reptiles and amphibians are described in Section 4.0 of the draft EIS.

(8) Actions to Minimize Impacts. Alternative 3.1 incorporates actions to avoid and minimize impacts. Among these are reducing channel work in streams and ditches, reducing vegetated wetlands impacts, and maintaining a level of connectivity between the Mississippi River and the New Madrid Floodway as detailed in Section 4 of the draft EIS.

f. Proposed Disposal Site Determinations

(1) Mixing Zone Determination. The mixing zone is not anticipated to exceed criteria outlined in the State of Missouri water quality standards (10 CSR 20-7.031).

(2) Determination of Compliance with Applicable Water Quality Standards. The analysis conducted by Soballe and Ashby (2012) concluded that the effects of the proposed project on Mississippi River water quality would not be discernible. This was based on several lines of evidence; including (1) the ratio of project outflow volume to Mississippi River flow volume (< 1 percent), (2) the finding that the project would reduce the material load from the project area to the river relative to the existing condition, and (3) the finding that the project area would likely exhibit a net retention and processing of material that enters it from the Mississippi River, although this could be a small net loss of retention relative to the existing condition (See draft EIS, Section 4.0). Water quality certification would be obtained from Missouri prior to project construction.

(3) Potential Effects on Human Use Characteristics.

(a) Municipal and private water supply. The ditches and bayous in the project area are not currently used as a municipal water supply, nor are they expected to be used as such; therefore, effects on municipal and private water supplies are not anticipated.

(b) Recreational and commercial fisheries. No substantial commercial fishing takes place in the St. Johns Bayou Basin or New Madrid Floodway. Recreational fishing in streams and ditches is minimal due to low flows in most ditches. Closing the New Madrid Floodway gap is not expected to greatly impact fish species that use streams and ditches there, since the proposed Mud Ditch outlet structure would remain open for most of the year and because it is reasonable to expect that fish will navigate the structure.

(c) Water-related recreation. Other than fishing, aquatic recreation is essentially nonexistent within the study area. There are no recreational or commercial fisheries whose suitability for that use will be impacted by the project. Very little sight-seeing or canoeing occur in the area outside existing recreational areas and no negative impact to those areas are expected post-project. Excavated and fill material would not be placed in or near recreational areas such as Big Oak Tree State Park or Tenmile Pond nor would they hinder any recreational activities.

(d) Aesthetics. Construction activities would temporarily affect existing viewshed in the project area. Placement of fill material would cover vegetation with less aesthetically pleasing earthen material. These areas would be allowed to naturally re-vegetate and eventually would likely exceed pre-construction aesthetic values.

(e) Parks, National and Historical Monuments, National Seashores, Wilderness Areas, Research Sites, and Similar preserves. None found within the project construction rights-of-way (ROW). However, through compensatory mitigation, alternative 3.1 would restore hydrology to Big Oak Tree State Park, which has been designated a National Natural Landmark by the National Park Service, a Missouri Natural Area by the State of Missouri, and contains a number of current and past state and national champion trees by American Forests, a nonprofit conservation organization.

(g) Determination of Cumulative Effects on the Aquatic Ecosystem. Forest once covered 93% of the project area (Heitmeyer 2010). When comparing historic vegetation communities/habitat types to current conditions, the project area has already been drastically changed due to land clearing and farming operations and due to construction of levees and drainage systems for agricultural purposes. Despite the extent of these impacts, the project area has restoration potential that could be achieved through proposed mitigation measures (see draft EIS, Section 4.0). No further land clearing is expected after the project is completed and with mitigation, there will be more vegetated areas in the aquatic ecosystem than if the project is never implemented.

(h) Determination of Secondary Effects on the Aquatic Ecosystem. The proposed project would indirectly affect approximately 6,678 acres and 9,572 acres of vegetated wetlands lying within the 5-year floodplain (without the proposed project) in the St. Johns Bayou Basin and New Madrid Floodway, respectively. In addition, there would be indirect impacts to the 792 acres and 306 acres of farmed wetlands in the St. Johns Bayou Basin and New Madrid Floodway, respectively. Alternative 3.1 minimizes indirect impacts by incorporating water management options that would maintain connectivity between the Mississippi River and wetlands in the New Madrid Floodway. Compensatory mitigation is based on impacted wetlands functions, expressed as FCU, not on acreage. Tables 3 and 4 illustrate mitigation necessary to compensate for unavoidable impacts to wetlands for alternative 3.1.

Table 3. St. Johns Bayou Basin impacts and mitigation necessary to compensate for impacts. Mitigation assumes small tracts of LGRB.

	Impacts (FCU)		Mitigation (acres)	
Function	LGRB	LGRO	LGRB	LGRO
Detain Flood Water	-116	-397	**201**	**623**
Detain Precipitation	0	-307	0	340
Cycle Nutrients	0	-344	0	552
Export Organic Carbon	-115	-319	164	519
Maintain Plant Communities	-50	-374	67	573
Provide Fish and Wildlife Habitat	0	-210	0	476

Table 4. New Madrid Floodway impacts and mitigation necessary to compensate for impacts. Mitigation assumes large tracts of LGRB.

	Losses in FCU			Gains in FCU		Mitigation (acres)		
Function	LGRB	LGRO	CD	Flats	UCD	LGRB	LGRO	CD
Detain Flood Water	-3,487	-35	-97	NA	NA	**5,828**	55	161
Detain Precipitation	-2,423	0	0	1,910	NA	2,619	0	NA
Cycle Nutrients	-2,092	0	-94	2,088	110	2,899	0	141
Export Organic Carbon	-3,558	-35	-118	NA	NA	4,929	**57**	182
Maintain Plant Communities	-2,582	-35	-124	2,183	113	3,511	52	**215**
Provide Fish and Wildlife Habitat	-1,970	-12	-89	1,616	71	3,356	26	152

A total of 6,924 acres of wetlands mitigation may be needed to comply with the Clean Water Act.

It is estimated that 2,724 acres and 8,406 acres of wetlands would be restored in the St. Johns Bayou Basin and New Madrid Floodway, respectively, were alternative 3.1 selected. As illustrated in Tables 5 and 6, the functional value of wetlands will increase under alternative 3.1. A summary of wetland compensation benefits associated with several mitigation methods is provided in Section 6 of the draft EIS.

Table 5. Alternative 3.1 compensatory mitigation zone gains to wetlands expressed as FCU in St. Johns Bayou Basin.

Mitigation Zone	HGM Subclass	Acres	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Fish & Wildlife Habitat
BLH Restoration <285'	LGRB	400	232	372	288	280	300	108
BLH Restoration <5-year	LGRB/LGRO[1]	1193/623	690/396	638/562	859/450	835/437	891/467	315/373
Riparian Buffer Strips (Woody)	LGRO	70	44	63	43	43	46	31
Riparian Buffer Strips (Grass)	LGRO	N/C	N/C	N/C	N/C	N/C	N/C	N/C
Ecologically Designed Borrow pits	CD[2]	194	37	N/A	81	76	29	29
Seasonally Inundated Farmland		244	N/C	N/C	N/C	N/C	N/C	N/C

[1]Depending on location, mitigation could be LGRO or LGRB. However for the purpose of this table, 623 acres were assumed to be LGRO. Regardless, a minimum of 397 LGRO FCU is required to compensate for impacts to jurisdictional wetlands.
[2]Borrow pits would be designed so that half of each pit would have an average depth of less than three feet. Wetland vegetation is expected. 387 acres are proposed. Therefore, 194 acres of wetland functions would be provided.
N/A – not applicable
N/C – not calculated but would be calculated during the completion of site specific detailed mitigation plans, if applicable and necessary.

Table 6. Alternative 3.1 compensatory mitigation zone gains to wetlands expressed as FCU in the New Madrid Floodway.

Mitigation Zone	HGM Subclass	Acres	Detain Floodwater	Detain Precipitation	Cycle Nutrients	Export Organic Carbon	Maintain Plant Communities	Fish & Wildlife Habitat
Big Oak Tree State Park	LGRB	976	966	976	869	1044	957	761
Big Oak Tree State Park	CD	49	41	NA	33	41	48	35
Big Oak Tree State Park Surrounding Land	LGRB	1,800	1076	1665	1300	1300	1366	1078
BLH Restoration <285'	LGRB	387	232	360	279	279	286	228
BLH Restoration <5-year	LGRB	1,970	1,182	1,832	1,418	1,418	1,457	1,162
Batture Land Reforestation	LGRB	2,800	1,952	1,769	2,592	1,860	2,043	1,403
Batture Land Reforestation	LGRO	250	159	226	156	154	167	111
Ecologically Designed Borrow pits	CD[2]	30	6	N/A	20	20	17	18
Seasonally Inundated Farmland	tbd	1,286	N/C-tbd	N/C-tbd	N/C-tbd	N/C-tbd	N/C-tbd	N/C-tbd
Ten Mile Pond CA	tbd	1,917	N/C - tbd	N/C-tbd	N/C-tbd	N/C-tbd	N/C-tbd	N/C-tbd
Floodplain Lake Restoration	CD[3]	144	84	N/A	96	91	91	87

[1] Impacts are combined by summing across all agricultural lands, forested areas, and future WRP sites as well as LGRB, LGRO, CD, and UCD wetland types. Note there were impacts and gains to some categories. The value in the table is the sum of all categories. [2]Borrow pits would be designed so that half of each pit would have an average depth of less than three feet. Wetland vegetation is expected. 60 acres are proposed. Therefore, 30 acres of wetland functions would be mitigated. [3]Similar to borrow pits, it is assumed that one third of restored floodplain lakes would have an average depth of less than three feet. Wetland vegetation is expected. 432 acres of floodplain lakes are anticipated. Therefore, 144 acres of CD are expected.

N/A – not applicable, N/C – not calculated, tbd – to be determined during the development of site specific detailed mitigation plans.

III. Findings of Compliance for the Proposed Project

1. No substantial adaptations to the Guidelines, 40 C.F.R. part 230, were made for purposes of this evaluation, as per Engineer Regulation 1105-2-100, Appendix C.

2. Eight alternatives were carried forward for detailed analysis in the draft EIS. This range of alternatives, as described in Section 2 of the draft EIS, is the starting point for USACE's practicability analysis under the Guidelines. The alternatives are evaluated to determine which are practicable, and of those which is the least environmentally damaging. 40 C.F.R. § 230.10(a) states that "no discharge of dredged or fill material shall be permitted if there is a practicable alternative to the proposed discharge which would have less adverse impact on the aquatic ecosystem, so long as the alternative does not have other significant adverse environmental consequences. A practicable alternative, as defined in 40 C.F.R. § 230.10 (a)(2), is one that is "available and capable of being done after taking into consideration cost, existing technology, and logistics, in light of overall project purposes." Alternatives that do not meet the purposes of the proposed project are not practicable. Additionally, the Guidelines presume that practicable alternatives are available for projects that do not involve special aquatic sites, but do not presume that practicable alternatives are available for projects that are water dependent.

The statutory authorizations for and the objectives of the proposed project, as enumerated in Section 1 of the draft EIS, comprise the fundamental, essential or irreducible, i.e., basic, purpose of the proposed project, and are used to determine whether the project is water dependent under the Guidelines. A project is water dependent if it requires access or proximity to or siting within a special aquatic site to fulfill its basic purpose. The basic project purpose for the St. Johns Bayou-New Madrid Floodway project is to improve the means and methods of preventing and controlling destructive floodwaters in the project area. Both the St. Johns Bayou Basin and the New Madrid Floodway contain special aquatic sites, including wetlands and other areas defined in 40 C.F.R. part 230, subpart E, which the proposed project will likely affect.

The flood risk reduction improvements proposed to be constructed in St. Johns Bayou Basin and in the New Madrid Floodway must, in order to serve their intended purposes, achieve project objectives, and satisfy legal and policy requirements, be placed in proximity to, or be sited within, special aquatic sites, and the reasonably foreseeable impacts of the proposed project will unavoidably affect special aquatic sites. Section 2 of the draft EIS explains that no practicable alternatives were identified that would not impact special aquatic sites directly or indirectly. While alternatives such as relocations, buy-outs, ring levees, and conversion to flood tolerant crops were considered, none of those alternatives were shown to be reasonable and feasible, or practicable.

This practicability determination is not based on whether the cost of the proposed project is substantially greater than the cost normally associated with other similar projects. Rather practicability in this case is based on a benefit-to-cost ratio, much in the same way that profitability is determined for commercial development. USACE regulations that require all flood risk management civil works projects have a minimum benefit-to-cost ratio of 1.0, without which a project cannot be recommended for construction.

As approved by Congress, the overall purpose of the St. Johns Bayou-New Madrid Floodway project is to reduce the likelihood and adverse effects—on agricultural and urban lands—of backwater and headwater flooding in both the New Madrid Floodway and in the St. Johns Bayou Basin. The project purpose thus requires reduction of flood risk and flood damage in both basins. Accordingly, single-basin-only alternatives (Alternatives 2.1 and 2.2) are not practicable; they satisfy only a portion of the proposed project's purpose.

As described in Section 2 of the draft EIS, alternatives that did not have the required positive benefit-to-cost ratio were not carried forward for analysis. All of these were not practicable in terms of cost. Technology, however, was not a limiting factor. All alternatives were capable of being accomplished without technological constraints.

Logistics, on the other hand, expressed in terms of the availability of suitable mitigation land, was a limiting factor in the case of one alternative. Alternative 4.2 is not reasonably likely to be successful because it is not realistic to expect that 13,340 acres can be acquired in the New Madrid Floodway below the 289.5-foot elevation.

All other alternatives are considered practicable, but none of the four are clearly the least environmentally damaging. All of these alternatives appear to be mitigable to below the threshold of significance. Alternative 2.3 has the most impacts on LGRB, LGRO and CD wetlands. Alternative 4.1 has the fewest impacts on LGRB and CD wetlands, while Alternative 3.1 has the fewest impacts on LGRO wetlands.

Alternative 3.1, the TSP, is demonstrably the most practicable in light of all relevant factors. It avoids and minimizes impacts, provides adequate compensatory mitigation, and produces the greatest national economic benefit. A summary of the practicability criteria is summarized in Table 7.

Table 7. Practicability Analysis of Alternatives 2.3, 3.1., 3.2, 4.1, and 4.2.

Practicability Criteria	Alternative 2.3	Alternative 3.1	Alternative 3.2	Alternative 4.1	Alternative 4.2
Project purpose (total acres reduced flooding)	55,193	46,248	48,145	41,883	41,883
average day roads are innudated	17.4 SJB/0 NMF	11.9 SJB/0 NMF	11.9 SJB/0 NMF	11.9 SJB/0.2 NMF	11.9 SJB/ 0.2 NMF
meets project purposes	yes	yes	yes	yes	yes
Cost criteria					
total first costs ($000s)	200,616	164,779	178,429	151,357	179,619
excess annual benefits	7,101	8,252	8,125	8,228	6,367
differences compared to TSP	1,151	0	127	24	1,885
meets cost criteria	yes	yes	yes	yes	yes
Availability/logistics criteria					
acres of non-mitigation acquisition	0	0	0	0	reforest 13,340 acres below 289.5
meets logistics criteria	yes	yes	yes	yes	no
environmental criteria					
wetlands impacts LGRB detain floodwater FCU	-6,565	-3,598	-4156	-3,024	-75
wetlands impacts CD maintain plant communities FCU	-839	-432	-432	-583	-583
wetlands impacts CD maintain plant communities FCU	-179	-124	-138	-108	-196
overall practicability determination	yes	yes	yes	yes	no

3. A request for state water quality certification would be submitted to the Missouri Department of Natural Resources for the planned action.

4. The Toxic Effluent Standards of section 307 of the Clean Water Act would not be triggered.

5. Consultation with USFWS, regarding the endangered Internal Least Tern, is on-going. Additional measures may be taken according to any Biological Opinion issued by USFWS.

6. The proposed disposal of dredged material would not likely result in significant adverse effects on human health or welfare, municipal or private water supplies, recreational or commercial fishing, plankton, fish, shellfish, wildlife, or special aquatic sites. Further, in light of proposed mitigation, significant adverse effects would not likely occur to aquatic ecosystem diversity, to productivity and stability, or to recreational, aesthetic, and economic values. And finally, no other adverse environmental consequences are foreseeable, were alternative 3.1 selected. Additional information on impacts can be found in Section 4 of the draft EIS.

7. The proposed disposal sites for the discharge of dredged material comply with the requirements to include appropriate and practical conditions to minimize pollution and adverse effects on the aquatic ecosystem.

IV. Evaluation Responsibility

a. Water Quality Input Prepared by: Joshua M. Koontz

b. Project Description and Biological Input Prepared by: Joshua M. Koontz

_____ _____

Date

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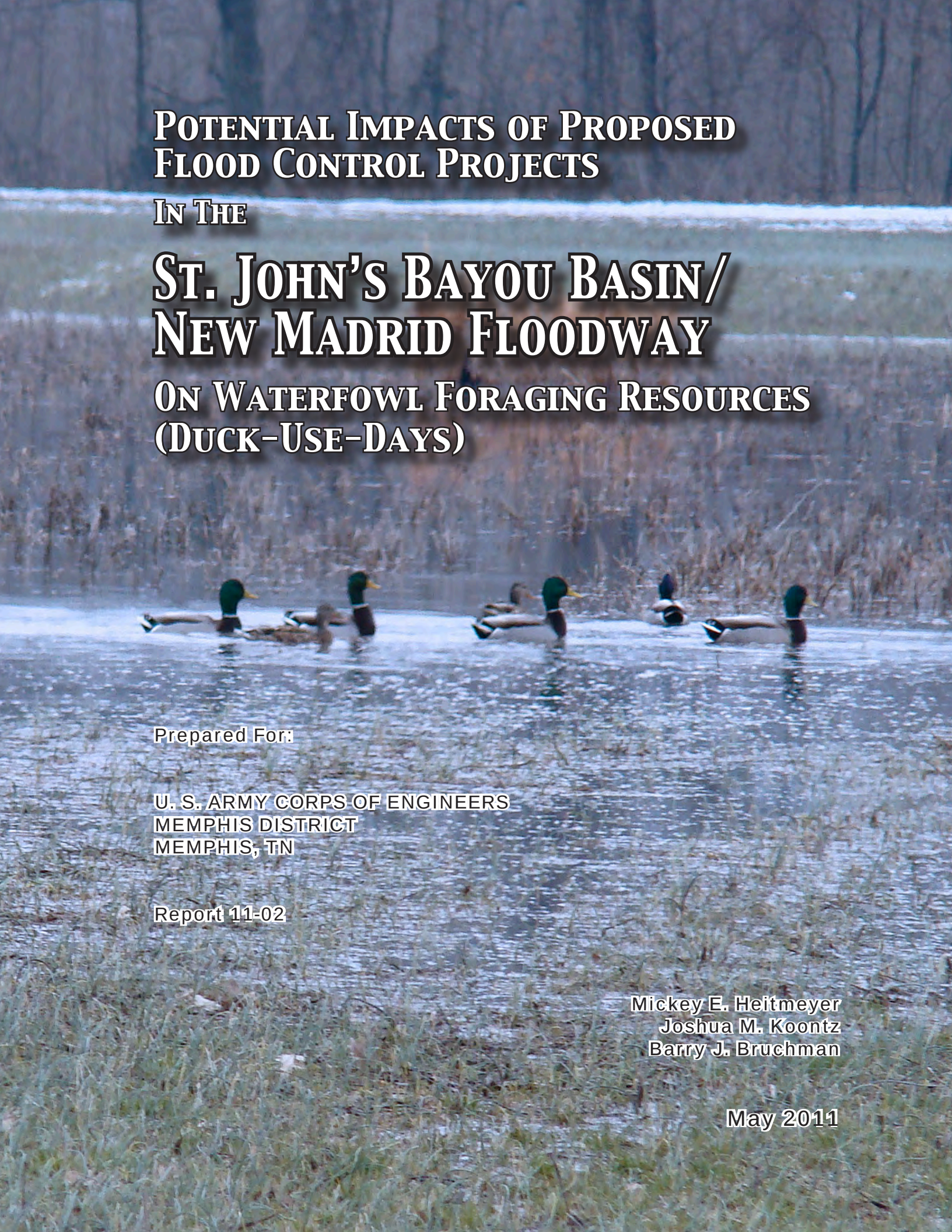
Appendix F
Part 1

Waterfowl Impacts

U.S. Army Corps of Engineers
Memphis District



Potential Impacts of Proposed Flood Control Projects In The St. John's Bayou Basin/ New Madrid Floodway On Waterfowl Foraging Resources (Duck-Use-Days)

Prepared For:

U. S. ARMY CORPS OF ENGINEERS
MEMPHIS DISTRICT
MEMPHIS, TN

Report 11-02

Mickey E. Heitmeyer
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May 2011

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POTENTIAL IMPACTS OF PROPOSED FLOOD CONTROL PROJECTS IN THE ST. JOHN'S BAYOU BASIN/NEW MADRID FLOODWAY (SJNM) ON WATERFOWL FORAGING RESOURCES (DUCK-USE-DAYS)

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INTRODUCTION AND BACKGROUND

The U.S. Army Corps of Engineers (USACE) proposed St. John's Bayou Basin (SJBB) and New Madrid Floodway (NMF) Project includes lands in the St. John's Bayou Basin, New Madrid Floodway, and Mississippi River Batture in portions of Scott, New Madrid, and Mississippi counties in southeastern Missouri (combined project area hereafter referred to as SJNM). Project alternatives contain works to protect over 400,000 acres of mostly agricultural land in the region from frequent backwater flooding from the Mississippi River and to reduce impounded interior runoff in the St. John's Bayou Basin in the vicinity of East Prairie, Missouri. The project also seeks to manage water to enhance natural resource conservation values and recreational opportunities using infrastructure that would be constructed for the project through various water management techniques/strategies.

Three major project alternatives have been identified for the SJNM including:

1. No Action

The No Action alternative includes two subalternative components:

1.1. Existing condition
1.2 . Future enrollment of WRP without (w/o) the project

The existing gravity outlet structure at the lower end of the St. John's Bayou Basin would continue to be operated in a manner that prevents backwater flooding from the Mississippi River. Impounded interior runoff would continue to occur when gates are closed at specified Mississippi River elevations. The gap at the lower end of the New Madrid Floodway would remain open, allowing Mississippi river backwater to enter the Floodway and inundate parts of the area. Operation of the New Madrid Floodway would continue as authorized during large flood events.

The future w/o condition anticipates certain changes to the SJNM region that includes projected future enrollment of flood-prone agriculture lands into the USDA Wetland Reserve Program (WRP).

2. Authorized Project (St. John's Bayou Basin and New Madrid Floodway, Phase I and New Madrid Floodway Closure)

Alternative 2 includes three subalternative components

2.1. St. John's Bayou Basin Improvements Only
2.2. New Madrid Floodway Improvements Only
2.3. Combined 2.1 and 2.2 Projects

These alternatives would variously enlarge and improve drainage along St. John's Bayou; construct a 1,000 cfs pumping station east of the existing gravity flow outlet at the lower end of St. John's Bayou; construct a 1,500 cfs pumping station in the New Madrid Floodway; close the 1,500-foot levee gap at the lower end of the New Madrid Floodway; construct gated box culverts in Mud Ditch; and construct other minor levee, ditch, and water-control features. Water management would impound interior runoff from December through January to provide waterfowl and other wildlife habitat.

3. Authorized Project with Avoid and Minimize Measures

Alternative 3 includes two subalternative components

3.1. Management Scenario 1
3.2. Management Scenario 2

Under this alternative, the authorized project would be constructed, and water-control structures and other infrastructure would be strategically managed to reduce flood risks association with the flood pulse while minimizing environmental damages. Because the project area currently is a highly manipulated environment, management of water-control infrastructure and pumps could restore lost ecological functions to the project area that currently are caused by anthropogenically induced flood regimes.

Scenario 1 would have the following management (numbers are NAVD88 elevation feet amsl)

Date	Close Gate	Start Pump	Stop Pump
15 Nov – 28 Feb	287.5	289.5	288
1 Mar – 15 Apr	286	288	287
16 Apr – 30 May	284	284	282
1 June – 14 Nov	278.5	279.5	278.5

Scenario 2 would have the following management (numbers are NAVD88 elevation feet amsl)

Date	Close Gate	Start Pump	Stop Pump
15 Nov – 28 Feb	287.5	289.5	288
1 Mar – 15 Apr	284	286	285
16 Apr – 30 May	282	282	280
1 June – 14 Nov	278.5	279.5	278.5

The purpose of this report is to calculate potential impacts of the above proposed SJNM project alternatives and water management scenarios on Duck-Use-Days (DUD) for the effected project area using certified DUD calculation models (Heitmeyer 2010a, hereafter "DUD Manual").

METHODS

This report uses methods and formulas provided in the Heitmeyer (2010a) DUD manual to determine energetic requirements of waterfowl and the availability of foods in various habitat types in the SJNM. All calculations were conducted to annualize DUD effects through 100-year flood frequency events.

Data inputs to the DUD Manual used in analyses of SJNM Project Alternatives were:

1. Elevations (NAVD88) that correspond to contemporary 1-, 2-, 5-, 10-, 25-, 50- and 100-year return interval flood recurrence were determined for November (Nov), December-January (Dec-Jan), and February-March (Feb-Mar) time periods for existing and project Alternative conditions in the SJBB and NMF, separately Appendix A) All flood recurrence interval elevations were based on at least 3 consecutive days of flooding, per the 2010 DUD manual. The data separation into Nov, Dec-Jan, and Feb-Mar categories cover the period of time when waterfowl are present in the SJNM and consistently compare project alternatives relative to proposed project operation schedules.

2. Acres of 11 habitat types within the above flood frequency elevation zones, month period, and SJBB and NMF areas were determined and differences between available (flooded) habitat areas in the project Alternatives were determined (Appendix A). Habitat categories were: 1) Corn, 2) Rice, 3) Soybeans, 4) Fallow Cropland, 5) Cypress-Tupelo Forest (C-T), 6) Bottomland Hardwood Forest (BLH), 7) Floodplain Forest, 8) Grassland/Pasture, 9) Seasonal Herbaceous Wetland

(SHW), 10) Open Water/Aquatic (OW-AQ), and 11) Shrub/Scrub (S/S). Descriptions of these habitats are provided in Heitmeyer (2010b, and USACE documents for the project area. Other land cover types in the SJNM included small amounts of developed lands (such as roads, residences, building sites, cities, etc.) and other agricultural lands including winter wheat and cotton (Appendix A). These land cover categories were not analyzed for DUDs because they do not provide significant available waterfowl food sources (e.g., cotton, developed lands) or they do not require flooding for waterfowl use. For example, winter wheat provides browse used mainly by dry-land grazing geese in the SJNM and foraging on this browse does not require flooding (in fact flooding may actually reduce or eliminate wheat browse value depending on depth and timing of flooding).

Forest area in the SJNM was separated into C-T, Floodplain Forest, and BLH categories based on historic and remnant presence of forest types within flood frequency zones of the SJNM. Annualized contemporary flood frequency contour maps (Fig. 1) and potential historic vegetation community maps (Fig. 2) were used to separate relative distribution of forest types into the following percentages:

Flood frequency zone	C-T	Floodplain Forest	BLH
1-Yr	100%	-	-
2-Yr	50%	50%	-
5-Yr	25%	25%	50%
10-Yr	10%	20%	70%
25-Yr	5%	15%	80%
50-Yr	-	-	100%
100-Yr	-	-	100%

Consequently, all forest area in the 1-Yr flood frequency zone was considered C-T; forest area in the 2-Yr flood frequency zone was 50% C-T and 50% Floodplain forest; and so on.

3. Food and energy values for the above 11 habitat types, by month period and flood frequency zone, were determined from the DUD manual. These energy values were standardized to a consistent daily existence energy (DEE) for a mallard (1 mallard DEE = 452.44 kcal/day) and divided by the number of acres affected by project Alternatives (Appendix A) to determine the potential DUDs/acre/month period/habitat type/flood frequency zone (Appendix B).

(Note: If total kcal available energy is desired, Appendix B figures can be multiplied by 452.44 to determine total potential kcal/acre.).

The basic formula for calculation energy values was formula #1 from the DUD manual:

$$\textbf{Species}_{1...m}\textbf{DUD} = \frac{\sum(F_{1..j})(T_{1...l})}{D_{1...m}}$$

Where,

F = the potential food yield (g/ha) for food types $_{1...j}$ in the habitat type $_{1...k}$
T= TME (kcal/g) of specific food types $_{1...l}$
D= DEE of species $_{1...m}$ in kcal/day and is 4x RMR
RMR = $100.7W^{0.74}$
And, W = weighted body mass of species $_{1...m}$ in kg

As an example calculation of potential food value for a habitat type (corn), month periods, and food frequency elevation zone, the below calculations indicate the data methodology:

			Kcal/ha[d]		
Food Type[a]	kg/ha[b]	TME[c]	Nov	Dec-Jan	Feb-Mar
HSD	10	2.50	17,500	13,740	8,750
INV	20	3.50	7,000	24,500	52,500
Corn	290	3.67	425,720	266,075	159,645
Total			450,220	303,900	220,895

DUD/ha for a mallard (divided by DEE= 452.44)	995.1	671.7	488.2
DUD/ha in the 2-Yr Flood Frequency Zone (divided by 0.5)	497.5	335.8	244.1
DUD/acre (multiplied by 0.892 conversion Ha to acre	443.8	299.5	217.7

[a] HSD = herbaceous seeds, INV = invertebrates, Corn = corn seeds.
[b] From Table 10 of the DUD Manual, except that INV is 20 kg/ha based on recent food availability studies in harvested crop fields in southern Illinois.
[c] From Table 16 of the DUD Manual.
[d] Food availability % used in determining food/month from Table 14 of the DUD Manual.

4. DUD amounts for Alternative 1.1 (Existing condition) were calculated and then differences (losses or gains) between Alternative 1.1 and Alternatives 1.2, 2.1, 2.2, 2.3, 3.1, and 3.2 were calculated by habitat type, time period, flood frequency zone, and SJBB and NMF areas (Appendix C).

5. Acres of BLH and SHW (such as moist-soil impoundments) needed to compensate for losses in DUD's (or that were potentially gained if differences were positive) were determined using the below food availability/energy estimates/acre (from the DUD Manual) for these habitats and month periods:

Month Period	Potential DUD acre in managed BLH	Potential DUD acre in managed SHW
November	1,839.00	4,978.60
Dec-Jan	1,935.30	4,149.72
Feb-Mar	1,519.89	3,210.40

RESULTS

St. John's Bayou Basin

Based on the above methodology of calculating DUD's, the SJBB currently has the potential to support about 6 million DUD's (Table 1), most of which occurs from December through March. The largest DUD amounts are within the 2-, 5-, and 10-year flood frequency zone. BLH in the 5-year zone contributes 909,468 DUD's in the combined Dec-Mar period, which is 14.8% of the total (Appendix C).

Future projected increases in WRP acreage, without the project, would potentially add 860,786 DUD's to the SJBB (Table 1); the largest increase would be gains in BLH in the 5-year flood frequency zone and SHW in the 2- and 5- year zones (Appendix C)

The authorized project in the SJBB alone would provide a net increase in DUD's by nearly 600,000 (Table 1). This increase is caused by a large gain in flooded C-T, Floodplain Forest, Open Water, and SHW in the 1- and 2-year flood frequency zones during Dec-Jan when the flood-control gates are closed and water is impounded behind the gates, when otherwise water would drain into the relative low stage Mississippi River. During Feb-Mar, the authorized project includes pumping interior runoff from the SJBB, which reduces flooded area and DUDs by 909,565 (Table 1). The primary lost DUD amount in Feb-Mar is caused by reduced flooding in BLH and soybean acreage in the 5-year flood frequency zone.

When the lost/gained DUD's are considered relative to the equivalent amount of waterfowl food and acres of BLH or SHW that would be potentially be gained or lost from the project alternatives, the without project would gain an equivalent of 519.7 acres of BLH or 231.3 acres of SHW, respectively and the authorized project would gain an equivalent of 178.1 or 83.8 acres of BLH or SHW, respectively for all months combined Nov-Mar (Table 2). If specific month periods are considered, then the primary lost DUD acreage value from the authorized project would be equivalent to 598.4 or 283.3 acres of BLH and SHW, respectively in Feb-Mar.

New Madrid Floodway

Total existing DUD's in the NMF are about 13.5 million (Table 3). The largest amounts of existing DUD's are from soybean acreage in the 2-, 5-, and 10-year flood frequency zones during Feb-Mar. While soybean land has low food availability compared to most other habitat types (Appendix B), the large total soybean acreage in the NMF ultimately contributes large amounts of DUD's (Appendix C). BLH acres in the 5- and 10-year zones also contribute large amounts of existing DUD's during the combined Dec-Mar period (Appendix C).

Future projected increases in WRP acreage in the NMF without the project would potentially increase DUD's by almost 800,000 (Table 3). Most of this increase is from new BLH in the 5- and 10-year flood frequency zones and SHW in the 2- and 5-year zones (Appendix C).

The authorized project in the NMF (Alternative 2.2) has little loss of DUD's in Nov, moderate loss of DUD's during Dec-Jan, and large DUD losses during Feb-Mar (Table 3). DUD's are actually gained from Alternative 2.2 during Dec-Jan in the 1- and 2-year flood frequency zones, (Appendix C), but are lost during all other months and flood frequency zones. The greatest DUD losses are from reduced flooding of BLH in the 5- and 10-year zones from Dec-Mar and reduced flooding in soybean acreage in the 2-, 5-, and 10-year zones (Appendix C).

DUD losses in the avoid-and-minimize Alternatives 3.1 and 3.2 are 48% and 44% less than in Alternative 2.2 (Table 3). Alternatives 3.1 and 3.2 have relatively low and similar losses in DUD's during Nov and Dec-Jan, but have large losses during Feb-Mar when closed flood-control gates prevent backwater flooding from the Mississippi River into the NMF. As with Alternative 2.2, the largest losses in DUD's during Feb-Mar are caused by reduced flooding of soybean acreage in the 2-, 5-, and 10-year flood frequency zones and reduced flooding of BLH in the 5- and 10-year zones. Reduced flooding of C-T and Floodplain Forest in the 2-year zone also is substantial.

Future WRP without the project would increase DUD's equivalent to 463.1 acres of BLH or 216.2 acres of SHW, respectively (Table 4). In other alternatives, losses in DUD's would be equivalent to 5,533.9, 2946.9, and 3,188.1 acres of BLH, respectively in Alternatives 2.2, 3.1. and 3.2. Similar equivalent losses in DUD's for SHW would be 2,609.7, 1,393, and 1,507 acres of SHW in Alternatives 2.2, 3.1, and 3.2, respectively.

DISCUSSION

The DUD Manual methodology of calculating potential DUD's within the SJNM provides a certified and validated way to evaluate the waterfowl carrying capacity of the region (the Existing Condition DUD's) and potential changes that might occur under various project alternatives. These data then can be used to determine relative losses/gains under the different alternatives and what, if any, mitigation might be needed to compensate for losses. The gains and losses also can be determined relative to specific areas (SJBB and NMF), month periods, habitat types, and flood frequency zones.

In general, the DUD analyses provided in this report indicate:

1. Both the SJBB and NMF potentially can support large numbers of waterfowl from December through March; DUD potential in November is relatively low because of low average rainfall and runoff and extremely rare backwater flooding from the Mississippi River during November.

2. Future projected increases in WRP acreage would potentially increase DUD's in both the SJBB and NMF by about 800,000 to 850,000 DUD's.

3. The authorized project has the potential for a net gain (all month periods combined) of 598,243 DUD's in the SJBB, primarily because of large increases in flooding during Jan-Dec caused by closing flood-control gates and allowing water to impound mainly in the 1-, 2-, and 5-year flood frequency zones. This increase occurs because little natural overbank flooding from the Mississippi River occurs in the SJNM during December and January. The authorized project also increases DUD's in the NMF in the 1- and 2-yr flood frequency zones in Dec-Jan, but is countered by larger losses in higher elevation flood frequency zones during these months. In both the SJBB and NMF, the authorized project causes losses in DUD's during Feb-Mar.

4. The largest losses of DUD's in the SJNM occur during Feb-Mar in the NMF from the authorized project. Avoid-and-minimize Alternatives 3.1 and 3.2 reduce total net DUD losses by 48% and 44% compared to Alternative 2.2.

5. The amount of BLH and SHW acres that would be needed to compensate for lost DUD's range from 1,507.2 acres of SHW under Alternative 3.2 to 5,533.9 acres of BLH in the NMF under Alternative 2.2.

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TABLES

Table 1. Duck-use-day (DUD) analyses for the St. John's Bayou Basin comparing DUD's in the existing condition (Alternative 1.1) and gains (+) or losses (-) in DUD's without the project (but with future WRP projections) (Alternative 1.2) and with the authorized project (Alternative 2.1).

Month Period	Alt. 1.1 Existing condition	Alt. 1.2 Δ Without project	Alt 2.1 Δ Authorized project
November	218,166	+7,375	-93,549
Dec-Jan	2,335,420	+326,128	+1,601,357
Feb-Mar	3,606,117	+527,283	-909,565
All months combined	6,159,603	+860,786	+598,243

Table 2. Acres of Managed Bottomland Hardwood Forest (BLH) or Seasonal Herbaceous Wetland (SHW) potentially gained (-) or lost (-) based on the Duck-use-day (DUD) analyses for the St. John's Bayou Basin comparing DUD's in the existing condition and gains (+) or losses (-) in DUD's without the project (but with future WRP projections) (Alternative 1.2) and with the authorized project (Alternative 2.1).

Month period and habitat	Alt. 1.2 Δ Without project	Alt. 2.1 Δ Authorized project
November		
BLH	+4.3	-50.9
SHW	+1.6	-18.8
Dec-Jan		
BLH	+168.5	+827.4
SHW	+65.5	+385.9
Feb-Mar		
BLH	+346.9	-598.4
SHW	+164.2	-283.3
All months combined		
BLH	+519.7	+178.1
SHW	+231.3	+83.8

Table 3. Duck-use-day (DUD) analyses for the New Madrid Floodway comparing DUD's in the existing condition (Alternative 1.1) and gains (+) or losses (-) in DUD's without the project (but with future WRP projections) (Alternative 1.2), with the authorized project (Alternative 2.2), and Alternatives 3.1 and 3.2.

Month Period	Alt. 1.1 Existing condition	Alt. 1.2 Δ Without project	Alt. 2.2 Δ Authorized project	Δ Alternative 3.1	Δ Alternative 3.2
November	132,310	+29,126	-85,926	-15,426	-15,426
Dec-Jan	5,299,733	+395,294	-1,446,738	-340,740	-340,740
Feb-Mar	8,069,675	+369,406	-7,203,625	-4,198,527	-4,565,165
All months combined	13,501,738	+793,826	-8,736,289	-4,554,693	-4,921,331

Table 4. Acres of Managed Bottomland Hardwood Forest (BLH) or Seasonal Herbaceous Wetland (SHW) potentially gained (-) or lost (-) based Duck-use-day (DUD) analyses for the New Madrid Floodway comparing DUD's in the existing condition and gains (+) or losses (-) in DUD's without the project (but with future WRP projections) (Alternative 1.2), with the authorized project (Alternative 2.2), and Alternatives 3.1 and 3.2

Month period and habitat	Alt 1.2 Δ Without project	Alt 2.2 Δ Authorized project	Δ Alternative 3.1	Δ Alternative 3.2
November				
BLH	+15.8	-46.7	-8.4	-8.4
SHW	+5.8	-17.3	-3.1	-3.1
Dec-Jan				
BLH	+204.3	-747.6	-176.1	-176.1
SHW	+95.3	-348.6	-82.1	-82.1
Feb-Mar				
BLH	+243.0	-4739.6	-2762.4	-3003.6
SHW	+115.1	-2243.8	-1307.8	-1422.0
All months combined				
BLH	+463.1	-5533.9	-2946.9	-3188.1
SHW	+216.2	-2609.7	-1393.0	-1507.2

FIGURES AND APPENDICES LIST

1. Flood frequency elevation (NAVD88) contour intervals for the St. John's Bayou Basin during November for existing (EX) and authorized (AU) project conditions.

2. Flood frequency elevation (NAVD88) contour intervals for the St. John's Bayou Basin during Dec-Jan for existing (EX) and authorized (AU) project conditions.

3. Flood frequency elevation (NAVD88) contour intervals for the St. John's Bayou Basin during Feb-Mar for existing (EX) and authorized (AU) project conditions.

4. Flood frequency elevation (NAVD88) contour intervals for the New Madrid Floodway during November for existing (EX) and authorized (AU) project conditions.

5. Flood frequency elevation (NAVD88) contour intervals for the New Madrid Floodway during Dec-Jan for existing (EX) and authorized (AU) project conditions.

6. Flood frequency elevation (NAVD88) contour intervals for the New Madrid Floodway during Feb-Mar for existing (EX) and authorized (AU) project conditions.

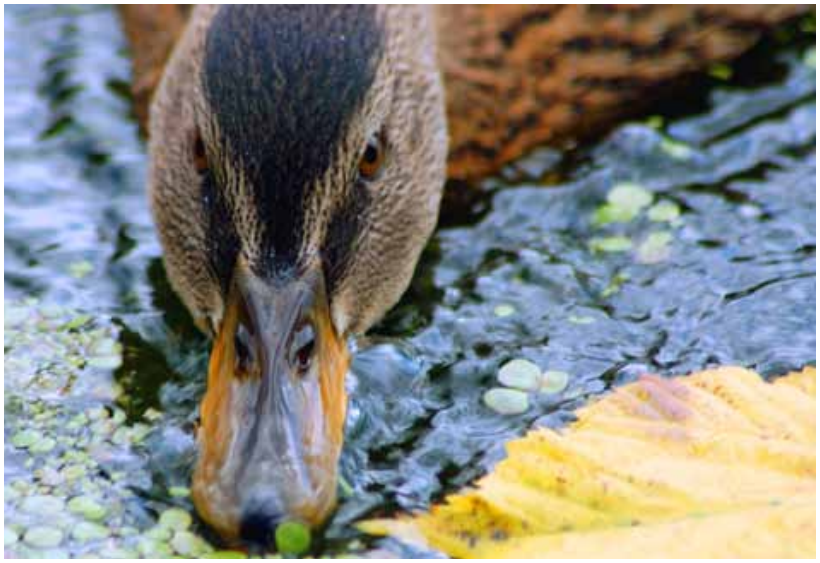
7. Map of potential distribution and types of historic vegetation communities in the St. John's Bayou Basin and New Madrid Floodway (from Heitmeyer 2010b).

(Appendices listed below and included with report on CD)

A. Stage-area landcover relationships for the St. John's Bayou Basin and New Madrid Floodway presenting elevations and acres of habitats related to flood frequency zone, month, and project alternatives. (Total of 8 Excel spreadsheets).

B. DUD energy amounts/acre for habitat types by month period and flood frequency zone. (Total of 3 Excel spreadsheets).

C. DUD amounts in the Existing St. John's Bayou Basin and New Madrid Floodway related to habitat type, month period, and flood frequency zone and comparisons of losses or gains in DUD's for project alternatives. (Total of 22 Excel spreadsheets).



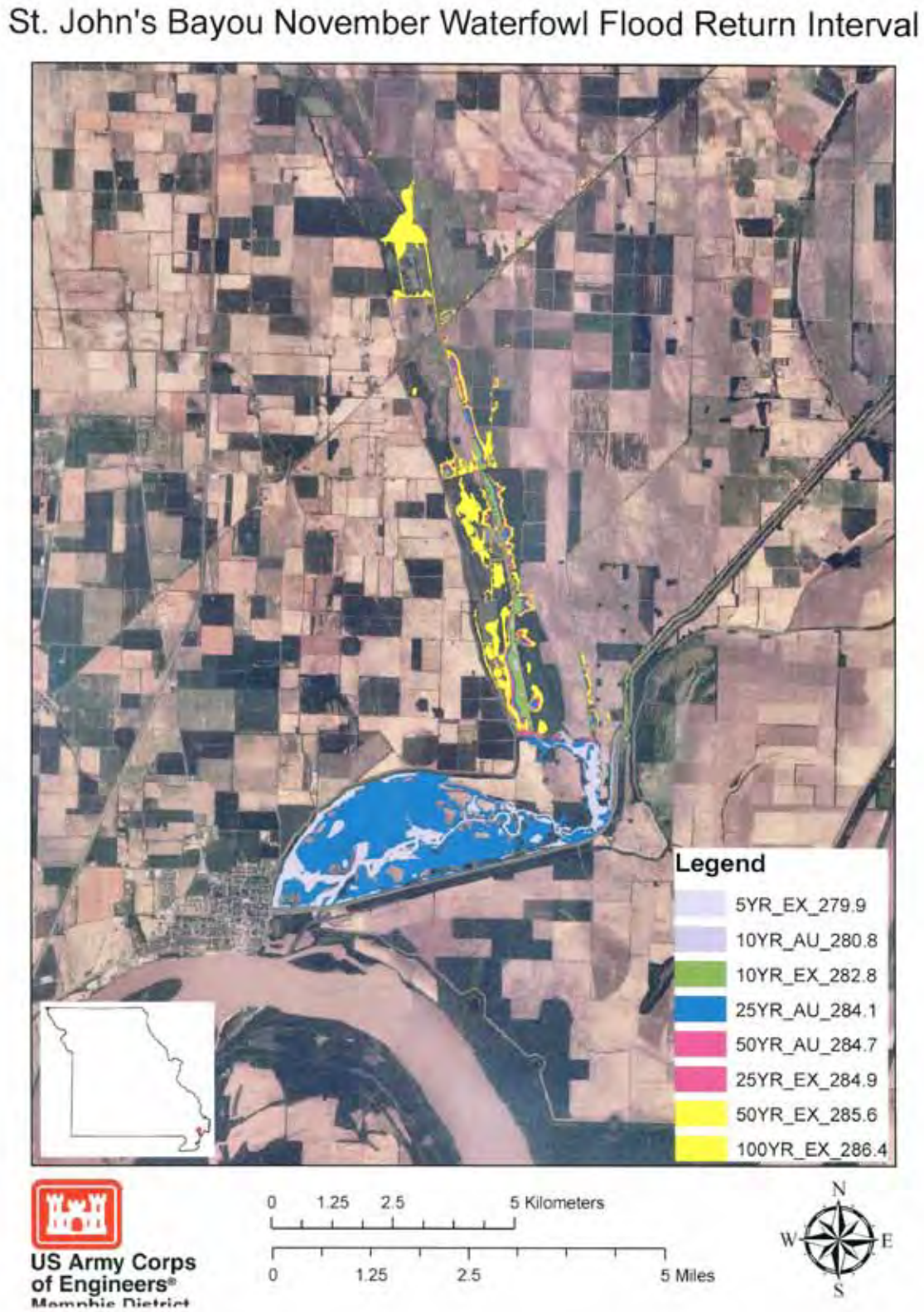


Figure 1. Flood frequency elevation (NAVD88) contour intervals for the St. John's Bayou Basin during November for existing (EX) and authorized (AU) project conditions.

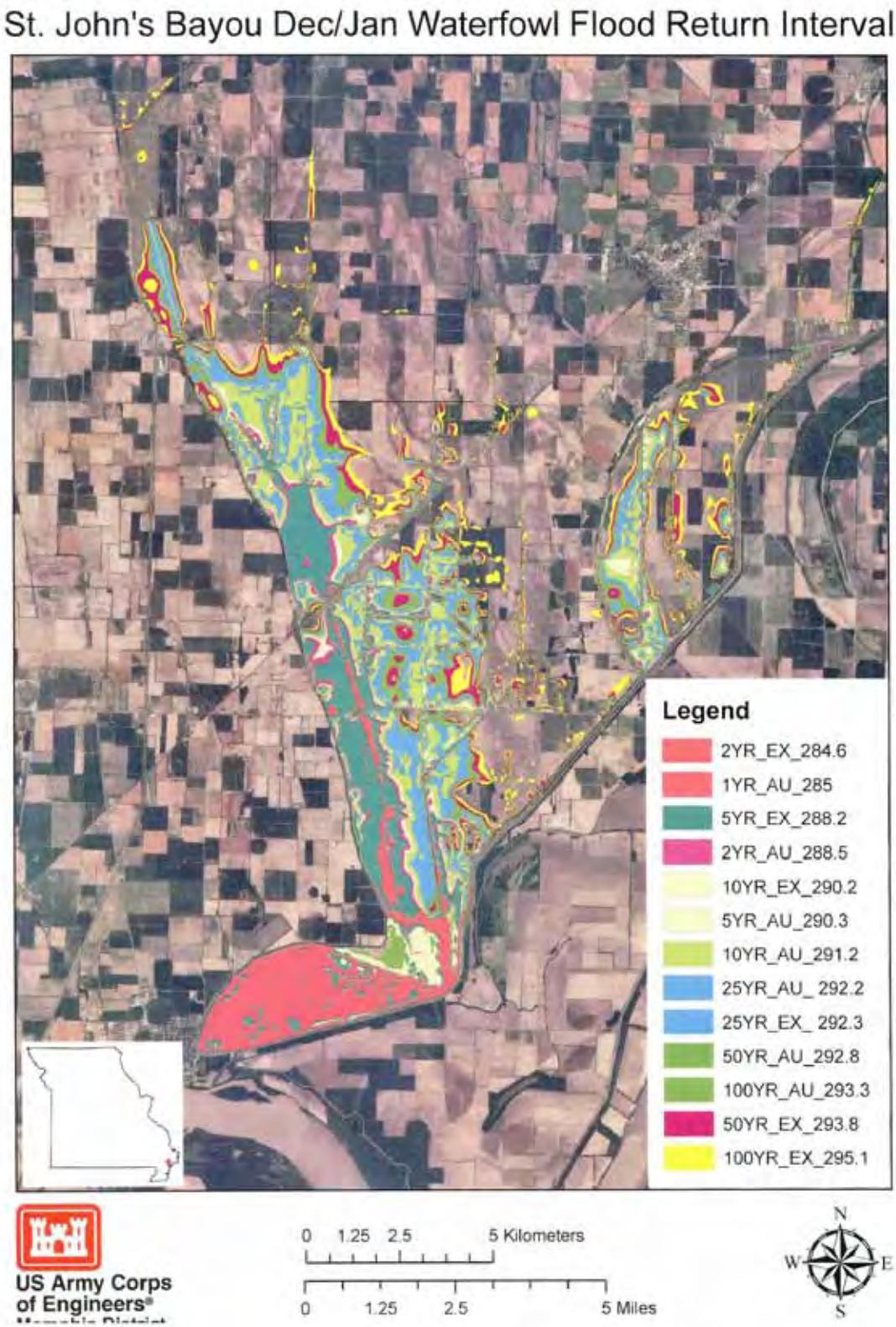


Figure 2. Flood frequency elevation (NAVD88) contour intervals for the St. John's Bayou Basin during Dec-Jan for existing (EX) and authorized (AU) project conditions.

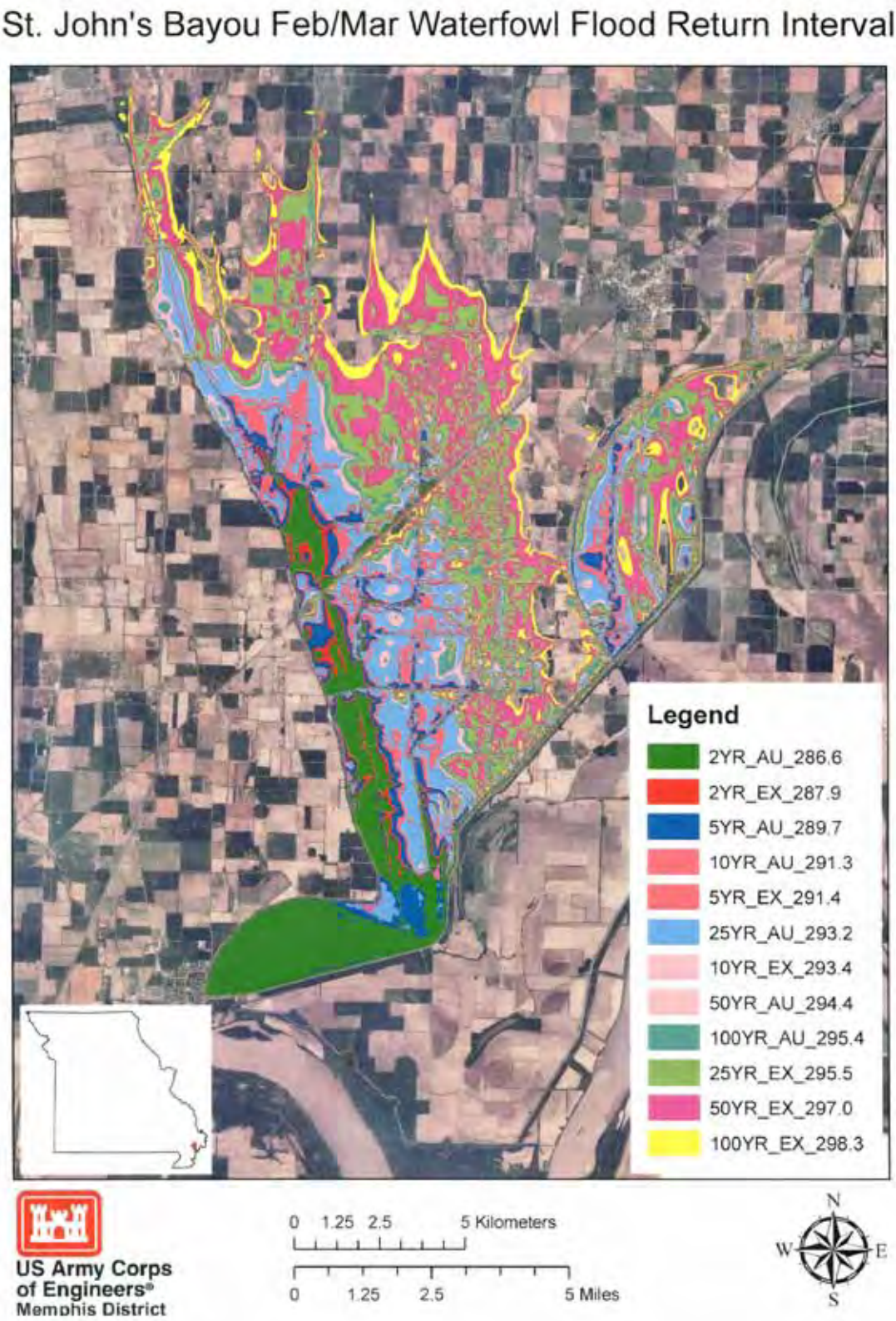


Figure 3. Flood frequency elevation (NAVD88) contour intervals for the St. John's Bayou Basin during Feb-Mar for existing (EX) and authorized (AU) project conditions.

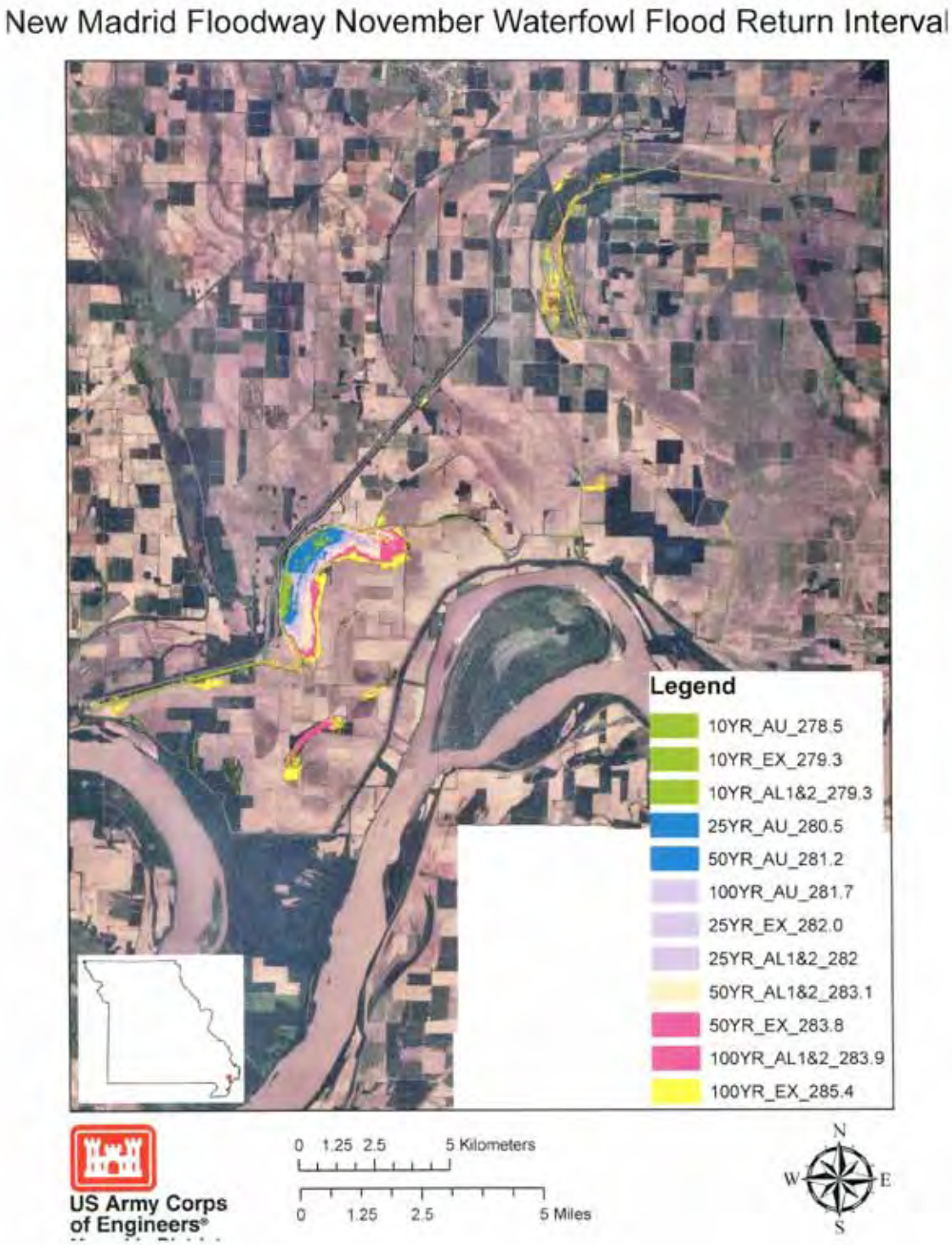


Figure 4. Flood frequency elevation (NAVD88) contour intervals for the New Madrid Floodway during November for existing (EX) and authorized (AU) project conditions.

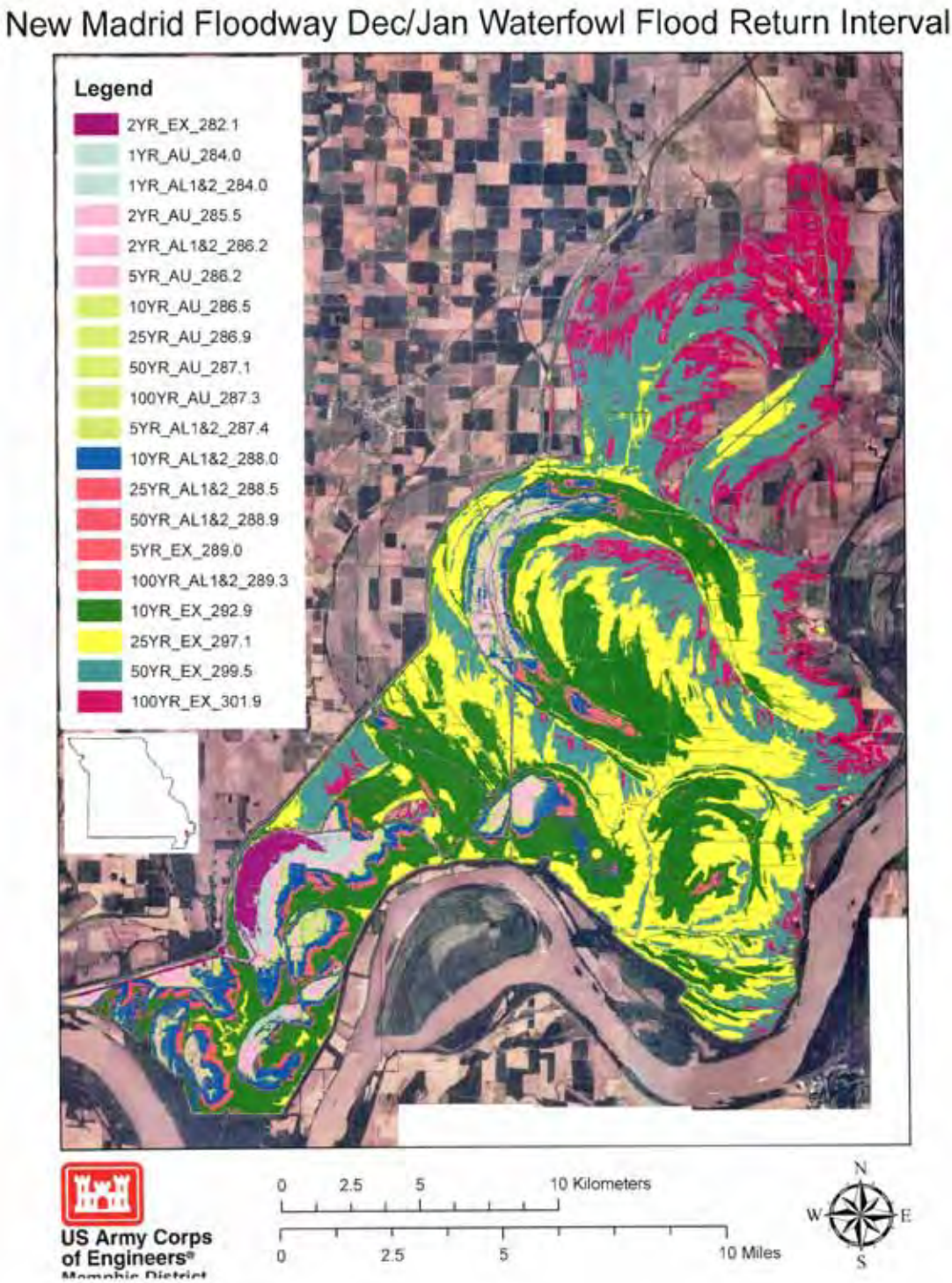


Figure 5. Flood frequency elevation (NAVD88) contour intervals for the New Madrid Floodway during Dec-Jan for existing (EX) and authorized (AU) project conditions.

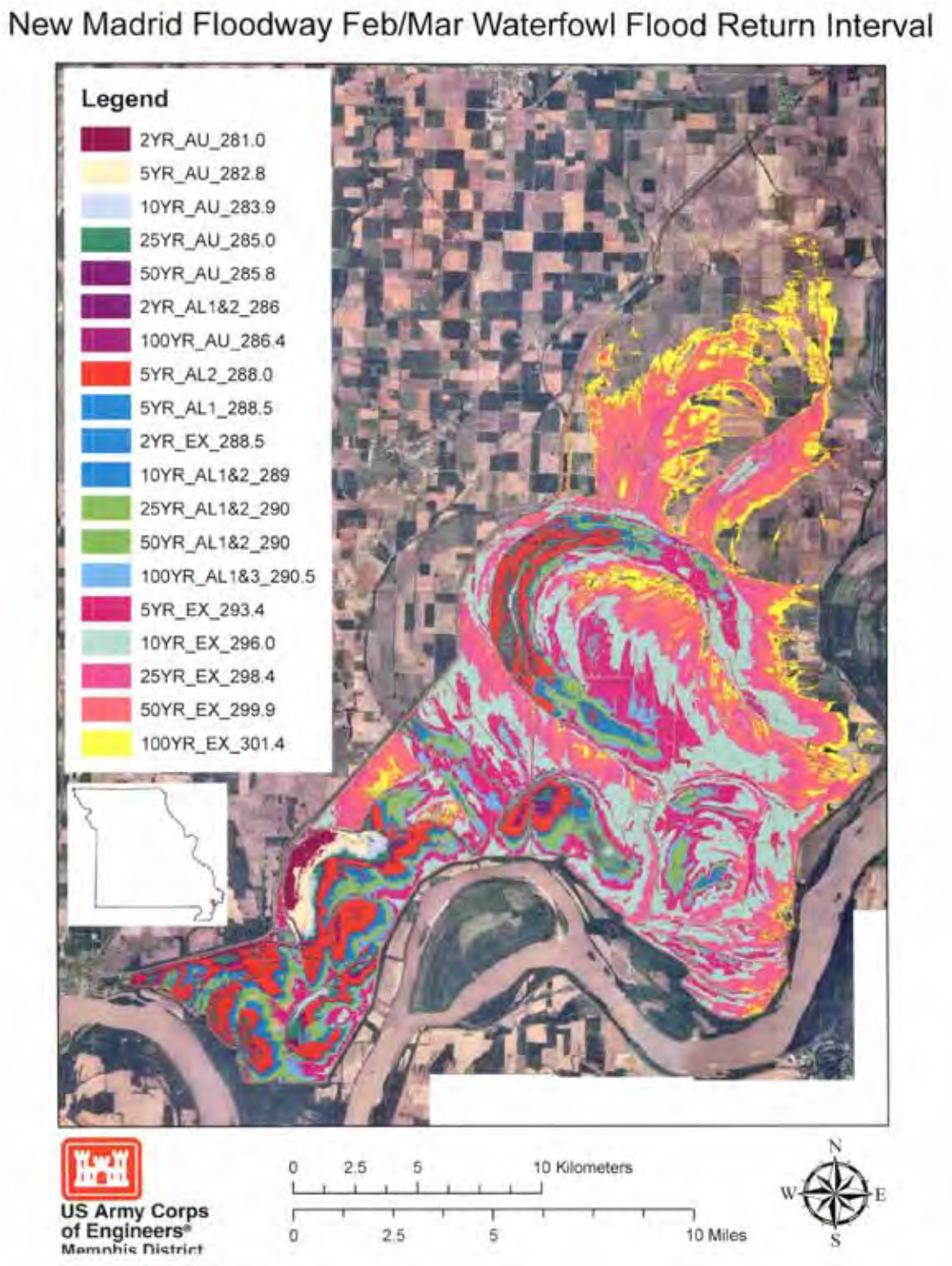


Figure 6. Flood frequency elevation (NAVD88) contour intervals for the New Madrid Floodway during Feb-Mar for existing (EX) and authorized (AU) project conditions.

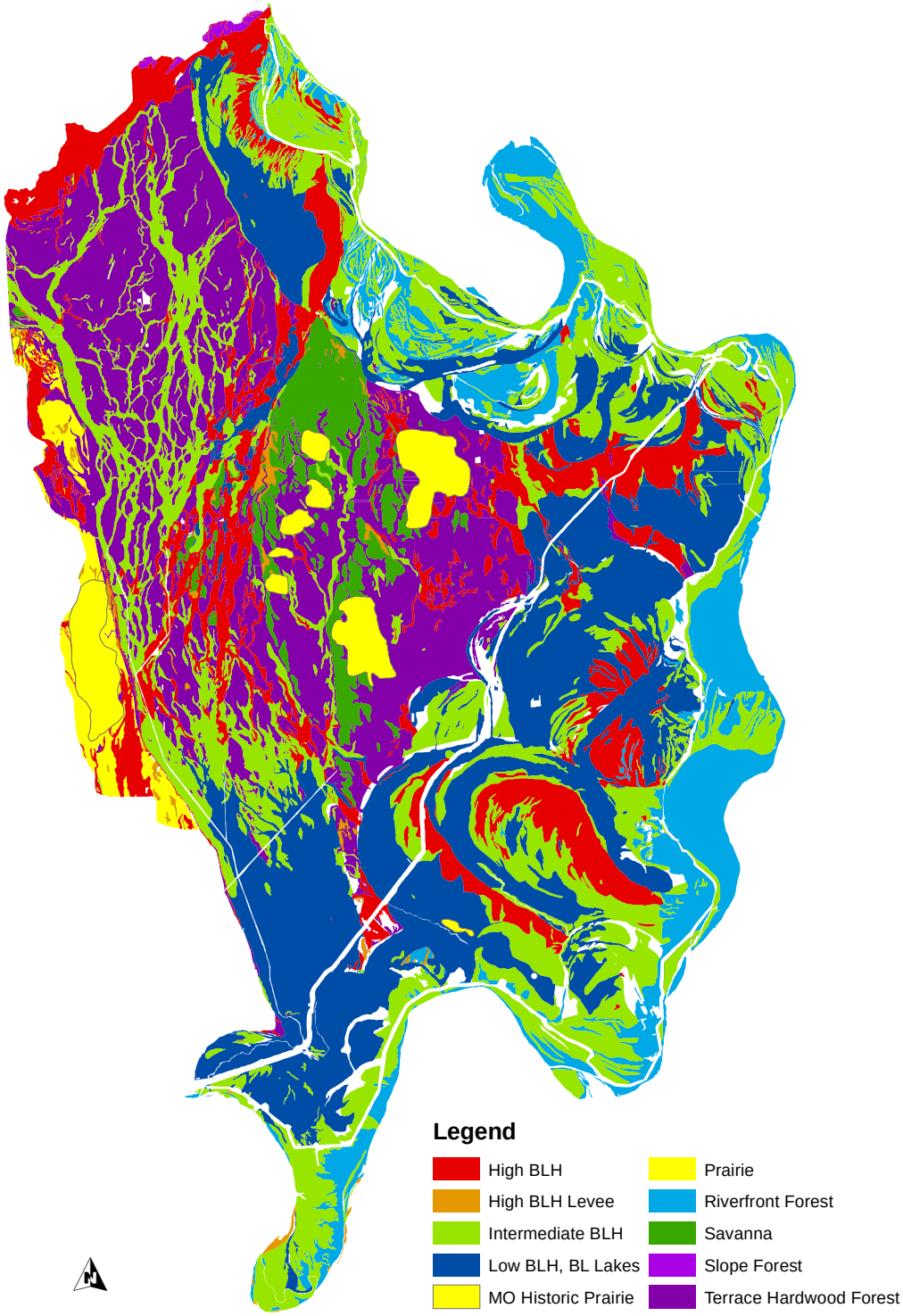


Figure 7. Map of potential distribution and types of historic vegetation communities in the St. John's Bayou Basin and New Madrid Floodway (from Heitmeyer 2010b).

NOTES:

ERRATA

The revised analyses of changes in duck-use-days (DUDs) for the new project Alternative 4 compared to the future without the project indicated gains in DUDs in all month periods except Alternative 4.1 during February and March (Table 1). Even this estimated loss of about 2.7 million DUDs under Alternative 4.1 during February and March is almost 58% lower than the loss of DUDs in this month period for Alternative 2. Alternative 4 is similar to Alternative 3 except that the NNF structure would not be closed and pumps would not be used until floods are greater than 289.5 feet. Alternative 4.2 would reforest agricultural lands below 289.5 while Alternative 4.1 would not. Consequently, substantial gains in DUDs accrue in all month periods under Alternative 4.2 because of the high potential food production in reforested areas. The gain of nearly 4.3 million DUDs during December and January is extremely high and the gain of about 1.4 DUDs in February and March is the only project scenario where DUDs increase during this time period. Collectively, Alternative 4, especially Alternative 4.2 represents up to a 5x reduction of loss of DUDs compared to other Alternatives, with an overall effect of mostly substantial gains in waterfowl habitat values.

Appendix F
Part 2

Waterfowl Assessment Appendix

U.S. Army Corps of Engineers
Memphis District

SJBB Alternative 2

SJBB A-2 NOVEMBER --- LOWER												
Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25 YR	-39.76	-27.97	-292.65	-34.28	-59.34	-6824.41	-251.95	-255.64	-73.44	0.00	0.00	-7859.44
50 YR	-76.72	-80.54	-133.69	-54.15	0.00	-11080.09	0.00	-1.38	-1282.64	-479.52	0.00	-13188.73
100 YR	-11.21	-52.45	-84.22	-18.85	0.00	-1707.70	0.00	-0.25	-71.71	-20.70	0.00	-1967.09
TOTAL	-127.69	-160.96	-510.56	-107.28	-59.34	-19612.20	-251.95	-257.27	-1427.79	-500.22	0.00	-23015.26

SBJJ A-2 PT EST NOVEMBER												
Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10 YR	-38.18	-72.65	-5862.84	-27.90	-1247.01	-44588.34	-3528.55	-3.63	-2739.14	-9069.47	0.00	-67177.71
25 YR	-39.76	-187.44	-292.65	-66.59	-59.34	-6824.41	-250.94	-1.01	-255.64	-73.44	0.00	-8051.22
50 YR	-93.45	-142.49	-133.69	-137.55	0.00	-11080.09	0.00	-1.38	-1289.52	-479.52	0.00	-13357.69
100 YR	-119.88	-98.78	-348.70	-139.04	0.00	-9859.73	0.00	-0.97	-1221.49	-515.52	0.00	-12304.11
TOTAL	-291.27	-501.36	-6637.88	-371.08	-1306.35	-72352.57	-3779.49	-6.99	-5505.79	-10137.95	0.00	-100890.73

SJBB A-2 NOVEMBER --- UPPER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 YR		-115.31	-11099.54	-6.02	-272.08	-2778.59	-384.89	0.00	-4813.55	-18072.26	0.00	-37542.24
10 YR	-266.40	-447.43	-17026.28	-230.72	-1247.01	-44588.34	-3528.55	-9.44	-4052.07	-9069.47	0.00	-80465.71
25 YR	-334.06	-365.68	-537.84	-453.15	-340.40	-27751.79	-1438.56	-3.92	-4322.48	-1679.76	0.00	-37227.64
50 YR	-438.06	-283.99	-1623.81	-468.52	0.00	-27174.58	0.00	-2.12	-3420.22	-1529.64	0.00	-34940.94
100 YR	-152.37	-141.11	-376.51	-260.34	0.00	-9859.73	0.00	-0.97	-1221.49	-515.52	0.00	-12528.04
TOTAL	-1190.89	-1353.52	-30663.98	-1418.75	-1859.49	-112153.03	-5352.00	-16.45	-17829.81	-30866.65	0.00	-202704.57

SJBB A-2 DECEMBER-JANUARY --- LOWER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	16,345.68	86,858.10	4,412.28	11,290.74	0.00	236,001.08	0.00	161,074.44	57,480.32	0.00	573,462.64
5 YR	10,306.39	18,412.82	53,916.84	9,260.25	22,273.43	334,891.82	46,557.28	0.00	40,371.49	10,790.60	0.00	546,780.92
10 YR	6,083.44	18,412.60	34,436.70	2,747.04	2,254.56	118,964.03	9,447.68	0.00	15,568.36	3,849.41	0.00	211,763.82
25 YR	2,163.36	6,819.33	12,834.65	535.77	243.26	29,335.12	1,529.26	-0.85	4,424.68	742.54	0.00	58,627.12
50 YR	447.00	1,702.72	3,338.14	50.77	0.00	7,995.37	0.00	-1.16	890.43	173.29	0.00	14,596.56
100 YR	-71.70	-158.88	-522.00	-5.95	0.00	-1,111.06	0.00	-0.22	-154.22	-23.27	0.00	-2,047.30
TOTAL	18,928.49	61,534.27	190,862.43	17,000.16	36,061.99	490,075.28	293,535.30	-2.23	222,175.18	73,012.89	0.00	1,403,183.76

SJBB A-2 DECEMBER-JANUARY --- PT. EST.

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	16,345.68	58,096.80	4,412.28	11,290.74	0.00	236,001.08	0.00	130,383.22	54,539.80	0.00	511,069.60
5 YR	10,306.39	18,412.82	53,916.84	6,273.23	12,084.38	181,699.48	25,259.52	0.00	33,107.70	8,505.99	0.00	349,566.35
10 YR	6,083.44	18,412.60	34,436.70	1,654.60	1,357.23	71,614.92	5,687.44	-3.06	12,531.45	2,038.80	0.00	153,814.12
25 YR	-143.52	-320.31	-1,044.00	-12.07	-14.78	-1,779.99	-92.75	-0.85	-306.86	-46.72	0.00	-3,761.85
50 YR	-725.16	-1,366.85	-4,433.94	-30.03	0.00	-8,481.65	0.00	-1.16	-1,091.09	-167.18	0.00	-16,297.06
100 YR	-1,209.00	-1,206.78	-4,927.79	-17.26	0.00	-7,321.72	0.00	-0.84	-775.66	-123.30		-15,582.35
TOTAL	14,312.15	50,277.16	136,044.61	12,280.75	24,717.57	235,731.04	266,855.29	-5.91	173,848.76	64,747.39	0.00	978,808.81

SJBB A-2 DECEMBER-JANUARY --- UPPER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	16,345.68	58,096.80	4,412.28	11,290.74	0.00	221,722.97	0.00	130,383.22	51,201.56	0.00	493,453.25
5 YR	10,306.39	18,412.82	53,916.84	4,776.53	9,451.87	142,114.83	19,756.88	0.00	30,174.70	5,972.32	0.00	294,883.18
10 YR	1,115.94	4,283.24	8,345.34	126.73	264.81	13,974.72	1,285.68	-7.96	2,225.73	434.88	0.00	32,049.11
25 YR	-2,832.72	-2,957.97	-13,936.90	-61.63	-152.38	-18,373.46	-957.79	-3.29	-2,605.63	-417.08	0.00	-42,298.85
50 YR	-11,100.36	-5,156.67	-30,202.42	-48.42	0.00	-35,102.99	0.00	-1.77	-3,582.49	-493.22	0.00	-85,688.34
100 YR	-9,543.96	-3,189.76	-22,397.42	-36.47	0.00	-28,164.45	0.00	-0.84	-2,995.44	-411.45	0.00	-66,739.79
TOTAL	-12,054.71	27,737.34	53,822.24	9,169.02	20,855.04	74,448.65	241,807.74	-13.86	153,600.09	56,287.01	0.00	625,658.56

SJBB A-2 FEBRUARY-MARCH --- LOWER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	-6,715.58	-69,592.96	-13,966.56	-32,430.10	0.00	-41,572.42	-33.77	22,724.91	-1,885.18	0.00	-143,471.66
5 YR	-6,791.18	-14,252.70	-50,875.38	-5,485.10	-15,237.85	-118,414.27	-19,530.86	-175.60	-21,325.75	-5,918.39	0.00	-258,007.08
10 YR	-6,490.20	-21,407.29	-64,846.60	-916.53	-2,879.87	-78,323.30	-7,382.03	-277.84	-14,324.16	-2,563.57	0.00	-199,411.39
25 YR	-2,482.81	-616.69	-24,201.76	-101.02	-459.11	-28,585.39	-1,772.38	-319.68	-3,738.35	-595.62	0.00	-62,872.81
50 YR	-1,431.58	-2,500.63	-10,820.43	-60.02	0.00	-14,727.42	0.00	-445.79	-1,838.65	-302.40	0.00	-32,126.92
100 YR	-2,292.71	-1,701.68	-9,822.06	-25.83	0.00	-10,067.40	0.00	-1,059.61	-4,921.08	-160.50	0.00	-30,050.87
TOTAL	-19,488.48	-47,194.57	-230,159.19	-20,555.06	-51,006.93	-250,117.78	-70,257.69	-2,312.29	-23,423.08	-11,425.66	0.00	-725,940.73

SJBB A-2 FEBRUARY-MARCH --- PT. EST.

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	-7,883.04	-69,592.96	-15,824.52	-32,430.10	0.00	-41,572.42	-33.77	22,724.91	-1,885.18	0.00	-146,497.08
5 YR	-13,372.46	-45,243.65	-109,069.10	-5,943.22	-17,606.08	-136,812.57	-22,566.31	-440.85	-31,892.34	-6,150.02	0.00	-389,096.60
10 YR	-6,490.20	-21,407.29	-64,846.60	-916.53	-2,879.87	-78,323.30	-7,382.03	-702.11	-14,324.16	-2,563.57	0.00	-199,835.66
25 YR	-7,318.61	-6,116.69	-34,076.84	-101.02	-459.11	-28,585.39	-1,772.38	-3,315.34	-3,738.35	-595.62	0.00	-86,079.35
50 YR	-11,155.92	-4,942.08	-40,007.14	-60.02	0.00	-34,131.73	0.00	-5,292.54	-3,899.78	-529.65	0.00	-100,018.86
100 YR	-5,903.22	-1,935.39	-17,735.22	-33.66	0.00	-32,050.87	0.00	-2,634.88	-12,990.77	-291.65	-0.79	-73,576.45
TOTAL	-44,240.41	-87,528.14	-335,327.86	-22,878.97	-53,375.16	-309,903.86	-73,293.14	-12,419.49	-44,120.49	-12,015.69	-0.79	-995,104.00

SJBB A-2 FEBRUARY-MARCH --- UPPER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	-7,919.92	-10,593.22	-76,213.70	-15,824.52	-32,430.10	0.00	-41,572.42	-33.77	22,724.91	-1,885.18	0.00	-163,747.92
5 YR	-14,081.45	-52,370.53	-140,947.45	-5,943.22	-17,606.08	-136,812.57	-22,566.31	-912.40	-32,604.85	-6,150.02	0.00	-429,994.88
10 YR	-10,074.60	-21,407.29	-64,846.60	-916.53	-2,879.87	-78,323.30	-7,382.03	-3,901.97	-14,324.16	-2,563.57	0.00	-206,619.92
25 YR	-25,174.49	-9,365.11	-81,946.88	-135.79	-1,002.59	-62,426.71	-3,870.62	-11,673.44	-8,751.60	-1,226.62	-0.31	-205,574.16
50 YR	-11,155.92	-4,942.08	-40,007.14	-76.59	0.00	-34,131.73	0.00	-5,292.54	-21,069.95	-529.65	-10.68	-117,216.28
100 YR	-5,903.22	-1,935.39	-17,735.22	-33.66	0.00	-32,050.87	0.00	-2,634.88	-12,990.77	-291.65	-6.00	-73,581.66
TOTAL	-74,309.60	-100,613.62	-421,696.99	-22,930.31	-53,918.64	-343,745.18	-75,391.38	-24,449.00	-67,016.42	-12,646.69	-16.99	-1,196,734.82

NMF Alternative 2

NMF A-2 NOVEMBER LOWER												
Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50 YR	0.00	0.00	0.17	-2.78	0.00	-5099.66	0.00	-2.04	-8150.62	-324.54	0.00	-13579.47
100 YR	-10.86	-5.15	-174.70	-3.72	0.00	-5030.05	0.00	-4.28	-7304.93	-393.93	0.00	-12927.62
TOTAL	-10.86	-5.15	-174.53	-6.50	0.00	-10129.71	0.00	-6.32	-15455.55	-718.47	0.00	-26507.09

NMF A-2 NOVEMBER PT. EST

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50 YR	0.00	0.00	0.17	-2.78	0.00	-5099.66	0.00	-2.04	-8150.62	-324.54	0.00	-13579.47
100 YR	-10.86	-5.15	-174.70	-3.72	0.00	-5030.05	0.00	-5.18	-7304.93	-393.93	0.00	-12928.52
TOTAL	-10.86	-5.15	-174.53	-6.50	0.00	-10129.71	0.00	-7.22	-15455.55	-718.47	0.00	-26507.99

NMF A-2 NOVEMBER UPPER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10 YR	0.00	0.00	0.00	-10.93	-388.60	-13,890.35	-1,099.04	-3.63	-31,004.50	-1,174.90	0.00	-47,571.95
25 YR	-292.16	-110.45	-6,075.81	-154.17	-300.38	-24,510.50	-1,269.11	-22.47	-25,574.11	-4,833.36	-2.98	-63,145.50
50 YR	-480.60	-276.79	-11,886.75	-779.70	0.00	-42,874.40	0.00	-6.64	-8,150.62	-5,388.30	-13.58	-69,857.38
100 YR	-493.86	-504.46	-14,630.24	-672.22	0.00	-45,861.80	0.00	-5.18	-7,304.93	-4,204.17	-14.14	-73,691.00
TOTAL	-1,266.62	-891.70	-32,592.80	-1,617.02	-688.98	-127,137.05	-2,368.15	-37.92	-72,034.16	-15,600.73	-30.70	-254,265.83

NMF A-2 DECEMBER-JANUARY --- LOWER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	5,984.51	2,371.25	147,469.50	9,614.87	52,957.68	0.00	110,697.66	279.99	406,587.45	74,292.14	165.94	810,420.99
5 YR	-1,650.84	-2,267.82	-65,949.84	-4,478.75	-11,068.93	-166,428.36	-23,136.96	0.00	-14,115.27	-15,426.32	-47.86	-304,570.95
10 YR	-9,710.99	-5,234.11	-222,155.46	-2,859.26	-7,303.38	-385,368.69	-30,604.20	-6.12	-20,636.59	-17,288.43	-63.30	-701,230.53
25 YR	-19,544.40	-6,016.69	-198,355.61	-862.65	-2,064.97	-248,981.06	-12,980.00	-4.03	-12,239.56	-7,249.01	-25.34	-508,323.32
50 YR	-21,296.88	-3,090.37	-126,909.65	-382.19	0.00	-178,083.63	0.00	-2.99	-6,527.47	-3,807.83	-27.10	-340,128.11
100 YR	-18,290.52	-1,549.70	-70,282.87	-169.19	0.00	-94,727.64	0.00	-1.67	-3,399.82	-1,793.16	-59.98	-190,274.55
TOTAL	-64,509.12	-15,787.44	-536,183.93	862.83	32,520.40	-1,073,589.38	43,976.50	265.18	349,668.74	28,727.39	-57.64	-1,234,106.47

NMF A-2 DECEMBER-JANUARY --- PT. EST.

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	5,984.51	2,037.57	128,394.00	7,555.81	52,957.68	0.00	110,697.66	279.99	406,587.45	74,292.14	135.06	788,921.87
5 YR	-1,650.84	-2,267.82	-65,949.84	-4,478.75	-11,068.93	-166,428.36	-23,136.96	0.00	-14,115.27	-15,426.32	-47.86	-304,570.95
10 YR	-9,710.99	-5,234.11	-222,155.46	-3,092.19	-7,303.38	-385,368.69	-30,604.20	-6.12	-20,636.59	-17,288.43	-63.30	-701,463.46
25 YR	-19,544.40	-6,016.69	-198,355.61	-1,078.21	-2,064.97	-248,981.06	-12,980.00	-4.03	-12,239.56	-7,249.01	-25.34	-508,538.88
50 YR	-21,296.88	-3,090.37	-126,909.65	-470.16	0.00	-178,083.63	0.00	-2.99	-6,527.47	-3,926.65	-27.10	-340,334.90
100 YR	-18,290.52	-1,568.26	-70,282.87	-191.73	0.00	-94,727.64	0.00	-1.67	-3,399.82	-1,892.93	-59.98	-190,415.42
TOTAL	-64,509.12	-16,139.68	-555,259.43	-1,755.23	32,520.40	-1,073,589.38	43,976.50	265.18	349,668.74	28,508.80	-88.52	-1,256,401.74

NMF A-2 DECEMBER-JANUARY --- UPPER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	5,453.18	2,037.57	127,477.80	7,555.81	52,957.68	0.00	110,697.66	1.53	29,098.83	50,168.14	135.06	385,583.26
5 YR	-32,304.07	-16,461.69	-618,570.00	-5,991.05	-41,133.38	-618,466.32	-85,979.52	-14.69	-47,326.89	-35,428.38	-131.24	-1,501,807.23
10 YR	-96,058.04	-15,473.71	-619,073.46	-3,092.19	-11,568.48	-610,431.71	-48,477.44	-14.69	-32,346.80	-19,401.56	-72.57	-1,456,010.65
25 YR	-126,131.28	-6,324.74	-317,466.00	-1,078.21	-2,676.32	-322,696.44	-16,822.96	-7.08	-13,472.36	-7,460.68	-250.91	-814,386.98
50 YR	-63,017.52	-3,090.37	-156,801.38	-470.16	0.00	-195,501.19	0.00	-3.48	-6,527.47	-3,926.65	-123.35	-429,461.57
100 YR	-31,484.64	-1,568.26	-77,434.88	-191.73	0.00	-94,727.64	0.00	-1.77	-3,399.82	-1,892.93	-60.75	-210,762.42
TOTAL	-343,542.37	-40,881.20	-1,661,867.92	-3,267.53	-2,420.50	-1,841,823.30	-40,582.26	-40.18	-73,974.51	-17,942.06	-503.76	-4,026,845.59

NMF A-2 FEBRUARY - MARCH --- LOWER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	-11,536.06	-494,091.52	-33,533.70	-240,342.35	0.00	-308,096.86	-280.90	-365,022.34	-129,674.51	-483.14	-1,583,061.38
5 YR	-30,579.94	-20,332.10	-820,528.69	-16,061.22	-91,009.77	-707,230.15	-116,650.30	-31.93	-77,803.78	-65,226.51	-256.07	-1,945,710.46
10 YR	-42,550.40	-13,751.28	-589,995.48	-8,132.05	-21,576.72	-586,845.53	-55,311.23	-11.36	-37,234.56	-31,906.04	-130.48	-1,387,445.13
25 YR	-35,856.35	-5,715.79	-288,045.52	-2,951.34	-4,788.22	-298,134.79	-18,484.93	-6.15	-14,726.25	-11,421.09	-132.19	-680,262.62
50 YR	-26,019.26	-2,899.42	-155,233.76	-1,086.17	0.00	-192,615.64	0.00	-3.23	-7,127.72	-4,959.70	-129.68	-390,074.58
100 YR	-17,824.44	-1,413.21	-79,820.48	-389.50	0.00	-90,826.97	0.00	-1.77	-3,278.47	-2,110.08	-66.52	-195,731.44
TOTAL	-152,830.39	-55,647.86	-2,427,715.45	-62,153.98	-357,717.06	-1,875,653.08	-498,543.32	-335.34	-505,193.12	-245,297.93	-1,198.08	-6,182,285.61

NMF A-2 FEBRUARY-MARCH -- PT. EST

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	-10,162.24	-11,536.06	-494,091.52	-33,533.70	-240,342.35	0.00	-308,096.86	-280.90	-394,418.91	-129,674.51	-483.14	-1,622,620.19
5 YR	-30,579.94	-20,332.10	-820,528.69	-16,061.22	-91,009.77	-707,230.15	-116,650.30	-55.26	-85,756.92	-65,226.51	-256.07	-1,953,686.93
10 YR	-42,550.40	-13,751.28	-589,995.48	-8,139.44	-21,576.72	-586,845.53	-55,311.23	-11.36	-37,234.56	-32,398.52	-130.48	-1,387,945.00
25 YR	-35,856.35	-5,715.79	-288,045.52	-3,217.19	-4,788.22	-298,134.79	-18,484.93	-6.15	-14,726.25	-12,580.96	-132.19	-681,688.34
50 YR	-26,019.26	-2,899.42	-155,233.76	-1,518.15	0.00	-192,615.64	0.00	-3.23	-7,501.72	-5,902.51	-129.68	-391,823.37
100 YR	-17,824.44	-1,458.16	-79,820.48	-665.63	0.00	-97,557.64	0.00	-1.77	-3,699.50	-2,715.83	-69.52	-203,812.97
TOTAL	-162,992.63	-55,692.81	-2,427,715.45	-63,135.33	-357,717.06	-1,882,383.75	-498,543.32	-358.67	-543,337.86	-248,498.84	-1,201.08	-6,241,576.80

NMF A-2 FEB-MARCH --- UPPER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	-32,785.62	-23,522.70	-1,204,065.02	-38,885.87	-382,338.85	0.00	-490,081.96	-280.90	-394,418.91	-158,276.64	-604.91	-2,725,261.38
5 YR	-109,819.16	-27,920.05	-1,287,833.09	-16,303.42	-112,626.22	-875,209.39	-144,356.83	-55.26	-85,756.92	-65,226.51	-265.50	-2,725,372.35
10 YR	-126,433.62	-14,419.21	-763,884.64	-8,139.44	-24,685.28	-671,389.86	-63,279.49	-16.27	-37,366.66	-32,398.52	-624.08	-1,742,637.07
25 YR	-91,754.72	-5,804.78	-339,165.30	-3,217.19	-4,920.70	-306,387.67	-18,996.54	-7.01	-14,726.25	-12,580.96	-268.16	-797,829.28
50 YR	-45,793.41	-2,899.42	-167,160.97	-1,518.15	0.00	-192,615.64	0.00	-3.54	-7,501.72	-5,902.51	-130.62	-423,525.98
100 YR	-23,115.22	-1,458.16	-79,820.48	-665.63	0.00	-97,557.64	0.00	-1.77	-3,699.50	-2,715.83	-69.52	-209,103.75
TOTAL	-429,701.75	-76,024.32	-3,841,929.50	-68,729.70	-524,571.05	-2,143,160.20	-716,714.82	-364.75	-543,469.96	-277,100.97	-1,962.79	-8,623,729.81

NMF Alternative 3.1

NMF A-3.1 NOVEMBER - LOWER												
Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25 YR	0.00	0.00	0.09	90.75	279.80	22,815.32	1,182.60	0.14	21,320.39	2,951.28	0.00	48,640.37
50 YR	0.00	0.00	0.04	1.80	0.00	3,400.85	0.00	4.01	5,831.60	269.46	0.00	9,507.76
100 YR	-1.78	-0.88	-29.11	-0.30	0.00	-257.84	0.00	-0.04	-246.24	-22.32	0.00	-558.51
TOTAL	-1.78	-0.88	-28.98	92.25	279.80	25,958.33	1,182.60	4.11	26,905.75	3,198.42	0.00	57,589.62

NMF A-3.1 NOVEMBER - PT EST

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25 YR	0.00	0.00	0.09	90.75	279.80	22,815.32	1,182.60	0.14	21,320.39	2,951.28	0.00	48,640.37
50 YR	0.00	0.00	0.04	1.80	0.00	3,400.85	0.00	4.01	5,831.60	269.46	0.00	9,507.76
100 YR	-1.78	-0.88	-29.11	-0.30	0.00	-257.84	0.00	-0.32	-246.24	-22.32	0.00	-558.79
TOTAL	-1.78	-0.88	-28.98	92.25	279.80	25,958.33	1,182.60	3.83	26,905.75	3,198.42	0.00	57,589.34

NMF A-3.1 NOVEMBER - UPPER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10 YR	0.00	0.00	0.00	-10.93	-388.60	-13,890.35	-1,099.04	-3.63	-31,004.50	-1,174.90	0.00	-47,571.95
25 YR	-203.06	-70.45	-4,584.75	-133.03	-113.85	-9,285.17	-481.30	-0.44	-1,936.75	-3,060.00	-2.98	-19,871.78
50 YR	-325.56	-217.43	-8,614.06	-690.52	0.00	-30,786.68	0.00	0.00	-1,854.50	-3,155.76	-11.72	-45,656.23
100 YR	-361.34	-449.02	-11,418.73	-490.85	0.00	-35,663.67	0.00	-0.32	-2,298.76	-2,483.91	-10.51	-53,177.11
TOTAL	-889.96	-736.90	-24,617.54	-1,325.33	-502.45	-89,625.87	-1,580.34	-4.39	-37,094.51	-9,874.57	-25.21	-166,277.07

NMF A-3.1 DECEMBER - JANUARY - LOWER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	4,061.22	1,595.88	96,677.00	3,703.48	208,310.73	0.00	0.00	279.99	1,086,244.65	131,730.08	23.15	1,532,626.18
2 YR	2,117.35	4,415.27	231,113.70	17,287.63	70,515.56	0.00	147,398.97	111.99	400,192.75	92,923.04	270.13	966,346.39
5 YR	1,681.99	2,714.16	67,606.56	1,449.20	7,556.11	113,614.00	15,794.24	0.31	13,173.36	9,111.05	61.76	232,762.74
10 YR	-8,532.16	-3,474.06	-174,927.78	-707.65	-4,680.48	-246,970.16	-19,613.00	-5.81	-10,989.53	-7,760.10	-9.26	-477,669.99
25 YR	-18,828.72	-5,021.20	-171,126.07	-293.09	-1,421.19	-171,358.80	-8,933.41	-3.66	-7,215.90	-3,292.52	-4.02	-387,498.58
50 YR	-20,818.92	-2,583.87	-110,657.84	-142.64	0.00	-127,931.37	0.00	-2.62	-4,097.72	-2,090.40	-17.25	-268,342.63
100 YR	-17,991.54	-1,279.17	-60,838.45	-63.39	0.00	-68,952.31	0.00	-1.30	-2,220.46	-981.89	-55.52	-152,384.03
TOTAL	-58,310.78	-3,632.99	-122,152.88	21,233.54	280,280.73	-501,598.64	134,646.80	378.90	1,475,087.15	219,639.26	268.99	1,445,840.08

NMF A-3.1 DECEMBER - JANUARY - PT EST

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	4,061.22	1,595.88	96,677.00	3,703.48	208,310.73	0.00	0.00	279.99	1,086,244.65	131,730.08	23.15	1,532,626.18
2 YR	2,117.35	2,948.35	179,063.10	12,990.53	68,247.45	0.00	142,657.93	111.99	400,192.75	90,011.86	216.10	898,557.41
5 YR	1,681.99	2,714.16	67,606.56	1,449.20	7,556.11	113,614.00	15,794.24	0.31	13,173.36	9,111.05	61.76	232,762.74
10 YR	-8,532.16	-3,474.06	-174,927.78	-1,009.96	-4,680.98	-246,970.16	-19,613.00	-5.81	-10,989.53	-8,635.09	-24.70	-478,863.23
25 YR	-18,828.72	-5,021.20	-171,126.07	-293.09	-1,421.19	-171,358.80	-8,933.41	-3.66	-7,215.90	-3,292.52	-4.02	-387,498.58
50 YR	-20,818.92	-2,583.87	-110,657.84	-149.67	0.00	-127,931.37	0.00	-2.62	-4,097.72	-2,090.40	-17.25	-268,349.66
100 YR	-17,991.54	-1,308.67	-60,838.45	-69.23	0.00	-68,952.31	0.00	-1.36	-2,222.30	-1,041.95	-55.52	-152,481.33
TOTAL	-58,310.78	-5,129.41	-174,203.48	16,621.26	278,012.12	-501,598.64	129,905.76	378.84	1,475,085.31	215,793.03	199.52	1,376,753.53

NMF A-3.1 DECEMBER - JANAUARY - UPPER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	4,061.22	1,595.88	96,677.00	3,703.48	208,310.73	0.00	0.00	279.99	1,086,244.65	131,730.08	23.15	1,532,626.18
2 YR	2,117.35	2,948.35	179,063.10	12,990.53	68,247.45	0.00	142,657.93	0.61	53,261.26	78,885.48	216.10	540,388.16
5 YR	-31,073.72	-14,713.10	-569,341.80	-3,096.91	-33,412.67	-502,380.45	-69,841.20	-7.34	-36,975.91	-24,869.89	-94.18	-1,285,807.17
10 YR	-93,672.82	-12,925.08	-537,814.62	-1,009.96	-8,246.07	-435,120.79	-34,555.40	-12.85	-20,189.10	-10,191.41	-24.70	-1,153,762.80
25 YR	-124,549.44	-5,263.72	-272,823.19	-293.09	-1,936.45	-233,481.42	-12,171.98	-5.25	-9,036.96	-4,125.37	-236.38	-663,923.25
50 YR	-61,922.40	-2,583.87	-130,779.29	-149.67	0.00	-136,532.53	0.00	-2.62	-4,336.57	-2,090.40	-117.66	-338,515.01
100 YR	-30,785.10	-1,308.67	-62,573.47	-69.23	0.00	-68,952.31	0.00	-1.36	-2,222.30	-1,041.95	-58.83	-167,013.22
TOTAL	-335,824.91	-32,250.21	-1,297,592.27	12,075.15	232,962.99	-1,376,467.50	26,089.35	251.18	1,066,745.07	168,296.54	-292.50	-1,536,007.11

NMF A-3.1 FEBRUARY - MARCH - LOWER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	-9,076.06	-311,646.12	-18,483.16	-135,637.33	0.00	-173,874.62	0.00	-51,839.49	-52,446.55	-267.10	-753,270.43
5 YR	-25,322.58	-13,970.78	-561,569.09	-1,366.96	-38,376.92	-298,223.14	-49,188.99	-14.12	-18,038.31	-11,536.89	-17.28	-1,017,625.06
10 YR	-38,548.40	-9,977.75	-410,438.99	-591.84	-9,211.20	-252,874.97	-23,833.98	-6.75	-13,537.09	-5,390.44	-10.22	-764,421.63
25 YR	-33,745.39	-3,954.64	-205,118.83	-221.07	-2,170.55	-135,148.94	-8,379.51	-4.18	-5,904.80	-2,673.89	-85.09	-397,406.89
50 YR	-24,797.35	-1,948.05	-110,073.34	-84.13	0.00	-88,896.92	0.00	-2.19	-3,178.45	-1,359.01	-108.02	-230,447.46
100 YR	-17,094.53	-941.22	-55,919.18	-50.59	0.00	-45,212.45	0.00	-1.12	-1,498.96	-648.09	-59.96	-121,426.10
TOTAL	-139,508.25	-39,868.50	-1,654,765.55	-20,797.75	-185,396.00	-820,356.42	-255,277.10	-28.36	-93,997.10	-74,054.87	-547.67	-3,284,597.57

NMF A-3.1 FEBRUARY - MARCH -PT EST

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	-5,675.44	-9,076.06	-311,646.12	-18,483.16	-135,637.33	0.00	-173,874.62	0.00	-51,839.49	-52,446.55	-267.10	-758,945.87
5 YR	-25,322.58	-13,970.78	-561,569.09	-1,449.89	-38,376.92	-298,223.14	-49,188.99	-14.12	-18,038.31	-11,536.89	-17.28	-1,017,707.99
10 YR	-38,548.40	-9,977.75	-410,438.99	-601.29	-9,211.20	-252,874.97	-23,833.98	-6.75	-13,537.09	-5,390.44	-10.22	-764,431.08
25 YR	-33,745.39	-4,019.54	-205,118.83	-237.80	-2,170.55	-135,148.94	-8,379.51	-4.18	-5,904.80	-2,767.97	-85.09	-397,582.60
50 YR	-24,797.35	-1,998.00	-110,073.34	-112.83	0.00	-88,896.92	0.00	-2.19	-3,178.45	-1,364.27	-108.02	-230,531.37
100 YR	-17,094.53	-977.97	-55,919.18	-55.10	0.00	-45,212.45	0.00	-1.18	-1,603.42	-662.87	-60.04	-121,586.74
TOTAL	-145,183.69	-40,020.10	-1,654,765.55	-20,940.07	-185,396.00	-820,356.42	-255,277.10	-28.42	-94,101.56	-74,168.99	-547.75	-3,290,785.65

NMF A-3.1 NOVEMBER - UPPER												
Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	-26,609.47	-18,867.66	-933,772.85	-18,483.16	-246,398.08	0.00	-315,859.75	-26.09	-76,228.87	-67,052.48	-302.45	-1,703,600.86
5 YR	-101,888.71	-20,405.26	-930,750.17	-1,449.89	-51,665.14	-401,484.54	-66,220.96	-15.35	-28,802.97	-12,217.24	-26.71	-1,614,926.94
10 YR	-120,324.04	-9,977.75	-540,523.44	-601.29	-11,337.95	-308,374.84	-29,064.87	-10.74	-15,734.56	-6,772.28	-515.62	-1,043,237.38
25 YR	-88,574.87	-4,019.54	-239,199.03	-237.80	-2,415.01	-150,369.58	-9,323.22	-4.55	-6,305.20	-2,767.97	-238.95	-503,455.72
50 YR	-43,928.65	-1,998.00	-113,815.18	-112.83	0.00	-88,896.92	0.00	-2.19	-3,178.45	-1,364.27	-119.01	-253,415.50
100 YR	-22,038.85	-977.97	-55,919.18	-55.10	0.00	-45,212.45	0.00	-1.18	-1,603.42	-662.87	-60.04	-126,531.06
TOTAL	-403,364.59	-56,246.18	-2,813,979.85	-20,940.07	-311,816.18	-994,338.33	-420,468.80	-60.10	-131,853.47	-90,837.11	-1,262.78	-5,245,167.46

NMF Alternative 3.2

NMF A-3.2 NOVEMBER - LOWER												
Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25 YR	0.00	0.00	0.09	90.75	279.80	22,815.32	1,182.60	0.14	21,320.39	2,951.28	0.00	48,640.37
50 YR	10.68	0.00	0.04	1.80	0.00	3,400.85	0.00	8.10	5,831.60	269.46	0.00	9,522.53
100 YR	-1.78	-0.88	-29.11	-0.30	0.00	-257.84	0.00	-0.04	-246.24	-22.32	0.00	-558.51
TOTAL	8.90	-0.88	-28.98	92.25	279.80	25,958.33	1,182.60	8.20	26,905.75	3,198.42	0.00	57,604.39

NMF A-3.2 NOVEMBER - PT EST												
Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25 YR	0.00	0.00	0.09	90.75	279.80	22,815.32	1,182.60	0.14	21,320.39	2,951.28	0.00	48,640.37
50 YR	10.68	0.00	0.04	1.80	0.00	3,400.85	0.00	8.10	5,831.60	269.46	0.00	9,522.53
100 YR	-1.78	-0.88	-29.11	-0.30	0.00	-257.84	0.00	-0.32	-246.24	-22.32	0.00	-558.79
TOTAL	8.90	-0.88	-28.98	92.25	279.80	25,958.33	1,182.60	7.92	26,905.75	3,198.42	0.00	57,604.11

NMF A-3.2 NOVEMBER - UPPER												
Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10 YR	0.00	0.00	0.00	-10.93	-388.60	-13,890.35	-1,099.04	-3.63	-31,004.50	-1,174.90	0.00	-47,571.95
25 YR	-203.06	-70.45	-4,584.75	-133.03	-113.85	-9,285.17	-481.30	-0.44	-1,936.75	-3,060.00	-2.98	-19,871.78
50 YR	-33.82	-217.43	-8,614.06	-690.52	0.00	-30,786.88	0.00	-260.17	-1,854.50	-3,155.76	-11.72	-45,624.86
100 YR	-361.34	-449.02	-11,418.73	-490.85	0.00	-35,663.67	0.00	-0.32	-2,298.76	-2,483.91	-10.51	-53,177.11
TOTAL	-598.22	-736.90	-24,617.54	-1,325.33	-502.45	-89,626.07	-1,580.34	-264.56	-37,094.51	-9,874.57	-25.21	-166,245.70

NMF A-3.2 DECEMBER - JANUARY - LOWER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	4,061.22	1,595.88	96,677.00	3,703.48	208,310.73	0.00	0.00	279.99	1,086,244.65	131,730.08	23.15	1,532,626.18
2 YR	2,117.35	4,415.27	231,113.70	17,287.63	70,515.56	0.00	147,398.97	111.99	400,192.75	92,923.04	270.13	966,346.39
5 YR	1,681.99	2,714.16	67,606.56	1,449.20	7,556.11	113,614.00	15,794.24	0.31	13,173.36	9,111.05	61.76	232,762.74
10 YR	-8,532.16	-3,474.06	-174,927.78	-707.65	-4,680.48	-246,970.16	-19,613.00	-5.81	-10,989.53	-7,760.10	-9.26	-477,669.99
25 YR	-18,828.72	-5,021.20	-171,126.07	-293.09	-1,421.19	-171,358.80	-8,933.41	-3.66	-7,215.90	-3,292.52	-4.02	-387,498.58
50 YR	-20,818.92	-2,583.87	-110,657.84	-142.64	0.00	-127,931.37	0.00	-2.62	-4,097.72	-2,090.40	-17.25	-268,342.63
100 YR	-17,991.54	-1,279.17	-60,838.45	-63.39	0.00	-68,952.31	0.00	-1.30	-2,220.46	-981.89	-55.52	-152,384.03
TOTAL	-58,310.78	-3,632.99	-122,152.88	21,233.54	280,280.73	-501,598.64	134,646.80	378.90	1,475,087.15	219,639.26	268.99	1,445,840.08

NMF A-3.2 DECEMBER - JANUARY - PT EST

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	4,061.22	1,595.88	96,677.00	3,703.48	208,310.73	0.00	0.00	279.99	1,086,244.65	131,730.08	23.15	1,532,626.18
2 YR	2,117.35	2,948.35	179,063.10	12,990.53	68,247.45	0.00	142,657.93	111.99	400,192.75	90,011.86	216.10	898,557.41
5 YR	1,681.99	2,714.16	67,606.56	1,449.20	7,556.11	113,614.00	15,794.24	0.31	13,173.36	9,111.05	61.76	232,762.74
10 YR	-8,532.16	-3,474.06	-174,927.78	-1,009.96	-4,680.98	-246,970.16	-19,613.00	-5.81	-10,989.53	-8,635.09	-24.70	-478,863.23
25 YR	-18,828.72	-5,021.20	-171,126.07	-293.09	-1,421.19	-171,358.80	-8,933.41	-3.66	-7,215.90	-3,292.52	-4.02	-387,498.58
50 YR	-20,818.92	-2,583.87	-110,657.84	-149.67	0.00	-127,931.37	0.00	-2.62	-4,097.72	-2,090.40	-17.25	-268,349.66
100 YR	-17,991.54	-1,308.67	-60,838.45	-69.23	0.00	-68,952.31	0.00	-1.36	-2,222.30	-1,041.95	-55.52	-152,481.33
TOTAL	-58,310.78	-5,129.41	-174,203.48	16,621.26	278,012.12	-501,598.64	129,905.76	378.84	1,475,085.31	215,793.03	199.52	1,376,753.53

NMF A-3.2 DECEMBER - JANAUARY - UPPER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	4,061.22	1,595.88	96,677.00	3,703.48	208,310.73	0.00	0.00	279.99	1,086,244.65	131,730.08	23.15	1,532,626.18
2 YR	2,117.35	2,948.35	179,063.10	12,990.53	68,247.45	0.00	142,657.93	0.61	53,261.26	78,885.48	216.10	540,388.16
5 YR	-31,073.72	-14,713.10	-569,341.80	-3,096.91	-33,412.67	-502,380.45	-69,841.20	-7.34	-36,975.91	-24,869.89	-94.18	-1,285,807.17
10 YR	-93,672.82	-12,925.08	-537,814.62	-1,009.96	-8,246.07	-435,120.79	-34,555.40	-12.85	-20,189.10	-10,191.41	-24.70	-1,153,762.80
25 YR	-124,549.44	-5,263.72	-272,823.19	-293.09	-1,936.45	-233,481.42	-12,171.98	-5.25	-9,036.96	-4,125.37	-236.38	-663,923.25
50 YR	-61,922.40	-2,583.87	-130,779.29	-149.67	0.00	-136,532.53	0.00	-2.62	-4,336.57	-2,090.40	-117.66	-338,515.01
100 YR	-30,785.10	-1,308.67	-62,573.47	-69.23	0.00	-68,952.31	0.00	-1.36	-2,222.30	-1,041.95	-58.83	-167,013.22
TOTAL	-335,824.91	-32,250.21	-1,297,592.27	12,075.15	232,962.99	-1,376,467.50	26,089.35	251.18	1,066,745.07	168,296.54	-292.50	-1,536,007.11

NMF A-3.2 FEBRUARY-MARCH LOWER												
Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	-9,684.00	-352,946.88	-23,521.22	-154,401.70	0.00	-197,928.82	0.00	-58,965.09	-63,234.58	-329.95	-861,012.24
5 YR	-26,916.51	-16,396.09	-643,933.43	-1,707.68	-51,369.27	-399,185.38	-65,841.73	-15.96	-29,394.44	-14,023.31	-20.42	-1,248,804.22
10 YR	-39,288.33	-10,300.82	-437,252.15	-653.49	-10,415.46	-283,282.36	-26,699.69	-8.29	-14,633.76	-6,383.78	-11.00	-828,929.13
25 YR	-34,128.36	-4,089.09	-213,684.65	-245.51	-2,317.48	-144,292.87	-8,946.40	-4.43	-6,128.65	-2,909.09	-85.41	-416,831.94
50 YR	-24,988.92	-1,999.19	-114,414.92	-119.31	0.00	-94,611.94	0.00	-2.26	-3,290.38	-1,410.98	-108.02	-240,945.92
100 YR	-17,227.72	-966.79	-58,753.51	-54.61	0.00	-47,177.68	0.00	-1.15	-1,582.03	-674.07	-60.12	-126,497.68
TOTAL	-142,549.84	-43,435.98	-1,820,985.54	-26,301.82	-218,503.91	-968,550.23	-299,416.64	-32.09	-113,994.35	-88,635.81	-614.92	-3,723,021.13

NMF A-3.2 FEBRUARY-MARCH PT EST												
Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	-6,655.09	-9,684.00	-352,946.88	-23,521.22	-154,401.70	0.00	-197,928.82	0.00	-58,965.09	-63,234.58	-329.95	-867,667.33
5 YR	-26,916.51	-16,396.09	-643,933.43	-3,196.15	-51,369.27	-399,185.38	-65,841.73	-15.96	-29,394.44	-19,942.82	-80.12	-1,256,271.90
10 YR	-39,288.33	-10,300.82	-437,252.15	-737.74	-10,415.46	-283,282.36	-26,699.69	-8.29	-14,633.76	-6,383.78	-11.00	-829,013.38
25 YR	-34,128.36	-4,154.11	-213,684.65	-262.40	-2,317.48	-144,292.87	-8,946.40	-4.43	-6,128.65	-3,003.17	-85.41	-417,007.93
50 YR	-24,988.92	-2,065.23	-114,414.92	-125.05	0.00	-94,611.94	0.00	-2.26	-3,290.38	-1,481.87	-108.02	-241,088.59
100 YR	-17,227.72	-1,020.09	-58,753.51	-62.57	0.00	-48,658.68	0.00	-1.21	-1,687.33	-730.30	-60.12	-128,201.53
TOTAL	-149,204.93	-43,620.34	-1,820,985.54	-27,905.13	-218,503.91	-970,031.23	-299,416.64	-32.15	-114,099.65	-94,776.52	-674.62	-3,739,250.66

NMF A-3.2 FEBRUARY-MARCH UPPER												
Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	-27,808.99	-20,758.73	-1,000,968.77	-23,521.22	-280,345.34	0.00	-359,377.02	-26.10	-87,811.43	-80,290.68	-353.52	-1,881,261.80
5 YR	-102,629.06	-20,728.60	-957,636.59	-3,196.15	-54,460.38	-423,206.08	-69,803.71	-16.58	-29,897.89	-19,942.82	-80.12	-1,681,597.98
10 YR	-121,281.92	-10,300.82	-561,996.84	-737.74	-12,073.42	-328,375.77	-30,949.81	-11.36	-16,294.59	-7,358.68	-515.62	-1,089,896.57
25 YR	-89,005.52	-4,154.11	-247,985.96	-262.40	-2,503.76	-155,890.08	-9,665.52	-4.67	-6,636.30	-3,003.17	-239.90	-519,351.39
50 YR	-44,143.97	-2,065.23	-118,268.80	-125.05	0.00	-94,611.94	0.00	-2.26	-3,290.38	-1,481.87	-119.32	-264,108.82
100 YR	-22,133.28	-1,020.09	-58,753.51	-62.57	0.00	-48,658.68	0.00	-1.21	-1,687.33	-730.30	-60.12	-133,107.09
TOTAL	-407,002.74	-59,027.58	-2,945,610.47	-27,905.13	-349,382.90	-1,050,742.55	-469,796.06	-62.18	-145,617.92	-112,807.52	-1,368.60	-5,569,323.65

NMF Alternative 4.1

NMF A-4.1 NOVEMBER LOWER												
Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25 YR	0.00	0.00	0.09	90.75	279.80	22,815.32	1,182.60	0.14	21,320.39	2,951.28	0.00	48,640.37
50 YR	0.00	0.00	0.04	1.80	0.00	3,400.85	0.00	4.02	5,831.60	269.46	0.00	9,507.77
100 YR	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	0.00	0.00	0.13	92.55	279.80	26,216.17	1,182.60	4.16	27,151.99	3,220.74	0.00	58,148.14

NMF A-4.1 NOVEMBER - PT EST												
Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25 YR	0.00	0.00	0.09	90.75	279.80	22,815.32	1,182.60	0.14	21,320.39	2,951.28	0.00	48,640.37
50 YR	0.00	0.00	0.04	1.80	0.00	3,400.85	0.00	4.02	5,831.60	269.46	0.00	9,507.77
100 YR	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	0.00	0.00	0.13	92.55	279.80	26,216.17	1,182.60	4.16	27,151.99	3,220.74	0.00	58,148.14

NMF A-4.1 NOVEMBER - UPPER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10 YR	0.00	0.00	0.00	-9.80	-346.98	-12,402.36	-981.30	-3.63	-27,692.85	-1,055.97	0.00	-42,492.89
25 YR	-203.06	-70.45	-4,584.75	-133.03	-113.85	-9,285.17	-481.30	-0.44	-1,936.75	-3,060.00	-2.98	-19,871.78
50 YR	-325.56	-217.43	-8,614.06	-690.52	0.00	-30,786.68	0.00	0.00	-1,854.50	-3,155.76	-11.72	-45,656.23
100 YR	-351.37	-444.05	-11,017.01	-467.51	0.00	-38,778.16	0.00	-0.26	-2,246.44	-2,397.15	-10.14	-55,712.09
TOTAL	-879.99	-731.93	-24,215.82	-1,300.86	-460.83	-91,252.37	-1,462.60	-4.33	-33,730.54	-9,668.88	-24.84	-163,732.99

NMF A-4.1 DECEMBER-JANUARY - LOWER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	4,061.22	1,595.88	97,677.00	3,703.48	208,310.73	0.00	0.00	559.98	1,086,244.65	131,730.08	23.15	1,533,906.17
2 YR	8,685.13	4,415.27	231,113.70	17,287.63	71,304.56	0.00	149,048.22	279.99	419,619.91	92,923.04	270.13	994,947.58
5 YR	240.80	387.64	9,658.08	207.03	1,079.44	16,230.12	2,256.32	0.00	1,880.47	1,301.39	9.26	33,250.55
10 YR	-8,532.16	-3,474.06	-174,927.78	-707.65	-4,680.48	-246,970.16	-19,613.00	-5.81	-10,989.53	-7,760.10	-9.26	-477,669.99
25 YR	-18,828.72	-5,021.20	-171,126.07	-293.09	-1,421.20	-171,358.80	-8,933.41	-3.66	-7,215.90	-3,292.52	-4.02	-387,498.59
50 YR	-20,818.92	-2,583.87	-110,657.84	-142.64	0.00	-127,931.37	0.00	-2.62	-4,097.72	-2,090.40	-17.25	-268,342.63
100 YR	-17,991.54	-1,279.17	-60,838.45	-63.38	0.00	-68,952.31	0.00	-1.30	-2,222.30	-981.89	-55.52	-152,385.86
TOTAL	-53,184.19	-5,959.51	-179,101.36	19,991.38	274,593.05	-598,982.52	122,758.13	826.58	1,483,219.58	211,829.60	216.49	1,276,207.23

NMF A-4.1 DECEMBER-JANUARY - PT EST

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	4,061.22	1,595.88	97,677.00	3,703.48	208,310.73	0.00	0.00	559.98	1,086,244.65	131,730.08	23.15	1,533,906.17
2 YR	8,685.13	3,130.50	189,197.10	14,076.77	73,304.56	0.00	149,098.22	279.99	419,619.91	93,157.76	231.54	950,781.48
5 YR	240.80	387.64	9,658.08	207.03	1,079.44	16,230.12	2,256.32	0.00	1,880.47	1,301.39	9.26	33,250.55
10 YR	-8,532.16	-3,474.06	-174,927.78	-1,009.96	-4,680.48	-246,970.16	-19,613.00	-5.81	-10,989.53	-8,635.09	-24.70	-478,862.73
25 YR	-18,828.72	-5,021.20	-171,126.07	-293.09	-1,421.20	-171,358.80	-8,933.41	-3.66	-7,215.90	-3,292.52	-4.07	-387,498.64
50 YR	-20,818.92	-2,583.87	-110,657.84	-149.67	0.00	-127,931.37	0.00	-2.62	-4,097.72	-2,090.40	-17.25	-268,349.66
100 YR	-17,991.54	-1,308.67	-60,838.45	-69.23	0.00	-68,952.31	0.00	-1.36	-2,222.30	-1,041.95	-55.52	-152,481.33
TOTAL	-53,184.19	-7,273.78	-221,017.96	16,465.33	276,593.05	-598,982.52	122,808.13	826.52	1,483,219.58	211,129.27	162.41	1,230,745.84

NMF A-4.1 DECEMBER - JANUARY UPPER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	4,061.22	1,595.88	97,677.00	3,703.48	208,310.73	0.00	0.00	559.98	1,086,244.65	131,730.08	23.15	1,533,906.17
2 YR	8,685.13	3,130.50	189,197.10	14,076.77	73,304.56	0.00	149,098.22	1.53	53,219.35	78,885.48	231.54	569,830.18
5 YR	-29,632.53	-12,386.58	-511,393.32	-1,854.74	-26,936.00	-404,999.73	-56,303.28	-14.08	-25,683.02	-17,060.23	-41.69	-1,086,305.20
10 YR	-93,672.82	-12,925.08	-537,814.62	-1,009.96	-8,246.07	-435,120.79	-34,555.40	-12.85	-20,189.10	-10,191.41	-24.70	-1,153,762.80
25 YR	-124,549.44	-5,263.72	-272,823.19	-293.09	-1,936.45	-233,481.42	-12,171.98	-5.25	-9,036.96	-4,125.37	-236.38	-663,923.25
50 YR	-61,922.40	-2,583.87	-130,779.29	-149.67	0.00	-136,532.53	0.00	-2.62	-4,336.57	-2,090.40	-117.66	-338,515.01
100 YR	-30,785.10	-1,308.67	-62,573.47	-69.23	0.00	-68,952.31	0.00	-1.36	-2,222.30	-1,041.95	-58.83	-167,013.22
TOTAL	-327,815.94	-29,741.54	-1,228,509.79	14,403.56	244,496.77	-1,279,086.78	46,067.56	525.35	1,077,996.05	176,106.20	-224.57	-1,305,783.13

NMF A-4.1 FEBRUARY -MARCH - LOWER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00
2 YR	0.00	-7,825.21	-257,397.32	-13,330.13	-109,280.71	0.00	-140,087.85	0.00	-42,478.53	-40,430.63	-208.18	-611,038.56
5 YR	-22,730.49	-12,840.98	-467,466.62	-972.88	-28,594.54	-222,202.77	-36,650.59	-9.21	-14,200.66	-8,146.32	-15.71	-813,830.77
10 YR	-36,447.78	-8,963.35	-360,789.08	-408.53	-7,547.22	-205,267.80	-19,346.63	-5.22	-12,141.82	-3,968.34	-9.43	-654,895.20
25 YR	-32,405.06	-3,603.20	-176,271.28	-164.82	-1,758.66	-109,500.26	-6,789.23	-3.57	-5,016.00	-2,158.91	-84.15	-337,755.14
50 YR	-24,031.75	-1,445.74	-93,855.42	-79.21	0.00	-73,981.25	0.00	-1.89	-2,625.15	-1,107.90	-107.07	-197,235.38
100 YR	-16,720.70	-532.60	-48,117.28	-42.23	0.00	-39,484.12	0.00	-0.99	-1,244.21	-555.18	-59.49	-106,756.80
TOTAL	-132,335.78	-35,211.08	-1,403,897.00	-14,997.80	-147,181.13	-650,436.20	-202,874.30	-20.88	-77,706.37	-56,367.28	-484.03	-2,721,511.85

NMF A-4.1 FEBRUARY - MARCH PT EST

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	-4,584.76	-7,825.21	-257,397.32	-13,371.19	-109,280.71	0.00	-140,087.85	0.00	-42,478.53	-40,430.63	-208.18	-615,664.38
5 YR	-22,730.49	-12,840.98	-467,466.62	-972.88	-28,594.54	-222,202.77	-36,650.59	-9.21	-14,200.66	-8,146.32	-15.71	-813,830.77
10 YR	-36,447.78	-9,226.97	-360,789.08	-444.29	-7,547.22	-205,267.80	-19,346.63	-5.22	-12,141.82	-3,968.34	-9.43	-655,194.58
25 YR	-32,405.06	-3,614.33	-176,271.28	-167.44	-1,758.66	-109,500.26	-6,789.23	-3.57	-5,016.00	-2,158.91	-84.15	-337,768.89
50 YR	-24,031.75	-1,794.47	-93,855.42	-79.21	0.00	-73,981.25	0.00	-1.89	-2,625.15	-1,107.90	-107.07	-197,584.11
100 YR	-16,720.70	-853.42	-48,603.02	-42.23	0.00	-39,484.12	0.00	-1.05	-1,332.67	-576.46	-59.49	-107,673.16
TOTAL	-136,920.54	-36,155.38	-1,404,382.74	-15,077.24	-147,181.13	-650,436.20	-202,874.30	-20.94	-77,794.83	-56,388.56	-484.03	-2,727,715.89

NMF A-4.1 FEBRUARY - MARCH UPPER												
Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	-25,407.77	-16,975.24	-866,577.84	-13,371.19	-212,449.21	0.00	-272,340.40	-27.63	-64,646.32	-53,817.08	-255.32	-1,525,868.00
5 YR	-98,321.96	-19,127.51	-845,533.87	-1,026.25	-44,138.60	-342,999.03	-56,573.93	-12.89	-26,390.34	-9,762.16	-26.71	-1,443,913.25
10 YR	-116,854.92	-9,226.97	-467,653.02	-444.29	-9,566.61	-260,195.38	-24,523.70	-9.52	-13,241.25	-5,579.38	-511.69	-907,806.73
25 YR	-86,780.06	-3,614.33	-205,073.42	-168.59	-2,101.41	-130,843.79	-8,112.59	-4.06	-5,215.65	-2,321.09	-237.38	-444,472.37
50 YR	-42,728.22	-1,794.47	-93,855.42	-79.21	0.00	-75,123.04	0.00	-1.89	-2,625.15	-1,107.90	-118.54	-217,433.84
100 YR	-21,116.79	-853.42	-48,603.02	-42.23	0.00	-39,484.12	0.00	-1.05	-1,332.67	-576.46	-59.64	-112,069.40
TOTAL	-391,209.72	-51,591.94	-2,527,296.59	-15,131.76	-268,255.83	-848,645.36	-361,550.62	-57.04	-113,451.38	-73,164.07	-1,209.28	-4,651,563.59

NMF Alternative 4.2

NMF A-4.2 NOVEMBER LOWER												
Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25 YR	0.00	0.00	0.00	90.75	279.80	22,815.32	1,182.60	0.14	21,320.39	2,951.28	0.00	48,640.28
50 YR	0.00	0.00	-0.09	1.80	0.00	3,401.14	0.00	4.02	5,832.40	269.46	0.00	9,508.73
100 YR	-10.86	-5.15	-174.75	0.00	0.00	695.60	0.00	2.23	3,981.82	0.00	0.00	4,488.89
TOTAL	-10.86	-5.15	-174.84	92.55	279.80	26,912.06	1,182.60	6.39	31,134.61	3,220.74	0.00	62,637.90

NMF A-4.2 NOVEMBER PT EST

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25 YR	0.00	0.00	0.00	90.75	279.80	22,815.32	1,182.60	0.14	21,320.39	2,951.28	0.00	48,640.28
50 YR	0.00	0.00	-0.09	1.80	0.00	3,401.14	0.00	4.02	5,832.40	269.46	0.00	9,508.73
100 YR	-10.86	-5.15	-174.75	0.00	0.00	695.60	0.00	0.36	698.72	0.00	0.00	1,203.92
TOTAL	-10.86	-5.15	-174.84	92.55	279.80	26,912.06	1,182.60	4.52	27,851.51	3,220.74	0.00	59,352.93

NMF A-4.2 NOVEMBER UPPER												
Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10 YR	0.00	0.00	-0.22	-9.80	-346.70	-12,402.36	-981.30	-3.63	-27,733.31	-1,055.97	0.00	-42,533.29
25 YR	-292.16	-110.45	-6,075.90	-133.03	-53.82	-4,385.62	-227.89	0.14	4,036.91	-3,060.00	-2.98	-10,304.80
50 YR	-480.60	-276.79	-11,886.88	-690.52	0.00	-16,370.50	0.00	4.02	5,832.40	-3,155.76	-11.72	-27,036.35
100 YR	-504.72	-509.65	-14,804.99	-467.51	0.00	-17,372.31	0.00	0.36	698.72	-2,397.15	-4.93	-35,362.18
TOTAL	-1,277.48	-896.89	-32,767.99	-1,300.86	-400.52	-50,530.79	-1,209.19	0.89	-17,165.28	-9,668.88	-19.63	-115,236.62

NMF A-4.2 DECEMBER - JANUARY LOWER												
Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	3,703.48	278,889.41	0.00	0.00	88.20	1,454,271.12	131,730.08	23.15	1,868,705.44
2 YR	0.00	0.00	-1.80	17,287.63	174,587.82	0.00	364,941.64	523.26	917,702.74	93,157.76	262.41	1,568,461.46
5 YR	-4,390.67	-3,593.94	-145,683.00	207.03	38,507.19	578,979.78	80,490.08	135.86	305,575.02	1,301.39	9.26	851,538.00
10 YR	-11,328.29	-6,235.85	-271,914.30	-707.65	5,823.30	307,119.41	24,402.40	74.05	179,295.13	-7,760.10	-9.26	218,758.84
25 YR	-20,291.76	-6,553.97	-222,216.19	-293.09	1,327.87	172,748.46	8,346.62	34.28	81,867.30	-3,292.52	-4.02	11,672.98
50 YR	-21,703.56	-3,401.98	-140,158.94	-142.64	0.00	131,676.41	0.00	19.64	45,724.15	-2,090.40	-17.25	9,905.43
100 YR	-18,510.42	-1,746.53	-77,567.02	-63.38	0.00	91,464.78	0.00	11.22	25,437.38	-981.89	-55.52	17,988.62
TOTAL	-76,224.70	-21,532.27	-857,541.25	19,991.38	499,135.59	1,281,988.84	478,180.74	886.51	3,009,872.84	212,064.32	208.77	4,547,030.77

NMF A-4.2 DECEMBER - JANUARY PT EST

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	3,703.48	278,889.41	0.00	88.20	1,454,271.12	131,730.08	23.15	0.00	1,868,705.44
2 YR	0.00	0.00	-1.80	14,076.77	153,026.02	0.00	319,870.94	523.26	917,702.74	93,157.76	262.41	1,498,618.10
5 YR	-4,390.67	-3,593.94	-145,683.00	207.03	38,507.19	578,979.78	80,490.08	132.80	293,243.02	1,301.39	9.26	839,202.94
10 YR	-11,328.29	-6,235.85	-271,914.30	-1,009.96	4,846.80	255,746.31	20,309.96	67.93	156,147.89	-8,635.09	-24.70	137,970.70
25 YR	-20,291.76	-6,553.97	-222,216.19	-293.09	1,140.55	137,516.72	7,169.18	30.74	72,881.93	-3,292.52	-4.02	-33,912.43
50 YR	-21,703.56	-3,401.98	-140,158.94	-149.67	0.00	97,457.53	0.00	16.53	39,790.63	-2,090.40	-17.25	-30,257.11
100 YR	-18,510.42	-1,746.53	-77,567.02	-69.23	0.00	59,354.60	0.00	9.36	21,712.82	-105.95	-55.52	-16,977.89
TOTAL	-76,224.70	-21,532.27	-857,541.25	16,465.33	476,409.97	1,129,054.94	427,928.36	1,455,051.74	1,633,209.11	80,358.34	170.18	4,263,349.75

NMF A-4.2 DECEMBER - JANUARY UPPER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	3,703.48	278,889.41	0.00	0.00	88.20	1,454,271.12	131,730.08	23.15	1,868,705.44
2 YR	-2,329.08	-701.22	-41,453.10	14,076.77	153,026.02	0.00	319,870.94	287.64	662,886.81	78,885.48	129.20	1,184,679.46
5 YR	-35,703.99	-18,694.04	-724,682.88	-1,854.74	25,974.02	390,535.68	54,292.48	132.80	293,243.02	-17,060.23	-41.69	-33,859.57
10 YR	-98,088.65	-17,041.21	-685,319.94	-1,009.96	4,846.80	255,746.31	20,309.96	67.93	156,147.89	-10,191.41	-24.70	-374,556.98
25 YR	-127,107.12	-7,198.59	-350,465.76	-293.09	1,140.55	137,516.72	7,169.18	30.74	72,881.93	-4,125.37	-236.38	-270,687.19
50 YR	-63,553.56	-3,571.39	-175,232.88	-149.67	0.00	97,457.53	0.00	16.53	39,790.63	-2,090.40	-117.66	-107,450.87
100 YR	-31,776.78	-1,785.70	-87,616.44	-69.23	0.00	59,354.60	0.00	9.36	21,712.82	-105.95	-58.83	-40,336.15
TOTAL	-358,559.18	-48,992.15	-2,064,771.00	14,403.56	463,876.80	940,610.84	401,642.56	633.20	2,700,934.22	177,042.20	-326.91	2,226,494.14

NMF A-4.2 FEBRUARY - MARCH LOWER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	0.00	-11,536.06	-494,093.36	-13,330.13	50,390.69	0.00	64,596.25	276.30	440,350.19	-40,430.64	-208.18	-3,984.94
5 YR	-30,633.07	-20,363.84	-821,986.78	-972.88	116,029.35	901,652.24	148,718.74	226.57	411,728.42	-8,146.32	-15.71	696,236.72
10 YR	-42,680.02	-13,820.14	-593,919.36	-408.53	33,189.86	902,703.93	85,081.14	135.08	248,549.63	-3,918.03	-9.43	614,904.13
25 YR	-35,408.65	-5,626.58	-280,689.74	-164.82	6,509.86	405,325.84	25,131.07	54.12	99,257.40	-2,158.91	-84.15	212,145.44
50 YR	-26,120.52	-2,457.43	-146,779.85	-79.21	0.00	247,785.19	0.00	26.72	49,511.82	-1,107.90	-344.46	120,434.36
100 YR	-17,480.23	-1,038.92	-74,350.04	-39.48	0.00	122,040.20	0.00	13.55	24,918.94	-555.18	-59.49	53,449.35
TOTAL	-152,322.49	-54,842.97	-2,411,819.13	-14,995.05	206,119.76	2,579,507.40	323,527.20	732.34	1,274,316.40	-56,316.98	-721.42	1,693,185.06

NMF A-4.2 FEBRUARY - MARCH PT EST

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	-10,162.24	-11,536.06	-494,093.36	-13,371.19	50,390.69	0.00	64,546.25	267.09	412,494.29	-40,430.64	-208.18	-42,103.35
5 YR	-30,633.07	-20,363.84	-821,986.78	-972.88	107,995.05	839,218.50	138,420.90	209.37	388,248.63	-8,146.32	-15.71	591,973.85
10 YR	-42,680.02	-13,820.14	-593,919.36	-444.29	29,094.55	791,316.40	74,582.93	127.40	229,106.75	-3,918.03	-9.43	469,436.76
25 YR	-35,408.65	-5,637.71	-280,689.74	-167.44	6,509.86	405,325.84	25,131.07	54.12	99,257.40	-2,158.91	-84.15	212,131.69
50 YR	-26,120.52	-2,806.16	-146,779.85	-79.21	0.00	247,785.19	0.00	26.72	49,511.82	-1,107.90	-344.46	120,085.63
100 YR	-17,480.23	-1,359.26	-74,350.04	-42.23	0.00	122,040.20	0.00	13.48	24,830.48	-576.46	-59.49	53,016.45
TOTAL	-162,484.73	-55,523.17	-2,411,819.13	-15,077.24	193,990.15	2,405,686.13	302,681.15	698.18	1,203,449.37	-56,338.26	-721.42	1,404,541.03

NMF A-4.2 FEBRUARY - MARCH UPPER

Flood Frequency	Corn	Rice	Soybean	Fallow	FOREST C-T	FOREST BLH	FOREST FF	Grass Pasture	SHM	OW-AG	S/S	TOTAL
1 YR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 YR	-32,785.62	-23,522.70	-1,204,066.85	-13,371.19	27,860.87	0.00	35,715.08	267.09	412,494.29	-53,817.08	-255.32	-851,481.43
5 YR	-110,161.47	-28,090.06	-1,298,713.91	-1,026.25	107,995.05	839,218.50	138,420.90	209.37	388,248.63	-9,762.16	-26.71	26,311.89
10 YR	-124,363.89	-14,039.38	-729,414.39	-444.29	29,094.55	791,316.40	74,582.93	127.40	229,106.75	-5,579.38	-511.69	249,875.01
25 YR	-89,783.65	-5,637.71	-289,596.55	-168.59	6,175.23	383,982.81	23,807.72	53.63	99,058.30	-2,321.09	-237.38	125,332.72
50 YR	-44,230.10	-2,806.16	-146,781.81	-79.21	0.00	246,643.39	0.00	26.72	49,511.82	-1,107.90	-118.54	101,058.21
100 YR	-21,876.32	-1,359.26	-74,350.04	-42.23	0.00	122,040.20	0.00	13.48	24,830.48	-576.46	-59.64	48,620.21
TOTAL	-423,201.05	-75,455.27	-3,742,923.55	-15,131.76	171,125.70	2,383,201.30	272,526.63	697.69	1,203,250.27	-73,164.07	-1,209.28	-300,283.39

Appendix G

Fisheries

U.S. Army Corps of Engineers
Memphis District

Appendix G

St. Johns Bayou and New Madrid Floodway Project
Fisheries

Background

Flood risk damage measures are being evaluated for the St. Johns Bayou and New Madrid Floodway (SJNM) basins, an agricultural landscape located in southeast Missouri. Measures include closing the gap and building a water control structure in the levee near the outlet of the New Madrid Floodway to prevent Mississippi River backwater flooding. Two pumping stations will also be built in both basins to help drain interior water when outlet structures are closed during high Mississippi River stages. The St. Johns Bayou basin encompasses 450 square miles in southeast Missouri. The basin is protected by levees forming a sump that is drained by a gravity outlet when the Mississippi River elevation is lower than the interior elevation. Closure of the gates protects the interior from high Mississippi River stages. The New Madrid Floodway, which is 207 square miles, lies between the Birds Point-New Madrid setback levee and the Mississippi River mainline levee. The Floodway can divert Mississippi River flow during extreme floods, thereby reducing stages at Cairo, Illinois. It has been opened twice, during the floods of 1937 and 2011. Unlike St. Johns Bayou, the New Madrid Floodway is frequently flooded from Mississippi River backwater through a 1,500 ft. wide opening of the levee at New Madrid that is designed to serve as an outlet during Floodway operation.

Beginning in the late 1990's, field surveys of fishes were conducted in the SJNM Basins by Southern Illinois University to establish a baseline condition for the Environmental Impact Statement of the project. Missouri Dept. of Conservation Open River Field Station was concurrently sampling fishes in the Mississippi River near the outlet of SJNM Basins, and in the late 2000's, the Corps (ERDC-EL) began bio-assessment and telemetry studies. This information was compiled to help parameterize EnviroFish, a hydraulic model used to estimate acres of floodplain habitat suitable for fish reproduction under a given set of project alternatives.

Objectives

This document evaluates and summarizes project impacts on Mississippi River fishes utilizing the SJNM Basins as spawning and rearing habitat. The objectives are:

1. Describe existing conditions of aquatic habitat and fish community in the project area.
2. Evaluate fish movement through the existing culverts in St. Johns Basin and use this information to develop a fish passage "weighting" factor for the proposed structure in the New Madrid Floodway.
3. Calculate impacts of the project on fish spawning and rearing habitat.

Scope

This document is written in five parts to address each objective and provide documentation of all aspects of the analysis:

Part I: Description of Existing Conditions
Part II: Fish Movements through the St. Johns Water Control Structure
Part III: Evaluation of Project Impacts
Part IV: Acknowledgments
Part V: Literature Cited

Part 1: Description of Existing Conditions

Introduction

The St. Johns and New Madrid Basins (SJNM) cover over 650 square miles in southeast Missouri. The alluvial floodplain deposits are typically rich in organic material, and consequently, intense agricultural activities and subsequent flood control measures now characterize these areas: over 80% of the lands are agriculture. Flooding from the Mississippi River typically occurs during winter and spring. Approximately 1,000 acres flood each year in both basins, with a 2-year flood frequency of 12,000 and 45,000 in the St. Johns and New Madrid Basins, respectively (Figure I-1). In the New Madrid Basin, floodwaters back through the levee gap into Mud Ditch and follow the network of drainage ditches and bayous. In St. Johns Basin, backwater flooding from the Mississippi River is minimized by closing the gravity outlet structure. Managing flood pulses, which drive ecological process in floodplain rivers (Junk et al. 1989), has resulted in agricultural intensification (i.e., cleared, leveled, drained, farmland) in both basins creating a homogenous landscape.

Delta streams, bayous, and ditches that occur in SJNM Basins are typical throughout the alluvial floodplain of the lower Mississippi River. Delta streams are most prevalent in the Mississippi Embayment, a 4748 square mile area of the lower Mississippi River valley, which is comprised of 62 percent agricultural land (Kleiss et al. 2000). Low water (from instream and groundwater withdrawals; drainage control), excessive sedimentation (from deforestation-induced erosion), and the accumulation of historically used organo-chlorine pesticides such as DDT have degraded these streams and bayous resulting in dominance of tolerant fish species (Killgore et al. 2007; Miranda and Lucas 2004; Sullivan et al. 2004; Wang et al. 1997).

Objectives

1. Characterize fish assemblages in the project area based on field collections and data from other sources.
2. Compare fish assemblages between the St. Johns and New Madrid Basins

Methods

Fishery data from the project area, which includes the Mississippi River and St. Johns-New Madrid basins, were obtained from Missouri Department of Conservation (Cape Girardeau Open River Field Station) and Southern Illinois University (Sheehan et al. 1998). Gears included gill nets, seines, and electroshocking in the SJNM Basins and also trawling in the Mississippi River. More recently, ERDC-Environmental Laboratory sampled bayous and ditches in both basins during summer 2007.

Field Collections

ERDC-EL sampled fishes with an 8’ x 10’ or 8’ x 20’ seine constructed of 3/16” mesh, and consisted of 10 or 5 hauls, respectively, stratified among all apparent microhabitats. The smaller seine was generally utilized in upper reaches of the sampled rivers where the water body was typically narrower. The larger seine was utilized in lower reaches. Sampling efforts taken at each station were pooled into a single composite sample.

Water quality parameters were determined for each river section sampled. Dissolved oxygen, pH, conductivity, and water temperature were measured with a Quanta Hydrolab®. Turbidity was measured with a Hach 2100P® turbidimeter. River width and sampling distance were measured using a Bushnell® laser rangefinder. Water depth (stadia rod) and velocity (Marsh-McBirney Flo-Mate) were taken at 10 equidistant points along a cross sectional transect within the sampled reach. Stations were georeferenced using a hand-held Magellan® or Delorme PN40 GPS unit.

Analyses

Analytical assessments of assemblage structure and similarity were computed with the procedures in the PRIMER (Plymouth Routines in Multivariate Ecological Research) version 6 statistical package (Clarke and Warwick 2001; Clarke and Gorley 2006). Abundance values in the final species matrix were square root transformed to reduce the influence of the most common species (Clarke and Gorley 2006). No species were excluded due to rarity. Resemblance matrices were created by computing Bray-Curtis similarity indices for each assemblage comparison.

Non-metric multi-dimensional scaling (MDS) was conducted to provide a graphical presentation of the similarity among samples in a low-dimensional space with those samples (i.e., points on the figure) occurring close together representing samples that are very similar in community composition. The reduction of the original dataset to a low-dimensional space is measured as "stress" and represents the effectiveness of the data reduction technique in depicting the similarity among samples in the original high-dimensional space. Values < 0.05 represent excellent representation of the low-dimensional solution with a value of 0.01 representing a perfect fit; < 0.1 represents a good solution; < 0.2 represents useful 2-dimensional solutions but signals need for additional analyses to evaluate internal structure within the dataset; and stress values > 0.3 represent solutions that differ little from randomized points (Clarke and Warwick 2001).

An analysis of similarity (ANOSIM) was conducted to assess differences in species assemblages between systems (New Madrid, St. Johns Bayou). This analytical approach is analogous to a 1-way ANOVA and assesses the degree of variability in similarity values within treatments in order to establish the strength of differences that may be found between treatments. The test statistic for ANOSIM, R, ranges from 0 to 1. Values close to 0 indicate little difference between groups and values approaching 1 represent complete separation of the groups (Clarke and Warwick 2001). We calculated similarity percentages (SIMPER) on the raw abundance values to determine which species contribute to the similarity pattern depicted within groups (i.e., typifying species) as well as those species that contribute to the dissimilarity between groups (i.e., discriminating species). We conducted a hierarchical clustering technique (CLUSTER) on the resemblance matrix and incorporated the SIMPROF option to test for significance (alpha = 0.05) of internal structure.

The matrix for the comparison of environmental conditions consisted of 10 variables (water temperature, dissolved oxygen, conductivity, pH, turbidity, sediment depth, water depth, water velocity, stream width and discharge). Data were square-root-transformed, normalized and a Euclidean distance matrix was produced before conducting further analyses. A MDS was generated to provide a graphical presentation of the similarity among stations along with an ANOSIM to evaluate the difference between systems based on measured environmental conditions. A BEST (Bio-Env + STepwise) routine (Clarke

and Gorley 2006) was conducted to assess differences in environmental condition factors between the respective groups of samples. The BEST routine provides a measure of agreement between structure in the biotic assemblage and any multivariate environmental pattern depicted for the same sampled stations.

Results and Discussion

Eighteen stations were sampled within the basin (St. Johns = 9; New Madrid = 9) with three stations located below the confluence of the two systems (St. Johns = 1; New Madrid = 2) (Figure I-2). These 3 stations were not included in any of the faunal or environmental analyses. Final resulting matrix included 15 stations (St. Johns = 8; New Madrid = 7).

Comparison of Fish Fauna

The results of the MDS provided a good solution for a 3-dimensional portrayal of the data (stress = 0.09). The 2-D solution had a slight reduction in fit (stress = 0.16) but is presented instead due to ease of interpretation (Figure I-3). Graphically, the MDS depicted a fairly clean separation between samples from the respective systems while also illustrating similarity among geographically proximal stations (e.g., St. Johns 1, 2, 3 and 4). Results of the SIMPROF indicated there was internal structure in terms of faunal similarity among the sampled stations (Global Pi = 2.239, p = 0.009) with the CLUSTER analysis (Figure I-4) depicting 4 major clusters among all sampled stations. For example, stations 15, 12, 11 and 14 were faunistically the most similar (group average = 47.07%) and the inclusive cluster was significantly different from remaining clusters.

The one-way ANOSIM indicated significant fish assemblage differences between the two systems (Global R = 0.329, p = 0.001). Average similarity among New Madrid stations based on raw abundance values was 30.37% with Western mosquitofish, Blacktail shiner and Bullhead minnow contributed the most to similarity within sites (i.e., typifying species) (68.5%) with 5 additional species contributing the remaining balance Table I-1). Average similarity among St. Johns stations was 26.27% with Western mosquitofish, Blacktail shiner and Ribbon shiner contributing 78.96% of that within group similarity. Four additional species contributed to the remaining balance.

The average dissimilarity between systems was 73.81% with most of these differences due to differences in relative abundance for commonly occurring species (i.e., Western mosquitofish, Bullhead minnow, Emerald shiner Bluntnose minnow) and species occurrence within only a single system (Table I-2). For example, of the 73.81% dissimilarity between systems, 21 species contributed 90% to that dissimilarity with 11 species occurring in both systems. Four species were found only within the New Madrid system; 6 only within the St. John system. Of those species found only within the New Madrid system, all are noted for being tolerant of poor water conditions (Orange spotted sunfish, Gizzard shad, Pugnose minnow).

Environmental Conditions

As with the comparisons of the fish fauna among stations, the results of the MDS for the environmental conditions provided a good solution for a 3-dimensional portrayal of the data (stress = 0.09). The 2-D solution had a slight reduction in fit (stress = 0.17) (Figure I-5) but illustrated a distinct separation between stations representing the respective systems and a grouping of stations similar to that depicted with the fish fauna MDS. The similarity in environmental conditions is depicted well with the results of the CLUSTER analysis (Figure I-6) although there was no internal structure indicated by the SIMPROF analysis (Global Pi = 0.108, p = 0.329). Results of the ANOSIM indicated that there were significant differences between systems in terms of measured environmental conditions (Global R = 0.282, p = 0.011)

Following the inclusion of all 10 environmental variables (Table I-3), the results of the BEST procedure indicated the best solution included 7 variables (Global Rho = 0.554, p = 0.02). Stepwise inclusion of each variable (BVSTEP) illustrated a substantial increase in correlated values with the addition of each explanatory variable. The best explanatory variables, in descending order of contribution, include dissolved oxygen, conductivity, pH, turbidity, depth, stream width and flow. Variables deemed non-significant in discriminating between stations were water temperature, sediment depth and water velocity. This suggests that sediment depth is relatively high throughout both basins and sluggish water persists, homogenizing the fish assemblage. Variation in some of the water quality and hydraulic variables may influence localized species richness, but overall, the summer fish assemblage in both basins are dominated by tolerant, ubiquitous species.

Summary

Ninety species of fish have been documented in the project area excluding the invasive Asian carp (silver, bighead, and grass carp) (Table I-4). Sampled fishes were characteristic of the lower Mississippi River and tributaries, and were dominated taxonomically by minnows (20 species), sunfishes (14 species), suckers (13 species), and darters (13 species).

There are two groups or guilds of fish species that that utilize the two basins for reproductive purposes: riverine (or transient) and permanent (Table I-4). Riverine species are those that occur primarily in the Mississippi River and will move onto flooded areas to spawn or rear during spring floods (e.g., buffalo). Collectively, the peak reproductive period of most Mississippi River fishes extends from March through June when water temperature ranges from 60-80 °F. Mississippi River fishes exhibit characteristic spawning chronologies: early-season spawners (March), mid-season spawners (April-May 15), and late-season spawners (May 16-June). Permanent species reside in the canals and bayous year-around (e.g., sunfishes). Although riverine species depend on Mississippi River flooding to complete critical life stages, permanent species are more dependent on habitat conditions in summer and fall (flow, sediments, and water quality). Therefore, Habitat Suitability Indices (HSI's) were developed specifically for the riverine species guild that spawn or rear in the two basins since spring flooding will be directly affected by the project.

In terms of the two basins, the St. Johns Bayou Basin is more diverse compared to the New Madrid Floodway. Sheehan et al (1998) documented 46 species in the floodway while 71 species were found in St. Johns Basin using multiple types of collecting gears. In 2007, ERDC-EL documented 42 species in St. Johns compared to 33 species in the floodway using seines to collect fish. Of the 42 species collected in St. Johns basin in 2007, 20 species were not found in New Madrid floodway. The fish assemblages in both basins are numerically dominated by widespread, tolerant species (e.g., mosquitofish, certain sunfishes and shiners). Characteristics of tolerant fish assemblages include adaptations to low dissolved oxygen and high pulses of suspended solids, no direct requirements for clean, firm substrates for spawning, and ability to live in shallow, slackwater pools for extended periods (Hoover and Killgore 1998; Scott and Hall 1997; Jester et al. 1992). However, St. Johns basin harbors more darters and minnows compared to the floodway. Darters and minnows, as well as a few other taxonomic groups typically occur in streams and bayous of higher habitat value, and differences in species richness between the two basins can be attributed to several factors:

1) St. Johns Basin is protected from unregulated Mississippi River flooding, which has resulted in reduced sedimentation in the streams. Typically, soft sediment depth in the streams is less than 1.0 ft in St. Johns compared to greater than 1 ft in New Madrid floodway. Turbidity is also higher in New Madrid Floodway, averaging 56 NTU's in summer 2008 but only 27 NTU's in St. Johns.
2) Flooding from the Mississippi River resets species composition in the New Madrid Floodway every 1-2 years reducing stability and persistence of fish species residing in the streams year around.
3) Channel degradation is accelerated in the New Madrid Floodway due to fluctuating water levels from Mississippi River floods. The ditches and bayous become incised and more homogeneous compared to St. Johns where the bayous are more sinuous.

Table I-1. Similarity percentages (SIMPER) on the raw abundance values by basin.

Group New Madrid
Average similarity: 30.37

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
WESTERN MOSQUITOFISH	47.71	10.36	0.92	34.11	34.11
BLACKTAIL SHINER	32.43	7.11	0.68	23.41	57.52
BULLHEAD MINNOW	15.29	3.33	0.68	10.98	68.50
ORANGESPOTTED SUNFISH	12.86	2.03	0.46	6.68	75.17
RIBBON SHINER	13.71	2.01	0.46	6.61	81.79
BROOK SILVERSIDE	6.86	1.20	0.58	3.96	85.75
GIZZARD SHAD	3.71	1.11	0.79	3.66	89.41
EMERALDSHINER	6.86	0.88	0.39	2.90	92.31

Group St. John
Average similarity: 26.97

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
WESTERN MOSQUITOFISH	88.63	13.56	1.33	50.27	50.27
BLACKTAIL SHINER	23.00	4.56	0.80	16.91	67.18
RIBBON SHINER	12.00	3.18	0.55	11.78	78.96
BLUNTNOSE MINNOW	9.88	0.96	0.79	3.54	82.50
BLUEGILL	5.50	0.79	0.34	2.91	85.41
BLACKSTRIPED TOPMINNOW	4.00	0.73	0.45	2.69	88.10
GREEN SUNFISH	4.88	0.64	0.50	2.39	90.49

Table I-2. Similarity percentages (SIMPER) on the raw abundance values showing dissimilarity among species and basins. Blue highlight indicates species not present in St. Johns system. Yellow highlight signifies those species not present in New Madrid system.

Groups New Madrid & St. John
Average dissimilarity = 73.81

Species	Group New Madrid Av.Abund	Group St. John Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
WESTERN MOSQUITOFISH	47.71	88.63	16.99	1.24	23.01	23.01
BLACKTAIL SHINER	32.43	23.00	10.13	0.99	13.73	36.74
BULLHEAD MINNOW	15.29	8.00	5.58	1.00	7.55	44.30
RIBBON SHINER	13.71	12.00	5.05	1.15	6.83	51.13
ORANGESPOTTED SUNFISH	12.86	0.00	4.21	0.64	5.71	56.84
BROOK SILVERSIDE	6.86	15.38	3.35	0.86	4.54	61.38
IRONCOLOR SHINER	0.00	24.38	3.04	0.51	4.12	65.50
EMERALD SHINER	6.86	0.38	2.17	0.71	2.94	68.44
BLUEGILL	2.00	5.50	2.02	0.80	2.73	71.17
BLUNTNOSE MINNOW	2.14	9.88	1.88	1.10	2.55	73.72
GOLDEN TOPMINNOW	0.00	6.75	1.76	0.37	2.38	76.11
BANDED PYGMY SUNFISH	0.00	6.00	1.61	0.44	2.18	78.29
GREEN SUNFISH	1.00	4.88	1.40	0.79	1.90	80.19
BLACKSTRIPED TOPMINNOW	0.57	4.00	1.24	0.83	1.68	81.87
GIZZARD SHAD	3.71	0.00	1.20	0.97	1.63	83.50
REDSPOTTED SUNFISH	0.00	3.38	0.89	0.85	1.21	84.71
PUGNOSE MINNOW	2.29	0.00	0.88	0.66	1.20	85.90
PIRATE PERCH	0.00	3.75	0.88	0.73	1.20	87.10
LEPOMIS SP	2.29	0.00	0.86	0.36	1.16	88.26
CYPRESS DARTER	0.00	3.88	0.84	0.47	1.14	89.40
BLACKSPOTTED TOPMINNOW	0.00	2.88	0.82	0.39	1.10	90.50

Table I-3. Water quality and hydraulic variables measured in the St. Johns Bayou (n=9)and New Madrid Floodway (n=9) Basins during summer 2007.

Variable	Mean	Std Dev	Minimum	Maximum
		New Madrid Floodway		
Water Temperature, C	30.3	2.0	26.3	32.2
Dissolved Oxygen, mg/l	6.7	2.0	3.1	9.3
Conductivity, umhos/cm	362.1	33.0	313.0	419.0
pH	7.7	0.2	7.4	7.8
Turbidity, NTU	56.7	9.1	45.4	67.9
Sediment Depth, ft	1.2	0.4	0.6	1.8
Water Depth, ft	2.4	2.0	0.3	6.3
Water Velocity, cm/s	0.4	0.4	0.0	1.1
Channel Width, ft	57.4	23.9	24.0	90.0
Discharge, cfs	32.5	42.6	0.0	137.8
		St. Johns Bayou		
Water Temperature, C	29.5	3.0	24.3	33.9
Dissolved Oxygen, mg/l	7.1	3.0	0.8	12.7
Conductivity, umhos/cm	300.4	26.2	265.0	335.0
pH	7.8	0.4	7.1	8.7
Turbidity, NTU	26.8	12.9	8.9	46.0
Sediment Depth, ft	1.0	0.4	0.3	1.6
Water Depth, ft	1.2	0.5	0.3	1.9
Water Velocity, cm/s	0.6	0.5	0.0	1.5
Channel Width, ft	50.4	30.2	20.0	93.0
Discharge, cfs	47.1	54.8	0.0	143.9

Table I-4. Guilds of fish species that occur in the St. Johns/New Madrid Project area based on substrate preferences for spawning (Balon 1984) and primary rearing location.

Pelagophils	Lithophils	Phytophils	Litho-Psammophils	Speleophils
Rear Primarily River Channel				
Skipjack herring Gizzard shad Threadfin shad Goldeye Mooneye Plains minnow Silver chub Speckled chub Emerald shiner River shiner Freshwater drum*	Shovelnose sturgeon Paddlefish Quillback Blue sucker Northern hog sucker Spotted sucker River redhorse Golden redhorse Shorthead redhorse White bass* Yellow bass Striped bass Smallmouth bass Sauger Walleye Chestnut lamprey		Silverband shiner River carpsucker Harlequin darter Logperch Blackside darter Saddleback darter Dusky darter River darter	Red shiner Spotfin shiner Blacktail shiner* Bullhead minnow Bluntnose minnow Blue catfish Flathead catfish Channel catfish* Freckled madtom Tadpole madtom Johnny darter
Rear Primarily in Floodplain				
Mimic shiner* Channel shiner		Spotted gar Longnose gar Shortnose gar Bowfin Grass pickerel Chain pickerel Smallmouth buffalo* Bigmouth buffalo Black buffalo Golden topminnow* Blackstripe topminnow Blackspotted topminnow Banded pygmy sunfish Mud darter Bluntnose darter Slough darter Cypress darter* Brook silverside Inland silverside	MS silvery minnow Ribbon shiner Golden shiner Ironcolor shiner Weed shiner Pugnose minnow Creek chubsucker Shadow bass Flier Green sunfish Warmouth Orangespotted sunfish Bluegill Longear sunfish* Redear sunfish Redspotted sunfish Spotted bass Largemouth bass* White crappie* Black crappie	Black bullhead Yellow bullhead Pirate perch*

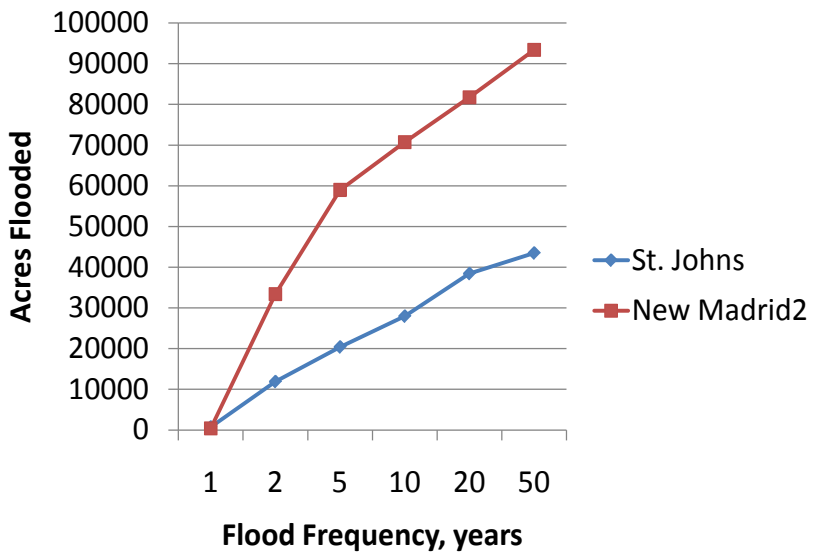


Figure 1-1. Acres flooded by flood frequency in St. Johns and New Madrid Basins.

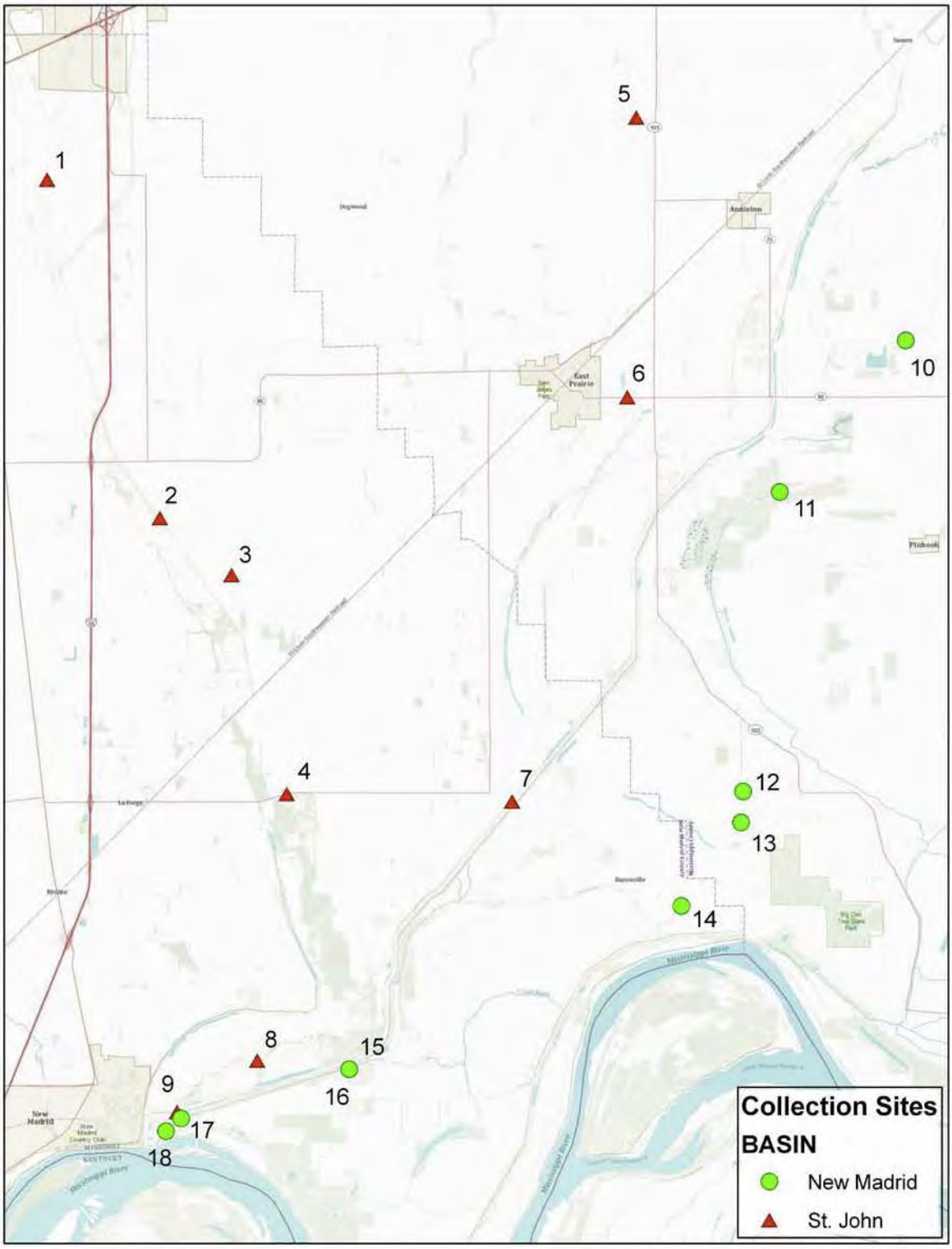


Figure I-2. Sampling sites during summer 2008.

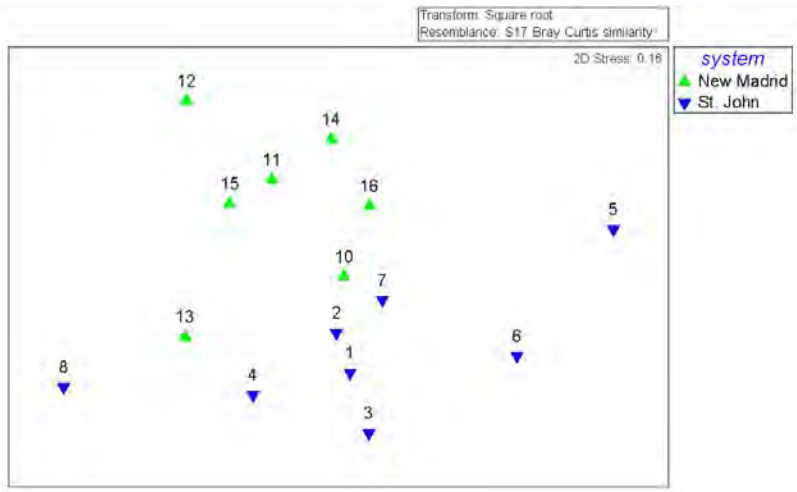


Figure I-3. Non-metric multi-dimensional scaling (MDS) of fish abundance for St. Johns and New Madrid Basins.

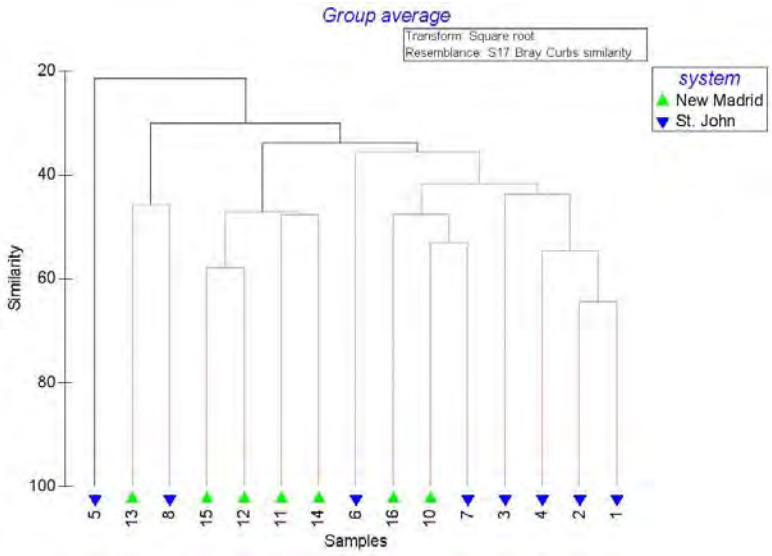


Figure I-4. Hierarchical clustering of sites based on the similarity of fish species abundance.

Figure I-5. Non-metric multi-dimensional scaling (MDS) of environmental variables for St. Johns and New Madrid Basins.

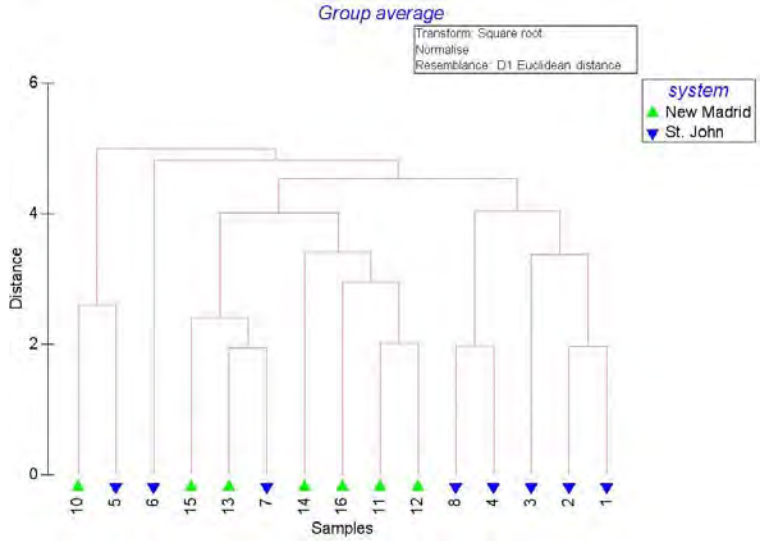


Figure I-6. Hierarchical clustering of sites based on the similarity of environmental conditions.

Part II: Fish Movements Through the St. Johns Water Control Structure

Introduction

Seasonal connectivity between rivers and floodplains created by flood pulses are considered critical for healthy riverine ecosystems (Junk et al. 1989; Winemiller 1996; Bowen et al. 2003; Sommer et al. 2004). Few riverine organisms can survive or develop without exploiting these seasonal floodplain habitats at some stage in their life (Feyrer et al. 2006; Flinn et al. 2008). Many riverine fish species rely upon seasonally predictable flood pulses, which provide access to floodplain areas that can be utilized for reproduction (i.e. spawning and rearing), foraging, overwintering, or as refuge from intolerable conditions (Knights et al 1995; Winemiller and Jepsen 1998; Barko and Herzog 2003, Bowen et al. 2003, Ickes et al. 2005). While the connection of a river to its floodplain is crucial for many riverine organisms, anthropogenic river modifications (e.g. navigation enhancements, water storage, and flood control) have impaired natural floodplain inundation, and as a result have reduced floodplain connectivity.

While there are still areas with direct connection to the river, most floodplains are separated from the river by levees for flood control measures. The long-term effects of reduced floodplain connectivity has yet to be understood, however the need to understand these effects has lead to the development of many floodplain management strategies. Often these management strategies have differing objectives (e.g. flood control, conserve floodplain connectivity); however, one of the most common options is to install a water control structure through levees which can aid in water level management but still provide connectivity (Henning 2004; Ickes et al 2005; Schultz et al. 2007). Although these water control structures can maintain floodplain connectivity, their effect on fish movement and passage is not yet certain (Ickes et al. 2005; Schultz et al. 2007).

Objectives

The main objective of this study was to evaluate fish movement through the St. Johns Bayou water control structure. The St. Johns Bayou basin extends from Commerce and Benton, Missouri to New Madrid, Missouri covering 450 square miles. It is separated from the Mississippi River by mainline and setback levees forming a sump that is drained by a gravity outlet when the Mississippi River is lower than the Bayou. The gravity outlet consists of six 10-foot by 10-foot gated concrete box culverts. During periods of high water on the Mississippi River (approximate elevation of 279 feet NAVD), the floodgates are closed, thus preventing Mississippi River backwater flooding. Closing the gates impounds interior runoff until the Mississippi River recedes to an elevation lower than the impounded landside water elevation. Structure remains open during the rest of the year. A similar structure is proposed for the New Madrid basin if a closure levee is constructed at the lower end of the Floodway. In order to determine fish passage through the existing structure, we conducted a telemetry study to evaluate fish movement and frequency of passage during spring 2010.

Methods

Fish were collected using a combination of gears including gill nets, electrofishing, trot lines, hoop nets, and trammel nets. All fish collected were marked with a floy to maintain a mark/recapture study increasing the chances of determining whether fish are passing through the water control structure. To further monitor fish passage and movement a subsample of 100 fish were implanted with ultrasonic transmitters. The majority of fish were collected downstream of the water control structure to increase our power to detect upstream movement into the potential spawning areas. Two groups of fish were implanted with tags; each group included a combination of species, representing mid-season spawners (April – May: largemouth bass, spotted bass, white bass, hybrid striped bass, freshwater drum, bowfin, river carpsucker, smallmouth buffalo, black buffalo, and bigmouth buffalo), and late season spawners (June – July: flathead catfish, blue catfish, channel catfish, and shortnose gar). The majority of tagging occurred in April 2010 when the study was initiated, so that all fish would be tagged before the mid-season spawning season commences; however remaining transmitters were implanted in early June when a second flood pulse occurred.

Ultrasonic transmitters implanted in fish were sized such that they did not exceed fish weight in water by 2-3%. Fish were anesthetized using a carbon dioxide and oxygen mixture; river water was circulated over fish gills during surgery. All surgical utensils were sanitized in 70% ethanol. Incisions were made ventrally, anterior to the anal openings. The incision areas were disinfected with betadine. A scalpel and curved hemostats were used to insert the tag and avoid damage to organs. The transmitter was pushed down and away from the incision site to alleviate any added stress on the wound. Incisions were closed with monofilament sutures attached to a curved cutting needle using simple interrupted sutures, as documented by Summerfelt and Smith (1990). The incision and sutures also were sealed with cyanoacrylate resin to prevent infection and to hold the wound and suture knots together securely. Immediately following the surgical procedure, tagged fish were placed in a recovery tank supplemented with oxygen and released after normal swimming occurred.

In order to monitor fish movement and passage through the water control structure, stationary receivers (Vemco VR2W) were placed at five locations within St. John's Bayou. Receivers were place immediately above and below the water control structure in St. Johns Bayou to constantly monitor fish movement around the structure. Other VR2W's were deployed downstream of the structure in Mud Ditch and near the Mississippi River to monitor fish movement out of the system into the Mississippi river, and in Mud Ditch above the St. Johns structure to monitor movement into or out of the New Madrid Floodway (Figure II-1). Stationary receivers were submerged on rebar stands with concrete anchors with the hydrophone oriented up (Figure II-2). These stands are retrieved with a boat mounted grappling hook rig on a monthly basis to download all data collected (Figure II- 3). The grappling hook rig is lowered to the riverbed near the stand and is dragged until it snags a retrieval cable between the stand and an anchor. In attempts to monitor long-range movements and movement out of the study area, we also incorporated data collected from our (SIUC and MDC cooperative) existing stationary receiver array in the Mississippi, Missouri, Illinois, and Ohio Rivers (Figure II-4).

All floy tag recaptures were documented to determine passage by marked fish. Detections by the stationary receivers were used to quantify fish movement and passage. For fish implanted with ultrasonic transmitters we summarized mean lengths and weights, number of detections, and passages. Passage occurred when a fish released on one side of the structure is detected on a receiver on the opposite side. Since stationary receivers directly above and below the water control structure were within close vicinity, fish were sometimes detected on both stationary receivers simultaneously. When this event occurred, passages were not recorded, until the fish was detected by receivers on one side of the structure. We also investigated the effects of river stage and water levels on number of detections within the bayou and passage through the water control structure.

Results and Discussion

Since 2008, over 2000 fish encompassing 38 different species have been floy tagged jointly by ERDC and SIU. While ten fish have been recaptured either by ERDC or SIU while sampling or by fisherman, no fish have been found on the opposite side of the water control structure in which they were tagged. Since recaptures were so limited, in April of 2010 we implanted 89 fish with ultrasonic transmitters (78 downstream of the water control structure and 11 upstream. Then in early June the remaining 11 fish were tagged downstream of the water control structure to increase our chances of detecting fish moving into St. John's Bayou to access the floodplain (Table II-1). Mean lengths and weights of the fish implanted with ultrasonic transmitters are summarized in Table II-2.

Since the first day of tagging (April 12) until the last day VR2W's were downloaded (Dec 9), 1,264,717 detections have been made by the stationary receiver array in the bayou and in the Mississippi and Ohio Rivers. All 100 fish were detected multiple times by multiple VR2W's. While the majority (99%) of the detections where collected by the St. John's –New Madrid array, fifteen fish were detected moving out of St. John's Bayou into the Mississippi and Ohio Rivers. There were 2894 detections collected in the Ohio River, 38 detections in the Middle Mississippi River at River Mile 1.3, and 88 detections in the Lower Mississippi River at Caruthersville, MO.

The stationary receiver array allows us to document movement by summing the distance moved from one receiver to the next. While movements made in between VR2W's cannot be determined, we can at least quantify the scale and directionality of movement. The fifteen fish detected moving out of the bayou and into the Mississippi and Ohio Rivers, included five different species moving up the Mississippi River into the Ohio or Middle Mississippi River, or fish were detected moving downriver to Caruthersville, Missouri on the Lower Mississippi River. Seven of these fifteen fish that moved out of the bayou were later detected moving back into the Bayou. Total movement by these fish with maximum movement upriver and downriver is summarized in Table II-3. Even though most fish (85) remained within the bayou, theses fish still moved among receivers within the bayou array (Table II-3).

In order to determine the effects of water level on number of fish that remained in the bayou, we used Mississippi River stage at New Madrid, Missouri as a surrogate for water entering or leaving the bayou (e.g. if the river stage was falling we assume water was leaving the bayou). Correlation showed that there was a positive relationship between increasing river stages

and the number of fish detected by VR2W's in St. John's Bayou ($r = 0.73$, $P < 0.0001$; Figure II-5). This suggests that as river stages increase and water drains into the bayou making the floodplain connected and more accessible, more fish are found in the bayou. The St. Johns Bayou gravity outlet is closed at a river elevation at the New Madrid gage of approximately 29 feet. During 2010, the gate was open 34% when fish tagging began (April 14) to the end of the pre-defined spawning season (June 30) in 2010, assuming that the structure was closed when New Madrid elevation reaches 29 feet. Therefore, fish passage opportunities were limited particularly in May.

Thirteen of the 14 species tagged moved upstream through the structure (93%). Flathead catfish was the only species not detected moving through the structure, although only one individual was tagged during the study. Of the 85 fish tagged below St. Johns structure, all accessed the New Madrid Floodway at some point during the study. Forty-seven of those passages being made by fish moving downstream from the bayou toward the Mississippi River and 45 passages were made by fish moving upstream through the structure to access the floodplain (Table II-4). All 11 fish tagged above the St. Johns structure traveled through the culvert and exited the basin. Overall, 29 of the 85 (34%) fish passed through the structure one or more times for a total of 92 passage events. Correcting for the time the structure was closed during the spawning and rearing season (66%), fish passage was (52%).

Passage occurred most frequently during spring and summer months in which the tagged species typically spawn (Table II-5). However fish passed through the water control structure at least once each month (Table II-5). To evaluate how water flow through the structure may affect fish passage, we used the change in the Mississippi River stage at New Madrid, Missouri as an indicator of water draining from the bayou or entering the bayou. When we plotted the number of passages per day against the change in river stage, it was clear that passage occurred under all conditions (Figure II-6).

Although the main purpose of the water control structure is to prevent backwater flooding, it also retains connectivity to the floodplain protected by levees. Our study confirms fish movement through large water control structures. While it is unlikely that study fish were completely unaffected by the presence of the water control structure in St. John's Bayou, our data indicates that individuals of each study species; except flathead catfish passed through the structure.

The stationary receiver array was successful at documenting fish passage through the water control structure. From this data we were able to determine that the number of fish utilizing the bayou increased with rising water levels. With the majority of passages occurring during the spring and summer we assume that fish are accessing the floodplain through the water control structure to find suitable spawning habitat. Another peak in river stage during December 2010, followed by increased numbers of fish detected in the bayou shows that fish may also be using the floodplain for overwinter habitat as well. Not only has the receiver array within the bayou allowed us to quantify passage through the water control structure, but in addition we have also documented some long range movements by study species into the Mississippi and Ohio Rivers. While fifteen fish moved out of the bayou into these major rivers, seven of those fish moved back down into the bayou, showing that some species have a degree of site fidelity.

We recommend continued monitoring of fish passage and movements around the water control structure across multiple years to more fully understand how water-levels affect the connectivity to the floodplain and species ability to navigate the structure and access the floodplain. To improve the resolution of our data and expand our knowledge of passage and movement, we recommend increasing the number of transmitters implanted each year and attempt to tag more species in equal proportions. By continuing telemetry efforts we will be able to fully understand how the nuances in river stage and fish behavior interact to predict fish passage through water control structures along the Mississippi River.

Summary

Fish passage through the St. Johns water control structure near New Madrid, MO was evaluated in 2008 using telemetry. Stationary receivers were placed strategically at 5 locations below and above the structure in St. Johns Bayou, in New Madrid Floodway, and the outlet to the Mississippi River. A total of 100 individuals comprising 14 species were tagged. Total number of detections between April - Dec 2010 were 1,264,717. Fifteen individuals comprised of five species moved into the Mississippi and Ohio Rivers; 7 individuals returned to St. Johns Bayou. Thirteen of the 14 species moved upstream through the structure. Of the 85 individuals that stayed in the bayou, 29 fish passed through the structure for a total of 92 passage events. The downstream: upstream passage was roughly 50:50. Passage was correlated with river rise with frequency of passage higher in spring, but passage occurred each month through December 2008 when the study ended.

Table II-1. Species and number of fish surgically implanted with sonic transmitters during 2010 upstream and downstream of the water control structure in St. John's Bayou.

Location Tagged	Species	Date Tagged						Total
Upstream	Mid-Season Spawners	4/12/2010	4/13/2010	4/14/2010	4/29/2010	4/30/2010	6/11/2010	
	Bowfin			1				1
	Freshwater Drum			3				3
	Largemouth Bass			1				1
	River Carpsucker			1				1
	Black Buffalo			1				1
	Smallmouth Buffalo			4				4
Downstream	Mid-Season Spawners							
	Freshwater Drum		2			2	1	5
	Hybrid Striped Bass						1	1
	Largemouth Bass					1	1	2
	River Carpsucker	1	1				1	3
	Bigmouth Buffalo	1	7		5	1		14
	Black Buffalo					6	1	7
	Smallmouth Buffalo	3	22		2	3	2	32
	Spotted Bass	2	1		1			4
	White Bass	2				7	3	12
	Late-Season Spawners							
	Blue Catfish		2					2
	Channel Catfish		1				1	2
	Flathead Catfish		1					1
	Shortnose Gar	2			2			4
	Total	11	37	11	10	20	11	100

Table II-2. Mean lengths and weights of species implanted with ultrasonic transmitters in 2010.

Species	N	Mean TL (mm)	StdDev	Mean Wt (g)	StdDev
Bigmouth Buffalo	14	565.79	68.25	3135.93	1123.78
Black Buffalo	8	567.00	91.34	3093.25	1427.60
Blue Catfish	2	712.00	322.44	5875.00	6965.00
Bowfin	1	581.00	N/A	1892.00	N/A
Channel Catfish	2	562.00	189.50	2871.00	3010.86
Flathead Catfish	1	670.00	N/A	3750.00	N/A
Freshwater Drum	8	541.38	62.73	2782.50	980.24
Hybrid Stripped Bass	1	430.00	N/A	1010.00	N/A
Largemouth Bass	3	357.67	105.94	829.67	752.03
River Carpsucker	4	454.25	74.70	1458.25	697.85
Shortnose Gar	4	690.33	55.50	1212.25	203.55
Smallmouth Buffalo	36	586.67	100.54	3713.14	1900.81
Spotted Bass	4	367.75	42.15	772.00	220.31
White Bass	12	330.00	29.47	480.75	109.28

Table II-3. Total distance moved by indiviual fish within each species with maximum upriver and downriver movement shown for those speices which moved outside St. John's Bayou.

Movement Outside the Bayou		Total Distance	Maximum Distance Upriver	Maximum Distance Downriver
Species	Bigmouth Buffalo	64.2	64.1	0.1
	Black Buffalo	130.8	65.6	65.2
	Freshwater Drum	52.1	1	51.1
	Smallmouth Buffalo	134.3	67.1	67.2
	White Bass	85.8	74.9	51.4
Movement Within the Bayou				
Species	Bigmouth Buffalo	29.1		
	Black Buffalo	21.7		
	Blue Catfish	23.5		
	Bowfin	3		
	Channel Catfish	2.6		
	Flathead Catfish	11.8		
	Freshwater Drum	2.6		
	Hybrid Striped Bass	2.3		
	Largemouth Bass	12.8		
	River Carpsucker	16.8		
	Shortnose Gar	15.1		
	Smallmouth Buffalo	38.5		
	Spotted Bass	10.7		
	White Bass	43.2		

Table II-4. Fish passage through the water control structure in St. John's Bayou. Passsage was detected by stationary receivers placed above and below the structure. N represents the number of fish within each species that passed through the structure. The numbers depict the total number of passages.

Spawning Group	Species	N	Passage Downstream	Passage Upstream	Total
Mid-Season Spawners	Bigmouth Buffalo	3	2	4	6
	Black Buffalo	2	3	3	6
	Bowfin	1	1		1
	Freshwater Drum	3	3		3
	Hybrid Striped Bass	1		1	1
	Largemouth Bass	1	1		1
	River Carpsucker	1	1		1
	Smallmouth Buffalo	9	20	19	39
	Spotted Bass	1	3	3	6
	White Bass	3	9	9	18
Late Season Spawners	Blue Catfish	1	1	1	2
	Channel Catfish	1		1	1
	Shortnose Gar	2	3	4	7
	Total	29	47	45	92

Table II-5. Fish passage through the water control structure in St. John's Bayou. Passsage was detected by stationary receivers placed above and below the structure. The numbers depict the total number of passages per month.

		Passage Downstream									
Spawning Group	Species	April	May	June	July	August	September	October	November	December	Total
Mid-Season Spawners	Bigmouth Buffalo			1	1						2
	Black Buffalo		1	1						1	3
	Bowfin								1		1
	Freshwater Drum	2	1								3
	Largemouth Bass			1							1
	River Carpsucker	1									1
	Smallmouth Buffalo	3	2	8	3	3			1		20
	Spotted Bass							3			3
	White Bass		1				6	2			9
Late Season Spawners	Blue Catfish			1							1
	Shortnose Gar		1	1		1					3
	Total	6	6	13	4	4	6	5	2	1	47

		Passage Upstream									
Spawning Group	Species	April	May	June	July	August	September	October	November	December	Total
Mid-Season Spawners	Bigmouth Buffalo	2		1					1		4
	Black Buffalo			1	1			1			3
	Hybrid Striped Bass					1					1
	Smallmouth Buffalo	1	3	8	2	3				2	19
	Spotted Bass							3			3
	White Bass		1	1			6	1			9
Late Season Spawners	Blue Catfish	1									1
	Channel Catfish				1						1
	Shortnose Gar	1	1	1		1					4
	Total	5	5	12	4	5	6	5	1	2	45

Figure II-1. Locations of VR2W's in St. John's Bayou around the water control structure near New Madrid, Missouri. VR2W locations are shown in the white rectangles.

Figure II-2. Boat mounted winch system with grappling contraption of bow of boat that is used to retereive stationary recievers.

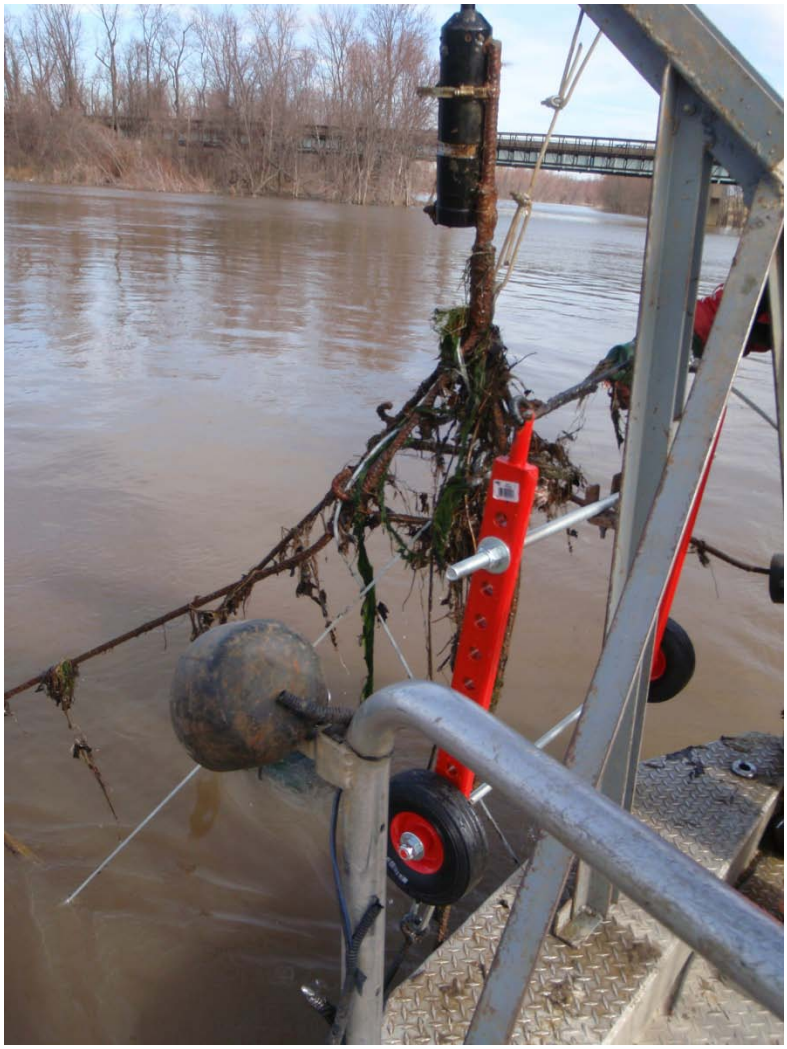


Figure II-3. VR2W on the rebar stand being winched up from the bottom, so that the data can be downloaded.

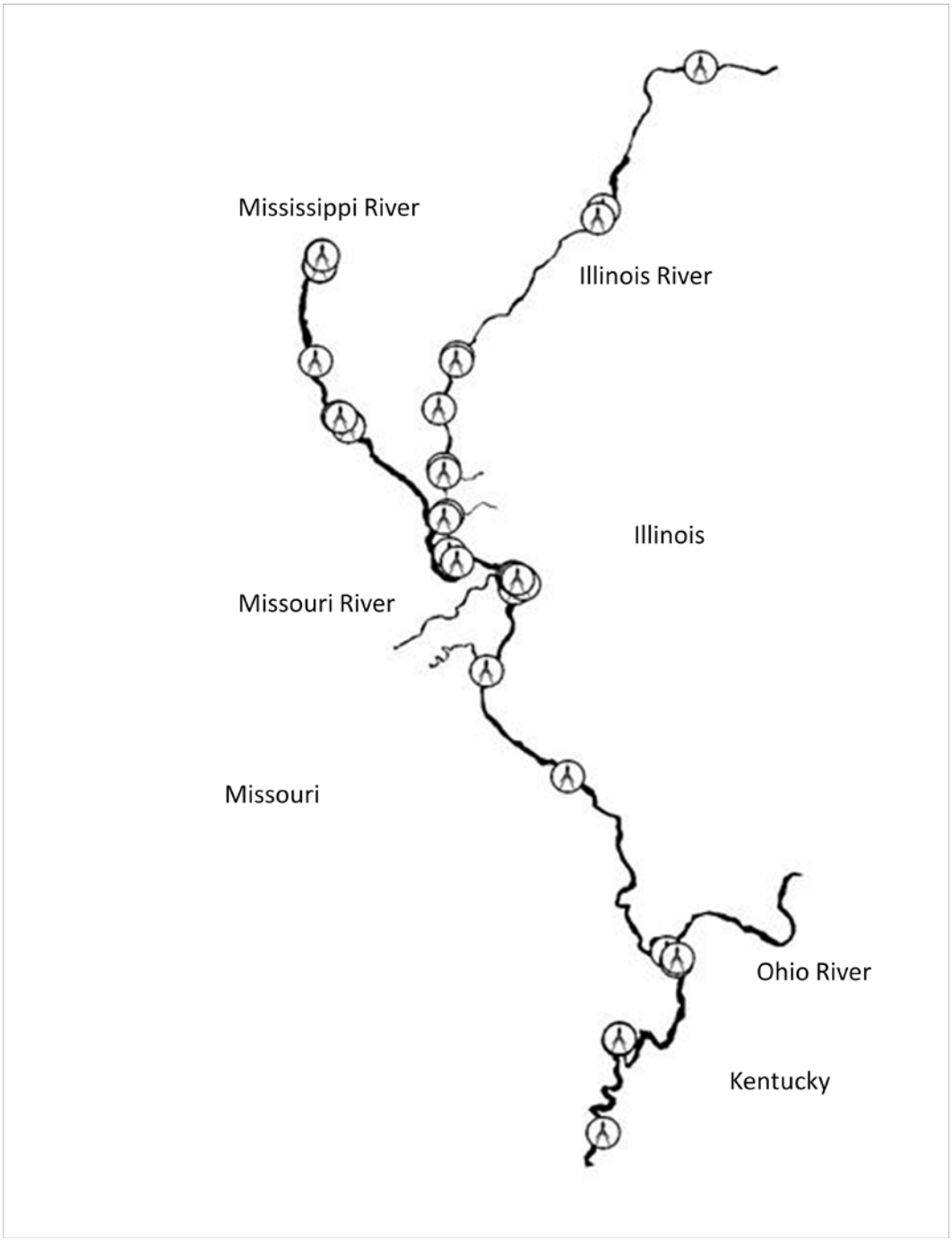


Figure II- 4. Locations of all VR2W's in our cooperative stationary receiver array covering the Mississippi, Illinois, Missouri, and Ohio Rivers. VR2W locations are shown with in the circles.

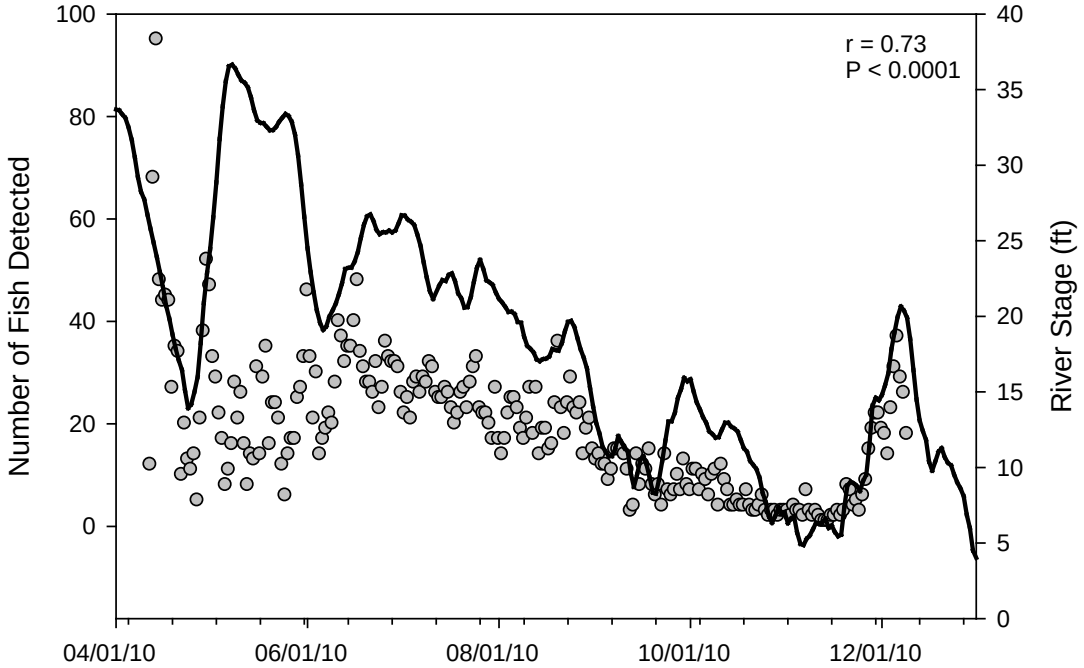


Figure II-5. Grey circles represent number of fish detected with the bayou each day plotted against Mississippi River stage at New Madrid, Missouri.

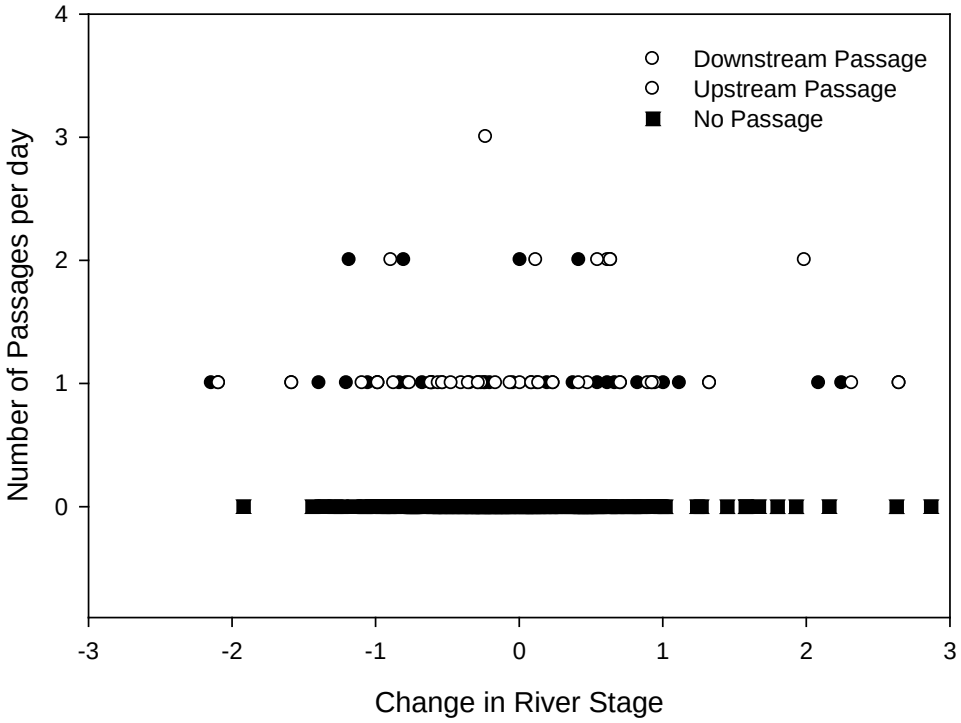


Figure II-6. The number of passages per day were plotted in relation to if the water levels at New Madrid, Missouri were falling (negative numbers) or rising (positive numbers), showing that passage occurs under all conditions.

Part III: Evaluation of Project Impacts

Introduction

Evaluation of project impacts on fisheries focused on spawning and rearing in the SJNM basins. Reproductive cycles of most floodplain fishes are closely related to timing, spatial extent, and duration of flooding, commonly referred to as the flood pulse (Junk et al 1989). Numerous fish species undergo regular migrations to use inundated floodplains for a variety of reproductive purposes such as spawning, short-term incubation of eggs, and eventually as nursery habitat for yolk-sac (non-feeding) larvae (Guillory 1979; Ross and Baker 1983; Finger and Stewart 1987; Copp 1989; Scott and Nielson 1989). Once the yolk-sac is gone, larval fish join adults in using temporarily inundated floodplains and waterbodies as foraging habitat, especially for the small insects and zooplankton that are often the initial food items (Lietman *et al* 1991). These early life history stages are often the limiting factor in population growth, and interannual variations in flooding regimes of rivers affect reproductive success and year-class strength of many species (Starrett 1951; Guillory 1979; Killgore et al. 1996) . Thus, any changes to the flood pulse will have both direct and indirect impacts to fishes that utilize the SJNM for spawning and rearing.

Objectives

The Habitat Evaluation Procedure (HEP) was used to quantify impacts of the project on fish habitat (USFWS 1980). The objectives of this part of the study were to:

1. Document methodology and assumptions used to calculate impacts
2. Evaluate fisheries impacts for each project alternative

Methods

The ecological model EnviroFish (Killgore *et al.*, 2011) was used to quantify the amount of fish spawning and rearing habitat in the project area under future without project conditions and each respective alternative. EnviroFish is a hydraulic model coupled to a spreadsheet that estimates acres of floodplain habitat suitable for fish reproduction under a given set of hydrologic conditions. Utilizing the results of the hydrologic model (*i.e.,* daily elevations), EnviroFish integrates the daily flood elevations, floodplain land use, and Habitat Suitability Indices (HSI) to calculate a response variable. The response variable is in the form of a Habitat Unit so the Habitat Evaluation Procedure (U.S. Fish and Wildlife Service 1980) can be used to complete the analysis of project alternatives. Like any ecological model, it is important to note that EnviroFish does not quantify actual spawning and rearing habitat. EnviroFish compares changes in potential spawning and rearing habitat among alternative scenarios (Battelle, 2010 – EnviroFish). Specific components of EnviroFish are described below.

Delineation of Floodplain Habitats

Five habitat types delineated from satellite imagery and ground-truthing characterized the majority of floodplain landuse in the SJNM Basins. The actual acres of each habitat type by

stage elevation (i.e., stage-area curves) were entered into the EnviroFish software to calculate Average Daily Flooded Acres. Habitat Types are defined as follows:

a. Agriculture – all areas in which an agricultural product was grown including developed and pasture lands.
b. Fallow – agricultural lands that have been abandoned where there is a prevalence of herbaceous, non-woody cover.
c. Bottomland Hardwoods – All forested areas.
d. Marsh – areas that remain inundated/saturated for long periods of time during the growing season that do not support woody vegetation. These areas usually go dry during late summer/early fall. These areas include herbaceous wetland complexes that are managed for waterfowl and scrub-shrub.
e. Waterbodies – areas that retain water for the majority of the year or at least during the reproductive season. These areas include borrow pits, crevasse lakes/blue holes, floodplain lakes (*i.e.,* Riley Lake), oxbow lakes (*i.e.,* Hubbard Lake), artificial lakes (*i.e.,* Big Oak Tree Lake), scatters, breaks, and sloughs. It is important to note that some of these areas have been observed as dry during dry conditions. However, for the purpose of the model, they are classified as waterbodies.

Habitat Suitability Index Values

The majority of species that spawn and rear in riverine floodplains are pre-adapted to structurally complex habitats such as bottomland hardwoods. Therefore, cleared lands have less value for spawning and rearing habitat. The HSI values reflect this trend, with optimum conditions occurring for bottomland hardwoods, waterbodies, and marshes (HSI = 1.0); intermediate values for fallow fields (HSI = 0.5); and the lowest value for cleared, agricultural lands (HSI = 0.2). The final HSI values used in EnviroFish to weight acres were agreed upon by consensus of an interagency team of biologists (Delphi technique), independent peer review, supplemented by field data from tributaries of the lower Mississippi River (Table III-1).

HSI values are for combined life stages of spawning and rearing. They represent a community-level perspective on the biological response of warmwater fishes to flooding in riverine systems. In most large floodplain river systems, this would encompass a very large assemblage of fish species. Species within a guild are assumed to share similar reproductive requirements. In this particular case, fish species in the Lower Mississippi River Valley (including the St. Johns Bayou and New Madrid Floodway project area) are grouped on substrate used by spawning adults and characteristic habitat (*e.g.,* channel vs. floodplain) used by larvae (Table I-3). For species that spawn and rear in floodplains, different substrates or structural conditions are preferred to deposit eggs or construct nests: vegetation, sand, and/or crevices. For these reasons, bottomland hardwoods, marshes, and waterbodies have optimum HSI values because of their habitat heterogeneity.

In summary, at least three assumptions were made using these values:

1) Larval fish have the potential of utilizing the same habitat as spawning sites, with one exception. Larval fish have smaller physical dimensions and motility that allow access to more shallow (<1.0 ft) water than physically available for spawning needs (typically ≥ 1.0 ft depth, 8 days duration). The EnviroFish software can be used to define minimum and maximum allowable depths for spawning and/or rearing to accurately represent a specific situation.
2) The majority of species that spawn and rear in riverine floodplains are pre-adapted to structurally complex habitats such as bottomland hardwood wetlands (BLH). Therefore, cleared lands have less value for spawning and rearing. HSI values reflect this trend, with optimum conditions occurring for BLH and marshes (i.e., HSI = 1.0), intermediate values for fallow fields (HSI = 0.5), and the lowest value for cleared, agricultural lands (HSI = 0.2).
3) Similar to BLH, waterbodies are optimum (HSI=1.0) for spawning and rearing if the waterbody is periodically connected to the mainstem river during the reproductive season. This assumes that waterbodies provide adequate spawning substrates for egg deposition, and larval fish have high growth rates for survival in waterbodies that retain water during periods of early development.

Impact Assessment

HSI values were multiplied by area (acres of floodplain or riverbank habitats) to express project alternatives as Habitat Units (HU) according to the following equation:

$$HU = HSI \ X \ AREA$$

The "AREA" used to calculate HU's were Average Daily Flooded Acres (ADFA) quantified for each of the seasonally inundated floodplain habitats (*i.e.,* waterbodies were excluded, see below) for specific seasons (*i.e.,* early, mid, and late season). ADFA is a unit of measure of inundation. An ADFA is an area equivalent to one acre that is inundated on average every day of a defined season of a year for a specified number of years. For example, if that acre and an adjoining acre (two real-on the ground acres) were flooded for every day but in only half the specified number of years, the result would still be one ADFA. Similarly, if one acre was flooded every day but in only half the specified number of years, the result would be 0.5 ADFA.

Habitat Units were quantified for Year 0 for each respective basin and each respective season by multiplying ADFA by the HSI value for seasonally inundated floodplain habitat and surface acres by the HSI value for floodplain waterbodies. This process was repeated for Year 50 to account for future WRP enrollment. An Average Annual Habitat Unit (AAHU) was calculated by the following formula:

$$AAHU = \frac{HU_{Year\ 0} + HU_{Year\ 50}}{2}$$

Project impacts were calculated by the following formula:

Project Impacts = (AAHU Future Without Project x Fish Access Reduction)
– (AAHU Future With Project x Fish Access Reduction)

To facilitate calculations, EnviroFish output was transferred to an Excel spreadsheet which automatically averages 'Average Daily Flooded Acres' by alternative, season, and habitat. For Habitat Units, ADFA is multiplied by the appropriate Habitat Suitability Index. Summary statistics were calculated with VBA code (macro). Three temporary matrices (one per season) were constructed with the total of the five habitats' ADFA or HU from each year (67 values per matrix). These matrices were then randomly sampled from, with replacement, to populate a bootstrapped matrix of 67 values (years) for each season. This process is repeated 1000 times and the mean of each bootstrapped matrix is taken to produce 1000 bootstrapped means, from which summary statistics are calculated. To calculate confidence intervals, the 1000 bootstrapped means are sorted from smallest to largest and the 26th and 976th values are selected as this interval contains 95% of the calculated means. Bootstrapping is recommended when data are not normally distributed, such as hydrographic data, and thus, assumptions of parametric tests are violated (Sokal and Rohlf, 1995).

Alternatives were evaluated using the Habitat Evaluation Procedure. The analyses and reporting of results were separated by basin: St. Johns Bayou and New Madrid Floodway. The season with the maximum loss in HU's would be selected as the impact target. Specific assumptions and parameters used in EnviroFish are as follows:

1) Habitat was quantified for floodplain habitat. This is defined as species and individuals who spawn and rear on the floodplain and not necessarily reside in the network of drainage ditches or isolated waterbodies found in the project area.

2) Spawning and rearing habitat are combined into one life stage. Therefore, there is no separate spawning habitat and separate rearing habitat.

3) Many factors dictate the overall timing of the spawning and rearing period. Optimum conditions for spawning occur when the flood pulse and temperature are coupled (Junk *et al.,* 1989. Although there are multiple variable that dictate when fishes will actually spawn, the model assumed that spawning and rearing takes place from 1 March to 30 June (Pflieger 1997). To account for seasonality, the spawning and rearing season was further refined during the following periods:

    a. Early Season = 1 to 30 March
    b. Mid-Season = 1 April to 15 May
    c. Late Season = 16 May to 30 June

4) Depending on land use, the upper boundary of the functional floodplain will be confined to the two-year flood frequency for sub-optimal habitat (*i.e.* agriculture and fallow areas) and the five-year flood frequency for optimal habitat (*i.e.,* bottomland hardwoods, marsh, and waterbodies).

5) Specific hydrologic requirements of optimal and sub-optimal floodplains are as follows:

a. Optimal Habitat – minimum depth = 0.1 feet and minimum duration = one day. Once hatched, rearing fishes (including yolk-sac and post yolk-sac larval phases) can potentially use any area of the inundated floodplain regardless of flood depth and duration (Killgore *et al,* 2012).

b. Sub-optimal habitat – minimum depth = 1.0 feet and minimum duration = 8 consecutive days. Killgore *et al.* (2012) stated, a minimum water depth of one foot allows adults to access shallow, flooded areas, although a water depth less than one foot is not considered realistic due to physical limitations in the spawning process. Flood duration of at least eight consecutive days ensures that suitable time is allowed for nest construction and other spawning activities by the adults and recognizes that shorter durations may result on the eggs becoming stranded and desiccated if water recedes too quickly. The minimum one foot, eight-day duration rule is considered a conservative value to delineate spawning and rearing requirements for warmwater fish species found in the Mississippi River basin (Breder and Rosen, 1966; Carlander, 1969; Carlander, 1977; Becker, 1983; Robison and Buchanan 1988). If the water recedes too rapidly off the floodplain, organic matter, nutrients, and newly hatched aquatic organisms may be carried into the river instead of remaining in the floodplain and permanent backwaters (Sparks 1995). This rule guarantees an effective spawning window, emphasizes longer development times, and provides a margin for temporal variation in spawning activities (*i.e.,* adult movement onto the floodplain, nest construction, and guarding/dispersal of fry) [Killgore *et al* 2012].

   Based on the Phase 2 IEPR discussions, the justification for different hydrologic criteria according to land cover types is due to mortality and stranding factors on agricultural areas. Agricultural areas provide sub-optimal habitat and quickly drain as Mississippi River stages fall due to the vast network of drainage ditches and structures. Therefore, agricultural areas need to be inundated for 8-day duration to be suitable spawning and rearing habitat.

6) Based on the Phase 2 IEPR recommendations, fishery analysis will be split into two different zones regarding flood frequencies. Zone 1 will be within the two-year flood frequency. Analysis will be conducted on all habitat types (optimal and sub-optimal) utilizing the hydrologic criteria outlined above. Zone 2 (*i.e.,* areas that fall between the two-year and five-year frequencies) analysis will only be confined to "optimal habitat" (*i.e.,* waterbodies, marsh, and bottomland hardwoods). Sub-optimum habitat (*i.e.,* fallow and agricultural areas) will be excluded from the analysis.

   The justification for the different zones is based on the following:

   a. The floodplain closest to the river provides immediate access to reproductive fishes undergoing spawning migrations. Fish may have to travel miles from the mainstem river to reach lands corresponding to a 3-year or greater flood frequency. Therefore, fish are less likely to use the sub-optimal areas at greater distances from the river due to the long distance required

b. Even if adults do move great distances to spawn, eggs deposited in cleared lands far removed from the main stem river have a greater risk of becoming trapped and or desiccated. Rapid declines in water level increase the proportion of young fish stranded on the floodplain (Sparks 1995).
c. The independent review conducted for the EnviroFish model recommended weighting between optimal and sub-optimal habitat. Battelle (2010) stated the following:

    i. In reality, a small area of high-quality habitat is likely to outperform a large number of low-quality habitat areas, even if they both have equal HU values. This assumption allows the potential for rationally choosing a project alternative that provides a lot of corn field stubble and not bottomland hardwood forest over one where bottomland hardwood forest is present in moderate amounts. This assumption precludes the model from an organizing the output to maximize the highest quality habitat type.

    ii. …EnviroFish should not allow the opportunity to increase lots of acreage of really poor habitat for an alternative or future situation without regard for the absolute acreage of very high quality habitat. It might be more appropriate to calculate total Hus using only habitats with HSIs greater than some minimum value, for example 0.4. The planning decisions would be based on changes from what is known to be fair/good habitat to other fair/good habitat because the value of Hus would be much more comparable. Other avenues to correct for very poor or very good habitat (e.g., weighting) should also be considered.

7) The modified stage area curve will be used to account for Mississippi River connectivity within the New Madrid Floodway.

8) The H+H period of record will be used to describe future without project hydrologic conditions as well as alternatives. The period of record is highly variable from year to year (*e.g.,* there are some drought years, flood years, and average years). This hydrologic variability is expected to continue under future without project conditions. However, there are no anticipated changes that would significantly change Mississippi River hydrology, drainage patterns, or precipitation in the project area.

9) Although changes in agricultural practices are likely under with several alternative conditions (*i.e.,* conversion of soybeans to other more valuable crops based on risk minimization and market conditions), the only anticipated land use change would be a result of lands enrolled in the Wetland Reserve Program.

10) Several alternative conditions assume hydrologic changes (*i.e.,* reduced frequency and durations) without any changes to land use.

Floodplain Waterbodies

Floodplain waterbodies are important floodplain habitats because they support a major proportion of riverine fish fauna (Lubinski *et al.,* 2008). EnviroFish assumes that floodplain waterbodies provide spawning and rearing habitat regardless of river conditions (*i.e.,* since the waterbody retains water regardless of river conditions, fish will utilize it throughout the spawning and rearing season). Therefore, a separate analysis is required than that which is conducted on seasonally inundated lands. Fish find refugia in floodplain waterbodies, tributaries, or the main channel when flood waters recede (Junk *et al.,* 1989). Fish may reside in these waterbodies until subsequent floods re-connect them to the floodplain and or main channel.

ADFA is not calculated for floodplain waterbodies because they are assumed to retain water for the duration of the spawning and rearing period. Therefore, ADFA would be equal to surface acres. Although isolated waterbodies can provide a diverse assemblage of fish, the flood pulse must connect them at some point to be of benefit to the remainder of the floodplain/Mississippi River fishery. As previously stated, the five-year floodplain is the upper limit of the functional floodplain for fish spawning and rearing habitat.

Fish Access

A major concern is fish access to floodplain habitats above gated structures, such as the one proposed for New Madrid Basin. Typical problems at culverts include a perched outlet, water velocities that exceed burst swimming speeds of fish, shallow depths that hamper swimming, and long distances between resting areas. None of these problems will exist for the proposed authorized culvert design in the New Madrid Floodway for the following reasons:

- Water will be flowing into the basin during most operations periods, so excessive water velocity will not be an impediment to movement. In addition, those fishes that were spawned or are rearing in the basin can be easily transported back to the river when water direction is reversed during falling river stages.
- There will be no outlet or inlet drop in elevation.
- Culvert slope is nearly level.
- A relatively short distance will be required for fish to access the backwater.
- Water depth will be equal to the river stage up to the 10-foot height of the culvert, which is more than adequate for swimming fishes.

In order to estimate a “correction factor” to reduce habitat value upstream of structures, fish passage was monitored through the existing St. Johns Bayou gravity outlet structure (see Part II). Since the proposed New Madrid Floodway culverts are of similar design to the existing St. Johns Bayou gravity outlet structure, results from the St. Johns Bayou fish access study can be used to make predictions regarding fish passage in the New Madrid Floodway. A fish access reduction factor was determined based upon the following:

- Fish can pass through an open culvert. Thirteen of the 14 species tagged moved upstream through the structure (93%).
- The fish access study concluded:
    - 100 fish were tagged with transmitters (11 above the St. Johns structure, 85 below the structure at the confluence of the New Madrid Floodway).

- All 11 fish tagged above the St. Johns structure traveled through the culvert and exited the basin. Therefore, egress is 100% for the year 2010.
- Of the 85 fish tagged below the structure, all 85 accessed the Floodway at some point during the study. Therefore, assume the existing Floodway has 100% ingress.
- Of the 85 fish tagged below the structure, 29 accessed the St. Johns Bayou Basin through the structure. Therefore, assume the St. Johns Bayou Basin has 34% ingress.
- It is important to note that the structure was closed, due to flood conditions in the St. Johns Basin during the study, 34% of the time when fish tagging began (April 14) to the end of the pre-defined spawning season (June 30) in 2010. This assumes that the structure was closed when New Madrid elevation on the Mississippi river reaches 29 feet. Therefore, the 34% ingress occurred prior to gate closure.

- Once fish can access the basin, assume that they can access available inundated habitat within the constraints outlined by EnviroFish (*e.g.,* 5 or 2-year floodplain, spawning and rearing hydrologic criteria, etc.).

- Fish Access = $\frac{\text{(Ingress + Egress)}}{2}$
- Based on the 2010 fish access study, assume egress is 1.0
- Based on the 2010 fish access study, assume ingress is 0.52 based on the following rationale:
  - Ingress without correcting for days gate was closed = 0.34
  - Ingress with correcting for days gate was closed (0.66 - individuals weighted by gate opening):

$$\frac{.34x}{.66} = \frac{x}{1}$$

$$.66x = .34$$

$$x = 0.52$$

  - Considering that 93% of the species and 52% of the total individuals passed through the structure, the fish correction factor was determined to be the mean between the two values.

- Therefore, the fish access reduction factor is 0.73

Results and Discussion

St. Johns Bayou Basin – Agricultural lands and bottomland hardwoods were the most common habitats affected by the project (Table III-1). Overall, mid-season impacts were greatest among the three fish spawning and rearing seasons. There was a reduction of 618 AAHU, or a 31% decrease, for the authorized alternative for mid-season values. Details on alternatives are found in the SEIS. Bootstrapped summary statistics provide the 95% confidence interval in AAHU's (Table III-2). Note that values in Tables III-1 and III-2 did not incorporate the fish passage coefficient.

Table III-1. Average Daily Flood Acres (Acres) and Habitat Units (HU) by alternative, habitat, and season for St. Johns Basin

Alternative/Habitat (n=67)	Spawning and Rearing Season					
	March		1 Apr - 15 May		16 May - 30 Jun	
	Acres	HU	Acres	HU	Acres	HU
Existing						
Agricultural Land	1042.13	208.43	1039.46	207.89	374.78	74.96
Fallow Land	39.88	19.94	40.18	20.09	12.44	6.22
Bottomland Hardwoods	1174.54	1174.54	1256.89	1256.89	558.38	558.38
Herbaceous Wetlands	71.56	71.56	78.16	78.16	33.23	33.23
Permanent Waterbodies	390.38	390.38	390.38	390.38	390.38	390.38
Sum	**2718.48**	**1864.84**	**2805.07**	**1953.41**	**1369.22**	**1063.17**
Authorized						
Agricultural Land	574.47	114.89	555.69	111.14	143.65	28.73
Fallow Land	25.70	12.85	24.00	12.00	5.32	2.66
Bottomland Hardwoods	781.11	781.11	797.61	797.61	298.32	298.32
Herbaceous Wetlands	45.81	45.81	47.55	47.55	16.85	16.85
Permanent Waterbodies	380.54	380.54	380.54	380.54	380.54	380.54
Sum	**1807.62**	**1335.19**	**1805.38**	**1348.83**	**844.67**	**727.09**

Table III-2. Bootstrapped Summary Statistics for Average Daily Flood Acres (Acres) and Habitat Units (HU) by alternative and season for St. Johns Basin

Alternative (n=67)	Spawning and Rearing Season					
	March		1 Apr - 15 May		16 May - 30 Jun	
	Acres	HU	Acres	HU	Acres	HU
Existing						
Mean	2711.195	1860.033	2812.706	1960.922	1367.26	1065.671
St. Dev.	383.4148	212.3229	371.0548	209.3465	201.2108	128.1183

CV	11.53653	12.41957	11.0058	12.07625	13.62113	15.83273
95% lower CL	2015.223	1461.77	2123.22	1527.078	1012.094	825.8855
95% upper CL	3523.434	2303.694	3577.763	2367.026	1779.552	1342.691
Authorized						
Mean	1806.232	1337.582	1815.65	1351.945	848.6981	726.2518
St. Dev.	272.3804	178.5451	255.1608	158.9334	114.5583	77.76353
CV	13.51715	14.22326	12.84113	14.11163	16.61409	18.46708
95% lower CL	1329.784	999.9622	1350.271	1053.992	640.3418	581.6953
95% upper CL	2373.805	1699.007	2326.114	1671.146	1088.965	893.0007

New Madrid Floodway – Similar to the St. Johns Basin, agricultural lands and bottomland hardwoods were the most common habitats affected by the project. However, depending on alternative, different seasons had the greatest impacts (Table III-3). The authorized alternative had a reduction of AAHU ranging from 65-79%, followed by alternative 3.2 that ranged from a 48-61% reduction. Impacts for the recommended alternative (3.1) ranged from 36-51%, whereas alternative 4.1 ranged from 17-27% reduction. Alternative 4.2 had a net increase in AAHU ranging from 24-26%. Bootstrapped summary statistics for all alternatives, including the 95% confidence intervals, are shown in Table III-4. Note that values for Tables III-3 and III-4 did not incorporate the fish passage coefficient.

Table III-3. Average Daily Flood Acres (Acres) and Habitat Units (HU) by alternative, habitat, and season for the New Madrid Floodway

Alternative/Habitat (n=67)	**Spawning and Rearing Season**					
	March		**1 Apr - 15 May**		**16 May - 30 Jun**	
	Acres	**HU**	**Acres**	**HU**	**Acres**	**HU**
Existing						
Agricultural Land	3123.44	624.69	3016.56	603.31	933.77	186.75
Fallow Land	21.20	10.60	22.93	11.46	10.08	5.04
Bottomland Hardwoods	1570.06	1570.06	1629.08	1629.08	733.53	733.53
Herbaceous Wetlands	315.20	315.20	306.40	306.40	157.05	157.05
Permanent Waterbodies	728.47	728.47	728.47	728.47	728.47	728.47
Sum	**5758.37**	**3249.02**	**5703.43**	**3278.72**	**2562.91**	**1810.84**
Authorized						
Agricultural Land	23.31	4.66	11.46	2.29	7.45	1.49
Fallow Land	2.44	1.22	2.35	1.18	1.62	0.81
Bottomland Hardwoods	97.08	97.08	88.01	88.01	62.41	62.41
Herbaceous Wetlands	14.30	14.30	14.45	14.45	6.13	6.13
Permanent Waterbodies	557.99	557.99	557.99	557.99	557.99	557.99
Sum	**695.12**	**675.25**	**674.26**	**663.91**	**635.60**	**628.83**
Alternative_3.1						
Agricultural Land	723.01	144.60	311.30	62.26	16.15	3.23

Fallow Land	9.41	4.71	5.75	2.87	2.03	1.02
Bottomland Hardwoods	977.82	977.82	672.08	672.08	151.23	151.23
Herbaceous Wetlands	301.39	301.39	277.80	277.80	75.15	75.15
Permanent Waterbodies	653.03	653.03	653.03	653.03	653.03	653.03
Sum	**2664.65**	**2081.54**	**1919.95**	**1668.04**	**897.58**	**883.65**
Alternative_3.2						
Agricultural Land	365.88	73.18	114.88	22.98	9.05	1.81
Fallow Land	5.17	2.59	3.87	1.94	1.98	0.99
Bottomland Hardwoods	659.64	659.64	405.10	405.10	122.22	122.22
Herbaceous Wetlands	297.59	297.59	211.67	211.67	41.82	41.82
Permanent Waterbodies	644.14	644.14	644.14	644.14	644.14	644.14
Sum	**1972.41**	**1677.12**	**1379.66**	**1285.82**	**819.20**	**810.98**
Alternative_4.1						
Agricultural Land	1134.13	226.83	1216.31	243.26	415.98	83.20
Fallow Land	11.41	5.70	11.67	5.84	4.99	2.50
Bottomland Hardwoods	1161.46	1161.46	1234.73	1234.73	586.38	586.38
Herbaceous Wetlands	303.25	303.25	292.88	292.88	151.96	151.96
Permanent Waterbodies	670.19	670.19	670.19	670.19	670.19	670.19
Sum	**3280.43**	**2367.42**	**3425.78**	**2446.89**	**1829.49**	**1494.21**
Alternative_4.2						
Agricultural Land	26.33	5.27	29.66	5.93	12.60	2.52
Fallow Land	11.41	5.70	11.67	5.84	4.99	2.50
Bottomland Hardwoods	3116.28	3116.28	3434.95	3434.95	1524.09	1524.09
Herbaceous Wetlands	485.01	485.01	497.58	497.58	239.12	239.12
Permanent Waterbodies	670.19	670.19	670.19	670.19	670.19	670.19
Sum	**4309.22**	**4282.45**	**4644.05**	**4614.49**	**2450.99**	**2438.42**

Table III-4. Bootstrapped Summary Statistics for Average Daily Flood Acres (Acres) and Habitat Units (HU) by alternative and season for the New Madrid Floodway

Alternative (n=67)	**Spawning and Rearing Season**					
	March		**1 Apr - 15 May**		**16 May - 30 Jun**	
	Acres	**HU**	**Acres**	**HU**	**Acres**	**HU**
Existing						
Mean	5788.41	3247.16	5711.04	3266.39	2575.08	1812.53
St. Dev.	912.85	383.11	879.72	378.31	449.87	218.33
CV	15.78	11.81	15.42	11.59	17.48	12.05
95% lower CL	4196.73	2540.34	4086.67	2571.10	1782.28	1424.44
95% upper CL	7520.08	4000.44	7548.46	4080.37	3532.94	2295.04
Authorized						
Mean	692.56	675.83	674.14	664.66	635.56	629.13

St. Dev.	38.25	29.80	15.46	13.81	10.51	9.99
CV	5.53	4.41	2.30	2.08	1.65	1.59
95% lower CL	638.21	630.76	648.03	642.24	619.21	612.51
95% upper CL	785.32	739.75	708.20	694.87	657.48	652.40
Alternative_3.1						
Mean	2667.21	2087.18	1922.45	1668.14	897.75	883.22
St. Dev.	254.23	158.36	138.09	99.92	26.85	25.62
CV	9.54	7.59	7.19	5.99	2.99	2.90
95% lower CL	2159.31	1792.85	1675.75	1471.65	848.71	833.85
95% upper CL	3148.59	2380.18	2201.12	1862.96	952.80	934.42
Alternative_3.2						
Mean	1964.17	1677.49	1378.07	1287.79	819.88	810.32
St. Dev.	141.59	99.13	67.76	57.85	17.40	16.23
CV	7.21	5.91	4.92	4.50	2.12	2.00
95% lower CL	1689.46	1483.19	1248.06	1183.51	785.96	779.43
95% upper CL	2244.86	1869.28	1517.88	1404.95	854.94	843.00
Alternative_4.1						
Mean	3297.17	2369.82	3408.13	2460.57	1841.43	1496.86
St. Dev.	369.43	211.36	371.53	211.78	220.22	138.23
CV	11.21	8.93	10.91	8.61	11.97	9.24
95% lower CL	2621.97	1994.92	2722.81	2084.60	1437.35	1245.04
95% upper CL	4073.38	2798.02	4145.86	2891.77	2331.38	1799.15
Alternative_4.2						
Mean	4330.18	4293.11	4649.50	4624.24	2453.15	2435.08
St. Dev.	485.72	494.41	507.02	494.56	311.68	308.73
CV	11.23	11.52	10.91	10.70	12.71	12.69
95% lower CL	3404.92	3339.17	3689.24	3671.30	1913.89	1850.81
95% upper CL	5294.88	5267.48	5671.37	5637.60	3138.47	3090.78

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Appendix H
Part 1

Potential Impacts to Shorebirds

U.S. Army Corps of Engineers
Memphis District

26 June 2012

HABITAT FOR MIGRATING SHOREBIRDS IN SOUTHEAST MISSOURI:
Potential Impact of St. Johns-New Madrid Project

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Abstract. Shallow, seasonal floodwater on areas of non-forest land cover provides potential foraging habitat for migrating shorebirds (Charadriiformes). Historical records of river stage (elevation), from 1943 through 2009, provide insight regarding the long-term variability in flood conditions within the St. Johns and New Madrid Basins in southeastern Missouri during spring (15 March – 15 June) and fall (1 July – 30 October). I estimated the daily availability of shorebird foraging habitat associated with historical flood conditions under assumptions that shorebirds optimally forage in water depth <6 cm, also forage in water depth between 6 – 15 cm, and use mudflat habitat for 3 days after post-inundation exposure. Suitability of habitat was weighted to account for water depth, duration of mudflat exposure, temporal availability of habitat within the migration periods of shorebirds, and average planting and harvesting dates of agricultural crops. Under existing flood conditions, average daily shorebird foraging habitat within the St. Johns and New Madrid Basins, based on replicated random samples of 50 years drawn from 1943 to 2009, is 964 ha during spring and 33 ha during fall. Adjustments to account for habitat quality resulting from hydrological fluctuation (i.e., water depth and duration of mud exposure) and vegetation change (i.e., crop growth and harvest), as well as temporal coincidence with shorebird migration, suggest that the optimally equivalent area of shorebird habitat is 489 ha during spring and 12 ha during fall but varied markedly among years, from <1 ha to 1840 ha during spring and from 0 to 275 ha during fall. Implementation of the St. Johns-New Madrid Project would complete a system of levees which, when water-control gates are closed, would isolate these basins from Mississippi River floodwaters. The proposed project includes pumps to transport drainage water, which accumulates and floods land behind closed water-control gates,

across levees to maintain or lower water elevations within these basins. Hydrological changes resulting from the St. Johns-New Madrid Project would reduce the area and temporal availability of shallow floodwater habitat used by foraging shorebirds. Under authorized water-management (i.e., flood reduction) conditions, the average daily area of shorebird foraging habitat would be reduced by 80%, to 208 (107 optimally equivalent) ha during spring and 9 (<3 optimal) ha during fall. Proposed alternative water management scenarios within the New Madrid Basin would allow floodwater to fluctuate above authorized elevations. The most liberal alternative water management scenario that permits flooding of lower elevations year-round provides continuance of nearly all shorebird foraging habitat during fall and retains nearly two-thirds extant habitat during spring. More conservative of water management scenarios that afford greater flood protection during spring and summer would likely provide 186 (95 optimal) ha of shorebird foraging habitat during spring but provides no increase shorebird foraging habitat during fall.

Key Words: digital elevation model, flood control, floodwater, habitat quality, mudflat, shorebird habitat, temporal availability

INTRODUCTION

After record flooding in 1937, concerted flood control measures were implemented along the Mississippi River and its tributaries (Stevens et al. 1975). These measures included extensive earthen levees intended to confine rivers within their battures, such that >3218 km of mainline river levees are present along the 1529 km course of the lower Mississippi River (Nunnally et al. 1987). In addition, a network of canals throughout southeastern Missouri was created to facilitate drainage from croplands. Hydrological alteration from levees and canals patently alters adjacent ecosystems (Gergel et al. 2002). As such, historically forested landcover within southeastern Missouri has largely been converted to agriculture (Fig. 1).

Despite marked hydrological change in the St. Johns and New Madrid Basins, these basins remain subject to seasonal inundation (Fig. 1). In part, continuance of flooding outside the batture has been due to a gap within the levee system that surrounds the New Madrid Basin. This gap permits Mississippi River floodwater to enter the New Madrid Basin during periods of high water. Historical data suggest that an average (2-year) backwater flood in the New Madrid

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Basin inundates circa 7000 ha, of which 4700 ha are in agriculture (unpublished data, U.S. Army Corps of Engineers, http://www.mvm.usace.army.mil/stjohns/overview/default.asp). Even so, during 1973 significant backwater flooding inundated over 20,000 ha in this basin. In addition, the New Madrid Floodway, authorized in 1928, was designed to convey Mississippi River water during extreme flood conditions: it served this function during floods of 1937 and 2011.

Conversely, contiguous levees protect the St. Johns Basin from Mississippi River backwater flooding but gravity-outlet, box culverts through this levee allow drainage when the Mississippi River elevation is lower than the interior water elevation. However, when culvet gates are closed, surface drainage from intra-basin precipitation accumulates and lands are inundated behind the protective levees. In the St. Johns Basin, headwater flooding after closure of culvert gates has resulted in average 2-year flood events that inundate circa 4000 ha, of which 2500 ha are in agriculture (unpublished data, U.S. Army Corps of Engineers).

Although agricultural production may be adversely affected by flooding in the New Madrid and St. Johns Basins when floods occur during the growing season, seasonal floods have many ecological benefits. Seasonal inundation of non-forested land, predominately cropland, within these basins provides shallow-water flooding and mudflats that are suitable for foraging by shorebirds (Charadriiformes). These birds comprise a diverse group of small to medium-large birds that generally forage for invertebrates in shallow water (Recher 1966, Brown et al. 2001). Away from coastal shorelines, most shorebird species forage in areas of sparse vegetation, such as those associated with harvested agricultural lands (Helmers 1992, Rottenborn 1996, Twedt et al. 1998, Isola et al. 2000, Cole et al. 2002).

Because most of southeastern Missouri was historically forested, it previously did not attract large flocks of shorebirds (Twedt and Loesch 2002, Smith et al. 1996). However, as most of the land within the New Madrid and St. Johns Basins has been converted to agriculture, these basins now have tremendous potential for providing foraging habitat for shorebirds. Even so, few shorebird species breed in this area, with only Killdeer (*Charadrius vociferus*) being a common breeding species (Missouri Breeding Bird Atlas 1986 – 1992 <http://mdc.mo.gov/nathis/birds/birdatlas/index.htm>). Similarly, few individuals and species of shorebirds are present during winter. For example, during the past 2 decades Big Oak Tree State Park Christmas Bird Counts, conducted within a 15-mile diameter circle in the New Madrid Basin, detected only 5 species of shorebird, with only Killdeer, Common Snipe

(*Gallinago gallinago*), and Least Sandpiper (*Calidris minutilla*) detected in more than 1 year. The greatest abundance and species diversity of shorebirds within this region occur during spring and fall, as en-route migrant shorebirds make "rest and refueling" stops during their northbound (spring) and southbound (fall) passages (Elliott and McKnight 2000; Skagen 1997, 2006). Based on conservation planning documents (Loesch et al. 2000; Elliott and McKnight 2000), and empirical observations of shorebird abundances reported to the Lower Mississippi Valley Joint Venture Shorebird Monitoring Program (http://www.lmvjv.org/shorebird/default.asp), shorebirds of small or medium body size comprise the preponderance of these shorebirds (Table 1).

Comprehensive, long-term monitoring data that document the temporal passage of shorebirds through southeastern Missouri during migration do not exist, but Skagen et al. (1999) provide a general latitudinal quantification of the temporal distribution of abundances for small and medium sized shorebirds. An assessment of these data suggests that spring migrants are present between 15 March and 15 June, whereas fall migration may begin as early as 1 July and continue through 30 October (Skagen et al. 1999). These two time periods encompass nearly the entirety of shorebird passage through southeastern Missouri. Even so, the numbers of shorebirds migrating through this region are not uniformly distributed within these intervals, but peak abundances are expected between late April and mid-May during spring and between mid-August and mid-September during fall.

Many factors contribute to habitat selection by shorebirds (Burger 1984, Jing et al. 2002). Even so, most small and medium size shorebirds forage primarily in water depths <6 cm. Some of these shorebirds, and other less abundant shorebirds, also forage in exposed mudflat habitats and in floodwater of depth from 6-15 cm, with a few, usually larger, species foraging at greater water depth (Table 1). Despite this diversity in foraging habitats, more than 70% of shorebird species forage in water depths <10 cm and many species are restricted to water depths of <5 cm (Helmers 1992, Skagen et al. 1999, Dinsmore et al. 1999). Indeed, shallow water depth was the most important predictor of shorebird abundance within the Rainwater Basin in Nebraska (Webb et al. 2010). Similarly, in an assessment of foraging habitat use by shorebirds in the Playa Lakes Region of Texas, Davis (1996) reported shallow (<4 cm depth) flooded habitats were used by 46% of foraging flocks, moderately flooded (4-16 cm depth) habitats were used by 29%, and mudflats were used by 19%, but only 5% of foraging flocks used habitats flooded deeper than 16 cm.

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Shorebirds forage within a variety of substrates that range from bare ground to >75% vegetative cover, but most species preferentially use sites with sparse (<25%) vegetative cover (Davis and Smith 1998, Dinsmore et al. 1999). Davis (1996) reported that in Texas, 95% of foraging flocks used sites with <33% vegetation. Moreover, abundance of some shorebird species was negatively correlated with vegetation height (Colwell and Dodd 1995) with most species found on sites where vegetation height was less than half of their body height.

Because prolonged duration of flooding stimulates production of aquatic invertebrates, water is often retained for long periods (weeks or months) on artificial wetlands (i.e., impoundments) that are managed for shorebird foraging habitat. However, natural wetlands and rivers harbor myriad aquatic invertebrates upon which shorebirds forage. In addition, terrestrial insects and other invertebrates found in cultivated fields in the Mississippi Alluvial Valley provide food for shorebirds when these fields are flooded. Thus, lands subjected to backwater flooding that have sparse or short vegetation (e.g., agricultural fields or grazed grasslands) may provide productive foraging sites for migrating shorebirds regardless of flood duration. Given current land use within southeastern Missouri, supplying the necessary mix of water depth and vegetative structure, within temporal windows that correspond with shorebird migration, is the most important issue for shorebird conservation in this region (Brown et al. 2001).

The U.S. Army Corps of Engineers (USACE) has proposed completion of an earthen levee to protect the New Madrid Basin and concurrent installation of water pumping facilities within both the St. Johns and New Madrid Basins (a.k.a., St. Johns-New Madrid Project). Proposed pumps would be capable of transporting headwaters, that accumulate behind closed water control gates, over the protective levees with subsequent deposition in the Mississippi River batture. Completion of the St. Johns-New Madrid Project is expected to eliminate backwater flooding from the Mississippi River and afford reduction of headwater flooding within both of these basins. Reduced flooding will likely diminish the area of habitat that is suitable for foraging shorebirds within both basis, but because the direct connection with the Mississippi River will be severed, habitat loss is anticipated to be greater within the New Madrid Basin.

To assess the effect of the St. Johns-New Madrid Project on shorebird habitat, I sought to quantify the area of shorebird habitat within the St. Johns Bayou and New Madrid Basins, and to predict the area of shorebird habitat that would be available under presumed post-flood control project conditions. Specifically, my objectives were to:

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1. Develop a methodology to quantify the area of potential shorebird habitat relative to intra-basin hydrological elevations (National Geodetic Vertical Datum: NGVD) that were derived from Mississippi River elevations (a.k.a., river stages), precipitation, topograph, and land cover,
2. Estimate the area of potential shorebird habitat within the St. Johns and New Madrid Basins that is associated with each ~3 cm (0.1 foot) increment of intra-basin water elevation,
3. Quantify the availability of shorebird habitat within the St. Johns and New Madrid Basins during periods of northward and southward migration of shorebirds, based on historical intra-basin water elevations, and
4. Predict future availability of shorebird habitat during periods of northward and southward migration of shorebirds within the St. Johns and New Madrid Basins based on projected post-project intra-basin water elevations.

METHODS

Study Area

Area of investigation included 126,325 ha in the St. Johns Bayou Basin and 47,670 ha in the New Madrid Basin of southeastern Missouri that would be impacted by the St. Johns-New Madrid Project (Fig. 1). Greater than 90% (163,235 ha) of landcover in these basins is cropland, pasture, or other sparse vegetation, that if shallowly inundated could provide habitat conditions suitable for foraging shorebirds (Fig. 1).

Landcover

I considered all lands with tall or dense vegetation (e.g., forest or shrubs) unsuitable for shorebirds. Similarly, areas in permanent water (i.e., lakes and ponds) were assumed to be predominately of depths that exceed shorebird foraging limits and thus not suitable shorebird habitat. Conversely, I assumed agricultural cropland, grassland, and other open lands were suitable shorebird foraging habitat when appropriately inundated.

Initial landcover classifications within the St. Johns and New Madrid Basins were obtained at 30-m resolution from the Multi-Resolution Land Characterization Consortium's 2001 National Land Cover data (available online at: http://www.mrlc.gov/nlcd01_data.php, Homer et al. 2004, 2007). These National Land Cover data were verified using aerial imagery

obtained from the U.S. Department of Agriculture, National Agricultural Imagery Program. Individual land use polygons were visually compared with aerial imagery and, where inconsistencies were identified, corrections were made to the land use data to conform with aerial imagery. Finally, land use was further verified by conducting site visits on 20% of the project area and crop types were assigned to agricultural lands (K. Pigott, personal communication).

I reclassified the USACE landcover raster into binary descriptors of shorebird habitat (suitable vs. non-suitable) where non-suitable habitat included all forest classes (including wooded wetlands), shrubland, open water, and high-density developed areas (i.e., cities). All other cover classes, including all crops, fallow fields, orchards, grassland, pasture, low- and medium density developed lands (i.e., farmsteads and suburban areas), and herbaceous or emergent wetlands, were considered potentially suitable as shorebird habitat.

Comparison of these 30-m data with 2007 aerial photography within these basins revealed marked discrepancies in areas deemed suitable shorebird foraging habitat. That is, some areas of forest cover were classified as 'open' habitats whereas other areas of 'open' habitat were classified as forested. Therefore, I converted this binary depiction of shorebird habitat to a vector format and subsequently employed 'heads-up' digitization to alter habitat polygons to reflect habitats identified from 2007 aerial photography. Only areas within the St. Johns and New Madrid Basins that had landcover suitable for shorebirds during 2007 were considered when estimating areas of potential shorebird foraging habitat (Table 2)

Wetland Reserve Program

Some areas deemed potentially suitable for shorebirds were known to have been previously enrolled in the U.S. Department of Agriculture's Wetland Reserve Program (WRP). As most WRP enrollments within this region are reforested or converted to semi-permanent water, these areas will likely harbor little potential shorebird habitat in the future. Thus, all lands enrolled in WRP were removed from consideration as shorebird habitat.

In addition, U.S. Department of Agriculture personnel, in cooperation with USACE personnel, estimated that WRP enrollment over the next 50 years will increase by 345 ha in the New Madrid Floodway and by 1200 ha within the St. John's Basin. Based on the area of existing WRP enrollments (i.e., average contract size: 87 ha in St. John's, 67 ha in New Madrid), enrollment of as few as 2 contracts per year would realize these WRP projections within 10

years. Therefore I assumed 10% of projected future enrollment in WRP occurred each year for 10 years and thereafter remained stable. Elevations (decifoot) of projected WRP enrollments were assumed comparable to elevations within existing WRP enrollment. Therefore proportionally equivalent areas were annually (for 10 years) removed from potential shorebird habitat. If insufficient area for removal remained within a decifoot elevation, proportional removal was increased among remaining decifoot elevations until projected area of removal was attained.

Foraging habitat

Because most shorebirds rarely forage in dry habitats, I assumed only areas that were inundated or recently exposed from inundation (i.e., mudflats) were suitable for use by foraging shorebirds. However, based on differential habitat use reported by Davis (1996), I assumed only habitats that were shallowly flooded with ≤6.1 cm (0.2 ft) of water provided optimal foraging conditions. These shallowly flooded areas were assigned maximum habitat suitability (s = 1.0). Suitability of habitats flooded at greater depths, up to 15.25 cm (0.5 ft) was assumed inversely related to water depth. Therefore I assigned reduced suitability scores to flood depths 6.1 − 9.15 cm (s = 0.8), 9.15 − 12.2 cm (s = 0.7), and 12.2 − 15.25 cm (s = 0.6). Similarly, because of relatively less use of mudflats by foraging shorebirds (Davis 1966), presumed spatial heterogeneity in mudflat habitat conditions, and uncertainty regarding the temporal stability of exposed mudflats due to variation in drainage and rates of evapo-transpiration, I assumed mudflats were less than optimal for most foraging shorebird species. Therefore, I inversely weighted suitability of mudflats relative to length of exposure after inundation as: exposed 1 day (s = 0.6), exposed 2 days (s = 0.5), and exposed 3 days (s = 0.4).

Migration Window

The quantitative distribution of shorebirds within spring and fall migration periods is not uniform, as fewer birds are present at the beginning and end of each migration period. Using temporal distribution data for small and medium shorebirds within 35° – 40° north latitude in North America provided by Skagen et al. (1999), I modeled abundance as a function of time (day) within each migration period. The best-fit regression models were:

$$\text{Spring shorebird abundance} = 1.012(\text{day}) + 0.0255(\text{day}^2) - 0.0004(\text{day}^3) \text{ and}$$
$$\text{Fall shorebird abundance} = 4.2538(\text{day}) - 0.0598(\text{day}^2) + 0.0002(\text{day}^3)],$$

where day was the interval after the presumed first day within each migration period (Fig. 2). From these regression models I estimated the intervals within each migration period wherein 50% and 90% of the migrating shorebird populations were predicted to be within the study area. Assuming the greatest benefit occurs when the greatest abundance of shorebirds have access to suitable foraging habitat, I assigned maximum value to those days wherein 50% of the population was predicted to be present (t = 1.0). For those remaining days of each migration period that harbored an additional 40% of the population (90% total), migration period value was reduced to 90% of maximum (t = 0.9). For all other days, during which only 10% of the shorebird population was predicted to be present, I reduced migration period value to 50% of maximum (t = 0.5). Using these migration period values, the daily area of shorebird foraging habitat equivalence, previously estimated from suitability of flood conditions in areas of suitable landcover, was modified to reflect temporal availability of habitat within each migration period.

Crops: Planting, Growth and Harvest

Suitability of inundated lands as shorebird habitat diminishes with increased density and stature of vegetation. Therefore, I evaluated the usual first and last planting and harvesting dates for crop grown in Missouri (USDA 1997). Using 9 reclassified land cover types (Table 2), I developed step-functions for each of 7 crop types that were potentially suitable as shorebird habitat to reflect a decreased suitability of habitat after planting (crop suitability; c = 0.75), an additional decrease in suitability upon presumed maturation (c = 0.5), followed by increased suitability upon initiation of harvest (c = 0.75), and subsequent return to maximum suitability (c = 1.0) upon completion of harvest (Figure 3). Land cover classified as fallow or developed (open, low density, or medium density) was assumed to be maintained in suitable condition as shorebird habitat and retained maximum suitability (c = 1.0), whereas land cover classes deemed unsuitable as shorebird habitat were assumed to have zero crop suitability (c = 0.0).

I calculated the area of each crop type class within each 3.05 cm contour elevation for each river basin and determined its proportion of all potentially suitable shorebird habitats within the respective contour elevation. For each day of the year (a.k.a., Julian day), I summed the products of proportion of crop type class (constant among days) and crop suitability index (varied among days) to determine an elevation-day crop development index. Where the elevation-day crop development index was the proportion of crop type class times the crop type

class suitability index for the day, summed over 8 crop type classes (Table 2). To account for temporal change in crop status within each contour elevation, I decreased the area of optimally suitable shorebird habitat using its corresponding elevation-day crop development index. Thus for each day, the optimally equivalent area of shorebird foraging habitat was calculated as:

Optimally equivalent area = Σ (ha*s*t*CDI), summed over all elevations, where
ha = area in hectares inundated <16 cm or exposed from inundation within the previous 3 days,
s = water depth or mud exposure suitability,
t = temporal suitability within spring or fall migration window.
CDI = elevation-day crop development index.

Water Elevations

Neither St. Johns Bayou nor the New Madrid Floodway had river gage (water elevation) records suitable for direct estimation of intra-basin water levels. Therefore U.S. Army Corps of Engineers personnel derived daily intra-basin water elevations for each of these basins from 1943 through 2009 based on: 1) period of record data from New Madrid river gage (MS115, -89.53222, 36.58306, 0.2 km downstream from the mouth of St. Johns Bayou at river navigation mile 889.0, http://www.mvm.usace.army.mil/hydraulics/docs/gagtitl/ms115hdr.htm); 2) regional precipitation records from weather stations at New Madrid and Sikeston, Missouri and Cairo, Illinois; 3) topography (conventional and LiDAR); and 4) land cover. From these data, daily intra-basin water elevations were calculated for the St. Johns Basin (Appendix A1) and the New Madrid Basin (Appendix 10) using the computer program HUXRAIN (pers. com., B. J. Bruchman, Memphis District, U.S. Army Corps of Engineers).

The model application does not consider how large scale land use changes and climate change may affect future water elevations. Use of historic data such as water elevation data to make future projections assumes stationarity – that natural systems fluctuate within an unchanging envelope of variability. The assumption of stationarity may not be appropriate but our current understanding of future land use and climatic conditions does not afford guidance on how to address non-stationarity of water resources.

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Flood assessment

I obtained digital vertical elevation (NGVD) contours at 0.305 m (1-foot), derived from light detection and ranging (LiDAR) data within the New Madrid Basin and derived from geodetic and hydrologic data within the St. Johns Basin, from U.S. Army Corps of Engineers (K. R. Pigott, Memphis District, U.S. Army Corps of Engineers; Appendix C). A fundamental underlying assumption for subsequent estimation of shorebird habitat within the St. Johns and New Madrid Basins was that these 1-foot elevation contours reasonably approximated the extent of floodwater associated with their respective intra-basin water elevations.

I used ArcMap 9.3 (ESRI, Redlands, California) geographic information system to spatially interpolate 3.05 cm (0.1-foot) interval elevations between each pair of 1-ft elevation contours. Because of computer memory limitations, separate interpolations were undertaken within subdivisions of each basin. Upon completion of interpolation, within each basin I merged all interpolated subdivisions into a unified digital elevation map (raster). Specifically for each basin I:

1. Used Hawth's Analysis Tools for ArcGIS (http://www.spatialecology.com/htools) to create grid cells (10,000 ft x 10,000 ft) which encompassed the entirety of the basin and clipped grid cells to the boundaries of each basin if cells extended beyond the boundaries of the basin.
    a. If resultant clipped grid cell was small, or lacked sufficient 1-ft contour lines for subsequent interpolation, it was merged with an adjacent cell [Analysis Tools; Overlay; Union].
2. Extracted separate pieces of the original 1-ft contour lines using each of the separate clipped grid cells as extraction boundaries [Analysis Tools; Extract; Clip].
3. Interpolated 0.1-ft elevation digital elevation model (DEM) for each extracted subdivision using ArcMap [Spatial Analyst Tools; Interpolation; Topo-to-Raster]. Interpolation was set at the default of 20 cells beyond the boundary of the grid cell extraction (i.e., overlap among subdivisions) and output cell size of resultant DEM specified at 3 ft x 3ft (0.9 m) horizontal spacing [i.e., 9 ft^2 raster pixel]. Resultant elevation models were 64-bit, floating point rasters.

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a. For a few subdivisions, Topo-to-Raster interpolation failed. In these instances, the area being interpolated was reduced through reiteration of the above methods but with smaller grid cells (5,000 ft x 10,000 ft or smaller).

4. Used ERDAS IMAGINE 2010 (Erdas Inc., Norcross, Georgia) to merge all subdivisions within each basin into a single digital elevation model (raster). Areas of overlap were assigned mean cell values.
5. Multiplied all cell values within each merged digital elevation model by 10 [Spatial Analyst Tools; Math; Timesand converted from a floating point raster to a 16-bit unsigned raster], such that each raster cell represented a 'decifoot' elevation (where 1 decifoot = 0.1 foot). For example, an original elevation of 294.823848 feet would be represented as 2948 decifeet.

The total area (ha) included in each presumed decifoot (3.05 cm) elevation, summed separately within each basin, represented the area inundated at each corresponding intra-basin water elevation.

Model Application

Within each river basin, for each day from 1 January 1943 through 30 November 2009, I projected intra-basin water elevations to estimate the area of landcover within 3.05 cm elevation intervals, and with habitat structure suitable for shorebird foraging, that was inundated with ≤15.25 cm of water. Concurrently, I projected inundations associated with water elevations for each of the previous 3 days. When inundation was greater during any of the previous 3 days (i.e., falling water levels), the area of suitable landcover exposed after inundation was estimated separately for each of these 3 days. That is, the area between the daily water-land interface contour (0 depth) and the contour representing the previous day's flood extent was summed to represent mudflat habitat exposed on each day. The total daily area of potential shorebird habitat with suitable land cover within the St. Johns and New Madrid Basins was the combined areas of inundation ≤15.25 cm in depth and mudflats exposed within the previous 3 days. For each day, this sum represented the total area (i.e., footprint) available to shorebirds for foraging.

As not all of the area available to shorebirds was considered optimal for foraging, the area of presumed suitable shorebird foraging habitat within each flood-depth interval was weighted by its depth-specified suitability (s). Similarly, the area of presumed suitable shorebird foraging habitat exposed as mudflats was weighted relative to suitability (s) associated with length of exposure (1, 2, or 3 days) after prior inundation.

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All suitable habitats were also temporally weighted to account for the likelihood of migrating shorebirds being present in the study area (t), and to account for seasonal change in vegetation on croplands (CDI). Daily sums of appropriately weighted foraging areas, that accounted for presumed foraging quality and temporal suitability, provided a measure of 'optimal' habitat equivalence (i.e., the equivalent area of suitable shorebird foraging habitat if quality and temporal availability were optimal).

To determine the area of shorebird foraging habitat available during spring and during fall under existing flood conditions, I determined the mean and variance associated with 200 bootstrap samples, with each sample consisting of 50 years of intra-basin water elevation data that were randomly selected (with replacement) from years 1943 – 2009. I assessed the extent of annual variation in available shorebird foraging habitat by identifying annual minimum and maximum areas of shorebird foraging habitat during spring and during fall.

Forecast Prediction

The authorized St. Johns-New Madrid Project will ostensibly restrict floodwater elevations from spring through fall to ≤279 feet NGVD within the St. Johns Basin and ≤278 feet NGVD within the New Madrid Basin. Pumping of impounded water would commence within each basin at these prescribed maximum elevations and would continue until sump elevations were reduced to 277 feet NGVD in the St. Johns Basin and 275 feet NGVD in the New Madrid Basin. Recognizing that extreme rainfall events and pump limitations will likely prevent strict adherence to authorized flood elevation limits, and that intentional retention of sump elevation above falling river elevation is possible, U.S. Army Corps of Engineers personnel (B. Bruchman, pers. com.) generated projected estimates of water elevations under authorized project flood restrictions for the St. Johns Basin (Appendix A2) and the New Madrid Basin (Appendix B2) using methodologies similar to those used to derive historical daily water elevations. I forecast the probable area of foraging habitat for shorebirds based intra-basin water elevations using the same methods described above, but with historical daily water elevations replaced with daily water elevations projected under post-project authorized flood restrictions.

Because flood events that do not impact crop production or imperil residential areas are socio-politically acceptable and environmentally beneficial, 3 alternative water management scenarios that allow greater inundation were evaluated within the New Madrid basin (Table 3). The most liberal of these proposed alternatives would provide flood protection to elevations

≥290 feet NGVD throughout the year (Table 3). A more conservative alternative allows water elevation up to 288 feet NGVD during the early portion of spring migration, with subsequent reduction in water elevation to ≤284 feet NGVD during later spring migration, and 279.5 feet during fall (Table 3). Using the methodologies described above, daily estimates of intra-basin water elevation were projected that reflect in impact of alternative water management (Appendices B3, B4, and B5) which were subsequently used to predict the daily area of shorebird foraging habitat that would be available under proposed alternative water management scenarios.

RESULTS

For each day within the spring and fall migration periods from 1943 through 2009, I estimated: (1) the total area of potential shorebird foraging habitat (i.e., open land) flooded regardless of depth, (2) total area of shorebird foraging habitat that was inundated with ≤15.25 cm or exposed from inundation for ≤3 days, (3) the equivalent area of shorebird foraging habitat after accounting for presumed quality of foraging habitat, (4) the equivalent area of shorebird foraging habitat that also accounts for temporal availability of habitat within migration periods, and (5) the optimally equivalent area of foraging habitat that accounts for habitat quality, temporal availability, as well as crop planting, growth, and harvest within the St. Johns Basin (Appendix A1) and New Madrid Basin (Appendix B1). Shorebird foraging habitat was available on >80% of days during spring but <50% of days during fall and was present on more days within the St. Johns Basin than within the New Madrid Basin (Table 4).

Despite a smaller area, the average daily available shorebird foraging habitat under existing conditions within the New Madrid Basin was markedly greater than that available within the St. Johns Basin (Table 5). Mean daily area of shorebird foraging habitat under existing conditions within both basins was 29 times greater during spring (964.3 ± 114.1 ha; x ± SD) than during fall ((33.2 ± 13.9 ha; Table 5).

After adjusting for habitat quality, temporal availability, and crop condition, mean daily 'optimally equivalent' area of shorebird foraging habitat under existing conditions within both basins, was >40 times more abundant during spring (488.9 ± 60.3 ha) than during fall (11.6 ± 5.3; Table 6). During an average spring day under existing flood conditions, shorebird foraging habitat was present on nearly 1000 ha of 3700 flooded ha, but habitat quality and temporal availability indicated <500 ha of optimally equivalent habitat were available for foraging. In

contrast, during an average fall day under existing flood conditions, only 33 ha of shorebird foraging habitat were present, with the equivalence of <12 ha optimal foraging habitat.

Adherence to water management as authorized upon completion of the St. Johns-New Madrid Project that restricts sump elevation to ≤279 ft NGVD within the St. Johns Basin would reduce the total availability of shorebird foraging habitat within this basin by ~30% in spring and by ~38% in fall (Table 5). Authorized restriction of sump elevation to ≤278 ft NGVD within the New Madrid Basin would reduce the total availability of shorebird foraging habitat within this basin much more markedly, by >98% in both spring and fall (Table 5). The optimally equivalent area of shorebird foraging habitat within the New Madrid Basin was similarly reduced during both migration periods (Table 6).

The alternative water management scenario that affords year-round flood protection only for elevations ≥290 feet NGVD within the New Madrid Basin (alternative 4) will provide nearly all existing shorebird foraging habitat during fall and retain nearly two-thirds of the existing shorebird foraging habitat during spring (Table 6). Moreover this liberal alternative water management scenario encompasses >50% of existing annual variation in shorebird foraging habitat (Table 6). In contrast, the alternative water management scenarios proposed for the New Madrid Basin, which allow increased inundation only during spring (alternatives 1 and 2) do not mitigate loss of shorebird foraging habitat during fall, and would likely reduce the availability of total shorebird foraging habitat (Table 5) and optimally equivalent area of shorebird foraging habitat (Table 6) during spring by 70% – 85%.

DISCUSSION

I assumed that 1-foot elevation contours developed by U.S. Army Corps of Engineers' personnel provided a reasonable approximation of the ground elevation and drainages within the St. Johns and New Madrid Basins. As such, the extent of floodwater associated with each respective intra-basin water elevation was accurately depicted through conformity to these elevation contours. Interpolated 0.1 foot elevation contours between adjacent 1-foot elevation contours are undoubtedly inexact. However, this shorebird foraging habitat model assumes that variation in flooded area is unbiased within the landscape and, thus on average provides a reasonable approximation of suitably flooded areas. That is, the exact geographic distribution of areas assumed to be suitable for shorebird foraging may not be accurately depicted but the total

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area of suitably inundated and recently exposed (mudflat) habitat is presumed to be an accurate representation of daily conditions.

Because reduction in the area of shorebird foraging habitat associated with completion of the St. John-New Madrid Project was great within the New Madrid Basin, alternative water management scenarios were proposed to lessen loss of shorebird foraging habitat. Even though these alternatives increased the area of available shorebird foraging habitat during spring, both proposed alternatives resulted in a marked reduction (70% or 85%) in the area of shorebird foraging habitat. Furthermore, all proposed post-project management scenarios nearly eliminate shorebird foraging habitat during fall in the New Madrid Basin.

I assumed intra-basin water elevations would fluctuate with river stage but intentional retention of water within management pools, at elevations that exceed river stage, would increase the area of shorebird foraging habitat above that identified by this model. Thus, additional targeted management actions, within either of these basins, could enhance the availability of shorebird foraging habitat without increased flooding beyond proposed management scenarios.

Grassland vegetation conditions range from very short to relatively tall and rank. Grazed or hayed grasslands likely have vegetation structure during fall or spring that when flooded constitutes suitable habitat for shorebird foraging.

During the past 15 years, >2300 ha of agricultural land have been enrolled in WRP with >1500 additional ha anticipated to be enrolled within the St. Johns and New Madrid Basins. I assumed these additional enrolments would occur within the next 10 years and that the elevation distribution of future enrollment will be similar to past enrollment. Therefore, as the geo-spatial coordinates of any future WRP enrollments become known, increased precision of these predictions is possible.

These model projections assumed stationarity of future flood conditions. However, if future flood events are less frequent and of lower intensity, the area of shorebird foraging habitat will suffer reduction. The annual effects of the St. John-New Madrid Project on shorebird habitat should be lessened – but the resultant further reduction in diminished foraging area may detrimental to migrating shorebird populations. Conversely, if future flood events are more frequent and of greater intensity (i.e., higher elevation), shorebird foraging habitat would likely increase in area and duration of availability. Under these conditions, although the St. John-New

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Madrid Project would likely reduce shorebird foraging habitat, the extent and availability of suitable shorebird foraging habitat may be sufficient to support migrating shorebird populations.

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Figure 1. St. Johns and New Madrid Basin study area in southeastern Missouri. Forest, open water, and urban landcover were deemed unsuitable for foraging shorebirds. Relative flood frequency was based on multi-temporal analysis of satellite imagery (Ducks Unlimited, unpublished data).

Figure 2. Predicted relative abundance of small and medium shorebirds between 35° and 40° N latitude in North America during a 93 day (15 March – 15 June) spring migration period and during a 122 day (1 July – 30 October) fall migration period. Polynomial approximations are based on shorebird abundances reported by Skagen et al. (1999). Assessment of the area under predicted curves indicates 50% of the spring population present 24 April – 23 May and 90% present 3 April – 8 June. During fall migration, 50% of the shorebird population occurs 5 August – 16 September and 90% present 14 July – 13 October.

Figure 3. Step functions used to characterize crop-type suitabilty for every day of year based on first and last planting and havesting dates within Missouri and a presumed 4 week period of rapid initial growth (U.S. Department of Agriculture 1997).

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Table 1. Shorebird species, body size, presumed foraging depth (cm), and numbers of southward (fall) migrating shorebirds detected on surveys in the 4 states (Missouri, Kentucky, Tennessee, and Arkansas) near the St. Johns-New Madrid study area that were reported to the Lower Mississippi Valley Joint Venture Shorebird Monitoring Program.

Family	Common Name	Scientific Name	Size[1]	Depth	Number[2]
Charadriidae	Piping Plover	*Charadrius melodus*	S	<3	25
Charadriidae	Semipalmated Plover	*Charadrius semipalmatus*	S	<3	1672
Charadriidae	Killdeer	*Charadrius vociferus*	M	<3	15292
Charadriidae	American Golden-Plover	*Pluvialis dominica*	M	<9	80
Charadriidae	Black-bellied Plover	*Pluvialis squatarola*	M	<9	518
Recurvirostridae	Black-necked Stilt	*Himantopus himantopus*	L	<20	4082
Recurvirostridae	American Avocet	*Recurvirostra americana*	L	<12	793
Scolopacidae	Spotted Sandpiper	*Actitis macularia*	M	<4	535
Scolopacidae	Ruddy Turnstone	*Arenaria interpres*	M	<6	10
Scolopacidae	Upland Sandpiper	*Bartramia longicauda*	M	<6	19
Scolopacidae	Sanderling	*Calidris alba*	M	<3	257
Scolopacidae	Dunlin	*Calidris alpina*	M	<6	152
Scolopacidae	Baird's Sandpiper	*Calidris bairdii*	S	<6	925
Scolopacidae	Red Knot	*Calidris canutus*	M	<6	2
Scolopacidae	White-rumped Sandpiper	*Calidris fuscicollis*	S	<6	540
Scolopacidae	Stilt Sandpiper	*Calidris himantopus*	M	<9	8785
Scolopacidae	Western Sandpiper	*Calidris mauri*	S	<6	2521
Scolopacidae	Pectoral Sandpiper	*Calidris melanotos*	M	<6	42549

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Scolopacidae	Least Sandpiper	*Calidris minutilla*	S	<6	46626
Scolopacidae	Semipalmated Sandpiper	*Calidris pusilla*	S	<6	11817
Scolopacidae	Calidris spp. (peeps)	*Calidris spp.*	S	<6	4674
Scolopacidae	Willet	*Catoptrophorus semipalmatus*	L	<12	19
Scolopacidae	Common Snipe	*Gallinago gallinago*	M	<6	92
Scolopacidae	Short-billed Dowitcher	*Limnodromus griseus*	M	<12	1097
Scolopacidae	Long-billed Dowitcher	*Limnodromus scolopaceus*	M	<12	4622
Scolopacidae	Dowitcher spp.	*Limnodromus spp.*	M	<12	1377
Scolopacidae	Marbled Godwit	*Limosa fedoa*	L	<12	18
Scolopacidae	Hudsonian Godwit	*Limosa haemastica*	L	<12	0
Scolopacidae	Long-billed Curlew	*Numenius americanus*	L	<9	0
Scolopacidae	Whimbrel	*Numenius phaeopus*	L	<12	0
Scolopacidae	Red-necked Phalarope	*Phalaropus lobatus*	M	various	18
Scolopacidae	Wilson's Phalarope	*Phalaropus tricolor*	M	various	598
Scolopacidae	Greater Yellowlegs	*Tringa melanoleuca*	M	<12	787
Scolopacidae	Solitary Sandpiper	*Tringa solitaria*	M	<6	267
Scolopacidae	Lesser Yellowlegs	*Tringa. flavipes*	M	<12	6533
Scolopacidae	Buff-breasted Sandpiper	*Tryngites subruficollis*	M	<3	371

[1] Body size: S = body length ≤190 mm, M = body length 195 - 350 mm, and L = body length > 350 mm (Skagen and Knopf 1993).

[2] Lower Mississippi Valley Joint Venture Shorebird Monitoring Program <http://www.lmvjv.org/shorebird/default.asp>.

Table 2. Circa 2007 land cover classes identified within U.S. Army Corps of Engineers (USACE) digital land cover raster and their respective crop type class and shorebird habitat class (Shorebird) used for quantitative assessment of the area of

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shorebird foraging habitat within the St. Johns and New Madrid Basins in southeastern Missouri. Slight discrepancy in area between USACE and Shorebird habitat designations attributed to differences in scale (pixel size) and delineation of land enrolled in USDA Wetland Reserve Program.

			New Madrid Basin (ha)		St. Johns Basin (ha)	
Land cover class	Crop type class	Habitat class	USACE	Shorebird	USACE	Shorebird
barren	n/a	Unsuitable	0		1	
deciduous forest	n/a	Unsuitable	529		2,165	
developed/high intensity	n/a	Unsuitable	2		179	
evergreen forest	n/a	Unsuitable	0		284	
mixed forest	n/a	Unsuitable	0	4,949	17	10,304
open water	n/a	Unsuitable	492		380	
shrub	n/a	Unsuitable	5		17	
woody wetland	n/a	Unsuitable	3,596		5,389	
Wetland Reserve Program	n/a	Unsuitable	0		0	
corn	corn-sorghum	Suitable	5,228		23,797	
popcorn	corn-sorghum	Suitable	1	6,260	2	23,897
sorghum	corn-sorghum	Suitable	1,158		583	
cotton	cotton	Suitable	123	120	2,641	2,589
developed/low intensity	fallow	Suitable	238		2,536	
developed/medium intensity	fallow	Suitable	21	2,721	719	11,224
developed/open space	fallow	Suitable	2,440		7,905	
fallow	fallow	Suitable	78		292	
grassland	grass-herbaceous	Suitable	1		3	
herbaceous wetlands	grass-herbaceous	Suitable	56		112	
herbs	grass-herbaceous	Suitable	33	329	12	3,707
pasture/hay	grass-herbaceous	Suitable	156		3,536	
wetlands	grass-herbaceous	Suitable	123		120	
soybean	soybean	Suitable	24,820	24,326	32,863	32,209
wheat/soybean (double)	wheat	Suitable	7,309	7,200	27,140	27,948
winter wheat	wheat	Suitable	37		1,376	

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rice	rice	Suitable	257	252	1,440	1,412
oats	other crops	Suitable	0		7	
other small grains	other crops	Suitable	18		272	
peaches	other crops	Suitable	0	20	0	340
potatoes	other crops	Suitable	0		58	
watermelon	other crops	Suitable	2		11	
Totals			46,723	46,178	113,857	113,630

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Table 3. Water elevations (feet NGVD) proposed for alternative water management scenarios to be implemented upon completion of contiguous Mississippi River levee and installation of pumps to remove water from the New Madrid Basin, compared to authorized intra-basin water elevations of 278.0 feet attained before starting to pump water from inside levees, with continued pumping until an elevation of 275.0 feet is achieved.

	Close Gate			Start Pump			Stop Pump		
Dates	Alt. 1	Alt. 2	Alt. 4	Alt.1	Alt. 2	Alt. 4	Alt.1	Alt. 2	Alt. 4
15 November – 28 February	287.5	287.5	287.5	289.5	289.5	289.5	288	288	288
1 March – 15 April	286	284	287.5	288	286	2289.5	287	285	288
16 April – 30 May	284	282	287.5	284	282	289.5	282	280	288
1 June – 14 November	278.5	278.5	287.5	279.5	279.5	289.5	278.5	278.5	288

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Table 4. Annual number of days during which shorebird foraging habitat was available during spring (93 days) or fall (122 days) migration periods within the New Madrid and St. John's Basins in Missouri, 1943 to 2009 (n = 67).

Basin	Migration	Mean	SE	Minimum	Maximum
New Madrid	Spring	77.6	2.1	20	93
	Fall	23.5	2.7	0	122
St. John's	Spring	90.4	0.8	51	93
	Fall	60.7	3.6	4	122

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Table 5. Daily area (ha) of shorebird habitat, irrespective of presumed habitat quality and temporal availability (i.e., total 'footprint' of foraging habitat regardless of suitability or date within migration window), during spring (15 March - 15 June) and fall (1 July - 30 October) migration periods within the St. Johns and New Madrid Basins in southeastern Missouri. Based on 200 bootstrap samples, each of 50 years, randomly selected (with replacement) from daily intra-basin water elevations, 1943 – 2009, assuming current flood conditions (existing), presumed intra-basin water elevations under conditions authorized upon completion of levees and operation of pumps associated with the St. John-New Madrid Flood Control Project (authorized), and 3 alternative water management scenarios wherein intra-basin water elevations exceed authorized elevations.

			50 year projections						Annual variation	
Basin	Migration	Conditions	Mean	SD	95% lcl	95% ucl	Min	Max	Low	High
St. John's	Fall	Existing	13.0	3.0	7.1	18.9	6.6	21.7	0.0	158.0
St. John's	Fall	Authorized	8.1	2.1	4.1	12.1	2.9	15.5	0.0	91.9
St. John's	Spring	Existing	278.8	35.7	208.9	348.7	195.1	374.4	0.9	1242.4
St. John's	Spring	Authorized	196.9	29.0	140.0	253.8	136.6	281.2	0.4	775.1
New Madrid	Fall	Existing	20.2	10.9	0.0	41.5	1.0	55.0	0.0	532.0
New Madrid	Fall	Authorized	0.4	0.1	0.2	0.7	0.2	0.9	0.0	7.1
New Madrid	Fall	Alternative 1	0.7	0.2	0.3	1.0	0.3	1.2	0.0	15.9
New Madrid	Fall	Alternative 2	0.7	0.2	0.3	1.0	0.3	1.4	0.0	15.9
New Madrid	Fall	Alternative 4	19.2	10.0	0.0	38.7	3.3	50.6	0.0	471.7
New Madrid	Spring	Existing	685.5	78.4	531.8	839.2	478.6	870.6	0.0	2082.7
New Madrid	Spring	Authorized	11.5	4.9	1.9	21.1	4.0	28.4	0.0	286.4
New Madrid	Spring	Alternative 1	197.9	23.6	151.6	244.1	135.1	252.6	0.0	601.9
New Madrid	Spring	Alternative 2	103.4	11.2	81.5	125.3	78.0	131.0	0.0	428.3
New Madrid	Spring	Alternative 4	388.5	43.4	303.4	473.6	267.2	518.5	0.0	928.0

Table 6. Daily area (ha) of 'optimally equivalent' shorebird habitat during spring (15 March - 15 June) and fall (1 July - 30 October) migration periods within the St. Johns and New Madrid Basins in southeastern Missouri. Equivalency was based on reduced suitability due to presumed sub-optimal foraging conditions: 1) on habitats flooded at depth >6 cm; 2) with increased duration of mudflat exposure; and 3) associated with increased vegetation height and density related to crop planting, growth, and harvest dates; as well as the presumed abundance of shorebirds within migration periods. Based on 200 bootstrap samples, each of 50 years, randomly selected (with replacement) from daily intra-basin water elevations, 1943 – 2009, assuming current flood conditions (existing), presumed intra-basin water elevations under conditions authorized upon completion of levees and operation of pumps associated with the St. John-New Madrid Flood Control Project (authorized), and 3 alternative water management scenarios wherein intra-basin water elevations exceed authorized elevations.

			50 year projections						Annual variation	
Basin	Migration	Conditions	Mean	SD	95% lcl	95% ucl	Min	Max	Low	High
St. John's	Fall	Existing	4.2	1.1	2.0	6.4	1.9	7.5	0.0	61.1
St. John's	Fall	Authorized	2.6	0.7	1.2	4.0	0.8	5.4	0.0	33.1
St. John's	Spring	Existing	147.8	20.0	108.6	187.0	100.9	202.9	0.5	741.6
St. John's	Spring	Authorized	102.0	15.8	71.0	133.0	66.9	151.4	0.2	442.9
New Madrid	Fall	Existing	7.4	4.2	0.0	15.6	0.3	21.7	0.0	213.5
New Madrid	Fall	Authorized	0.2	0.0	0.1	0.2	0.1	0.3	0.0	2.7
New Madrid	Fall	Alternative 1	0.2	0.1	0.1	0.4	0.1	0.5	0.0	6.4
New Madrid	Fall	Alternative 2	0.2	0.1	0.1	0.4	0.1	0.5	0.0	6.4
New Madrid	Fall	Alternative 4	7.1	4.1	0.0	15.2	0.9	19.6	0.0	203.8
New Madrid	Spring	Existing	341.1	40.3	262.0	420.1	236.1	436.6	0.0	1098.7
New Madrid	Spring	Authorized	5.0	1.9	1.4	8.7	1.9	10.9	0.0	99.0
New Madrid	Spring	Alternative 1	100.3	12.2	76.3	124.3	67.5	128.7	0.0	339.2
New Madrid	Spring	Alternative 2	48.8	5.3	38.4	59.3	36.8	64.3	0.0	164.5
New Madrid	Spring	Alternative 4	218.0	25.5	167.9	268.0	147.2	292.4	0.0	560.4

Appendix A1 [Shorebird_Habitat_SJ_Existing_Appendix_A1_20110810.xlsx]. Daily intra-basin water elevations (feet NGVD) for St. Johns Basin derived from river elevations at the New Madrid gage (MS115; navigation mile 889.0) on the Mississippi River, regional precipitation, topography, and land cover under current flood conditions (existing) and projected areas of potential shorebird foraging habitat associated with these intra-basin water elevations.

Appendix A2 [Shorebird_Habitat_SJ_Authorized_Appendix_A2_20110810.xlsx]. Daily intra-basin water elevations (feet NGVD) for St. Johns Basin derived from river elevations at the New Madrid gage (MS115; navigation mile 889.0) on the Mississippi River, regional precipitation, topography, and land cover predicted under authorized flood reduction conditions presumed upon completion of the St. Johns-New Madrid Project (Authorized) and projected areas of potential shorebird foraging habitat associated with these intra-basin water elevations.

Variables within Appendices A1, A2, B1, B2, B3, B4, and B5.

Date = day/month/year; 1/Jan/1943.

River_stage = intra-basin water elevation in feet (NGVD).

Total_open_flood = total area of open land (potential shorebird foraging habitat) inundated, regardless of depth.

All_suitable = total area of suitable shorebird foraging habitat (i.e., total area of open land inundated at depth ≤15.25 cm and total area of open land exposed from inundation within the previous 3 days).

Quality_adjusted = Total ‘equivalent’ area of shorebird foraging habitat, adjusted for habitat quality by lowing quality of lands inundated >6.1 cm and mudflats.

Time_adjusted = Total ‘equivalent’ area of shorebird foraging habitat, adjusted for habitat quality and reduced suitability during migration when fewer shorebirds are presumed to be present.

Crop_type_adjusted = Total ‘optimally equivalent’ area of shorebird foraging habitat, adjusted for habitat quality, with reduced suitability during migration when fewer shorebirds are presumed to be present, and with decreased suitability on lands with more mature crops.

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Appendix B1 [Shorebird_Habitat_NM_Existing_Appendix_B1_20110810.xlsx]. Daily intra-basin water elevations (feet NGVD) for New Madrid Basin derived from river elevations at the New Madrid gage (MS115; navigation mile 889.0) on the Mississippi River, regional precipitation, topography, and land cover under current flood conditions (existing) and projected areas of potential shorebird foraging habitat associated with these intra-basin water elevations.

Appendix B2 [Shorebird_Habitat_NM_Authorized_Appendix_B2_20110810.xlsx]. Daily intra-basin water elevations (feet NGVD) for New Madrid Basin derived from river elevations at the New Madrid gage (MS115; navigation mile 889.0) on the Mississippi River, regional precipitation, topography, and land cover predicted under authorized flood reduction conditions presumed upon completion of the St. Johns-New Madrid Project (Authorized) and projected areas of potential shorebird foraging habitat associated with these intra-basin water elevations.

Appendix B3 [Shorebird_Habitat_NM_Alternative1_Appendix_B3_20110810.xlsx]. Daily intra-basin water elevations (feet NGVD) for New Madrid Basin derived from river elevations at the New Madrid gage (MS115; navigation mile 889.0) on the Mississippi River, regional precipitation, topography, and land cover predicted upon completion of the St. Johns-New Madrid Project but with water elevations allowed to exceed authorized elevations (Alternative 1; Table 3) and projected areas of potential shorebird foraging habitat associated with these intra-basin water elevations.

Appendix B4 [Shorebird_Habitat_NM_Alternative2_Appendix_B4_20110810.xlsx]. Daily intra-basin water elevations (feet NGVD) for New Madrid Basin derived from river elevations at the New Madrid gage (MS115; navigation mile 889.0) on the Mississippi River, regional precipitation, topography, and land cover predicted upon completion of the St. Johns-New Madrid Project but with water elevations allowed to exceed authorized elevations (Alternative 2; Table 3) and projected areas of potential shorebird foraging habitat associated with these intra-basin water elevations.

Appendix B5 [Shorebird_Habitat_NM_Alternative4_Appendix_B5_20120613.xlsx]. Daily intra-basin water elevations (feet NGVD) for New Madrid Basin derived from river elevations at

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the New Madrid gage (MS115; navigation mile 889.0) on the Mississippi River, regional precipitation, topography, and land cover predicted upon completion of the St. Johns-New Madrid Project but with water elevations allowed to exceed authorized elevations (Alternative 4; Table 3) and projected areas of potential shorebird foraging habitat associated with these intra-basin water elevations.

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Appendix C: Descriptors of contour shapefiles (.shp) of digital vertical elevation (NGVD) contours at 1-foot (0.305 m) elevation intervals obtained from U.S. Army Corps of Engineers (K. R. Pigott, Memphis District, U.S. Army Corps of Engineers). Data for the New Madrid Basin (2 files) were derived from light detection and ranging (LiDAR) data. Data for the St. John's Basin were derived from geodetic and hydrologic data.

Geographic Coordinate System:	GCS_North_American_1983
Datum:	D_North_American_1983
Prime Meridian:	Greenwich
Angular Unit:	Degree
Projected Coordinate System:	NAD_1983_UTM_Zone_16N
Projection:	Transverse_Mercator
False_Easting:	1640416.66666667
False_Northing:	0.00000000
Central_Meridian:	-87.00000000
Scale_Factor:	0.99960000
Latitude_Of_Origin:	0.00000000
Linear Unit:	Foot_US

File Name:	SJ_Contours.shp (St. John's Basin)
Geometry Type:	Line
Contour Values range:	260 – 601 (1-foot interval elevation contour lines)

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File Name:	SJNM_Elevation_1.shp (Northern New Madrid Basin)
Geometry Type:	Polygon
GridCode Values	217 – 362 (1-foot interval elevation lines)

File Name:	SJNM_Elevation_1.shp (Southern New Madrid Basin)
Geometry Type:	Polygon
GridCode Values	221 – 326 (1-foot interval elevation lines)

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Appendix H
Part 2

Shorebird Model Validation

U.S. Army Corps of Engineers
Memphis District

Validation of Shorebird Habitat Models:
St. Johns-New Madrid Basins, Missouri.

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Abstract: *In response to proposed completion of levees and installation of pumps as part of the St. Johns-New Madrid Project, a model quantifying potential shorebird habitat within the St. Johns-New Madrid Basins in Missouri was developed. Model outputs were contingent upon several underlying assumptions regarding water distribution, shorebird distribution and behavior, and shorebird response to floodwater conditions. Verification of the validity of the assumptions specified during model development is needed to ensure the model accurately predicts the availability and suitability of potential foraging habitat for shorebirds. I propose laboratory and field validation of 6 underlying assumptions which influence model predictions of the availability of potential foraging habitat for shorebirds.*

Background:

Flood control measures implemented along the Mississippi River and its tributaries after the record flooding in 1937 include an extensive network of earthen levees. In southeastern Missouri, a gap within the levee system surrounding the New Madrid Basin permits Mississippi River floodwater entry during periods of increased water (i.e., high river stage) whereas levees around the adjacent St. Johns Bayou drainage isolate this basin from Mississippi River floodwater when gates at the mouth of St. Johns Bayou are closed. However, gate closure denies St. Johns Bayou an outlet, such that during prolonged closure flood water accumulates behind the protective levee. Within both of these basins, most land is in agriculture with an extensive system of canals to drain floodwaters concurrent with Mississippi River stages.

The U.S. Army Corps of Engineers has proposed completion of the earthen levee surrounding the New Madrid Basin, and installation of water pumping stations within both the St. Johns and New Madrid Basins that are capable of transporting accumulating headwaters over the protective levee for deposition in the Mississippi River batture (a.k.a., St. Johns-New Madrid Project). Completion of the St. Johns-New Madrid Project is expected to eliminate backwater

flooding from the Mississippi River and afford reduction of headwater flooding within both of these basins.

Reduced flooding with these basins, on areas of sparse vegetation such as those associated with harvested agricultural lands, decreases the area of potential foraging habitat available to shorebirds (Charadriiformes). Because the necessary congruence of water depth and vegetative structure at the appropriate times is the most important issue for shorebird conservation in this region (Brown et al. 2001), reduced flooding likely negatively affects migrating shorebirds. In response to concerns regarding potential reduction in shorebird foraging habitat resulting from completion of the proposed St. Johns-New Madrid Project, a habitat model was developed to assess the historical area of potential shorebird habitat and predict the future area of potential shorebird habitat available under presumed post-project flood conditions upon completion of the St. Johns-New Madrid Project.

A model quantifying potential shorebird habitat within the St. Johns-New Madrid Basins was developed based on several assumptions regarding water distribution and shorebird response to floodwater conditions (Twedt 2011). These assumptions included: 1) a presumed linkage between river stage (i.e., water elevation) and the extent of flooding, 2) presumed dates for planting and harvest of crops, 3) presumed proportions of shorebirds of different body size within these basins, 4) presumed temporal distribution of relative abundance of shorebirds within these basins, 5) presumed shallow-water foraging depths used by shorebirds (Davis 1996, Davis and Smith 1996), and 6) presumed availability and suitability of mudflat habitat within these basins. Verification of the validity of the assumptions specified during model development is needed to ensure the model of shorebird habitat accurately predicts the availability of potential shorebird habitat.

Study Objectives:

Habitat validation -

1. Validate the presumed geographic extent of floodwater within the SJNM Basins predicted by the shorebird habitat model relative to river elevation derived from hydrological models.
2. Verify dates of crop planting and harvest and determine growth rates for predominant crops within the SJNM Basins to validate temporal changes in habitat suitability value assigned to each of these crops.

Shorebird validation -

3. Estimate abundances of shorebirds of different body sizes within the SJNM Basins during spring and fall migrations to validate presumed body size of shorebirds within these basins.
4. Evaluate the temporal change in relative abundances of shorebirds within the SJNM Basins to validate presumed change in shorebird abundance during spring and fall migration periods.

Habitat-shorebird interaction validation -

5. Quantify foraging depths used by shorebirds within the SJNM Basins during spring and fall migration to validate presumed depth-dependent suitability value of flooded habitat.
6. Quantify post-exposure duration of mud-flat conditions and relative daily change in shorebird use of mud-flats after floodwaters recede in order to validate the presumed duration and daily change in habitat suitability of mud-flats.

Methods:

Habitat validation – floodwater extent.

The shorebird habitat model developed for the SJNM Basins relies upon daily water elevations (i.e., river stages) derived from hydrological extrapolations of water elevations reported by river gauging stations after adjustment to reflect previous river conditions (e.g., the duration of flood events) as well as concurrent regional meteorological information (e.g., rainfall, temperature, etc.). The geospatial extent of floodwater presumed to be inundated in concordance with each daily water elevation is the foundation upon which the predictive model estimates the area of shorebird foraging habitat.

Although resultant model outputs of daily area of shorebird foraging habitat within the SJNM basins rely on no explicit assumption regarding the geospatial location of shorebird habitat within these basins, the relative accuracy of model output likely reflects the congruency between the presumed topographic elevations used to predict the extent of floodwater and the actual physical distribution of floodwater within these basins. To identify the actual physical extent of floodwaters, I will use standard band (wavelength image) combinations of Thematic Mapper (TM) imagery (e.g., normalized difference moisture index, tasseled cap wetness index, or other combinations such as [TM4 + TM7; the 0.76 to 0.90 µm, reflective infrared and the 2.08 to 2.35 µm, mid-infrared bands]) to differentiate between water (or saturated soil) and dry land. This classification will be used to delineate the water-land interface present on the date of

imagery. Verification of the SJNM Basins shorebird habitat model's predictive ability for each date of satellite imagery will be assessed based on comparison of the area of predicted shorebird habitat with the area associated with the water-land interface identified on classified Landsat TM imagery.

Verification – Satellite imagery of the study area with known date of origin, will be obtained from 'in-house' imagery within the archives of U.S. Geological Survey, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, and Ducks Unlimited. These images will be classified into binary depictions of water versus land (dry) with a linear contour established at all water-land interfaces. Interior (water-side) buffer distances will be generated from these linear contours that represent optimal (shallow) flooding and sub-optimal (moderate) flooding. Similarly, an exterior (land-side) buffer depicting mudflat habitat will be established, if appropriate for the date of the imagery as indicated by a falling river stage, at a distance representative of the maximum 2-day previous floodwater extent. The areas of presumed shorebird habitat (sparsely vegetated landcover classes) within these buffers will be extracted and quantified. Correlation between the area of predicted foraging habitat from shorebird habitat model output and the area adjacent to the water-land interface that is identified on satellite imagery will provide a measure of the reliability of habitat predictions associated with river stage data. Model verification based on ≥10 satellite images from different dates (if available within accessible archives) will be used to provide verification of predictions associated with different water elevations (i.e. river stages).

Validation –For each day a TM image of the study area is available, the spatial depictions of predicted shorebird habitat associated with the appropriate, day-specific, river stage will be generated. This spatial representation will be compared with the area of presumed shorebird habitat associated with the water-land interface on TM images. Areas of estimated shorebird habitat that coincide or are in reasonable proximity (distance yet to be determined) between these 2 depictions of shorebird habitat will be assumed to be validated. The proportion of estimated shorebird habitat that is validated versus the proportion that is not validated provides an estimate of overall confidence in the validation. Model validation will use ≥10 satellite images from different dates (if available within accessible archives) for validation.

Habitat validation – crop condition.

Within the shorebird foraging habitat model (Twedt 2011), the suitability of flooded cropland is dependent upon the physical condition of each crop which is assumed to be temporally dynamic (Fig. 1). Maximum suitability (SI = 1.0) is attained when cropland is devoid of actively growing crops (i.e., post-harvest until replanted). Minimum suitability for each crop was set at half the maximum suitability (SI = 0.5) from the average date the crop was assumed to attain maximum physical stature until average date that harvest begins. An intermediate suitability (SI = 0.75) was assumed from presumed first date of harvest until last date of harvest, as well as from presumed date of initial planting until the date maximum physical stature is attained. Within the shorebird habitat model, presumed dates used for different crops (Fig. 1) were based on reported state-wide planting and harvest dates (U.S. Department of Agriculture 2010).

Verification – Consultations with local agricultural specialists (state extension service, FSA, NRCS, etc.) will be used to verify and refine for each of 7 crop-types (Fig. 1; rice, corn, cotton, soybean, winter wheat, hay [grassland], and other crops) within the SJNM Basins: 1) the average dates of first and last sowing, 2) the average dates of first and last harvest, and 3) the number of days from sowing until maximum physical stature is attained.

Validation – Within the presumed spring and fall migration periods identified by the shorebird habitat model, planting, growth, and harvest status of crops will be validated within those portions of the SJNM Basins likely impacted by flooding. Planting and harvest dates will be based on visual evidence of these activities in fields that is visible from randomly selected roadside transects. Growth status of planted crops will be evaluated based on photographic and physical measurements obtained from a sample set of fields for each crop-type. Fields sampled for growth status of crops will be randomly chosen from fields along transects: fields actually sampled will be determined by crop-type present.

Shorebird validation – timing of migration.

The shorebird model assumes the timing (i.e., days of year) of shorebird passage through the SJNM Basins is similar to the timing of continental shorebird migration based on latitude (Skagen et al. 1999). As a consequence, the shorebird habitat model allocates greater value to foraging habitat that is available during the periods when more shorebirds are pressumed to be present within the SJNM Basins. However, many factors contribute to the timing and duration of stay at migratory stopover sites (Farmer and Wiens 1998, Skagen 1997, 2006, Skagen et al

2005). Even so, only habitat available during a 93 day (15 March – 15 June) spring migration period and during a 122 day (1 July – 30 October) fall migration period is assumed to be suitable foraging habitat with the SJNM Basins. Shorebirds are assumed to migrate through the SJNM Basins predominately during these migration periods within which their abundance follows a statistically normal distribution, such that populations are assumed to be greatest 24 April – 23 May in spring and 5 August – 16 September during fall, with abundance decreasing temporally both before and after. Quantifying temporal change in abundance of shorebirds during migration within the SJNM Basins is needed to validate changes in temporal suitability related to relative abundance of shorebirds.

Shorebird validation – species composition.

Based on regional observations from Missouri, Kentucky, Tennessee, and Arkansas, the shorebird model assumes most shorebirds using the SJNM Basins have small to medium body size (Table 1, http://www.lmvjv.org/shorebird/default.asp, Loesch et al. 2000, Skagen and Knopf 1993). Because small and medium body size shorebirds often forage in water depths <6 cm (Helmers 1992, Plauny 2000), maximum habitat suitability (SI = 1.0) was assigned to lands submerged by ≤6 cm floodwater. Quantification of the relative abundance of shorebirds with small, medium, and large body size within the SJNM Basins during migration is needed to validate restricting maximum habitat suitability to <6 cm.

Validation – Because bird surveyors are unlikely to encounter shorebirds unless suitable habitat is present, the most pragmatic approach for validation of both the timing of migration and species composition of migrant shorebirds is to restrict observations to locations with suitable habitat. Furthermore, restricting observations to sites where flood extent and depths can be managed (e.g., moist-soil management units being managed for shorebird habitat), and ideally can be maintained throughout the migration periods, decreases the likelihood that changes in shorebird abundance or composition are in response to change in habitat conditions. I will consult with Federal, State, and private land managers within southeastern Missouri to identify existing conservation lands currently being managed to provide shorebird habitat, or lands that have the capacity to be managed to provide shorebird habitat. All identified conservation lands being managed to provide shorebird habitat within SJNM Basins will be included for selection of sites subject to repeated periodic surveys to assess temporal distribution and species composition of shorebirds. At least 2 different locations, but likely fewer than 6 locations, will be surveyed

for shorebirds during spring and during fall. If insufficient area and number of suitable land holdings are present within the SJNM Basins, managed lands within adjacent basins may be included in these shorebird surveys. If lands managed to provide shorebird habitat are unavailable either within or adjacent to the SJNM Basins, naturally flooded sites will be used for observations. The availability of naturally flooded locations however is dependent upon Mississippi River stages being sufficiently elevated such that inundation occurs within the SJNM Basins. Therefore, suitable foraging habitat for shorebirds may not be available at all times within the spring and fall migration periods.

Habitat interaction with shorebird validation -

Foraging depths – Presumed differential suitability of different water depths used for foraging by shorebirds is a primary determinant of habitat suitability within the shorebird habitat model. Maximum habitat suitability (SI = 1.0) was designated at depths ≤6 cm. Suitability of habitats flooded at greater depths, up to 15.25 cm, was assumed inversely related to water depth: flood depth 6.1 − 9.15 cm (SI = 0.8), 9.15 − 12.2 cm (SI = 0.7), and 12.2 − 15.25 cm (SI = 0.6). However, the proper or relevant assignment of these categorically based suitability scores is somewhat subjective. That is, at what increased depth should the foraging suitability score be lowered and by how much? Thus, quantifying foraging duration of shorebirds at different foraging depths on sites within the SJNM Basins is needed to validate or re-define these categorical model suitability indices.

Validation –Using the same conservation lands being managed to provide shorebird habitat within SJNM Basins (or adjacent basins), I will conduct repeated, periodic surveys of shorebirds throughout the spring and fall migration periods. For each observational survey, the water depth associated with foraging shorebirds will be recorded. Behavioral observations on foraging shorebirds will be undertaken to assess differences in behavior relative to depth of flooding and to quantify the duration of association between shorebirds and flooding depth.

Mudflat exposure – Similar to foraging depths, the shorebird habitat model assumes that the suitability of mudflat habitat is inversely related to the duration (i.e., number of days) of exposure after previously being flooded: A suitability of 0.6 was assumed for mudflats exposed 1 day (SI = 0.6), and suitability was temporally reduced concurrent with exposure: exposed 2 days

(SI = 0.5) and exposed 3 days (SI = 0.4). Mudflats exposed >3 days were assumed to be unsuitable until re-inundated.

Validation – As with foraging depths, the foraging duration of shorebirds using mudflats exposed for different duration (≥1day exposure) will be quantified via observational-behavioral surveys on sites that have receding water resulting in mudflats. Surveyed sites may be the same conservation lands being managed as shorebird habitat that are surveyed to quantify duration of foraging by shorebirds at different foraging depths. However, only sites with receding (falling elevation) water will have mudflats suitable for evaluation. Thus, managed sites may need to be supplemented with additional locations where floodwaters are receding. Concurrent with observations of foraging duration, the potential for shorebirds to probe mudflats that have been exposed for different duration will be quantified using a soil penetrometer (soil probe).

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Timeline for study (July 2012 – Dec 2014)	
July – Oct 2012	Identification and recruitment of conservation lands under management for shorebirds. Consultation with agricultural experts and preliminary crop validation.
Oct 2012 – Feb 2013	Flooded habitat verification and validation via TM image processing.
Feb 2013	Review and revise methodologies for model validation.
Mar – June 2013	Field evaluations of: 1) timing and species composition of shorebirds, 2) shorebird foraging duration association with floodwater depth, and 3) mudflat condition relative to length of exposure post-flooding during the spring migration period within the St. Johns and New Madrid Basins. Field assessment of crop planting growth and harvest.
July – Oct 2013	Field evaluations of: 1) timing and species composition of shorebirds, 2) shorebird foraging duration association with floodwater depth, and 3) mudflat condition relative to length of exposure post-flooding during the fall migration period within the St. Johns and New Madrid Basins. Field assessment of crop planting growth and harvest.
Nov – Dec 2013	Analysis and interim report.
Mar – June 2014	Field evaluations of: 1) timing and species composition of shorebirds, 2) shorebird foraging duration association with floodwater depth, and 3) mudflat condition relative to length of exposure post-flooding during the spring migration period within the St. Johns and New Madrid Basins. Field assessment of crop planting growth and harvest.
July – Oct 2014	Field evaluations of: 1) timing and species composition of shorebirds, 2) shorebird foraging duration association with floodwater depth, and 3) mudflat condition relative to length of exposure post-flooding during the fall migration period within the St. Johns and New Madrid Basins. Field assessment of crop planting growth and harvest.
Nov – Dec 2014	Analysis and final report.

Estimated Cost:

USGS PWRC BUDGET	
Personnel	
Salary (Principal Investigator)	$24,000
Field Technician 2013 (150 days @ $200/day)	$30,000
Field Technician 2014 (150 days @ $200/day)	$30,000
Other Expenses	
Field vehicles (Fuel & maintenance)	$ 5,000
Travel (lodging and per diem)	$ 5,000
Equipment and supplies	$ 1,000
Sub-total	$95,000
USGS Burdens	
Overhead	$ 45,403
Total	$140,403

Table 1. Shorebird species, body size, presumed foraging depth, and numbers of southward (fall) migrating shorebirds in the 4-States (MO, KY, TN, AR) adjacent to the St. Johns- New Madrid study area and in the entire Mississippi Alluvial Valley (MAV), as reported on surveys from the Lower Mississippi Valley Joint Venture Shorebird Monitoring Program[1], as well as an hypothesized abundance, based on International Shorebird Surveys (Manomet Bird Observatory 1993), used to establish management recommendations within the Lower Mississippi Valley/Western Gulf Coastal Plain Shorebird Conservation Plan[2] (Elliott and McKnight 2000).

Family	Common Name	Scientific Name	Body Size[3]	Depth (cm)	4-States[1] Number	4-States[1] Percent	MAV[1] Number	Plan[2] Number
Charadriidae	Piping Plover	*Charadrius melodus*	S	<3	25	0%	25	121
Charadriidae	Semipalmated Plover	*Charadrius semipalmatus*	S	<3	1672	1%	3028	4,765
Charadriidae	Killdeer	*Charadrius vociferus*	M	<3	15292	10%	60248	91,838
Charadriidae	American Golden-Plover	*Pluvialis dominica*	M	<9	80	0%	301	3000
Charadriidae	Black-bellied Plover	*Pluvialis squatarola*	M	<9	518	0%	403	690
Recurvirostridae	Black-necked Stilt	*Himantopus himantopus*	L	<20	4082	3%	21200	778
Recurvirostridae	American Avocet	*Recurvirostra americana*	L	<12	793	0%	6122	232
Scolopacidae	Spotted Sandpiper	*Actitis macularia*	M	<4	535	0%	1333	4,112
Scolopacidae	Ruddy Turnstone	*Arenaria interpres*	M	<6	10	0%	24	405
Scolopacidae	Upland Sandpiper	*Bartramia longicauda*	M	<6	19	0%	65	237
Scolopacidae	Sanderling	*Calidris alba*	M	<3	257	0%	267	5,052
Scolopacidae	Dunlin	*Calidris alpina*	M	<6	152	0%	1529	7,866
Scolopacidae	Baird's Sandpiper	*Calidris bairdii*	S	<6	925	1%	678	0
Scolopacidae	Red Knot	*Calidris canutus*	M	<6	2	0%	2	162
Scolopacidae	White-rumped Sandpiper	*Calidris fuscicollis*	S	<6	540	0%	1639	500
Scolopacidae	Stilt Sandpiper	*Calidris himantopus*	M	<9	8785	5%	14803	3,310
Scolopacidae	Western Sandpiper	*Calidris mauri*	S	<6	2521	2%	3232	3,382
Scolopacidae	Pectoral Sandpiper	*Calidris melanotos*	M	<6	42549	27%	77870	121,077
Scolopacidae	Least Sandpiper	*Calidris minutilla*	S	<6	46626	29%	132172	151,119
Scolopacidae	Semipalmated Sandpiper	*Calidris pusilla*	S	<6	11817	7%	26427	37,713
Scolopacidae	Calidris spp. (peeps)	*Calidris spp.*	S	<6	4674	3%	12897	0
Scolopacidae	Willet	*Catoptrophorus semipalmatus*	L	<12	19	0%	55	92
Scolopacidae	Common Snipe	*Gallinago gallinago*	M	<6	92	0%	6039	2,374
Scolopacidae	Short-billed Dowitcher	*Limnodromus griseus*	M	<12	1097	1%	1427	1,121
Scolopacidae	Long-billed Dowitcher	*Limnodromus scolopaceus*	M	<12	4622	3%	13939	1,121

Scolopacidae	Dowitcher spp.	*Limnodromus spp.*	M	<12	1377	1%	9810	0
Scolopacidae	Marbled Godwit	*Limosa fedoa*	L	<12	18	0%	47	39
Scolopacidae	Hudsonian Godwit	*Limosa haemastica*	L	<12	0	0%	0	0
Scolopacidae	Long-billed Curlew	*Numenius americanus*	L	<9	0	0%	0	0
Scolopacidae	Whimbrel	*Numenius phaeopus*	L	<12	0	0%	2	0
Scolopacidae	Red-necked Phalarope	*Phalaropus lobatus*	M	s-d	18	0%	32	0
Scolopacidae	Wilson's Phalarope	*Phalaropus tricolor*	M	s-d	598	0%	748	171
Scolopacidae	Greater Yellowlegs	*Tringa melanoleuca*	M	<12	787	0%	5344	3,235
Scolopacidae	Solitary Sandpiper	*Tringa solitaria*	M	<6	267	0%	1166	1000
Scolopacidae	Lesser Yellowlegs	*Tringa. flavipes*	M	<12	6533	4%	26753	21,120
Scolopacidae	Buff-breasted Sandpiper	*Tryngites subruficollis*	M	<3	371	0%	504	964
	Large Shorebird		L	<12	54	0%	231	0
	Medium Shorebird		M	<9	148	0%	16205	0
	Small Shorebird		S	<6	1888	1%	9316	0

[1] Data from Lower Mississippi Valley Joint Venture Shorebird Monitoring Program <http://www.lmvjv.org/shorebird/default.asp>.

[2] Data from Loesch et al. 2000.

[3] Body size is denoted by "S" (small, total body lengths of <190mm), "M" (medium, body length <350mm) and "L" (large, body lengths exceed 350mm) after Skagen and Knopf (1993).

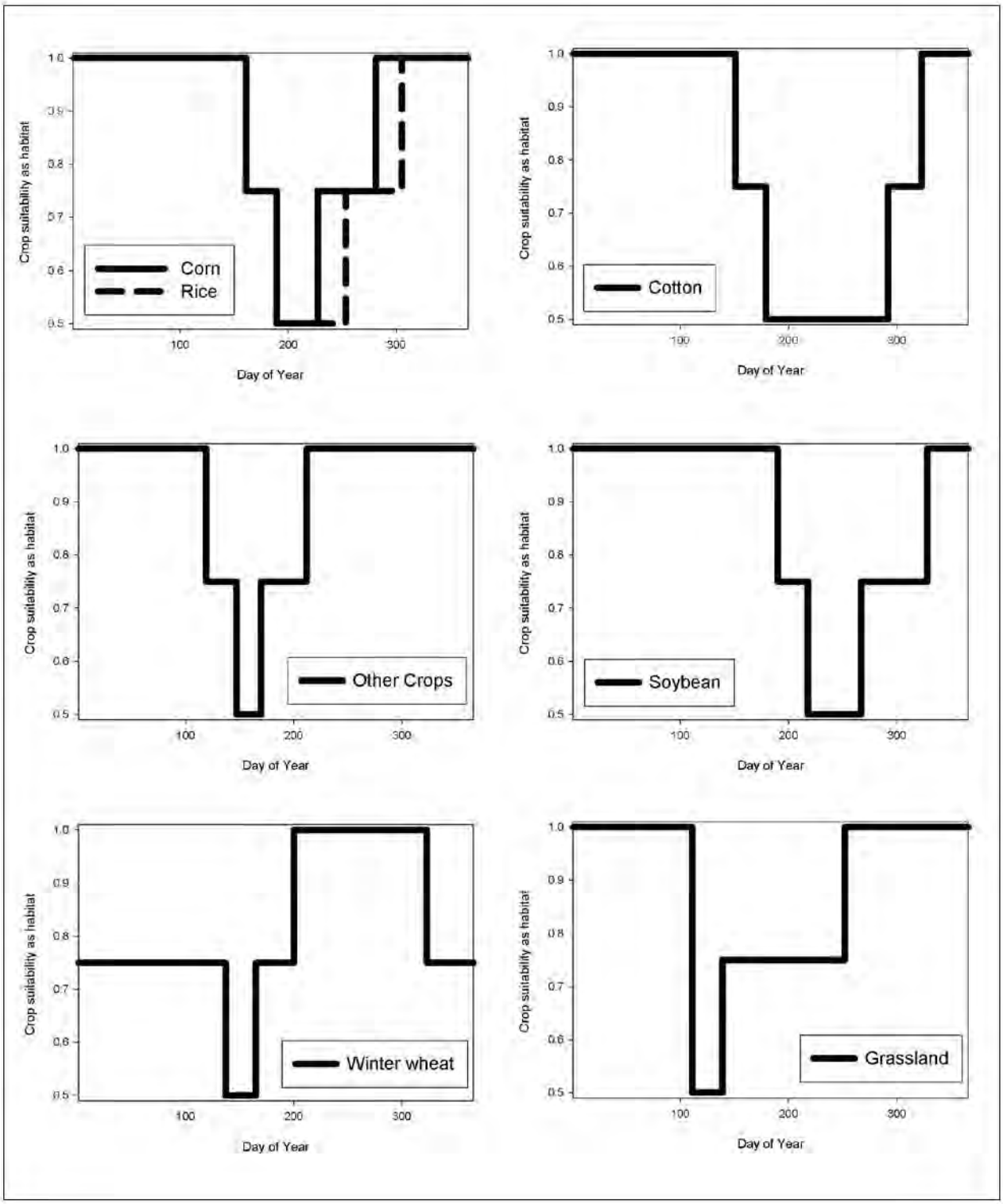

Figure 1. Temporal dynamics of crop suitability within the St. Johns and New Madrid Basins in southeastern Missouri that reflect presumed dates of planting, duration until maturity, and dates of harvest.

Study Plan Signature Page

BASIS Number: 2302-9S2 Task XX

Title: Validation of Shorebird Habitat Models: St Johns-New Madrid Basins, Missouri.

Submitted by: _____28 February 2012__

Principal Investigator Date

Peer Review Clearance: _____

Research Manager assigned Date

Revision Clearance: _____

Research Manager Date

PWRC Approval: _____

Center Director Date

Appendix I

Water Quality

U.S. Army Corps of Engineers
Memphis District

ERDC/EL SR-11-XX

Environmental Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

Water Quality Analysis – St. Johns Bayou and New Madrid Floodway: 2012 Revision

David M. Soballe and Steven L. Ashby

May 2012

ERDC/EL SR-12-xx
May 2012

Water Quality Analysis – St. Johns Bayou and New Madrid Floodway: 2012 Revision

Report Subtitle <if applicable, otherwise blank>

David M. Soballe and Steven L. Ashby

Environmental Laboratory
U.S. Army Engineer Research and Development Center
Waterways Experiment Station

3909 Halls Ferry Rd. Vicksburg MS 39180

Special Report

Prepared for U.S. Army Engineer District, Memphis

Executive Summary

An analysis was conducted to update and refocus the supplemental assessment of water quality reported by Ashby et al. (2000). Overall, these results confirm those earlier findings. The purpose of this analysis and its predecessor was to describe potential, water quality impacts that may result from the proposed flood control project in the St. Johns Bayou and New Madrid Floodway. Existing water quality data from Federal and state resource agencies and literature-based information on land use effects on water quality were compiled for evaluation. Results of this evaluation were used to describe existing water quality conditions and, in conjunction with land cover and hydrology information, to estimate the transport of selected materials under the differing hydrologic regimes that would result from various project alternatives. This updated analysis agrees with the conclusions of Ashby et al. (2000).

In Ashby et al. (2000), spreadsheet calculations were used to assess relative impacts with and without the project. The rationale for inputs and assumptions in the spreadsheets was discussed with representatives of Federal and state agencies prior to application. In this revision, those earlier assumptions and inputs are carried forward.

Water quality in the project area reflects conditions typical for landscapes dominated by agriculture. In general, nutrient concentrations (with the exception of phosphorus) were not excessively high except during periods of elevated flow, and basin concentrations did not differ substantially from observations for the Mississippi River. As expected, sediment concentrations were generally lower than concentrations in the Mississippi River and increased with runoff. Point sources were the most notable sources of extremes (high nutrients or low dissolved oxygen concentrations).

Material transport differs among constituents and project alternatives, but overall the basin is expected to retain (or remove) material from headwaters and floodwaters during periods of inundation. The authorized project alternatives tend to increase this retention. However, in most years, and during most of each year there is no significant inundation and the overall, long-term functioning of the project area will be to export nutrients and sediment to the Mississippi River.

Based on mass-balance considerations, the impacts of the authorized project on the water quality in the Mississippi River are not expected to be discernible. Further, the project is expected to result in a net reduction in the delivery of nutrients and sediment to the Mississippi River from the project area.

The situation with regard to project impacts at Big Oak Tree State Park has changed dramatically since the previous study. Ashby et al. (2000) concluded that potential impacts to Big Oak Tree State Park from the authorized project were most likely to result from decreased supply of sediments and a decline in sustainability of the site because groundwater was to be used to provide seasonal flooding. However, the plan for mitigation (Section 1.4.2 of Draft EIS) has been altered and now calls for hydrologic reconnection of the Park to the Mississippi River main stem during high water. The park will thus re-experience the natural flood and sedimentation regime; concerns related to the use of groundwater are eliminated, and the park will now serve as a trap for sediments and nutrients that enter the park with Mississippi River floodwaters.

The authorized project, with or without the avoid-and-minimize alternatives, is expected to reduce, or not significantly change, the export of materials from the project area into the Mississippi River. This is a generally positive ecological effect. Further, the limited water quality data that exists for water bodies within the project area give no indication that the project will degrade water quality in these water bodies. Consequently there is little to indicate that additional, water quality, mitigation measures are needed. Mitigation associated with the project that is planned for habitat purposes (e.g., Big Oak Tree State Park) are anticipated to have water quality benefits, but they will not be detectable.

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Preface

This study was conducted for the U. S. Army Engineer District by the Environmental Laboratory, U.S. Army Engineer Research and Development Center. At the time of publication, Dr. Mark Farr was Chief, CEERD-EP-P; Warren Lorentz was Chief, CEERD-EPD; and Patrick Deliman was the Technical Director. The Director of ERDC-EL was Dr. Beth Fleming.

COL Kevin J. Wilson was the Commander and Executive Director of ERDC, and Dr. Jeffery P. Holland was the Director.

Unit Conversion Factors

Multiply	By	To Obtain
Acres	4,046.873	square meters
acre-feet	1,233.5	cubic meters
angstroms	0.1	nanometers
atmosphere (standard)	101.325	kilopascals
Bars	100	kilopascals
British thermal units (International Table)	1,055.056	joules
centipoises	0.001	pascal seconds
centistokes	1.0 E-06	square meters per second
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
cubic yards	0.7645549	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
fathoms	1.8288	meters
Feet	0.3048	meters
foot-pounds force	1.355818	joules
gallons (U.S. liquid)	3.785412 E-03	cubic meters
hectares	1.0 E+04	square meters
horsepower (550 foot-pounds force per second)	745.6999	watts
inches	0.0254	meters
inch-pounds (force)	0.1129848	newton meters
kilotons (nuclear equivalent of TNT)	4.184	terajoules
Knots	0.5144444	meters per second
microinches	0.0254	micrometers
microns	1.0 E-06	meters
miles (nautical)	1,852	meters
miles (U.S. statute)	1,609.347	meters
miles per hour	0.44704	meters per second
Mils	0.0254	millimeters
ounces (mass)	0.02834952	kilograms
ounces (U.S. fluid)	2.957353 E-05	cubic meters

Multiply	By	To Obtain
pints (U.S. liquid)	4.73176 E-04	cubic meters
pints (U.S. liquid)	0.473176	liters
pounds (force)	4.448222	newtons
pounds (force) per foot	14.59390	newtons per meter
pounds (force) per inch	175.1268	newtons per meter
pounds (force) per square foot	47.88026	pascals
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
pounds (mass) per cubic inch	2.757990 E+04	kilograms per cubic meter
pounds (mass) per square foot	4.882428	kilograms per square meter
pounds (mass) per square yard	0.542492	kilograms per square meter
quarts (U.S. liquid)	9.463529 E-04	cubic meters
Slugs	14.59390	kilograms
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
tons (force)	8,896.443	newtons
tons (force) per square foot	95.76052	kilopascals
tons (long) per cubic yard	1,328.939	kilograms per cubic meter
tons (nuclear equivalent of TNT)	4.184 E+09	joules
tons (2,000 pounds, mass)	907.1847	kilograms
tons (2,000 pounds, mass) per square foot	9,764.856	kilograms per square meter
Yards	0.9144	meters

1 Introduction

The St. Johns Bayou and New Madrid Floodway project was authorized for construction by the Water Resources Development Act of 1986 (PL 99-662). The project will close the gap in the Mississippi River levee in New Madrid, Mississippi, and Scott Counties in Missouri. The primary purpose of the project is to provide flood control in the St. Johns Bayou Basin and the New Madrid Floodway. The project is designed to eliminate the physical and economic barriers created by frequent flooding in East Prairie, Missouri, and the surrounding area. The project includes channel enlargements and a 1,000-cfs1 pumping station for the St. Johns Bayou Basin and closure of a 1,500-ft gap in the levee and a 1,500-cfs pumping station in the New Madrid Floodway. Complete details of the project are provided in the Environmental Impact Statement (EIS) by the U.S. Army Corps of Engineers, Memphis District (2011).

Areas of controversy early in the project development process included potential impacts on the hydrology and water quality associated with closure of the 1,500-ft gap in the levee. Water quality concerns included the potential impacts of changed hydrology on material transport into and out of the project area, change in pesticide application associated with potential changes in agricultural land use, and impacts to Big Oak Tree State Park, which under the original project design would no longer receive periodic floodwaters from the Mississippi River. However, the current project design calls for hydrologic reconnection of the State Park to the Mississippi River main stem, and the current version of the project should have strong positive effects on the Park. Concerns about material transport were centered on the potential loss of wetland functions that improve water quality of floodwaters and the relationship of this potential loss to the overall water quality of the Mississippi River and the hypoxic zone in the Gulf of Mexico. This analysis revisits that issue.

The objective of the previous study (Ashby et al. 2000) was to compile sufficient water quality data to evaluate the primary concerns relative to the project alternatives. The issues have changed somewhat as seasonal flooding of Big Oak Tree State Park is now intended to

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use Mississippi River water and follow the natural hydrograph (instead of pumped ground water). The specific objectives from the earlier work that remain relevant include:

- Describe the general water quality in the project area with the most recent available data.
- Qualify the effects of hydrologic changes on water quality for both the area impacted by the proposed project and in relationship to the overall water quality of the Mississippi River.
- Determine the potential effects on water quality associated with potential changes in pesticide use.

The present study revises the work reported by Ashby et al. (2000) and is based on an expanded hydrologic period of record that extends from 1 Oct, 1942 to 12 Nov, 2009 (67 years). Four, differing scenarios that involve the water level regime (existing conditions, authorized project authorized project with added avoid and minimize features, and modified hydrology with elimination of agriculture) were considered for the New Madrid Floodway. Two such scenarios (existing condition and authorized project) were considered for Saint Johns Bayou (avoid and minimize actions are not expected to have substantial, added influence on the water levels). The existing (without project) condition for both basins was represented by the actual, daily, hydrologic data and project alternatives were evaluated using simulated daily water elevations provided by the Memphis District.

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2 Methods

Ashby et al. (2000) assessed the potential for project impacts on water by compilation of existing data, evaluation of applicable water quality constituents, and an assessment of potential impacts based on relative changes in mass associated with representative hydrologic conditions with and without the project. In order to describe potential relative changes in mass export of selected water quality constituents, a literature review was conducted to describe general conditions of nutrient transport for wetlands and agricultural lands. Processing (i.e., retention or transport) of constituents was then estimated based on the expected flux of material. The current study expanded on that previous effort by searching for more current data (little was found), expanding the hydrologic period of record to 67 years, and using a modified approach for the analysis of export (SAS software code replaced the spreadsheet).

2.1 Water Quality Assessments

Data collection (Ashby et al. 2000, Appendix A) included a retrieval of water quality data from EPA's Storage and Retrieval System (STORET), and data requests from the University of Missouri Agricultural Research Extension Service, the U.S. Geological Survey (USGS), MDNR, and the U.S. Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS).

Data retrieved from sources other than STORET were compared to STORET data to ensure that data were not duplicated. Results of data retrievals were compiled into a database (Ashby et al. 2000, Appendix B) for subsequent analyses.

For this revision, the data search was repeated, but newer data were indentified and obtained from only one, additional, surface water monitoring location (St. Johns Ditch at Henderson's Mound, USGS site 07042450).

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2.2 Effects of Project on Material Exports

The water quality analysis reported by Ashby et al. (2000) was revised with updated land cover data (provided by the Memphis District), an expanded hydrologic period of record, and a modified approach that uses the actual (or simulated) daily water elevations and places the export of material from the project area into a more complete context. In this revision, instead of evaluating five, representative hydrologic scenarios, the extent and duration of inundation in each season within the 67- year period of record was evaluated under each project alternative to produce a time-series (yearly interval) of exports. Further, the analysis now fully incorporates export from the land within the project area that remains above the level of inundation in each season. This approach allows the influence of various project alternatives to be viewed within the context of total export from the project area. The approach used previously emphasized the relative differences between alternatives. In both the original and revised analysis, only the period of potential inundation (November through May) is addressed directly as this is the period that the proposed project will influence with regard to water levels.

To make use of detailed (daily) hydrologic data (and simulations), and to improve the overall transparency of the analyses, SAS® program code was used to implement the equations from the spreadsheet used by Ashby et al. (2000). Some advantages to this approach are that; (1) the results are calculated as a time-series that can be more easily visualized, (2) the equations and parameters used in the calculations are centralized into a few tables and a series of sequential steps that can be viewed in text form, and (3) the modification of inputs and assumptions is greatly simplified compared with a spreadsheet approach.

A significant change from the approach used in Ashby et al. (2000) was a calculation of the actual 30-day inundation contour on each day in the period of record. In this process, the highest elevation that had been submerged continuously for at least the previous 30 days was identified on each date. These 30-day contours were then screened to determine the maximum 30-day contour for each flood season (two seasons per year). The calculations of export then assumed that all area below this peak contour during the season would behave as “flooded” land and that all areas above it would function as “dry land” during the

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season. A major advantage to this approach is that it allows us to evaluate the estimated export under the actual, existing condition and compare it to the export expected under any altered (i.e., project) hydrograph. Secondly, this approach computes both the dry land and inundation export/trapping during each season within the inundation period (Nov-May), so that a net, total export for the two inundation periods (seasons) in each year can be calculated separately with differing parameters as appropriate and then summed within each water year to create a time series based on 67 individual years that can then be used for statistical analyses.

In both the previous analysis and the current revision, hydrologic and land cover data were used in conjunction with water quality data to develop export estimates for each basin and each of two "seasons" under differing hydrologic regimes. The estimates were based on water volumes and acres of each land cover type found beneath each one-foot elevation contour (Appendix C). Material transport estimates were then calculated using expected loads and wetland function factors to yield a value, referred to as wetland retention ("wetland function value" in Ashby et al 2000). Wetland retention is thus an estimate of the material that is retained by the land cover (i.e., removed from the floodwater) during inundation. It can be negative or positive depending on whether flooding of an area provokes removal or addition of material.

As in Ashby et al. (2000), the approach was applied separately to the St. Johns Bayou area and the New Madrid Floodway. Two seasons were defined based on proposed changes in the inundation due to flooding. Increased inundation from watershed inputs, associated with proposed changes to winter waterfowl habitat, was used for season 1 (November – January). In season 2 (February - May), decreased inundation is expected as a result of the project removing watershed discharges and preventing Mississippi River backwater flooding.

Calculations in season 2 for both basins assume that backwater flooding retained for waterfowl (season 1) will be partially removed via pumping/gravity flow. Further, it is assumed that Mississippi River water will be allowed to enter into the project level to some extent. The concentration used in the calculations is an expected flood water value based

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on a review of existing water quality data for both water sources (Mississippi River and Headwater).

In the original analysis, loading estimates were calculated for each scenario using estimated concentrations for two sources of floodwater (i.e., the headwaters and Mississippi River water) derived from the database and wetland function factors. A literature review was conducted to develop general ranges of wetland water quality functions and export coefficients for runoff from upland and agricultural lands. Discussions with a water quality specialist with the USGS and agricultural experts at the University of Missouri Delta Research Center were also conducted to provide input into the development of function factors used in the analyses. The function factors from this previous effort were carried forward in their entirety into this revision.

Ashby et al. (2000) developed wetland function factors for two general types of land covers, (a) those that are described as wetlands, and (b) upland and agricultural lands that are flooded. The first step in assigning a wetland function factor was to determine if the land cover would generally remove materials from the floodwater or export to the floodwater more material than it retained. A negative value was assigned for net removal and a positive value was assigned for net export. As an initial classification, land covers that can be considered as wetlands (cypress/tupelo, scrub/shrub marsh, marsh, bottomland hardwood, riparian, sandbars, open water, and rivers) were assigned a negative function factor for each constituent (except for carbon as described below). Upland and agricultural lands, when flooded, were considered to remove material via sedimentation but also to export material via perturbations to the land associated with farming practices and crop type for a positive net export. The rationale for wetland function factors and export coefficients and the vetting of these values with stakeholders and regional experts are described in Ashby et al. (2000).

2.3 Overview of Water Quality Processes in Wetlands

General information on the impacts of wetland hydrology and wetland type was used to assign wetland function factors, although it is recognized that responses in material cycling are often quite variable. For example, wetlands subjected to different flooding regimes

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provide a different response for some processes. Litter decomposition can be slightly higher in manipulated (pumping) areas than in natural and impounded wetlands (Conner and Day 1991). In natural and impounded areas, nitrogen was immobilized during spring and summer but mineralized in the manipulated area during the same period (Conner and Day 1991). Phosphorus was not immobilized in the natural and impounded area but was mineralized at a slower rate than in the managed area (Conner and Day 1991). The general conclusion was that burial, or net accumulation of organic matter, nitrogen, and phosphorus, was more prevalent in stagnant, more flooded areas, and mineralization and/or export was greater for the managed areas. Significant removal of nitrogen has been observed for alluvial floodplains (Brinson, Bradshaw, and Kane 1984) and forested wetlands (e.g., bottomland hardwoods in the Atchafalaya Basin flooded for 67 days (Lindau, DeLaune, and Pardue 1994). Removal of total phosphorus by various types of wetlands can also be significant. Kadlec (1997) observed a 94 to 99 percent reduction in total phosphorus concentrations in wastewaters that were subjected to wetland treatments. Often, removal may be attributed to sedimentation of particulate phosphorus, which can be the dominant phase (Lindau, DeLaune, and Pardue 1994). However, relationships of small upland wetlands to the watershed can be highly variable depending on watershed conditions and runoff events. In a watershed that is primarily pasture for sheep grazing, the receiving wetland retained 23 percent of the nitrogen and 38 percent of the phosphorus entering the system (Raisin 1996). Sediment retention is also highly variable and averages about 30 percent of the total entering with a maximum retention of about 95 percent (numerous studies summarized in Adamus et al. 1991). In riparian zones, denitrification is also an important removal process (Pinay and Decamps 1988). Nitrate loss in riparian zones can be as much as 50 to 100 percent in headwater streams with only 15 percent removal associated with sediments (Cooper 1990). As observed for other wetland types (Raisin 1996), retention function of riparian buffers varies with width and frequency of gaps (Weller, Jordan, and Correl 1998). In open water systems and rivers with sandbars, nitrogen and phosphorus removal processes are also occurring but probably to a lesser extent than in vegetated wetland systems such as marshes, swamps, and bottomland hardwoods. More variable hydrologic regimes in the latter systems would tend to increase the transport of materials and result in higher removal rates. Results of intensive studies conducted in the Cache River system in northeastern Arkansas provide

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relative information on wetland processes for a system in the immediate vicinity of the study area and may be used to provide better estimates of wetland function factors. For example, DeLaune et al. (1996) measured nitrate reductions between 59 and 82 percent, which are consistent with studies described above. Conversely, Dortch (1996) estimated removal efficiencies of 29.5 percent for inorganic suspended solids, 21.4 percent for total nitrogen, and only 3 percent for total phosphorus. These values are probably lower than would be expected in the study area since they were calculated for a flow-through system and represent annual conditions. However, backwater flooding of bottomland hardwood systems during winter and spring may be less effective at nutrient transformation and removal since biological activity is greatly reduced during these seasons (Harris and Gosselink 1990) and estimates from Dortch (1996) may not be that low. Kleiss (1996) estimated a 14 percent decrease in suspended sediment load, which is also lower than would be expected for the study area due to the anticipated hydrology of a gradual flooding and dewatering. However, review of the 1993 flood data for the Mississippi River upstream of the study area (Holmes 1993) indicated that there was little sedimentation in the backwater areas downstream of St. Louis, MO, and a decrease of only 10 to 20 percent may be reasonable.

Wetland function factors for wetland land covers were estimated from the above information, in consultation with wetland experts when possible, and were reviewed by representatives from the Memphis District, EPA, FWS, and MDNR (see Ashby et al. 2000, Table 4). In general, the wetland function factor is an estimation of the percentage of mass of the constituent (nitrogen, phosphorus, carbon, and sediment) that will be retained by (including removal) or transported to the system. This value is usually measured from a mass balance approach and accounts for material already in the land cover. Vegetated wetland types were considered to be similar in removal efficiencies and more efficient than non-vegetated or sparsely vegetated types (e.g., open water, rivers, and sandbars). Values assigned were based on estimates from references noted in Table 4 of Ashby et al. (2000). We reexamined these values, but found no strong justification for altering them from the original values. Further, we were reluctant to make changes that would alter the fundamental, underlying assumptions of the previous analyses and render comparisons with that earlier work more problematic. Values for wetland types where little information

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was available were assigned relative to values used for cypress/tupelo systems. For many of the land covers, carbon was assumed to be converted to dissolved forms and easily transported, so a positive function factor is suggested. Observations in bottomland hardwood systems in Mississippi (Ashby et al. 1991) and other systems (Harris and Gosselink 1990) support this assumption.

2.4 Estimation of Upland and Agricultural Export Coefficients in Wetlands

Wetland function factors or export coefficients for periodically flooded upland and agricultural land covers have not been developed. Consequently, consideration of material from two sources, (a) material available for export from the land (traditionally measured as export coefficients), and (b) removal from or export to the floodwaters (such as processes observed for wetlands), is required. Export loads for nitrogen, phosphorus, sediment, and carbon were estimated using initial export coefficients (EC) (Beaulac and Reckhow 1982; Peterjohn and Correll 1984; Lowrance et al. 1984), soil fertility measurements (University of Missouri 1996), and representative concentrations. The initial export load was adjusted to account for changes in the availability of material associated with flooding versus runoff. Based on discussions with agricultural experts in the study area, relatively low slopes in the area (1 to 2 ft/mile, Luckey and Fuller 1984), and gradual changes in stage height with flooding and receding, sediment export from the upland and agricultural land covers is expected to be relatively low. Phosphorus concentrations in the soils are relatively high (23 to >70 lb/acre) and similar by cropping options (University of Missouri 1996) but are considered to be less mobile than nitrogen due to a lower solubility. Nitrate does not attach to soil particles but remains soluble and is easily transported with water (Killpack and Buchholz 1993) both as surface flow and subsurface flow. Legume crops such as soybeans can add up to 30 to 50 lb/acre of nitrogen in the study area (Killback and Buchholz 1993) and would result in a higher export coefficient than for other crop types.

These factors were used to adjust the export coefficient (EC), and an individual load was then calculated for each constituent. The individual load for each constituent was then added to the load associated with the floodwaters for estimation of the total load available. Since estimates of loads account for processes that impact concentrations and mass, a

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wetland function factor of positive 1 is assigned to all upland and agricultural land covers (i.e., 100 percent of the estimated load is available for transport when the floodwaters recede). The net yield is then calculated by reducing the load associated with floodwaters by 10 percent to describe losses from sedimentation.

2.4.1 Nitrogen and Phosphorus

Export coefficients from Beaulac and Reckhow (1982) were used to estimate initial export loads for nitrogen and phosphorus. The median value of the export coefficient was considered as the initial mass available for export. Land covers in the study area that were not represented by those in Beaulac and Reckhow (1982) were assigned a value from a similar land cover. Because the literature-based loads represent annual loads, the initial estimated loads are reduced by a percentage that estimates the available load during the period of flooding. It was recommended that the initial nitrogen load be reduced by 25 percent and the initial phosphorus load be reduced by 50 percent. The rationale for these reductions is based on an expected decrease in the annual export coefficient because consideration is given to the wet period only and a higher particulate phase for phosphorus than for nitrogen. Adjusted export coefficients represent the amount exported for the period of inundation.

Calculation of export coefficients for nitrogen and phosphorus for various land covers is described in Ashby et al (2000, page 8-9).

2.4.2 Carbon

Carbon transport was considered to occur primarily as dissolved organic carbon since there is a considerable amount of tillage and burning of residue which would greatly reduce the export of particulate organic carbon. Export of carbon was based on dissolved carbon concentrations, soil fertility measurements, and export coefficients. Organic matter content in the study area ranges from 1 to 3 percent (University of Missouri 1996). Runoff coefficients for individual land covers were not available and estimates from Peterjohn and Correll (1984) were highly variable, 58.2 to 61.3. A winter value of 3.6 kg/ha (Peterjohn and Correll 1984) was considered representative and an adjustment to account for land cover was not applied.

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2.4.3 Sediment

Export of sediment was based on suspended sediment concentrations (USGS data and STORET data) and reported daily loads (Holmes 1993). Sediment retention during inundation was estimated to be 10 percent since there is little evidence of sediment deposition following flooding in the study area. Suspended sediment concentrations were highly variable and ranged from 45 to 451 mg/L . Holmes (1993) reported a mean daily concentration of 317 mg/L and median daily load of 717,000 tons/day for the 1993 flood (measured in the Mississippi River at Thebes, IL). Corresponding values of 302 mg/L and 139,000 tons/day were presented for the period of record. These concentrations were somewhat higher than concentrations observed in the headwater region (e.g., USGS data from Morehouse, station 7024070); therefore, instantaneous sediment loads were estimated at 4.63 kg/sec based on concentrations and discharge measurements. A 60-day period of rain was used to calculate the total load which was then divided by the total area (184,855 ha) to estimate the initial export coefficient.

2.4.4 Calculation of Exports

In 2000, Ashby et al. determined from discussions with Fish and Wildlife Service personnel and agricultural experts that export coefficients for with- and without-project condition would be more representative if transport from the system prior to inundation (existing conditions) was considered. We found no reason to revise that assumption. Under existing conditions, rainfall in November and December can result in high runoff or export. With the project in place, this same period results in retention of rainfall and a decrease in export. Therefore, export coefficients for “with-project” conditions were reduced by 50 percent to account for decreased transport from the project area prior to flood inundation. Material retained or transported in the upland or agricultural land was then calculated in the spreadsheet using the following equations. Appropriate conversions were made to express mass in kilograms and runoff in kilograms per acre.

For export from inundated areas, the volume of water overlying each land cover type from project minimum elevation (260 ft for St. Johns and 263 ft for New Madrid) to seasonal peak elevation is calculated by summing over elevation increments for each basin as:

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$$V_{lc} = \sum(A_{zlc} \times V_{z)} \quad (1)$$

∑ is from z=project minimum to z=peak seasonal elevation

Where

V_{lc} = total volume (acre-ft) overlying a specific land cover type (lc) at peak inundation

A_{zlc} = area (acres) of selected land cover type (lc) at a selected elevation (z)

V_z = volume increment (acre-ft) per unit area (acre) extending upward from a selected elevation (z) to the elevation of seasonal peak inundation.

The total export (kg) of a selected constituent (total phosphorus, total nitrogen, or sediment) when flood waters retreat from inundated areas is calculated as:

$$Load_c = k \times C \times V_{lc} \quad (2)$$

Where:

$Load_c$ = mass (kg) of constituent (c) exported during drawdown of flood waters.
k = factor (1.233) that converts mg/L × acre-ft to kg
C = concentration of constituent (mg/L) in flood water.

For areas that are not inundated (i.e., "dry land") the export is calculated from a seasonal export coefficient (kg/acre) and summing across land cover types as:

$$Load_d = \sum A_{lc} \times EC_{lc} \quad (3)$$

Where:

$Load_d$ = mass (kg) of constituent (c) exported during periods without inundation

A_{lc} = Total area (acres) of a specific land cover type above the 30-day, seasonal inundation contour

EC_{lc} = seasonal export coefficient (kg/acre) for selected land cover type and constituent. Note that $EC = EC \times 0.5$ with project in place (Ashby 2000).

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The total export for a given land cover type is the sum of export under inundation and dry land adjusted for retention effects as appropriate:

$$\text{Load} = \text{Load}_c + \text{Load}_d \quad (4)$$

$$\text{Wetland Retention (kg)} = \text{Load} \times \text{Wetland Function Factor} \quad (5)$$

$$\text{Net Yield}_{\text{wetland}} = \text{Load} - \text{Wetland Retention} \quad (6)$$

$$\text{Net Yield}_{\text{upland}} = (\text{Load}_d \times 0.90) - \text{Wetland Retention} \quad (7)$$

The calculation for upland areas assumes a 10 percent reduction in the load due to sedimentation during transport.

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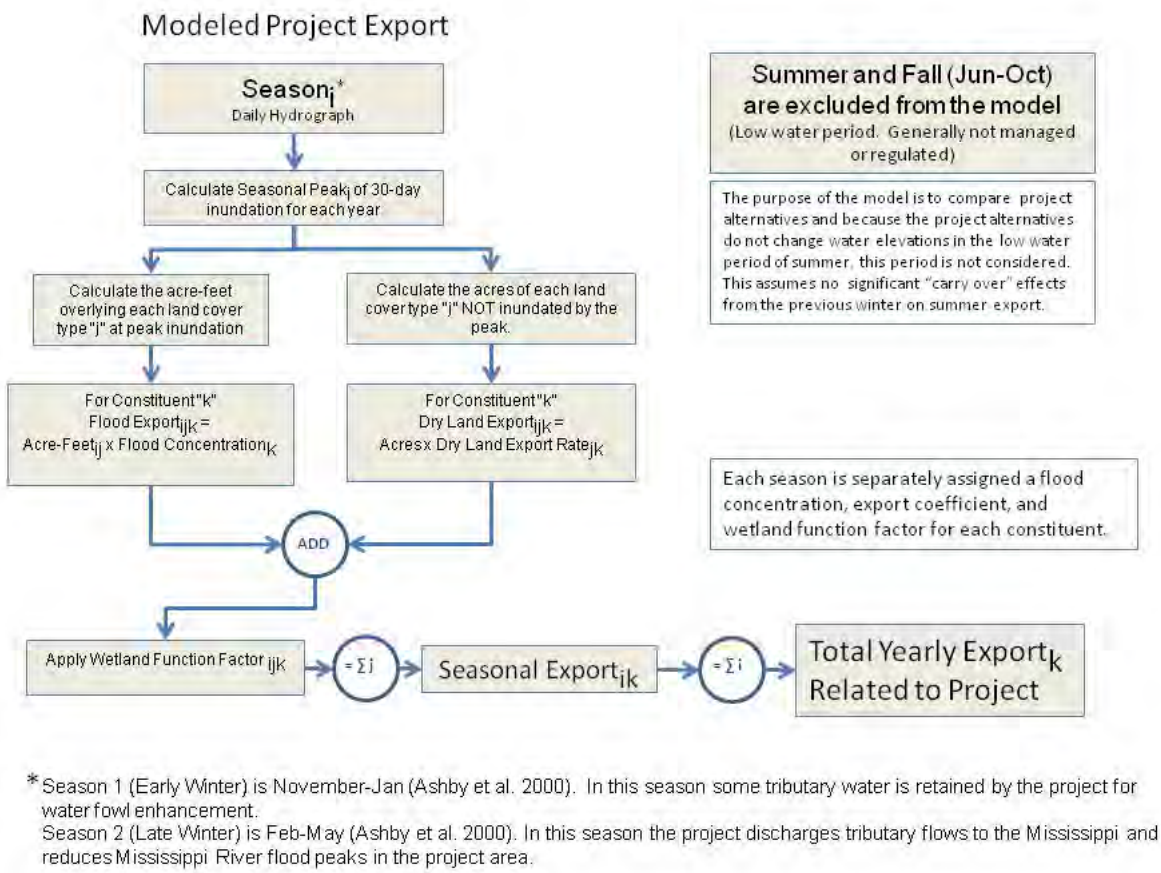

Figure 1. Diagram of calculations used to estimate constituent export in two parts of the inundation season (Nov – May) .

2.5 Evaluation of Project Impacts on Water Quality of the Mississippi River

Ashby et al. (2000) evaluated the potential impacts on water quality in the Mississippi River using the output from the export spreadsheet and a water balance. The water balance included discharge data from 1943 to 1974 and from 1975 to 1998. Although a longer period of record is now available for this analysis, the 23 year record that was used still provides a good representation of the average condition, and the results of that analysis are robust to relatively minor changes in the long-term hydrology. Consequently, this earlier approach and the result were not revised. In summary, the earlier approach used the limited water quality data for the Mississippi River that were available from Hickman, KY, for 1969 and 1970 and from Thebes, IL, for 1994 through 1998. Data from

USGS stations at New Madrid and Caruthersville, MO, were not applicable. While the data from Hickman are not very recent, and the data from Thebes represent values upstream from the confluence of the Mississippi River and the Ohio River, these data were the best available.

Existing conditions allow for periodic movement of water from the Mississippi River into the project area and result in mixing with headwaters in the area, and transport of material into and out of the project area. Hydrologic information provided by the Memphis District indicated that monthly mean flows were highly variable from 1943 to 1974 and from 1975 to 1998. Mean values of 800,000 and 700,000 cfs were considered to represent volumes that would provide floodwaters at elevations of 290 and 282 ft, respectively. A period of 5 days was considered to represent the time of inundation of a representative flood, and relative volumes of headwaters and Mississippi River waters were then calculated for the flooded area. Concentrations for nitrogen, phosphorus, organic carbon, and suspended sediments for the headwaters and the Mississippi River were then multiplied by relative volumes to determine total mass available for each volume. The expected percent removed for each basin was then applied to the total mass available in the appropriate basin, and the difference to the total mass available in the Mississippi River was then expressed as a percentage.

2.6 Evaluation of Potential Changes in Pesticide Usage on Water Quality

Ashby et al. (2000) conducted a literature review to describe the transport of herbicides in surface and subsurface drainages in the region. They also evaluated potential changes in pesticide use and pesticide impact on water quality based on existing water quality data for existing conditions (current practices and existing acreage) and a qualitative extrapolation of potential increase in pesticide usage under the authorized project. They determined that identification of the potential pesticide impact using a spreadsheet analysis was inappropriate because there are limited data that show measurable concentrations in the study area. Experts at the University of Missouri Delta Research and Extension Service were consulted on potential changes in crops, pesticide application rates, and pesticide interactions with crop types and soils. Data used to assess pesticide concentrations in the project area were extracted from the STORET retrieval database. Data from the USGS

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National Water-Quality Assessment (NAWQA) study and well-water data from the USDA NRCS were also evaluated. Summary statistics for water quality data from surface sites were presented in Ashby et al (Appendix B; 2000) for detected pesticides. Pesticide data from the NRCS study and the NAWQA data (Morehouse and Rives stations) were also included in their Appendix B. Records from public drinking supplies in the area were also evaluated. Parameters with measurable concentrations at Morehouse were evaluated for application rates using distribution maps from the NAWQA Pesticide National Synthesis Project available at http://water.wr.usgs.gov/pnsp.

2.7 Evaluation of Potential Impacts to Big Oak Tree State Park

The previous analyses by Ashby et al. (2000) that assessed the potential impacts of the authorized project on Big Oak Tree State Park are no longer applicable, as the planned operation of the project no longer includes pumping of groundwater to create seasonal flooding. Instead, the design now calls for reconnection of the Park with the main stem of the River so that the natural flooding regime is restored. A strong, positive effect of this on the ecology within the Park is anticipated. Further, because the Park will now serve as a trap (sink) for sediment and nutrients delivered from the Mississippi River main stem during natural high water, the plan for the Park under the authorized project will have a net positive (albeit non-detectable) influence on water quality in the Mississippi River.

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3 Results

The analyses presented here are intended as an update and revision of those presented by Ashby et al. (2000). Consequently, an attempt is made only to present enough of those previous results to allow interpretation of these revisions without continuous reference to the earlier work. Many of those earlier findings are still fully applicable and were not revised here, but are summarized briefly for reference.

3.1 Existing Conditions

3.1.1 Water Quality in Surface Waters

Water quality in the surface waters reflects current land use practices that are predominantly agriculture operations (e.g., row crops). The most detailed data for assessing existing conditions were collected in 1994-1998 as part of the National Water Quality Assessment Program (NAWQA) conducted by the USGS and summarized in Ashby et al. (2000). Water quality observations exhibited seasonal patterns and the influence of flow regime. In general, temperature and dissolved oxygen concentrations fluctuated by season with dissolved oxygen concentrations near 4-6 mg/l in mid-summer. Nitrate/nitrite concentrations were typically less that 2 mg/l in surface waters. Total phosphorus concentrations were quite variable with relatively high values often occurring greater than 0.1 mg/l. Total organic carbon values were mostly less than 2 mg/l with higher values on occasion. Suspended sediments accounted for approximately 58% of the total residue and varied between less than 100 mg/l to values near 300 to 400 mg/l. In 2006, two sites were identified on the 303(d) list in the project area. These sites were a site on the Mississippi River (Water Body IDs: 1707 & 3152) for chlordane and PCBs and Spillway Ditch (Water Body ID: 3134) for sediment (habitat loss).

A query of state agencies and Federal databases resulted in only one station in the project area with recent water quality data. St. Johns Ditch at Henderson Mound, MO, site # 7042450 – New Madrid County has been sampled approximately monthly between 1999 and 2010 for temperature, dissolved oxygen, pH and hardness, suspended and dissolved solids, total nitrogen, total phosphorus, and discharge by the USGS. Discharge reflected seasonal and annual variability with

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values ranging from near 0 to over 2000 cubic feet per second (Figure 1, bottom panel). In general, dissolved oxygen concentrations were similar to observations between 1994 and 1998 of the NAWQA study. Temperatures varied seasonal with maximum values near 25 – 30 OC (Figure 1-B). Dissolved oxygen concentrations varied between near 4 mg/l and over 9 mg/l (Figure 1-C). Values of pH were mostly between 7 and 8 standard units with hardness concentrations near 125 mg/l with occasional lower values coincident with increased discharge (Figure 1-A). Suspended solids concentrations were predominantly below 50 mg/l except during periods of increased discharge when concentrations ranged between 100 and 200 mg/l (Figure 2-C). Dissolved solids concentrations were mostly between 125 and 150 mg/l with concentrations below 100 mg/l during some periods of increased discharge (Figure 2-B). Total nitrogen was highly variable with concentrations ranging from less than 0.5 to greater than 2.0 mg/l with higher concentrations occurring during periods of increased discharge (Figure 2-C). Total concentrations ranged from near 0.25 to over 0.5 mg/l with higher concentrations occurring during periods of increased discharge (Figure 2-C).

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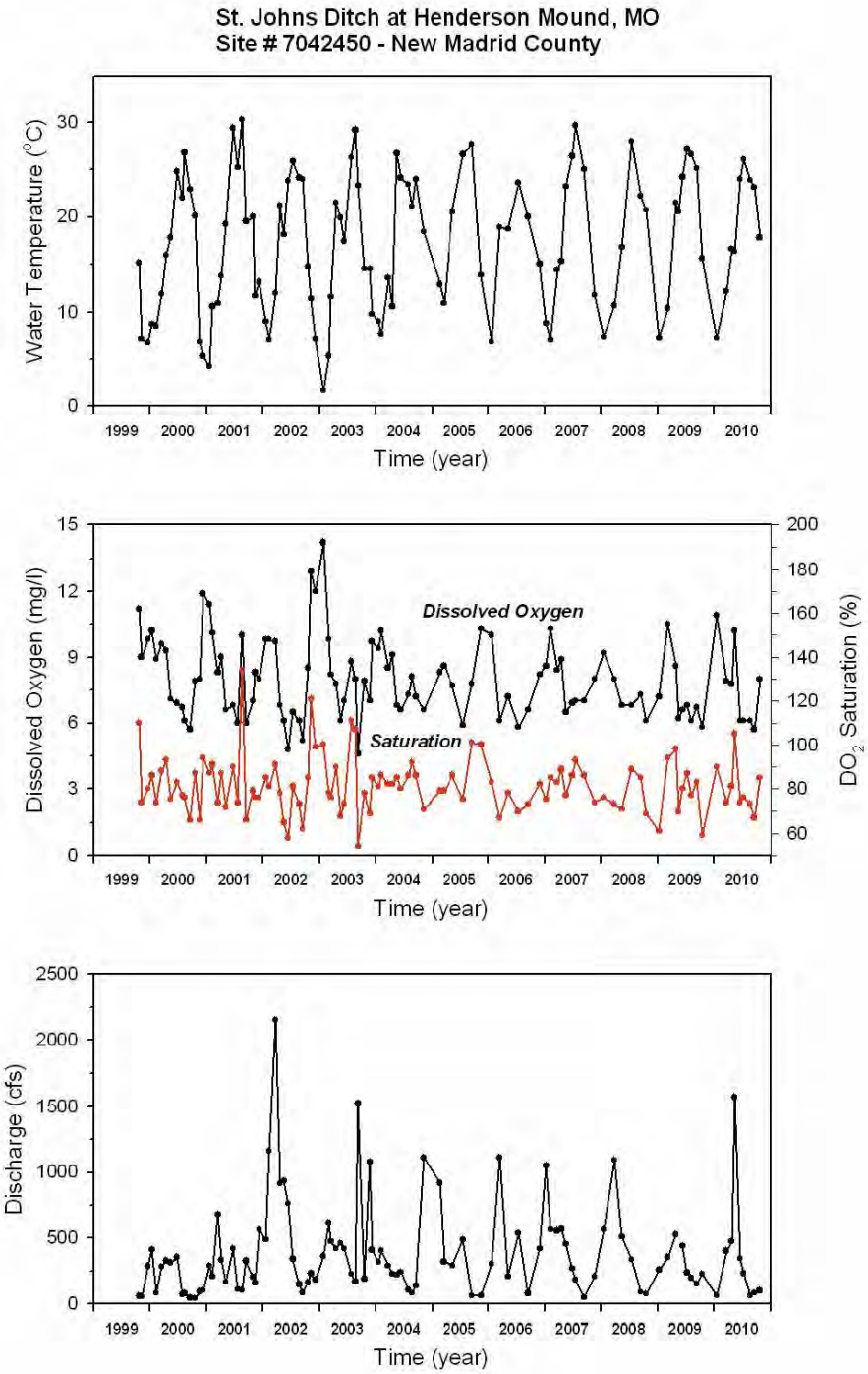

Figure 2. Existing conditions in St. Johns Ditch from 1999 to 2010. Upper panel (A) is the time series of water temperature, middle panel (B) is dissolved oxygen as mg/L or percent saturation, lower panel (c) is discharge in cubic feet per second.

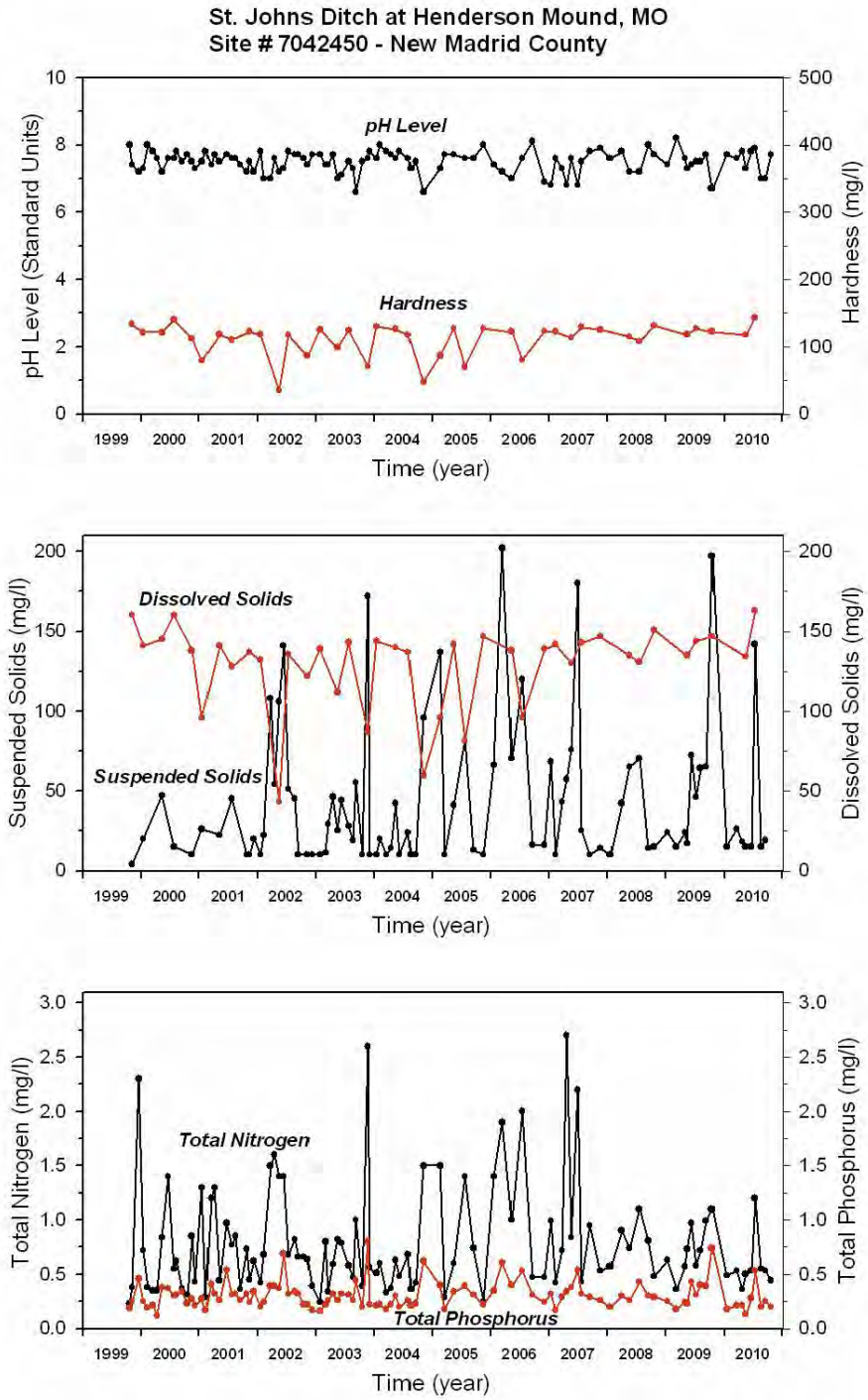

Figure 3. Existing conditions in St. Johns Ditch from 1999 to 2010. Upper panel (A) is the time series of pH and Hardness (mg/L as CaCO3), middle panel (B) is suspended solids (black) and dissolved solids (red) as mg/L, lower panel (c) is total nitrogen (black) and total phosphorus (red) as mg/L.

The 303(d) listings for 2006 and 2010 indicate that water quality in the project area is mostly within acceptable limits with low dissolved oxygen concentrations as the major impairment, but at only a few sites. A review of the proposed 2010 Missouri 303(d) list showed the following impaired waters in the project vicinity; Maple Slough Ditch for low dissolved oxygen in Mississippi and New Madrid Counties and St. John's Ditch for mercury from atmospheric deposition and bacteria in Scott and New Madrid Counties, and Stevenson Bayou for low dissolved oxygen in Mississippi County. Sites listed in the 2006 303(d) list (Mississippi River and Spillway Ditch) were not listed on the 2010 303(d) list.

3.1.2 Export of Nutrients and Sediments

The revised analysis addresses the export of nutrients and sediment from the project area under the existing hydrologic regime and several alternatives. Although these are estimates, the same assumptions are applied to all "with project" alternatives and provide a basis for comparison to existing conditions. The analysis estimates that, overall, there are substantial exports of nitrogen, phosphorus, carbon, and sediment from the project area under existing conditions. This is consistent with the dominance of high-intensity agriculture (row crop), and upland (not inundated) conditions in this landscape. The overall effect of the authorized project (discussed in the next sections) is to increase inundation and thus trap and process (remove) a greater fraction of these materials from the export stream.

3.2 Potential Influences of Authorized Project on Surface Water Quality

The data that could be identified do not provide a thorough baseline of water quality for the few, relatively small, water bodies located within the project areas. But there is indication that these waters are influenced primarily by land use and runoff as typical of an agricultural landscape. Major existing impairments are periods of low dissolved oxygen concentrations (e.g., >10% of observations are < 5 mg/l). Dissolved oxygen concentrations above 9 mg/l indicate higher levels of in-stream primary productivity typical of nutrient enrichment Increased loading (terrestrial export) of sediments and nutrients in periods of high discharge were observed. It is likely that periods of inundation are accompanied by increased sediment accumulation, depressed oxygen levels (during warmer weather), and elevated inputs of plant nutrients to these water bodies. Such conditions are commonly

experienced by natural water bodies within an unregulated floodplain. However, the net balance of positive or negative influences of the altered inundation regime on an individual water body can only be evaluated with additional, site-specific data.

3.3 Potential Influences of Authorized Project on Material Exports

The primary emphasis of this revision was the effects of the authorized project and alternatives on the export of material relative to the existing condition. The results show the expected export (under the differing project alternatives) of phosphorus, nitrogen, organic carbon, and sediment from the project area over the period 1943-2009 (Table 1 and Figures 3-10). Because the analysis now fully incorporates export via runoff, the estimates are substantially higher than those reported by Ashby et al. (2000). However, the effect of the authorized project on export, relative to the existing condition remains similar (i.e., 15% reduction in TP and TN export, up to 60% reduction in sediment export). The conclusion of no discernible impact on Mississippi River water quality is also reconfirmed.

Reductions in export from this area could show significant environmental benefits. An analysis by Robertson et al. (2009) showed the St. Johns –New Madrid basin as the number two exporter of nitrogen and phosphorus in the Mississippi-Atchafalaya basin in terms of yield per unit area, with an estimated 400 kg of TP and 3024 kg of TN delivered per square km per year to the river. Our result, limited to about 1/2 of the year (i.e., the inundation period from November through May) when exports are expected to be at a minimum, indicate yields of about 40-60 kg/km^2 of TP and 300-900 kg/km2 of TN between about 10 and 15% of the annual phosphorus rate and between about 10 and 30% of the nitrogen rates reported by Robertson et al. (2009). If these rates are extrapolated to a year (12/7 = 1.7X) they become 17-25% of the SPARROW rate for TP and 17-50% for TN. These lower numbers are in the same general range as the SPARROW estimates and are consistent with retention or trapping of nutrients under inundated conditions.

In the presentation that follows, export from the two areas (i.e., St. Johns Bayou and the New Madrid Floodway) within the overall project is addressed separately. The analysis assumes that effects in the two areas are independent and thus strictly additive. Therefore

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the effect of any combination of management actions in two separate areas on export can be inferred by adding the separate effects together.

The effect of the project alternatives on material export varies considerably among the constituents and between the two project areas (Table 1). For example, in the New Madrid Floodway, net, average export of total phosphorus export is reduced by about 15-20% by either the Authorized Project or the Avoid and Minimize Scenarios. However, in the St. Johns Bayou, the authorized project shows little effect on total phosphorus export. Likewise, total nitrogen export shows no discernable influence of the authorized project in St. Johns Bayou, but in the New Madrid basin, the authorized project or avoid and minimize scenarios all reduce average N export by about 15%. Likewise, with organic carbon, the project shows little influence on export of the authorized project in the St. Johns Bayou (possibly a 10-15% increase), but in the New Madrid basin, the authorized project cuts export in half, and the avoid and minimize scenarios reduce organic carbon export by about 40%. The pattern of sediment is similar to carbon. The authorized project has little influence on sediment export from the St. Johns Bayou (possible 10% increase), but cuts export from the New Madrid floodway by nearly 60%. The avoid-and-minimize scenarios reduce sediment export from the New Madrid Floodway by about half.

Time series presentations of these same data emphasize the effects of the project and show the strong, positive influence of high water on material export. For example, the difference between existing conditions and the authorized project export of total phosphorus in the New Madrid basin during high water is dramatic (Figure 3), but only accounts for a 15% difference in average, total export over the period of record (Table 1). This is more easily understood in the context of the relatively high "baseline" export (e.g., 30 metric tons/y) of phosphorus that occurs in extended periods without inundation.

Table 1. Total of Season 1 plus Season 2 estimated export (metric tons) of phosphorus, nitrogen, organic carbon and sediment from 81,700 acres () in the New Madrid Floodway (NM) and 47,500 acres in the St. Johns Bayou (STJ) during the period of record 1943 to 2009. Five alternatives for hydrology and land use are modeled in the New Madrid basin, while two are considered in the St. Johns Bayou.

	Minimum	Maximum	Mean	N

T O T A L P H O S P H O R U S

New Madrid				
1. Existing	29	134	38	67
2. Authorized	30	33	31	67
3.1 Avoid/Minmze 1	30	40	32	67
3.2 Avoid/Minmze 2	30	40	32	67
4.2 Reforestation	24	28	25	67
Saint Johns Bayou				
1. No Action	17	72	22	67
2. Authorized	20	66	24	67

T O T A L N I T R O G E N

New Madrid				
1. Existing	370	1200	440	67
2. Authorized	370	390	380	67
3.1 Avoid/Minmze 1	370	440	390	67
3.2 Avoid/Minmze 2	370	440	380	67
4.2 Reforestation	150	180	160	67
Saint Johns Bayou				
1. Existing	200	520	230	67
2. Authorized	200	470	230	67

O R G A N I C C A R B O N

New Madrid				
1. Existing	220	3300	500	67
2. Authorized	250	350	280	67
3.1 Avoid/Minmze 1	250	590	320	67
3.2 Avoid/Minmze 2	250	590	310	67
4.2 Reforestation	200	470	260	67
Saint Johns Bayou				
1. Existing	130	1500	260	67
2. Authorized	200	13000	290	67

S E D I M E N T

New Madrid				
1. Existing	7600	180000	22000	67
2. Authorized	8700	110000	9700	67
3.1 Avoid/Minmze 1	8700	23000	11000	67

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3.2 Avoid/Minmze 2	8700	23000	10700	67
4.2 Reforestation	6000	20000	7500	67
Saint Johns Bayou				
1. Existing	4600	74000	10000	67
2. Authorized	7500	62000	11000	67

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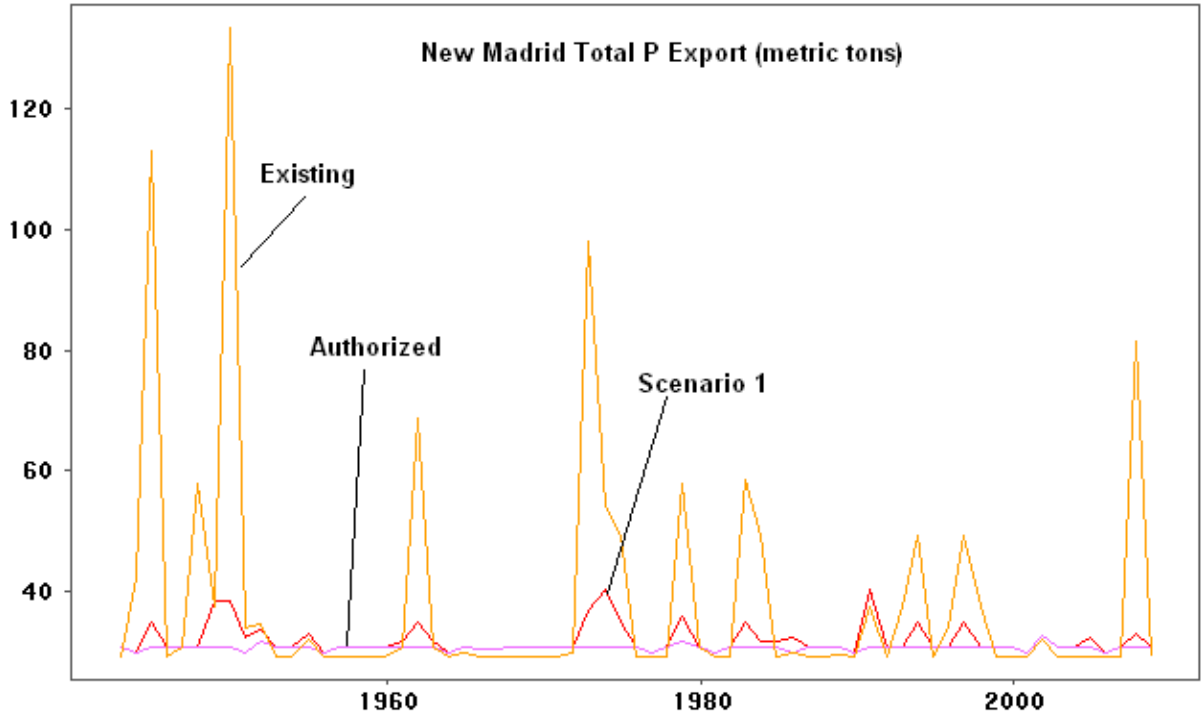

Figure 4. Expected export of total phosphorus (TP) in metric tons per flood season (Nov-May) from the New Madrid Floodway, for the period 1943 to 2009. Existing conditions use the observed hydrograph to calculate expected transport. Simulated hydrographs were used to estimate export for the authorized project, and management scenario 1. Management Scenario 2 is not shown, but very similar to scenario 1. The reforestation alternative is below the line for authorized project but generally parallel to it.

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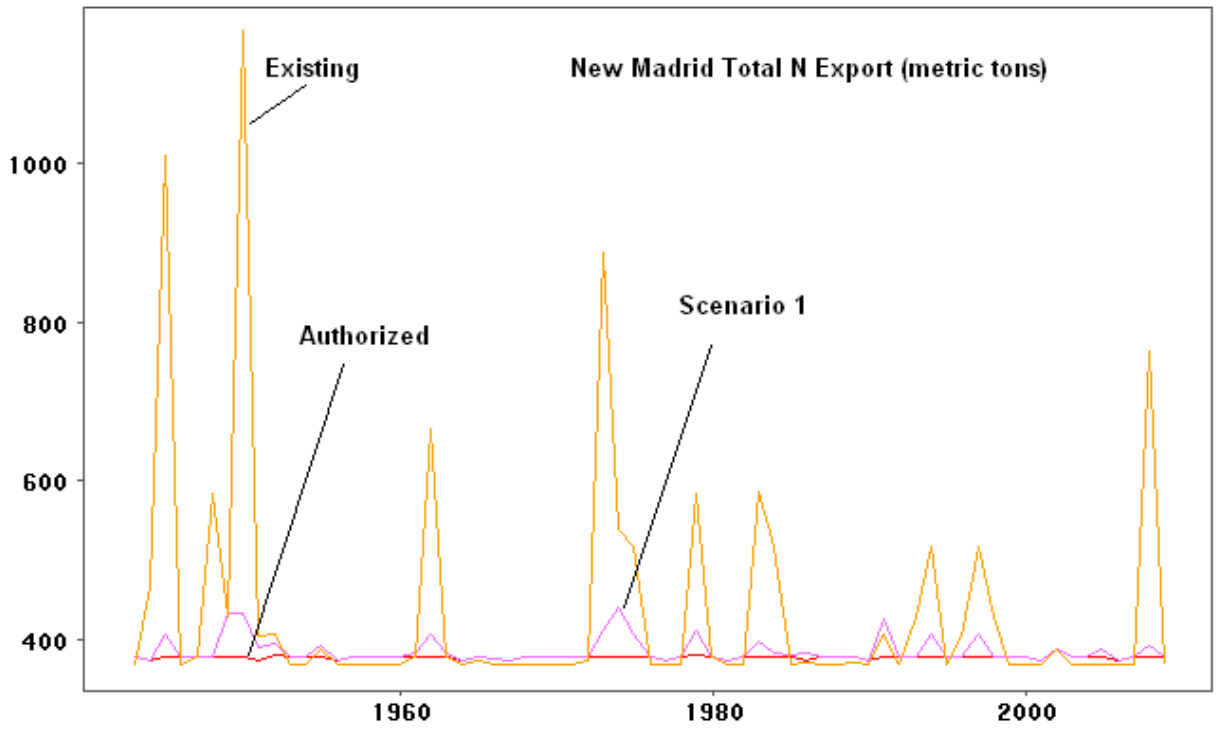

Figure 5. Expected export of total nitrogen (TN) in metric tons per flood season (Nov-May) from the New Madrid Floodway for the period 1943 to 2009. Existing conditions use the observed hydrograph to calculate expected transport. Simulated hydrographs were used to estimate export for the authorized project, and management scenario 1. Management Scenario 2 is not shown, but very similar to scenario 1. The reforestation alternative is below the line for authorized project but generally parallel to it.

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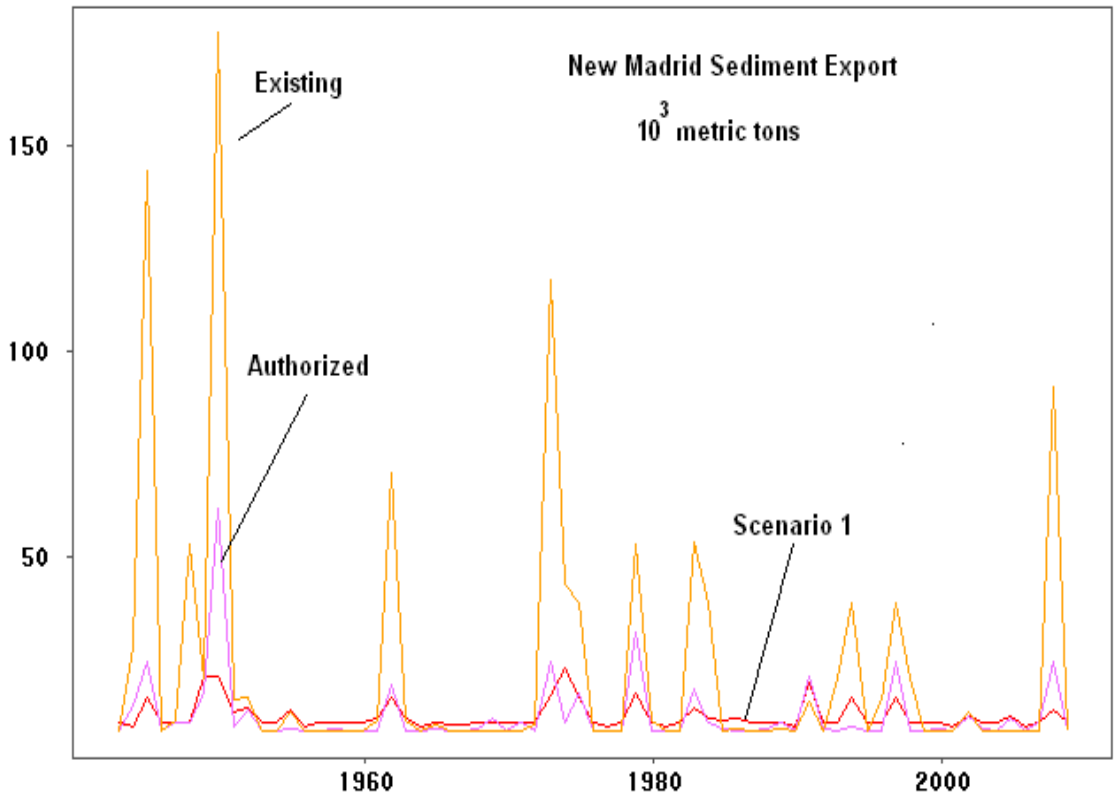

Figure 6. Expected export of sediment in thousands of metric tons per flood season from the New Madrid Floodway for the period 1943 to 2009. Existing conditions use the observed hydrograph to calculate expected transport. Simulated hydrographs were used to estimate export for the authorized project, and management scenario 1. Management Scenario 2 is not shown, but very similar to scenario 1. The reforestation alternative is below the line for authorized project but generally parallel to it.

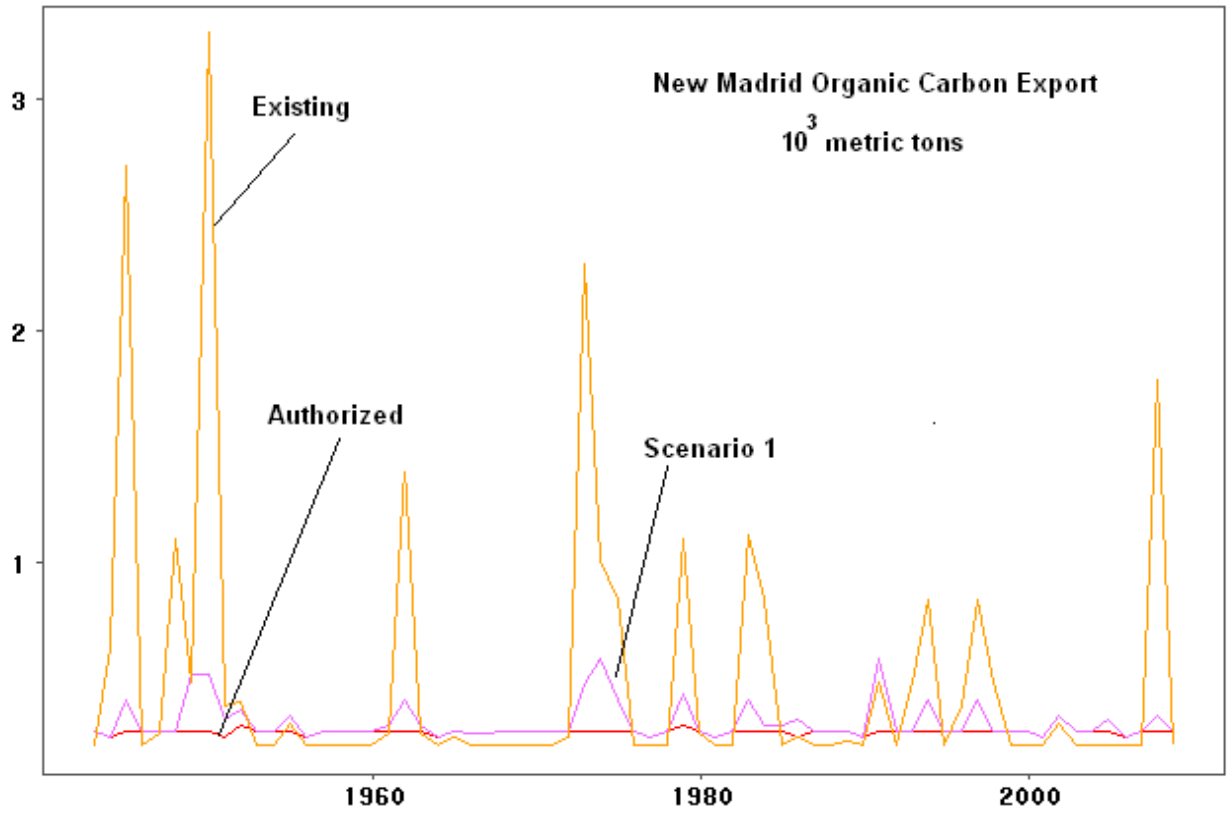

Figure 7. Expected export of total organic carbon (TOC) in thousands of metric tons per flood season (Nov-May) from the New Madrid Floodway for the period 1943 to 2009. Existing conditions use the observed hydrograph to calculate expected transport. Simulated hydrographs were used to estimate export for the authorized project and management scenario 1. Management Scenario 2 is not shown, but very similar to scenario 1. The reforestation alternative does not apply to St. Johns Bayou.

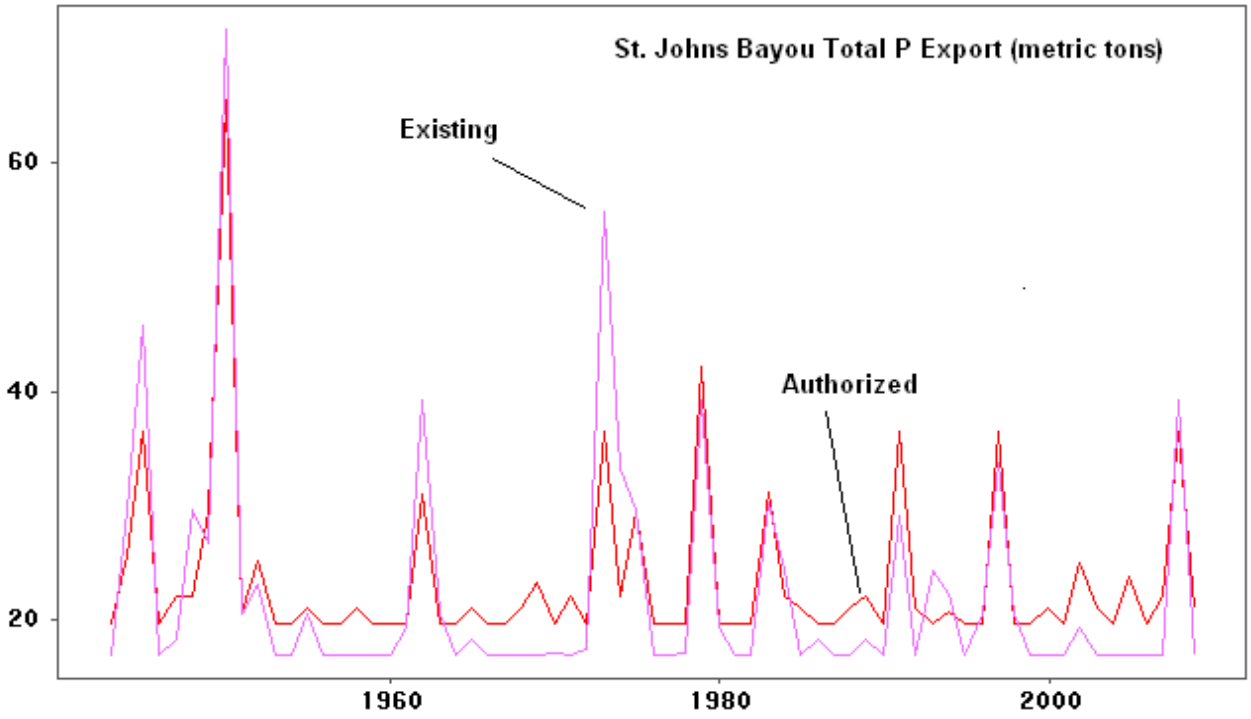

Figure 8. Expected export of total phosphorus (TP) in metric tons per flood season (Nov-May) from the St. Johns Bayou for the period 1943 to 2009. Existing conditions use the observed hydrograph to calculate expected transport. Simulated hydrographs were used to estimate export for the authorized project. The reforestation alternative does not apply to St. Johns Bayou.

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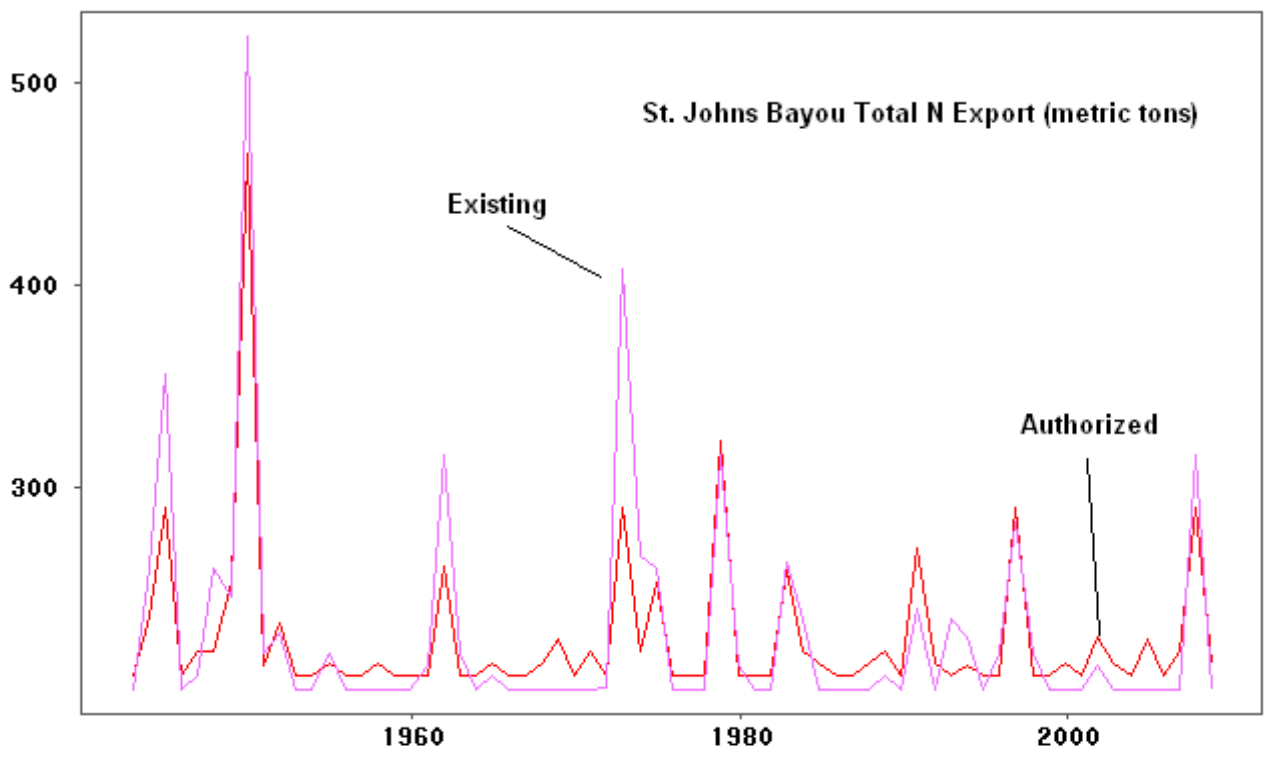

Figure 9. Expected export of total nitrogen (N) in metric tons per flood season (Nov-May) from the St. Johns Bayou for the period of record, 1943 to 2009. Existing conditions use the observed hydrograph to calculate expected transport. Simulated hydrographs were used to estimate export for the authorized project. The reforestation alternative does not apply to St. Johns Bayou.

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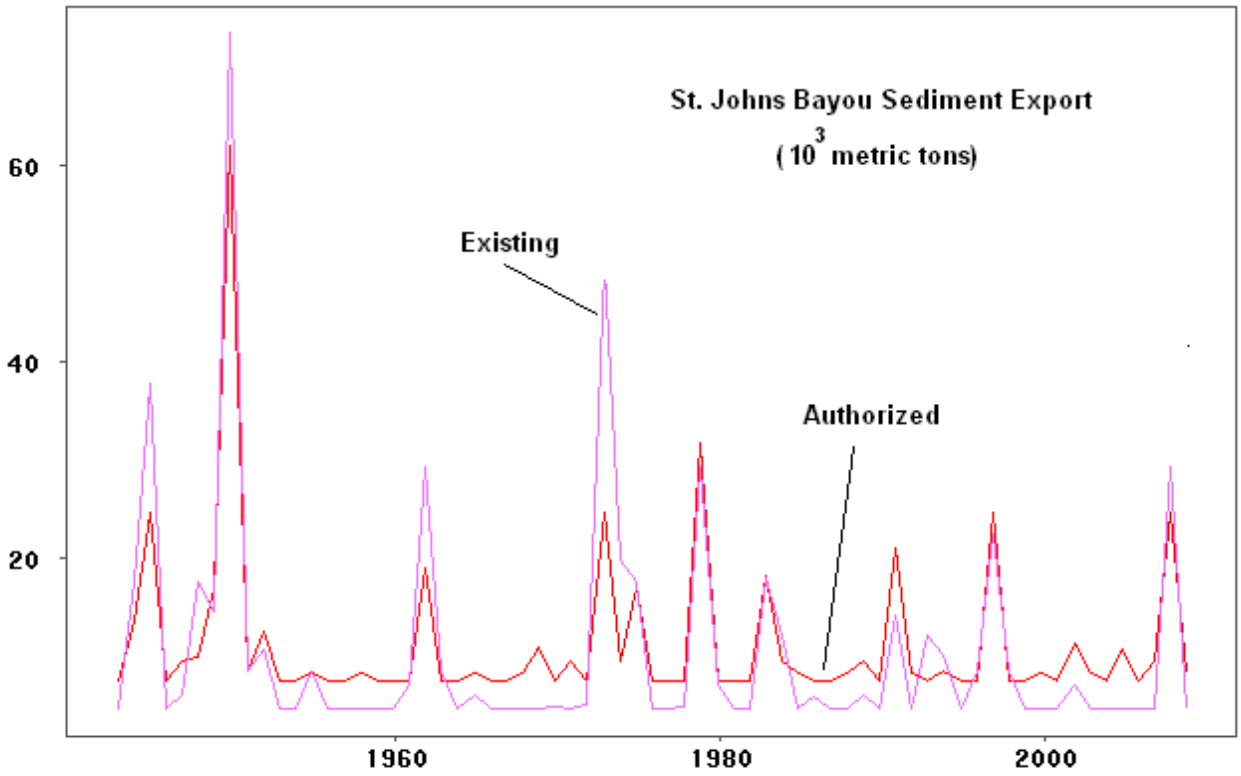

Figure 10. The expected export of sediment in thousands of metric tons per flood season (Nov-May) from the St. Johns Bayou for the period of record, 1943 to 2009. Existing conditions use the observed hydrograph to calculate expected transport. Simulated hydrographs were used to estimate export for the authorized project. The reforestation alternative does not apply to St. Johns Bayou.

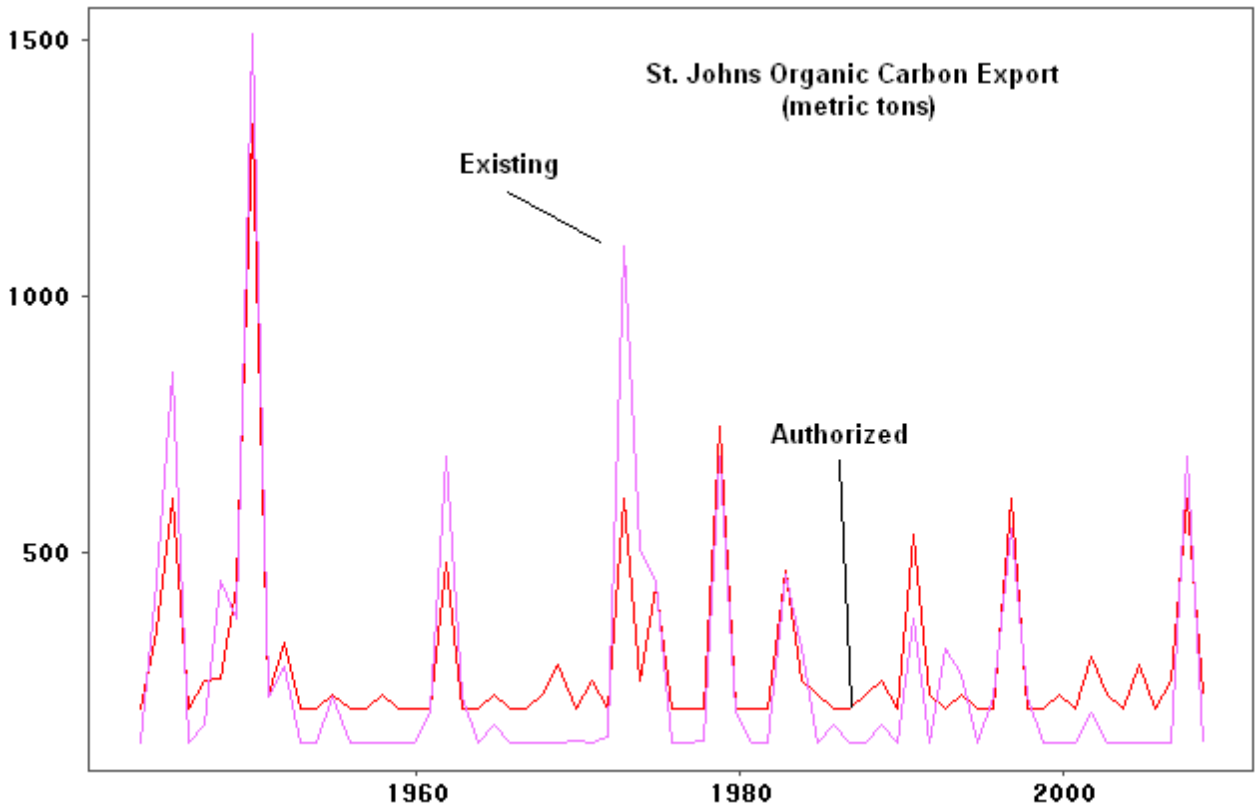

Figure 11 . The expected export of total organic carbon (TOC) in metric tons per flood season (Nov-May) from the St. Johns Bayou for the period of record, 1943 to 2009. Existing conditions use the observed hydrograph to calculate expected transport. Simulated hydrographs were used to estimate export for the authorized project. The reforestation alternative does not apply to St. Johns Bayou.

3.4 Potential Impacts of Authorized Project on Water Quality of the Mississippi River

The analysis by Ashby et al. (2000) concluded that the effects of the project on Mississippi River water quality would not be discernible and that conclusion is not altered by this revision to the analysis. The original conclusion was based on several lines of evidence; including (1) the ratio of project outflow volume to Mississippi River flow volume (< 1 percent), (2) the finding that the project would reduce the material load from the project area to the river relative to the existing condition, and (3) the finding that the project area would likely exhibit a net retention and processing of material that enters it from the Mississippi River, although there could be a small net loss of retention from Mississippi River water relative to the existing condition due to reductions in natural flooding. Ashby et al. (2000) used a mass balance approach to estimate potential impacts of the authorized project on the water quality of the Mississippi River as a percent decrease in material loading in the river relative to a moderate high flow condition. They found the material export for each constituent evaluated was 0.1 percent or less of the main river transport. This is consistent with water balances conducted for the project that indicated a ratio of basin water (22,840 cfs/day) to Mississippi River water (22,840 cfs/day + 4,000,000 cfs/day) equal to about 0.0057.

The project will tend to increase retention relative to the existing (without project condition), but overall the basin will still be an overall net exporter of these materials. The modeling study by Robertson et al. (2009) showed that the basin that includes the project area is the number two exporter (on an area basis) in the Mississippi-Atchafalaya basin so that the effects of the project to increase retention in this basin, particularly in the reforestation alternative (4.2), has the potential for significant, ecological benefits.

There is a potential that a change in flood timing under project operations would also reduce transport of material from the study area to the Mississippi River. The change in hydrology is expected to reduce the transport of particulate material from fallow agricultural lands, although an increase in soluble material could occur with inundation. Conversely, a reduction in backwater flooding from the Mississippi River would decrease

the retention of material that might otherwise be processed during flooding. Overall, therefore, the net effect on water quality in the Mississippi River should not be detectable.

3.5 Evaluation of Potential Changes in Pesticide Use on Water Quality

This segment of the previous study was not altered in this revision. Atrazine is still used extensively on crops within the project area and although USEPA has convened a Science Advisory Board to review the use of this pesticide in general, there is no indication that additional restrictions will be imposed on the use of atrazine in the near future. Based on information provided by the University of Missouri Delta Research and Extension Service, Ashby et al. (2000) estimated that 95 percent or more of the corn in the project area will be treated with atrazine at a rate of approximately 2 lb active ingredient per acre (ai/acre). Post-emergence application will be applied to approximately 75 percent and pre-emergence treatment rates will be between 1 and 2 lb ai/acre. About 50 percent of the land receiving pre-emergence treatments will likely receive a second application between 0.5 and 1.5 lb ai/acre. Farmers use arithmetic to keep total atrazine applications below 2.5 and 2 lb ai/acre on a single application.

The literature review by Ashby et al. (2000) indicated that the potential for unacceptable contamination of water resources from atrazine application to corn and corn/soybean rotation is limited (Ashby et al., 2000; Appendix D). The primary concern appears to be the relationship between application timing and precipitation frequency. The worse scenarios for surface-water contamination are high flow/precipitation immediately following the pesticide application. Groundwater concentrations appear to be maximal during precipitation events that produce little run off, at sites subjected to repeated (multi-year), high rates of atrazine application. However, because of the soil types that dominate the project area, infiltration or percolation of pesticides is expected to be of minor importance and the authorized project is therefore expected to have no effect on groundwater concentrations of pesticides. Changes in cropping practices within the project area in response to the project are not expected to alter this conclusion.

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3.6 Evaluation of Potential Impacts to Big Oak Tree State

The previous analyses by Ashby et al. (2000) that assessed the potential impacts of the authorized project on Big Oak Tree State Park are no longer applicable, as the planned operation of the project no longer includes pumping of groundwater to create seasonal flooding. Instead, the design now calls for reconnection of the Park with the main stem of the River so that the natural flooding regime is restored. A strong, positive effect of this on the ecology within the Park is anticipated. Further, because the Park will now serve as a trap (sink) for sediment and nutrients delivered from the Mississippi River main stem during natural high water, the plan for the Park under the authorized project will have a net positive (albeit non-detectable) influence on water quality in the Mississippi River. Because the effects on water quality are expected to be non-detectable, but positive, this revision did not explore this quantitatively.

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4 Discussion

This revision to the earlier work by Ashby et al. (2000) was not intended to fully repeat that entire effort, but rather to update and refocus portions of that work as newly available data and modifications to the project plan made this appropriate. Substantial portions of the earlier work are copied into this report (with minor changes as needed) so that this document will be better able to stand alone. For the most, very limited new data was uncovered in the revision process. However, a slightly more elaborate approach to analysis was taken so that updated land cover and actual or simulated daily water level information could be easily incorporated, explicitly, into the analyses.

Ashby et al. (2000) reviewed the existing water quality in the project area in detail and those findings were summarized or referenced here. There has been little water quality monitoring activity in the area since that earlier study, and no indication of substantial changes. Thus, it can be concluded that the existing water quality in the project area is still indicative of an agricultural landscape. General patterns of surface water quality include low to moderate nitrogen concentrations, relatively high phosphorus concentrations, moderate to high organic carbon concentrations, and low to moderate sediment concentrations. Increased concentrations of these constituents likely occur in storm runoff. Extreme values were most frequently observed in the vicinity of point sources.

Potential impacts of the project on the water quality of the Mississippi River appear to be minimal based on the assumptions used in the earlier analyses. The present work does not alter that conclusion; any changes in concentration of water quality constituents in the Mississippi River as a result of the project will not be discernible.

Likewise, the earlier work showed that project operations, or changes in agricultural practices as a result of project operations, are not expected to have a significant impact on pesticide concentrations (Ashby et al. 2000). We did not alter that finding in this revision.

Analysis indicates that the authorized project, with or without the avoid-and-minimize alternatives, generally reduces, or does not significantly alter, the export of materials from

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the project area into the Mississippi River. This is a generally positive ecological effect. Further, the limited water quality data that exists for water bodies within the project area give no indication that the project will degrade water quality in these water bodies. Consequently there is little to indicate that mitigation measures for water quality are needed. Mitigation measures associated with the project that are planned for habitat purposes are anticipated to have a water quality benefit as well.

The potential for negative impacts of the authorized project on Big Oak Tree State Park has been eliminated by a new design that now calls for expanding the area of natural vegetation and restoration of the natural flood regime within the Park by gravity flows of Mississippi River flood water into and out of the Park. Under this design, the park will trap beneficially some of the nutrients and most of the sediments delivered from the River. Although this will have a positive effect on the River and the Park, it will make no measurable change in water quality in the Mississippi River.

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5 Conclusions

5.1 Existing Water Quality Conditions and Impacts on the Mississippi River

The Water quality within the project area with the authorized project fully implemented should be similar to conditions that exist now. Existing water quality in the project area is still indicative of an agricultural landscape. There should be no effect of the project during periods of normal, low water. During high water, we anticipate that conditions will generally follow the pattern that is typical of naturally inundated flood plain areas. It is commonly assumed that naturally inundated flood plains are characterized by accumulation of floodwater sediment and nutrients. Further, increased water levels in pre-existing water levels and the influx of organic material in the flood waters will promote oxygen depletion, particularly in deeper locations.

Impacts to the water quality of the Mississippi River with the proposed or alternative project in place are not expected to be discernible. Overall, trapping of nutrient and sediments in the project area is expected to increase, so the effect of the project on Mississippi River water quality should be positive, but it will not be detectable.

5.2 Export of Materials

The effect of the authorized project on material transport varies among constituents and (to a lesser degree) among management scenarios (Figures 3-10). In general the project is expected to reduce, or not significantly alter, the export of nutrients, sediments, and organic carbon relative to the existing condition.

5.3 Pesticides

The impact of pesticides, atrazine in particular, on public groundwater resources is expected to be minimal. Furthermore, the impacts to shallow water resources, i.e., private wells, are also expected to be minimal. A greater potential exists for atrazine contamination to surface waters. The optimal method for reducing this likelihood is the

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implementation of BMPs. It is a feasible assumption that through adoption of BMPs, in combination with monitoring efforts, the atrazine contamination to water resources can be maintained below drinking water standards. A 5 percent increase in corn should not change the behavior of pesticide application and runoff, so conditions expected for increased acreage should be similar to existing conditions.

5.4 Big Oak Tree State Park

The restoration of a natural, flood-driven, hydrology to Big Oak Tree State Park is likely one of the most critical processes for the recovery and sustainability of the Park. Allowing gravity-driven flows of main stem River water to enter and exit the Park (as compared to ground water pumping) should have a strong, positive influence on the ecology of the Park, but the positive effects on Mississippi River water quality will be too small to detect.

5.5 Mitigation

Analysis indicates that the authorized project, with or without the avoid and minimize alternatives, generally reduces export of materials from the project area into the Mississippi River. This is a positive ecological effect. Further, the limited water quality data that exists for water bodies within the project area give no indication that the project will degrade water quality in these water bodies. Consequently there is little to indicate that mitigation measures for water quality are needed. Mitigation measures associated with the project that are planned for habitat purposes are anticipated to have a water quality benefit as well.

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Appendix A: SAS Program Code for Calculating Material Exports.

This appendix includes the actual SAS code used to calculate material export. Because Alternative 4.2 includes land use changes (i.e., reforestation) and affects the New Madrid Floodway only, a separate segment of code (included at the end of the listing) is used to calculate loads for this alternative.

To execute this code on a local installation of SAS software, minimal editing is required to accommodate local folder names etc. This code uses input from three sources:

1. Daily elevation spreadsheets. One each for the New Madrid Floodway and St. Johns Bayou. The spreadsheets must have a column for the date and a separate column for the observed or simulated water stages for each scenario. A separate elevation spreadsheet is used for alternative 4.2

2. Two land cover spreadsheets, showing the cumulative acreages of land types below each foot elevation contour. One spreadsheet is used for each basin. A separate land cover spreadsheet is used for alternative 4.2

3. Export and concentration coefficient files (%include), one file is used for each parameter. Examples of the %include files used for this analysis are reported in appendix B.

- This code was run on SAS software version 8, but should be compatible with any version of SAS/BASE

```
OPTIONS SOURCE;
*-------------------------------------------;
* Version 06/21/2011;
*-------------------------------------------;
*-----------------------------------------------------------------------------;
* THIS SAS PROGRAM RELIES HEAVILY ON MACROS AND MACRO-VARIABLES
* THIS MAKES THE MODULE EASY TO USE and FLEXIBLE.
* MOST OF THE MACRO VARIABLES THE USER MIGHT WANT TO CHANGE ARE DEFINED
* AT THE TOP OF CODE AND REASONABLY WELL DOCUMENTED;
*-----------------------------------------------------------------------------;

* The bulk of the processing section is wrapped in an Overarching Macro called CALC_ALL
* That starts near the top of code So that the user can easily specify and combine (i.e., MERGE)
* Multiple data step runs (at the bottom);

* The code uses a SEPARATE INCLUDE FILE:
* This auxiliary file contains ALL the export coefs used in the analysis. The
* Separate file allows you to EASILY use alternative Coefs.
* %Let statements let You Specify the Columns in the Daily Elevation Spreadsheets
```

```
* To be used in the Analysis. It requires both spreadsheets use the SAME NAMES for columns.
* You can CHANGE "existing" "Authorized" "Alt1" and "Alt2" in the next lines
* To match the spreadsheet, but you would probably do better
* to alter the SPREADSHEET to match this code!;
* ELEVATION COLUMNS IN THE SPREADSHEETS;
%Let A0 = Existing;
%Let AA = Authorized;
%Let A1 = ALT1;
%Let A2 = ALT2;
*DEFINE THE LOCAL PATH TO ALL YOUR INPUT DATA;
%Let Local_Path = D:\usr2\New_Madrid_St.Johns_Floodway\Data;
*DEFINE THE DAILY ELEVATION INPUT SPREADSHEETS for New Madrid and St. Johns;
%LET NM_Elev_XLS = &Local_Path\NMElev3.xls;
%LET STJ_Elev_XLS = &Local_Path\STJElev3.xls;
*DEFINE THE LANDCOVER INPUT SPREADSHEETS;
%LET NewMadridLandCover_XLS =&Local_Path\Landcover\NMLandcover1.xls;
%LET STJohnsLandcover_XLS =&Local_Path\Landcover\STJLandcover1.xls;
*DEFINE THE FILES THAT HOLD THE VARIOUS COEFS FOR EACH LOADING VARIABLE;
%LET TPcoefFile =&Local_Path\Include_Coefs\PhosphorusCoefs.txt;
%LET TNcoefFile =&Local_Path\Include_Coefs\NitrogenCoefs.txt;
%LET SEDcoefFile =&Local_Path\Include_Coefs\SedimentCoefs.txt;
%LET TOCcoefFile =&Local_Path\Include_Coefs\CarbonCoefs.txt;
*========== THIS ALLOWS OPTIONAL USE OF DRY LAND EXPORT (DEFAULT) ====================;
* THIS IS CONTROLLED BY THE UseDryLandExport macro variable set to 1(yes) or zero(no)
* When 1 (YES), we apply export coef ONLY to the land area above the flood contour
* This export contributes to the "Total Load" that is then subjected to Wetland function
*==================================================================================;
%Let UseDryLandExport=1; *YES;
*Let UseDryLandExport=0; *NO;
*==============================================================;
OPTIONS NOSOURCE;
%MACRO Calc_all(NMPROJ_ELEV, STJPROJ_ELEV, LoadVar1);
*Let LoadVar1 = &LoadingVar;
%put;
%Put Calculating Loads for Variable &LoadVar1 Using NM Elevation Data &NmProj_Elev ;
*
OVERVIEW: the approach is taken from the Ashby report and spreadsheets.
the central concept is to use two "phases" of export:
1. straight export coefficients that account for export and processing material from "dry land" cond
2. export "concentrations" that apply to flood volumes during inundation.
These coefs or concentrations are customized for differing landcover types within the project area
and are "pro rated" to adjust for the period of inundation.
This adjustment has involved expert opinion to consider seasonality of exports and the
fact that the period of interest (inundation) would be only a fraction of the year and
primarily in the colder months.
The amount (or concentration) that is "available" based on export coefs. and concentration is multip
by the area or the volume of water to calculate a potential export mass. The volume of water is the
peak volume (above flood stage) during the season.
The original analysis assumed water would reach 285 during season 1, and 280 in season 2 with the
project in place. These assumptions are OK for season 1, but underestimate the flood level
in season 2 based on the historic and simulated hydrographs. As a result, in this analysis we see
a much larger flood-related export of TP and other constituents during season 2 than Ashby estimated

To provide a "credit" for runoff material that is trapped during the inundation period the "dry land" export coef
(pro-rated for time) was applied to the area of inundation. The rationale
was that material that would otherwise drain from the area of inundation is now being trapped.
The delivery from the non-inundated portion of the watershed was NOT addressed in the original analysis
of Ashby et al., and so it underestimates the total export from the project area.

The total "delivered material for export" is adjusted by a "Wetland Function Factor" (WFF) to arrive
WFF is a fraction that represents the functioning of the subject land cover type when it is inundated
For example, the cover type might REMOVE 80 percent of the "available" export during inundation,
and this is expressed as a "Wetland Function Factor" of -.8.
If the wetland AUGMENTS the dry land export by 10%, then the WWF is +.1. This is a very rough approx
as it does not allow for variations in the area of land cover type that is inundated.
The spreadsheet approach assumes that the "net available" material during inundation is
fully exported from the system (i.e. into the River).
*==============================================================
Note for the import of Memphis spreadsheets,
```

```
They had to be processed a little to make them "SAS friendly" -
i.e., remove extra heading lines etc. and use nice column titles
that could easily become SAS variable names
*================================================================
;
* Macro will skip repeated import of spreadsheet elevation data
* (very slow) processing during development or exploration AND
* to allow user flexibility in designating files at the very top of code;
%Macro ImportElev(OutData1,sourceXLS);
%if %sysfunc(exist(&SourceXLS))=1 %then
%DO;
%Put Input File Does Not Exist: &SourceXLS;
%End;
%if %sysfunc(exist(Work.&OutData1)) = 0 %then
%Do;
%Put Importing Elevation Spreadsheet from &SourceXLS to Dataset &OutData1;
PROC IMPORT OUT= WORK.&OutData1
DATAFILE="&SourceXLS"
DBMS=EXCEL2000 REPLACE;
GETNAMES=YES;
RUN;
%end;
%Else %Put Elevation Data Already Available - Import Skipped;
%Mend ImportElev;
%ImportElev(NMElev1,&NM_ELEV_XLS);
%ImportElev(STJElev1,&STJ_ELEV_XLS);
*2. ------------ Process the Elevation Data -----------------;
* To generate 30-day inundation contours
*
* The original Spreadsheet approach assumed that "inundation" behavior
* started immediately at full force once an area was under water for 30 days.
* and continued that way until water receded. - We do not change that here
* The algorithm tracks duration of inundation at each 1 foot contour in 1 day time steps.
* A day is added to the duration in each contour below the current level of inundation.
* The duration is reset to zero in all contours ABOVE the current level of inundation.
* We then search through the contours (starting at the bottom) to find the level where
* duration drops below 30 days. There are simpler codes to do this
* but this seems very straight forward.
* The next step is to cross reference this level of inundation with the total area in each
* landcover type BELOW this level - this is GIS based info provided by Memphis District.
;
* Elevation Range within New Madrid is 263 to 299 MSL = 37 one foot increments;
* NEW MADRID:
*New Madrid and St.Johns have slightly different configurations and so are run in separate steps;
%Put NM Elevation in Dataset NMElev1b is &NMProj_ELEV;
Data NMelev1b;
array ElevW[37] ElevW263-ElevW299; * 1 foot contours with project;
array ElevWO[37] ElevWO263-ElevWO299; *1 foot contours without project;
retain elevW263-elevW299 0.0 elevWO263-elevWO299 0.0;
keep day date2 &A0 &NMProj_ELEV Elev30dW Elev30dWO ElevDiff;
format date2 mmddyy10.;
rename date2 = date;
SET nmelev1;
if &A0 ne .; * "existing" is water elevation w/o project;
date2 = datepart(date);
ElevIndexWO = int(&A0) - 262;
ElevIndexW = int(&NMPROJ_ELEV) - 262;
*put date2= +3 &A0= + 3 ElevIndex=;
do i = 1 to elevIndexW;
ElevW[i] = ElevW[i] + 1;
end;
do i = ElevIndexW+1 to 37;
ElevW[i] = 0;
end;
do i = 1 to elevIndexWO;
ElevWO[i] = ElevWO[i] + 1;
end;
do i = ElevIndexWO+1 to 37;
ElevWO[i] = 0;
```

```
end;
*now find the elevation where duration drops below 30 days;
*With project;
i = 1;
do while ((i < 37) and (elevW[i] > 29));
i = i + 1;
end;
Elev30dW = .;
if i > 1 then
Elev30dW = 261+i;
*now find the elevation where duration drops below 30 days;
*WithOUT project;
i = 1;
do while ((i < 37) and (elevWO[i] > 29));
i = i + 1;
end;
Elev30dWO = .;
if i > 1 then
Elev30dWO = 261+i;
ElevDiff = Elev30dW - Elev30dWO;
run;
*========= END NEW MADRID ELEVATIONS ================;
*================ Process St. Johns Elevation Data ================
* To generate 30-day inundation contours;
* THIS SETUP IS A LITTLE DIFFERENT FROM NEW MADRID - ELEVATIONS;
* Elevation Range in STJ is 260 to 299 = 40 one foot increments;
*==================================================================;
Data STJelev1b;
array ElevW[40] ElevW260-ElevW299;
array ElevWO[40] ElevWO260-ElevWO299;
retain elevW260-elevW299 0.0 elevWO260-elevWO299 0.0;
keep day date2 &A0 &STJProj_ELEV Elev30dW Elev30dWO ElevDiff;
format date2 mmddyy10.;
rename date2 = date;
SET STJelev1;
if &A0 ne .;
date2 = datepart(date);
ElevIndexWO = int(&A0) - 259;
ElevIndexW = int(&STJPROJ_ELEV) - 259;
do i = 1 to elevIndexW;
ElevW[i] = ElevW[i] + 1;
end;
do i = ElevIndexW+1 to 40;
ElevW[i] = 0;
end;
do i = 1 to elevIndexWO;
ElevWO[i] = ElevWO[i] + 1;
end;
do i = ElevIndexWO+1 to 40;
ElevWO[i] = 0;
end;
*now find the elevation where duration drops below 30 days;
*With project;
i = 1;
do while ((i < 40) and (elevW[i] > 29));
i = i + 1;
end;
Elev30dW = .;
if i > 1 then
Elev30dW = 258+i;
*now find the elevation where duration drops below 30 days;
*WithOUT project;
i = 1;
do while ((i < 40) and (elevWO[i] > 29));
i = i + 1;
end;
Elev30dWO = .;
if i > 1 then
Elev30dWO = 258+i;
```

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```
ElevDiff = Elev30dW - Elev30dWO;
run;
* ------------- END St. Johns Elevation Data ------------;
* ---------------------------------------------------------------------------------
* The GetPeak30DayElev macro is now used to skip processing if it is already complete,
* but more importantly, to centralize the code for finding seasonal PEAK inundation;
*-----------------------------------------------------------------------------------;
%Macro GetPeak30DayElev(seg);
* EXTRACT THE SEASONAL PEAKS of INUNDATION, with and without project;
* Cannot skip based on existance of Peaks, because Elev Var might change;
%if (%sysfunc(exist(Work.&seg.Peaks)) = 0) %then
%Do; %end;
%Put Calculating &Seg 30 day Peak Inundation Elev ;
Data &seg.Peaks;
set &seg.Elev1b;
retain oldseason 3 peakW peakWO 0;
keep date PeakW PeakWO Season;
seas = 3;
if (month(date) > 10) or (month(date) < 2) then seas = 1;
if (month(date) > 1) and (month(date) < 6) then seas = 2;
if seas ne oldseason then
do; *process the peak from the previous season;
if peakW < 281 then peakW = .;
if peakWo < 281 then peakWo = .;
Season = OldSeason;
if season < 3 then
output; *set to ignore "off season" floods;
peakW = 0;
peakWO = 0;
end;
if Elev30dW > PeakW then PeakW = Elev30dW;
if Elev30dWo > PeakWo then PeakWo = Elev30dWo;
oldseason = seas;
run;
*End;
*Else Put &Seg 30 day Peak Inundation Elev Already Calculated, Step Skipped;
%Mend GetPeak30dayElev;

%GetPeak30DayElev(NM);
%GetPeak30DayElev(STJ);

* Matching Landcover to the original analysis creates an issue because
the export coefs used by Steve Ashby are linked to landcover types
that do NOT match the landcover types provided by Memphis
So some recombinimg/recoding is required.
* Note that Ashby table 4 treats all "natural cover" the same:
(i.e., cypress/tupelo, scrub, marsh, bottomland hardwood) all have the
same wetland function factors. this carries through into the spreadsheets for nitrogen
check that this is also true for phos.
to keep things simple, we process the landcover in the steps that follow
We read in the land cover at each elevation - these are cumulative i.e. total landcover below a
certain elevations.
NOTE:
In winter (season 1) Nov-Feb, the PROJECT holds water for ducks etc.,
In spring and summer (season 2), natural flooding occurs from the Mississippi
(the project can clip the flood peaks).
Because of this clipping, in most summers the elev is lower with the proj. than without.
Ashby analysis split winter into two flood "seasons"
Season 1 is Nov-Jan - held water (internal source)
Season 2 is Feb-May - spring flood water from MissR.
We can ASSUME that the peak during each "season" is the "volume" that drains off and exports
P,N, Carbon. Steve assumed a specific "typical" elevation for the flood seasons. In this revision
we use actual (or simulated) data to get REAL about that, but its still a simplification.
Algorithm note: We step through the data, date by date. When season changes we process the
previous season (we will know the previous peak at that point) and start to capture the
peak for the new season. We actually have three seasons 1. Fall-Winter, 2. Winter-Spring,
and 3. Summer-fall. Bear in mind that seasons 1 and 2 are COLD.
;
```

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```
*PROCESS LANDCOVER
We Process the landcover and export conc/coefs into two "Lookup Tables",
one each for NM and STJ.
we then MERGE these with the peak Elevation dataset to calculate export;
* A Macro is used here to avoid repeated (very slow)processing of Excel spreadsheet
* During development or exploration;
%Macro ImportLandCover;
%if %sysfunc(exist(Work.NmLC)) = 0 %then
%Do;
%Put Importing the Land Cover Spreadsheets;
PROC IMPORT OUT= WORK.NMLC
DATAFILE="&NewMadridLandCover_XLS"
DBMS=EXCEL2000 REPLACE;
GETNAMES=YES;
RUN;
PROC IMPORT OUT= WORK.STJLC
DATAFILE= "&STJohnsLandcover_XLS"
DBMS=EXCEL2000 REPLACE;
GETNAMES=YES;
RUN;
%End;
%Else %Put *** Landcover Previously Input, Import Skipped ***;
%Mend ImportLandCover;
%ImportLandCover;


* Now rework the raw landcover input to get it into more useable form.
Keep in mind that stage below 280 in New Madrid is NON-Flooded
and can be treated as "dry land" conditions.
the original approach is to assume the cumulative acreage of each LC type
below the 30-day inundation level is the area that exports in a flood.
The original analysis uses static scenarios with the water reaching a specific elevation.
Consequently the "Volume" associated with the scenario is a simple constant.
Steve assumes that this volume reaches equilibrium with the designated concentration
and Wetland function factor.
Steve does not use acres directly in his spreadsheet to calculate volumes,
but rather uses a fraction of the total inundated area x the total inundated volume
to get the water volume associated with each inundated LC type. This does not fully
address the elevation distribution of the LC type because it assumes that
all inundated land has the same depth of overlying water.
We have the information (i.e., landcover below each 1 foot contour) to do a little better.
We multiply the area at each elev by the depth of water above it.
==========================================
L A N D C O V E R R E G R O U P I N G
==========================================
WE REGROUP the LC into the effective classes Ashby used as follows:
LC class Ashby Class
Corn RowCrop
Cotton RowCrop
Rice RowCrop
Soybeans Soybeans + XX to allow N behavior.
Wwheat RowCrop
WwheatSoy Mixed_Ag
Other_Ag Mixed_Ag??
Fallow Pasture
Forest Forest
Woody_Wet Forest
Developed Urban
Grass Pasture
HerbWetlands Water
Wetlands Water
Open_Water Water
ShrubLand Forest
Pasture Pasture
;
%Macro MakeLCAreasAndVolumes(seg);
* This Macro Calculates Landcover volumes below each elevation contour AND
* Reclassifies the Landcover into a rough match to original classes of Ashby
* See page 10 of ERDC report (2000).
```

```
* We must keep soybeans and soybean mixes separate to allow separate handling for nitrogen.
;
%*this "IF" was intended to prevent unnecessary re-runs of this code segment;
%*if %sysfunc(exist(Work.&seg.Volumes)) = 0 %then
%Do;
%Put Calculating &Seg Land Cover Flood Volumes and Areas;
Data _null_; *Extract the "grand total" area for each class - hold as Variables for later in Macro;
set &Seg.lc end=last;
if last then
do; *save the total acres of each LC as a macro variable for use in volume calc coming next;
call symput('ForestTotal',sum(forest, woody_wet, HerbWetlands, shrubland));*Acres;
call symput('RowCropTotal',sum(Corn,Cotton,WWheat,Rice));
call symput('WetlandTotal',Wetlands);
call symput ('SoybeanTotal',Soybeans);
call symput('NonRowCropTotal',Other_Ag);
call symput('PastureTotal',Sum(Pasture,Grass));
call symput('MixedAgtotal',Sum(WWheatSoy));
call symput('UrbanTotal',Developed);
call symput('UnfloodedTotal',Total);
end;
run;
Data &Seg.volumes;
* dz is one foot, so sum is acre-feet, our value of dz includes conversion to hm3
* volume is just the cumulative sum of areas x dz.;
* areas in THIS VERSION are the UNFLOODED areas that remaining at each elev for dry land export
* this is where the totals (Macro Variables) from immediately above are utilized;
* We hold the accumulating Volumes;
keep Elev_cuml Foresthm3 Wetlandhm3 rowcrophm3 nonrowcrophm3 soybeanhm3 pasturehm3 mixedaghm3 Urba
Forestha Wetlandha rowcropha nonrowcropha soybeanha pastureha mixedagha Urba
MaxHA;
retain Foresthm3 wetlandhm3 rowcrophm3 nonrowcrophm3 soybeanhm3 pasturehm3 mixedaghm3 Urbanhm3 Tot
dz 1.2335 e-3; *dz (1 foot) also converts acre-feet to cubic HM.;
SET &Seg.lc;
*Forest;
Incrmt = Forest + Woody_Wet + HerbWetlands + Shrubland;*combine Acreages;
%IF (&usedrylandexport = 1) %Then
%do;
Forestha = (&ForestTotal - Incrmt)*0.4047; *convert acres to HA;
%End;
%Else %do;
Forestha = (Incrmt)*0.4047; *convert acres to HA;
%End;
Foresthm3 = Foresthm3 + Incrmt*dz;
*Wetlands;
Incrmt = Wetlands;
%IF (&usedrylandexport = 1) %Then
%do;
WetlandHA = (&WetlandTotal - Incrmt)*0.4047;
%End;
%Else %do;
Wetlandha = Incrmt*0.4047;
%End;
Wetlandhm3 = WetlandHm3 + Incrmt*dz;
*RowCrop;
Incrmt = Sum(Corn,Cotton,WWheat,Rice);
%IF (&usedrylandexport = 1) %Then
%do;
RowCrophA = (&RowCropTotal- Incrmt)*0.4047;
%End;
%Else %do;
RowCrophA = (Incrmt)*0.4047;
%End;
Rowcrophm3 = RowCrophm3 + Incrmt*dz;
*Non RowCrop;
Incrmt = Other_Ag;
%IF (&usedrylandexport = 1) %Then
%do;
NonRowCropHA = (&NonRowCropTotal-Incrmt)*0.4047;
%end;
```

```
%Else %do;
NonRowCropHA = (Incrmt)*0.4047;
%End;
NonRowCrophm3 = NonRowCrophm3 + Incrmt*dz;
*Soybeans;
incrmt = Soybeans;
%IF (&usedrylandexport = 1) %Then
%do;
SoyBeanHA = (&SoyBeanTotal-Incrmt)*0.4047;
%End;
%Else %Do;
SoybeanHA = Incrmt*0.4047;
%End;
SoybeanHm3 = SoybeanHm3 + Incrmt*dz;
*Pasture;
Incrmt = Sum(Pasture,Grass);
%IF (&usedrylandexport = 1) %Then
%do;
PastureHA = (&PastureTotal - Incrmt)*0.4047;
%End;
%Else %Do;
PastureHA = (Incrmt)*0.4047;
%End;
Pasturehm3 = Pasturehm3 + Incrmt*dz;
*Mixed Ag;
Incrmt = WWheatSoy;
%IF (&usedrylandexport = 1) %Then
%do;
MixedAgHA = (&MixedAgTotal - Incrmt)*0.4047;
%end;
%Else %Do;
MixedAgHA = (Incrmt)*0.4047;
%end;
MixedAghm3 = MixedAghm3 + Incrmt*dz;
*WATER;
*Water = Waterhm3 + (Wetlands + Open_Water)*dz;
*Urban;
Incrmt = Developed;
%IF (&usedrylandexport = 1) %Then
%do;
UrbanHA = (&UrbanTotal - Incrmt)*0.4047;
%End;
%Else %Do;
UrbanHA = (Incrmt)*0.4047;
%End;
Urbanhm3 = UrbanHm3 + Developed*dz;
*TOTAL;
Incrmt = Total;
%IF (&usedrylandexport = 1) %Then
%do;
TotalHA = (&UnfloodedTotal - Incrmt)*0.4047;
%End;
%Else %Do;
TotalHA = (Incrmt)*0.4047;
%end;
MaxHA = &UnfloodedTotal * 0.4047;
Totalhm3 = Totalhm3 + Incrmt*dz;
rename Elev_cuml = PeakElev;
run;
%*%End;
%*%Else %Put &Seg LandCover Flood Volumes and Areas Previously Calculated;
%Mend MakeLCAreasAndVolumes;
%MakeLCAreasAndVolumes(NM);
%MakeLCAreasAndVolumes(STJ);
*==============================================================================
NOW WE ARE READY TO DO THE FINAL CALCULATIONS USING THE PROCESSED INPUT DATA
WE First define the Flood Concentrations (mg/L) with Suffix C
and non-flood export coefficients (kg/ha/season) with suffix X
AND WETLAND FUNCTION FACTORS (WWF)
```

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```
The Suffix 1 or 2 on Macro names refers to Season
THESE ALL COME FROM EXTERNAL FILES TO KEEP THIS CODE A LITTLE NEATER
*==============================================================================
;
%Put;
%Put ==== Reading Coefs from Include Files =====;
%Put;
*=======================================;
* T O T A L P H O S P H O R U S
*=======================================;
%Put Phosphorus Coefs;
%Include "&TPcoefFile" ;
*=======================================;
* T O T A L N I T R O G E N
*=======================================;
%Put Nitrogen Coefs;
%Include "&TNcoefFile";;
*=======================================;
* O R G A N I C C A R B O N
*=======================================;
%Put TOC Coefs;
%Include "&TOCCoefFile";
*=======================================;
* S E D I M E N T
*=======================================;
%Put Sediment Coefs;
%Include "&SEDCoefFile";
%Macro GetExports(Seg,FluxVar,OutData,PeakVar,SeasX);
*seg is segment 'NM' or 'STJ';
*FluxVar is TP, TN, OC, or SED;
*Seasx is season 1 or 2;
* Create Generic Versions of Datasets for the Merge
* This allows TEMPORARY modifications and simplifies coding;
Data ForMerge1; * Use this approach to leave Orig. Dataset Alone and rename Elev to PeakVar;
set &seg.volumes; * resulting dataset has flood volumes and UNFLOODED areas for each LC type;
rename PeakElev = &PeakVar;
run;
%Put Creating &Seg Merge File for Season &Seasx and Flood Elev. &PeakVar with Use Dry Land = &UseDry
Data ForMerge2;
set &seg.Peaks;
if (Season=&seasx);
%If &UseDryLandExport=1 %then
%Do; *Force value to MAX dry land;
if &PeakVar = . then
do;
*put "Fixing missing Value for &PeakVar";
&PeakVar = 281;
end;
%End;
RUN;
*Prepare to Merge (Look up) landcover values to Associate with Time series of Peak Elevations;
proc sort data=ForMerge1; by &PeakVar; run;
proc sort data=ForMerge2; by &PeakVar; run;
* This Step generates an export dataset using the record of PEAK volumes and associated,
* non-flooded areas;
* Note that in season 1 (fall) there is almost NEVER any flooding without the project;
%Put Creating Season &SeasX Export of &LoadVar1 (&Outdata) by Merging Peak Flood with LC Export x El
data &OutData;
keep
Year date Season &PeakVar
Forestkg
Wetlandkg
RowCropkg
NonRowCropkg
Soybeankg
Pasturekg
MixedAgkg MixedAgHm3
ForestHa
RowCropHA
```

```
SoybeanHA
Urbankg Totalkg
TotKgPerHA
;
* ONE = season1 = Nov-Jan - held water (internal source)
* TWO = season2 = Feb-May - spring flood water from MissR.)
* PeakVar is either PeakW or PeakWO
* ForMerge1 is Landcover areas/volumes and ForMerge2 is the Seasonal Flood Peaks for Each year;
* Note that the MINIMUM flood peak isforced to 281 (forces maximum dry land);
;
merge ForMerge2(in=keeper) ForMerge1; by &PeakVar; if keeper;
if &PeakVar < 281 then
Do;
Foresthm3 = 0;
Wetlandhm3 = 0;
Rowcrophm3 = 0;
NonRowCrophm3 = 0;
Soybeanhm3 = 0;
Pasturehm3 = 0;
MixedAghm3 = 0;
*Water = 0;
Urbanhm3 = 0;
Totalhm3 = 0;
end;
* following uses seg, fluxvar, and seasx to define the macro
* to use - so triple &&& is needed for double substitution;
* in season 1 there is almost Never any flooding without project;
*the volumes and non-flooded areas are "picked" from the ForMerge Dataset;
*FOREST LOAD;
FloodLoad = foresthm3*&&&seg.Forest&fluxVar.C&seasx;*Vol x Conc;
NonFloodLoad = 0.5 * &&&Seg.Forest&FluxVar.X&seasx*(ForestHA); *Area x Export Coef;
WetlandEffect = (FloodLoad + NonfloodLoad)* &&&Seg.Forest&FluxVar.WFF&seasx;
Forestkg = FloodLoad + NonFloodLoad + WetlandEffect;
*Forestkg = foresthm3 *&&&seg.Forest&fluxVar.X&seasx *&&&seg.Forest&FluxVar.WFF&seasx;
*WETLAND LOAD;
FloodLoad = Wetlandhm3*&&&seg.Wetland&FluxVar.C&seasx;
NonFloodLoad = 0.5 * &&&Seg.Wetland&FluxVar.X&seasx*(WetlandHA); *Area x Export Coef;
WetlandEffect = (FloodLoad + NonfloodLoad)* &&&Seg.Wetland&FluxVar.WFF&seasx;
Wetlandkg = FloodLoad + NonFloodLoad + WetlandEffect;
*ROW CROP LOAD;
FloodLoad = RowCrophm3*&&&seg.RowCrop&fluxVar.C&seasx; *Vol x Conc;
NonFloodLoad = 0.5 * &&&Seg.RowCrop&FluxVar.X&seasx*(RowCropHA); *Area x Export Coef;
WetlandEffect = (FloodLoad + NonfloodLoad)*&&&Seg.RowCrop&FluxVar.WFF&seasx;
RowCropkg = FloodLoad + NonFloodLoad + WetlandEffect;
*RowCropkg = Rowcrophm3 *&&&seg.RowCrop&FluxVar.X&seasx *&&&seg.RowCrop&FluxVar.WFF&seasx
*NON ROW CROP LOAD;
FloodLoad = NONRowCrophm3*&&&seg.NONRowCrop&fluxVar.C&seasx;*Vol x Conc;
NonFloodLoad = 0.5 * &&&Seg.NONRowCrop&FluxVar.X&seasx*(NONRowCropHA); *Area x Export Coef;
WetlandEffect = (FloodLoad + NonfloodLoad)*&&&Seg.NONRowCrop&FluxVar.WFF&seasx;
NONRowCropkg = FloodLoad + NonFloodLoad + WetlandEffect;
*NonRowCropkg = NonRowcrophm3*&&&seg.NonRowCrop&FluxVar.X&seasx*&&&seg.NonRowCrop&FluxVar.WFF&se
*SOYBEAN LOAD;
FloodLoad = SoyBeanhm3*&&&seg.SoyBean&fluxVar.C&seasx;*Vol x Conc;
NonFloodLoad = 0.5 * &&&Seg.Soybean&FluxVar.X&seasx*(SoybeanHA); *Area x Export Coef;
WetlandEffect = (FloodLoad + NonfloodLoad)*&&&Seg.Soybean&FluxVar.WFF&seasx;
Soybeankg = FloodLoad + NonFloodLoad + WetlandEffect;
*PASTURE LOAD;
FloodLoad = Pasturehm3*&&&seg.Pasture&fluxVar.C&seasx;*Vol x Conc;
NonFloodLoad = 0.5 * &&&Seg.Pasture&FluxVar.X&seasx*(PastureHA); *Area x Export Coef;
WetlandEffect = (FloodLoad + NonfloodLoad)*&&&Seg.Pasture&FluxVar.WFF&seasx;
Pasturekg = FloodLoad + NonFloodLoad + WetlandEffect;
*Pasturekg = Pasturehm3 *&&&seg.Pasture&FluxVar.X&seasx *&&&seg.Pasture&FluxVar.WFF&seasx
*MIXED AG LOAD;
FloodLoad = MixedAghm3*&&&seg.MixedAg&fluxVar.C&seasx;*Vol x Conc;
NonFloodLoad = 0.5 * &&&Seg.MixedAg&FluxVar.X&seasx*(MixedAgHA); *Area x Export Coef;
WetlandEffect = (FloodLoad + NonfloodLoad)*&&&Seg.MixedAg&FluxVar.WFF&seasx;
MixedAgkg = FloodLoad + NonFloodLoad + WetlandEffect;
*MixedAgkg = MixedAghm3 *&&&seg.MixedAg&FluxVar.X&seasx *&&&seg.MixedAg&FluxVar.WFF&seasx
*URBAN LOAD;
```

```
FloodLoad = URBANhm3*&&&seg.URBAN&fluxVar.C&seasx;*Vol x Conc;
NonFloodLoad = 0.5 * &&&Seg.URBAN&FluxVar.X&seasx*(URBANHA); *Area x Export Coef;
WetlandEffect = (FloodLoad + NonfloodLoad)*&&&Seg.URBAN&FluxVar.WFF&seasx;
URBANkg = FloodLoad + NonFloodLoad + WetlandEffect;
*Urbankg = Urbanhm3 *&&&seg.Urban&FluxVar.X&seasx *&&&seg.Urban&FluxVar.WFF&seasx;
*TOTAL LOADS;
Totalkg = Sum(Forestkg,Rowcropkg,nonrowcropkg,Soybeankg,Pasturekg,MixedAgkg,urbankg);
TotKgPerHA = Totalkg/MaxHa;
Year = Year(date);
*if (&PeakVar ne . )then;
output;
RUN;
proc sort data=&OutData; by date; run;
* Do not need to delete ForMerge because we create it fresh each time;
* proc datasets lib=work;
* delete forMerge;
* run;
%Mend getExports;
*=================================================================;
*USE Single MACRO CALL TO PERFORM ALL THE CALCULATIONS for One Basin ;
*=================================================================;
%MACRO RunBasinExports(BasinID,Load);
%Let OutSet1 = &BasinID&Load;
%Put Calc. &Load Exports for &BasinId with Output to &OutSet1;
* FIRST, GET THE "WITHOUT" CONDITION;
%GetExports(&BasinID,&Load,&OutSet1._WO1,PeakWO,1);
%GetExports(&BasinID,&Load,&OutSet1._WO2,PeakWO,2);
*Prepare to Merge Season1 and Season2 results;
proc sort data=&OutSet1._wo1; by year season; run;
proc sort data=&OutSet1._wo2; by year season; run;
Data ExportWo;
merge &Outset1._wo1 &Outset1._wo2; by year season;
run;
*Now Sum across the two seasons;
proc sort data=ExportWo; by year;
proc means data=ExportWo noprint;
var totalkg ;*totkgperHa;
by year ;
output out=Mean_ExportWo sum = totalkgWo;
run;
*Second, GET THE "WITH PROJECT" ALTERNATIVE CONDITION for two seasons;
%GetExports(&BasinID,&LoadVar1,&OutSet1._W1,PeakW,1);*number is season;
%GetExports(&BasinID,&LoadVar1,&OutSet1._W2,PeakW,2);
*Prepare to Merge Season1 and Season2 results;
proc sort data=&OutSet1._w1; by year season; run;*Season 1;
proc sort data=&OutSet1._w2; by year season; run;*Season 2;
Data ExportW;
merge &OutSet1._w1 &OutSet1._w2; by year season;
run;
*Now Sum Across the Two Seasons;
proc sort data=ExportW; by year;
proc means data=ExportW noprint;
var totalkg ;*totkgperHa;
by year ;
output out=Mean_ExportW
sum = totalkgW;
run;
* Combine With and Without into One;
proc sort data=Mean_ExportW; by year; run;
proc sort data=Mean_ExportWo; by year; run;
Data Mean_Export&OutSet1;
merge Mean_exportW Mean_ExportWo;
by year;
drop _type_ _freq_;
if totalkgwo = . then totalkgwo=0;
run;
Title1 "Summary of Annual Mean &LoadVar1 Export from &BasinID";
Title2 "With and Without Alternative (&&&BasinID.Proj_Elev)";
proc means min max mean n data=mean_export&outset1;run;
```

```
Data &Outset1&&&BasinId.Proj_Elev; *BasinID + LoadVar + ELEV colmn;
set Mean_Export&OutSet1;
rename totalkgW = &Outset1&&&BasinId.Proj_Elev
totalkgWo = &Outset1.WO;
run;
%Mend RunBasinExports;
* Now run the two basins ;
* the next call creates TWO basin(2) x Elev_scenario(1) x exportvar(1) datasets;
options pageno = 1;
%RunBasinExports(NM,&LoadVar1);
%RunBasinExports(STJ,&LoadVar1);
* Now Sort the two basin datasets just created to allow merging by year
* Into a SINGLE, two-basin, elevation scenario;
Proc sort data=NM&LoadVar1&&NMProj_Elev; by year; run;
Proc sort data=STJ&LoadVar1&&STJProj_Elev; by year; run;
*NOW PERFORM THE MERGE;
Data Both&LoadVar1&&NMProj_Elev;
merge NM&LoadVar1&&NMProj_Elev STJ&LoadVar1&&STJProj_Elev; by year;
run;
%Mend Calc_All;
* The FinalMerger macro is used to allow the automatic merger of datasets
* from multiple consecutive runs (i.e., different loading variables, differing elev scenarios;
%Macro FinalMerger(LoadVar1,ELEV1,ELEV2,ELEV3);
%Put Creating ALL&LoadVar1 from;
%Put Both&LoadVar1&Elev1 Both&LoadVar1&Elev2 and Both&LoadVar1&Elev3;
Proc sort data=Both&LoadVar1&Elev1; by year; run;
Proc sort data=Both&LoadVar1&Elev2; by year; run;
Proc sort data=Both&LoadVar1&Elev3; by year; run;
Data All&LoadVar1;
Merge
Both&LoadVar1&Elev1
Both&LoadVar1&Elev2
Both&LoadVar1&Elev3;
by year;
run;
*Proc insight data=ALL&LoadVar1; *run;
%Mend FinalMerger;
%MACRO MakeFinalDataset(LV);
%CALC_ALL(&AA,&AA,&LV); * authorized project should be called first;
%CALC_ALL(&A1,&AA,&LV); * Only NM cares about ALT1, STJ stays with "Authorized";
%CALC_ALL(&A2,&AA,&LV); * Only NM cares about ALT2, STJ stays with "Authorized";
*Call FinalMerger to Generate Single Dataset for two Alternatives AND one Load Variable;
%FinalMerger(&LV,&AA,&A1,&A2);
%Mend MakeFinalDataSet;
%MakeFinalDataSet(TP);
%MakeFinalDataSet(TN);
%MakeFinalDataSet(TOC);
%MakeFinalDataSet(SED);


*-------------------------------------------------;
```

DRAFT

```
****** Version 05/1/2012 *****
*-----------------------------------------------------------------------------------------
* Alternative 4a - NEW MADRID ONLY *
* this code is derived from the segment above and is very similar
* it has been altered slightly to process the different land cover and
* to eliminate St. Johns Bayou (not part of Alternative 4.2)
*-----------------------------------------------------------------------------------------

* THIS SAS PROGRAM RELIES HEAVILY ON MACROs AND MACRO-VARIABLES TO MAKE IT
* FLEXIBLE FOR THE USER.  MOST OF THESE ARE DEFINED AT THE TOP OF THE CODE SEGMENT
* AND ARE REASONABLY WELL DOCUMENTED AS YOU GO THROUGH;


*================ THIS VERSION CAN USE EXPLICIT DRY LAND EXPORT =======================;
* THIS IS CONTROLLED BY THE UseDryLandExport macro variable set to 1(yes) or zero(no)
* When 1 (YES), we apply export coef ONLY to the land area above the flood contour
* This export contributes to the "Total Load" that is then subjected to Wetland function.

*NB: This calculates loads for the "WINTER" seasons of Ashby only - it ignores the low water period
of June-October (5 months) - we COULD assume no export, but the intent is to COMPARE alternatives.

*==================================================================================;
%Let UseDryLandExport=1; *YES;
*Let UseDryLandExport=0; *NO;



*DEFINE THE DAILY ELEVATION INPUT SPREADSHEETS for New Madrid and St. Johns;
%LET NM_Elev_XLS = C:\A_D\usr2\WOTS_DOTS\New_Madrid_St.Johns_Floodway\2012\Data\NMElev4.xls;
%Let NM_LC_XLS   = C:\A_D\usr2\WOTS_DOTS\New_Madrid_St.Johns_Floodway\2012\Data\NMLandcover1b.xls;

*Specify the name of the "With PROJECT" elevation column
           that you wish to compare to the "EXISTING" column
           NOTE THAT COLUMN LABELED "EXISTING" is required!;

* WITH EXISTING PGM STRUCTURE YOU MUST RESTART SAS FOR EACH ALTERNATIVE
*%LET NMPROJ_ELEV=Alt4;*WithProj; *NEW MADRID Alternative 4;
%LET NMPROJ_ELEV=Alt1;
*%LET NMPROJ_ELEV=Alt2;

*NOTE - the loading Variable is USED in the Macro Call at the very end
*%Let LoadName = TP; *define the loading variable TP,TN,SED,TOC;
*%Let LoadName = TN; *define the loading variable TP,TN,SED,TOC;
*%Let LoadName = SED; *define the loading variable TP,TN,SED,TOC;
*%Let LoadName = TOC; *define the loading variable TP,TN,SED,TOC;

%Let CoefPath = C:\A_D\usr2\WOTS_DOTS\New_Madrid_St.Johns_Floodway\2012\SAS\Include_Coefs;

options NOsource;
*

OVERVIEW:  the approach is taken from the Ashby report and spreadsheets.
the central concept is to use two "phases" of export:
1. straight export coefficients that account for export and processing material from "dry land" conditions
2. export "concentrations" that apply to flood volumes during inundation.
These coefs or concentrations are customized for differing landcover types within the project area
and are "pro rated" to adjust for the period of inundation.
This adjustment has involved expert opinion to consider seasonality of exports and the
fact that the period of interest (inundation) would be only a fraction of the year and
primarily in the colder months.

The amount (or concentration) that is "available" based on export coefs. and concentration is multiplied
by the area or the volume of water to calculate a potential export mass. The volume of water is the
peak volume (above flood stage) during the season.

The original analysis assumed water would reach 285 during season 1, and 280 in season 2 with the
```

```
project in place.  These assumptions are OK for season 1, but underestimate the flood level
in season 2 based on the historic and simulated hydrographs. As a result, in this analysis we see
a much larger flood-related export of TP and Other constituents? during season 2 than Ashby estimated.

To provide a "credit" for runoff material that is trapped during the inundation period in the orig. analysis,
the "dry land" export coef (pro-rated for time) was applied to the area of inundation.  The rationale for
this
is that material that would otherwise drain from the area of inundation is now being trapped.
The delivery from the non-inundated portion of the watershed was NOT addressed in this original
approach, and so underestimates the total export from the project area.

The total "delivered material for export" is adjusted by a "Wetland Function Factor" (WFF) to arrive at net

export.
WFF is a fraction that represents the functioning of the subject landcover type when it is inundated.
For example, the cover type might REMOVE 80 percent of the "available" export during inundation,
and this is expressed as a "Wetland Function Factor" of -.8.
If the wetland AUGMENTS the dryland export by 10%, then the WWF is +1.1.  This is a very rough approximation
as it does not allow for variations in the area of landcover type that is inundated.

The spreadsheet approach assumes that the "net available" material during inundation is
fully exported from the system (i.e. into the River).

*==================================================================

Note for the import of Memphis spreadsheets,
They had to be processed a little to make them "SAS friendly" -
i.e., remove extra heading lines etc. and use nice column titles
that could easily become SAS variable names

*==================================================================
;

* Macro is used for the import of spreadsheet elevation data to avoid repeated
* (very slow) processing during development or exploration AND
* to allow user flexibility in designating files at the very top of code;

%Macro ImportElevXLS(OutData1,sourceXLS);
%if %sysfunc(exist(&SourceXLS))=1 %then
%DO;
  %Put Input File Does Not Exist: &SourceXLS;
  %End;
%if %sysfunc(exist(Work.&OutData1)) = 0 %then
%Do;
 %Put Importing Elevation Spreadsheet from &SourceXLS to Dataset &OutData1;
 PROC IMPORT OUT= WORK.&OutData1
            DATAFILE="&SourceXLS"
            DBMS=EXCEL2000 REPLACE;
     GETNAMES=YES;
 RUN;
%end;
%Else %Put Elevation Data Already Available - Import Skipped;
%Mend ImportElevXLS;

%ImportElevXLS(NMElev1,&NM_Elev_XLS);

*%ImportElevXLS(STJElev1,&STJ_ELEV_XLS);



*2.   ------------ Process the Elevation Data -----------------
*               To generate 30-day inundation contours
*
* The original Spreadsheet approach assumed that "inundation" behavior
* started immediately at full force once an area was under water for 30 days.
* and continued that way until water receeded. - We do not change that here

* The algorithm tracks duration of inundation at each 1 foot contour in 1 day time steps.
* A day is added to the duration in each contour below the current level of inundation.
```

```
* The duration is reset to zero in all contours ABOVE the current level of inundation.
* We then search through the contours (starting at the bottom) to find the level where
* duration drops below 30 days. There are simpler codes to do this
* but this seems very straight forward.

* The next step is to cross reference this level of inundation with the total area in each
* landcover type BELOW this level - this is GIS based info provided by Memphis District.
;


* Elevation Range within New Madrid is 263 to 299 MSL = 37 one foot increments;


* NEW MADRID:
*New Madrid and St.Johns have slightly different configurations
and so are run in separate steps;

Data NMelev1b;
  array ElevW[37] ElevW263-ElevW299; * 1 foot contours with project;
  array ElevWO[37] ElevWO263-ElevWO299; *1 foot contours without project;
  retain elevW263-elevW299 0.0 elevWO263-elevWO299 0.0;

  keep day date2 existing &NMProj_ELEV Elev30dW Elev30dWO ElevDiff;
  format date2 mmddyy10.;
  rename date2 = date;

  SET nmelev1;
  if existing ne .; * "existing" is water elevation w/o project;
  date2 = datepart(date);
  ElevIndexWO  = int(existing) - 262;
  ElevIndexW   = int(&NMPROJ_ELEV) - 262;
  *put date2= +3 Existing= + 3 ElevIndex=;
  do i = 1 to elevIndexW;
    ElevW[i] = ElevW[i] + 1;
    end;
  do i = ElevIndexW+1 to 37;
    ElevW[i] = 0;
        end;
  do i = 1 to elevIndexWO;
    ElevWO[i] = ElevWO[i] + 1;
    end;
  do i = ElevIndexWO+1 to 37;
    ElevWO[i] = 0;
        end;
*now find the elevation where duration drops below 30 days;
*With project;
i = 1;
do while ((i < 37) and (elevW[i] > 29));
  i = i + 1;
  end;
Elev30dW = .;
if i > 1 then
Elev30dW = 261+i;

*now find the elevation where duration drops below 30 days;
*WithOUT project;
i = 1;
do while ((i < 37) and (elevWO[i] > 29));
  i = i + 1;
  end;
Elev30dWO = .;
if i > 1 then
Elev30dWO = 261+i;
ElevDiff    = Elev30dW - Elev30dWO;
run;
*========= END NEW MADRID ELEVATIONS ================;
```

DRAFT

```
* The GetPeak30DayElev macro is now used to skip processing if it is already complete,
* but more importantly, to centralize the code for finding seasonal PEAK inundation;

%Macro GetPeak30DayElev(seg);
* EXTRACT THE SEASONAL PEAKS of INUNDATION, with and without project;
%if %sysfunc(exist(Work.&seg.Peaks)) = 0 %then
%Do;
 %Put Calculating &Seg 30 day Peak Inundation Elev;
 Data &seg.Peaks;
  set &seg.Elev1b;
  retain oldseason 3 peakW peakWO 0;
  keep date PeakW PeakWO Season;
  seas = 3; *default;
  if (month(date) > 10) or (month(date) < 2) then seas = 1;
  if (month(date) > 1) and (month(date) < 6) then seas = 2;
  if seas ne oldseason then
  do; *process the peak from the previous season;
    if peakW  < 281  then peakW  = .;
        if peakWo < 281  then peakWo = .;
        Season = OldSeason;
        if season < 3 then
    output; *set to ignore "off season" floods;
        peakW = 0;
    peakWO = 0;
    end;
  if Elev30dW  > PeakW  then PeakW  = Elev30dW;
  if Elev30dWo > PeakWo then PeakWo = Elev30dWo;
  oldseason = seas;
  run;
  %End;
  %Else %Put &Seg 30 day Peak Inundation Elev Already Calculated, Step Skipped;
%Mend GetPeak30dayElev;

%GetPeak30DayElev(NM);
*%GetPeak30DayElev(STJ);



* Matching Landcover to the original analysis creates an issue because
  the export coefs used by Steve Ashby are linked to landcover types
  that do NOT match the landcover types provided by Memphis
  So some recombinimg/recoding is required.



* Note that Ashby's table 4 treats all "natural cover" the same:
  (i.e., cypress/tupelo, scrub, marsh, bottomland hardwood) all have the
  same wetland function factors.  this carries through  into the spreadsheets for nitrogen
  check that this is true for phos also


to keep things simple, we process the landcover in the steps that follow
We read in the land cover at each elevation - these are cumulative i.e. total landcover below a
certain elevations.

NOTE:
  In early winter (season 1)  Nov-Feb, the PROJECT holds water for ducks etc.,
  In late winter-spring and summer (season 2), natural flooding occurs from the Mississippi
  (the project can clip the flood peaks).
  Because of this clipping, in most summers the elev is lower with the proj. than without.

  Ashby's analysis split winter into two "seasons"
  Season 1 is Nov-Jan - held water (internal source)
  Season 2 is Feb-May - spring flood water from MissR.

  We can ASSUME that the peak during each "season" is the "volume" that drains off and exports
  P,N, Carbon. Steve assumed a specific "typical" elevation for the flood seasons.  In this revision
  we use actual (or simulated) data to get REAL about that, but its still a simplification.
```

```
  Algorithm note:  We step through the data, date by date.  When season changes we process the
  previous season (we will know the previous peak at that point) and start to capture the
  peak for the new season.  We actually have three seasons 1. Fall-Winter, 2. Winter-Spring,
  and 3. Summer-fall.  Bear in mind that seasons 1 and 2 are COLD.;

*PROCESS LANDCOVER
 We Process the landcover and export conc/coefs into two "Lookup Tables",
 one each for NM and STJ.
 we then MERGE these with the peak Elevation dataset to calculate export;

* A Macro is used here to avoid repeated (very slow)processing of Excel spreadsheet
* During development or exploration;

%Macro ImportLandCoverXLS;
%if %sysfunc(exist(Work.NmLC)) = 0 %then
%Do;
 %Put Importing the Land Cover Spreadsheets;

  PROC IMPORT OUT= WORK.NMLC
        DATAFILE= "&NM_LC_XLS"
        DBMS=EXCEL2000 REPLACE;
        GETNAMES=YES;
  RUN;
/*
  PROC IMPORT OUT= WORK.STJLC
            DATAFILE= "D:\usr2\New_Madrid_St.Johns_Floodway\New_Analyses\Landcover\STJLandcover1.xls"
            DBMS=EXCEL2000 REPLACE;
     GETNAMES=YES;
  RUN;
*/
  %End;
 %Else %Put ***  Landcover Previously Input, Import Skipped ***;
%Mend ImportLandCoverXLS;

%ImportLandCoverXLS;

* Now rework the raw landcover input to get it into more useable form.

 Keep in mind that stage below 280 in New Madrid is NON-Flooded
 and can be treated as "dry land" conditions.

 the original approach is to assume the cumulative acreage of each LC type
 below the 30-day inundation level is the area that exports in a flood.

The original analysis uses static scenarios with the water reaching a specific elevation.
Consequently the "Volume" associated with the scenario is a simple constant.
Steve assumes that this volume reaches equilibrium with the designated concentration
and Wetland function factor.

Steve does not use acres directly in his spreadsheet to calculate volumes,
but rather uses a  fraction of the total inundated area x the total inundated volume
to get the water volume associated with each inundated LC type. This does not fully
address the elevation distribution of the LC type because it assumes that
all inundated land has the same depth of overlying water.

We have the information (i.e., landcover below each 1 foot contour) to do a little better.
We multiply the area at each elev by the depth of water above it.

=============================================
  L A N D C O V E R    R E G R O U P I N G
=============================================
WE REGROUP the LC into the effective classes Ashby used as follows:
OLD
LC class      Ashby Class
Corn             RowCrop
Cotton           RowCrop
Rice             RowCrop
Soybeans         Soybeans + ?? to allow N behavior.
Wwheat           RowCrop
```

```
WwheatSoy        Mixed_Ag
Other_Ag         Mixed_Ag??
Fallow           Pasture
Forest           Forest
Woody_Wet        Forest
Developed        Urban
Grass            Pasture
HerbWetlands     Water
Wetlands         Water
Open_Water       Water
ShrubLand        Forest
Pasture          Pasture

The 2012 Alternative uses different LC types :< so here it is again
Agriculture     RowCrop
Fallow          Pasture
Forest          Forest
Developed       Urban
Herbaceous      Pasture
Open_Water      Water
Shrubland       Forest
Pasture         Pasture

;

%Macro MakeLCAreasAndVolumes(seg);
* This Macro Calculates Landcover volumes below each elevation contour AND
* Reclassifies the Landcover into a rough match to original classes of Ashby
* See page 10 of ERDC report (2000).
* We must keep soybeans and soybean mixes separate to allow separate handling for nitrogen.
;

%*this "IF" prevents unnecessary re-runs of this code;
%*%if %sysfunc(exist(Work.&seg.Volumes)) = 0 %then
 %Do;
 %Put Calculating &Seg Land Cover Flood Volumes and Areas;
 Data _null_; *Extract the "grand total" area for each class - hold as Variables for later in Macro;
   set &Seg.lc end=last;
   if last then
   do; *save the total acres of each LC as a macro variable for later calculations;
     call symput('ForestTotal',sum(forest,shrubland));*Acres;
         call symput('RowCropTotal',Agriculture);
            *call symput('WetlandTotal',Wetlands);
            *call symput ('SoybeanTotal',Soybeans);
            *call symput('NonRowCropTotal',Other_Ag);
         call symput('PastureTotal',sum(Pasture,Fallow,Herbaceous));
            *call symput('MixedAgtotal',Sum(WWheatSoy));
         call symput('UrbanTotal',Developed);
         call symput('UnfloodedTotal',Total);
         end;
   run;

 Data &Seg.volumes;
  * dz is one foot, so sum is acre-feet, our value of dz includes the conversion to hm3
  * volume is just the cumulative sum of volume increments (areas x dz) of inundation;
  * areas in THIS VERSION are the UNFLOODED areas that remaining at each elev for dry land export
  * this is where the totals (Macro Variables) calculated just above are utilized;
  * We hold the accumulating Volumes;
  keep Elev_cuml Foresthm3 rowcrophm3 pasturehm3 Urbanhm3 TotalHm3
                 Forestha  rowcropha  pastureha  Urbanha  TotalHa
                 MaxHA;
  retain Foresthm3 rowcrophm3 pasturehm3 Urbanhm3 Totalhm3  0
         dz 1.2335 e-3; *dz (1 foot) also converts acre-feet to cubic HM.;

  SET &Seg.lc;
  *Forest;
  Incrmt = Forest + Shrubland;*combine Acreages;
  %IF (&usedrylandexport = 1) %Then
  %do;
```

```
    Forestha       = (&ForestTotal - Incrmt)*0.4047; *convert acres to HA;
        %End;
  %Else %do;
    Forestha       = (Incrmt)*0.4047; *convert acres to HA;
        %End;
  Foresthm3      = Foresthm3 + Incrmt*dz;

  *RowCrop;
  Incrmt         = rowcrophm3;
  %IF (&usedrylandexport = 1) %Then
  %do;
    RowCrophA      = (&RowCropTotal- Incrmt)*0.4047;
        %End;
  %Else %do;
   RowCrophA      = (Incrmt)*0.4047;
   %End;
  Rowcrophm3     = RowCrophm3    + Incrmt*dz;

  *Pasture;
  Incrmt         = Pasture;
  %IF (&usedrylandexport = 1) %Then
  %do;
    PastureHA      = (&PastureTotal - Incrmt)*0.4047;
        %End;
  %Else %Do;
    PastureHA      = (Incrmt)*0.4047;
        %End;
  Pasturehm3     = Pasturehm3    + Incrmt*dz;

  *Urban;
  Incrmt         = Developed;
  %IF (&usedrylandexport = 1) %Then
  %do;
    UrbanHA        = (&UrbanTotal - Incrmt)*0.4047;
        %End;
  %Else %Do;
    UrbanHA        = (Incrmt)*0.4047;
        %End;
  Urbanhm3       = UrbanHm3      + Developed*dz;

  *TOTAL;
  Incrmt         = Total;
  %IF (&usedrylandexport = 1) %Then
  %do;
    TotalHA        = (&UnfloodedTotal - Incrmt)*0.4047;
        %End;
  %Else %Do;
    TotalHA        = (Incrmt)*0.4047;
        %end;
  MaxHA          = &UnfloodedTotal * 0.4047;
  Totalhm3       = Totalhm3 + Incrmt*dz;
  rename Elev_cuml = PeakElev;
  run;
  %*%End;
  %*%Else %Put &Seg LandCover Flood Volumes and Areas Previously Calculated;

%Mend MakeLCAreasAndVolumes;

%MakeLCAreasAndVolumes(NM);
*%MakeLCAreasAndVolumes(STJ);



*==============================================================================
  NOW WE ARE READY TO DO THE FINAL CALCULATIONS USING THE PROCESSED INPUT DATA
  WE First define the Flood Concentrations (mg/L) with Suffix C
  and non-flood export coefficients (kg/ha/season) with suffix X
  AND WETLAND FUNCTION FACTORS (WWF)
  The Suffix 1 or 2 on Macro names refers to Season
```

```
  THESE ALL COME FROM EXTERNAL FILES TO KEEP THIS CODE A LITTLE NEATER
*================================================================================
 ;


*=========================================;
*     T O T A L   P H O S P H O R U S
*=========================================;

%Include "&CoefPath\PhosphorusCoefs.txt";


*=========================================;
*       T O T A L   N I T R O G E N
*=========================================;
%Include "&CoefPath\NitrogenCoefs.txt";


*=========================================;
*       O R G A N I C   C A R B O N
*=========================================;
%Include "&CoefPath\CarbonCoefs.txt";


*=========================================;
*       S E D I M E N T
*=========================================;
%Include "&CoefPath\SedimentCoefs.txt";


%Macro GetExports(Seg,FluxVar,OutData,PeakVar,SeasX);
*seg is segment 'NM' or 'STJ';
*FluxVar is TP, TN, OC, or SED;
*Seasx is season 1 or 2;

* Create Generic Versions of Datasets for the Merge
* This allows TEMPORARY modifications and simplifies coding;

Data ForMerge1;      * Use this approach to leave Orig. Dataset Alone and rename Elev to PeakVar;
  set &seg.volumes; * resulting dataset has flood volumes and UNFLOODED areas for each LC type;
  rename PeakElev = &PeakVar;
  run;

%Put Creating Merge File for Season &Seasx and Flood Elev. &PeakVar with Use Dry Land = &UseDryLandExport;
Data ForMerge2;
  set &seg.Peaks;
  if (Season=&seasx);
  %If &UseDryLandExport=1 %then
  %Do; *Force value to MAX extent of dry land;
     if &PeakVar = . then
     do;
          *put "Fixing missing Value for &PeakVar";
      &PeakVar = 281;
         end;
        %End;
RUN;


*Prepare to Merge (Look up) landcover values to Associate with Time series of Peak Elevations;
proc sort data=ForMerge1;  by &PeakVar; run;
proc sort data=ForMerge2;  by &PeakVar; run;

* This Step generates an export dataset using the record of PEAK volumes and associated, non-flooded areas;
* Note that in season 1 (fall) there is almost NEVER any inundation without the project;

%Put Creating Season &SeasX Export of &LoadVar1 (&Outdata) by Merging Peak Flood with LC Export x Elev;
data &OutData;
keep
  Year date Season &PeakVar
```

```
  Forestkg
  RowCropkg
  Pasturekg
  ForestHa
  RowCropHA
  Urbankg Totalkg
  TotKgPerHA
;

  * ONE = season1  = Nov-Jan - held water (internal source)
  * TWO = season2  = Feb-May - spring flood water from MissR.)
  * PeakVar is either PeakW (with) or PeakWO (without)
  * ForMerge1 is Landcover areas/volumes and ForMerge2 is the Seasonal Flood Peaks for Each year;

  * Notes:  MINIMUM flood peak is forced to 281 (forces maximum of dry land);
  * Ashby reduced Export Coefficients by 50% for upland and ag land covers in Season 1
  *       and had ZERO exports for Ag and Upland in Season 2.
;
  *ForMerge2 is the peak elev., ForMerge1 is landcover area and volume at each elevation;
  merge ForMerge2(in=keeper) ForMerge1; by &PeakVar; if keeper;
  if &PeakVar < 281 then
  Do;* zero inundation!;
   Foresthm3      = 0;
   Rowcrophm3     = 0;
   Pasturehm3     = 0;
   *Water         = 0;
   Urbanhm3       = 0;
   Totalhm3       = 0;
   end;

 *  following uses seg, fluxvar, and seasx to define the macro
 *  to use - so triple & is needed for double substitution;

 * in season 1 there is almost Never any flooding without project;
   *the volumes and non-flooded areas are "picked" from the ForMerge Dataset;


   *FOREST LOAD;
   FloodLoad      = foresthm3*&&&seg.Forest&fluxVar.C&seasx;                    * = Vol x Conc;
   NonFloodLoad    = 0.5 * &&&Seg.Forest&FluxVar.X&seasx*(ForestHA);               * = Area x Export Coef x
1/2;
   WetlandEffect  = (FloodLoad + NonfloodLoad)* &&&Seg.Forest&FluxVar.WFF&seasx; * = negative fraction or one

(second half);
   Forestkg       = FloodLoad + NonFloodLoad + WetlandEffect;
   *Forestkg      = foresthm3    *&&&seg.Forest&fluxVar.X&seasx    *&&&seg.Forest&FluxVar.WFF&seasx;

   *WETLAND LOAD;
   *FloodLoad      = Wetlandhm3*&&&seg.Wetland&FluxVar.C&seasx;
   *NonFloodLoad   = 0.5 * &&&Seg.Wetland&FluxVar.X&seasx*(WetlandHA); *Area x Export Coef;
   *WetlandEffect  = (FloodLoad + NonfloodLoad)* &&&Seg.Wetland&FluxVar.WFF&seasx;
   *Wetlandkg      = FloodLoad + NonFloodLoad + WetlandEffect;

   *ROW CROP LOAD;
   FloodLoad      = RowCrophm3*&&&seg.RowCrop&fluxVar.C&seasx; *Vol x Conc;
   NonFloodLoad   = 0.5 * &&&Seg.RowCrop&FluxVar.X&seasx*(RowCropHA); *Area x Export Coef;
   WetlandEffect  = (FloodLoad + NonfloodLoad)*&&&Seg.RowCrop&FluxVar.WFF&seasx;
   RowCropkg      = FloodLoad + NonFloodLoad + WetlandEffect;
   *RowCropkg     = Rowcrophm3   *&&&seg.RowCrop&FluxVar.X&seasx   *&&&seg.RowCrop&FluxVar.WFF&seasx;

   *NON ROW CROP LOAD;
   *FloodLoad      = NONRowCrophm3*&&&seg.NONRowCrop&fluxVar.C&seasx;*Vol x Conc;
   *NonFloodLoad   = 0.5 * &&&Seg.NONRowCrop&FluxVar.X&seasx*(NONRowCropHA); *Area x Export Coef;
   *WetlandEffect  = (FloodLoad + NonfloodLoad)*&&&Seg.NONRowCrop&FluxVar.WFF&seasx;
   *NONRowCropkg   = FloodLoad + NonFloodLoad + WetlandEffect;
   *NonRowCropkg  = NonRowcrophm3*&&&seg.NonRowCrop&FluxVar.X&seasx*&&&seg.NonRowCrop&FluxVar.WFF&seasx;

   *SOYBEAN LOAD;
   *FloodLoad      = SoyBeanhm3*&&&seg.SoyBean&fluxVar.C&seasx;*Vol x Conc;
```

```
   *NonFloodLoad   = 0.5 * &&&Seg.Soybean&FluxVar.X&seasx*(SoybeanHA); *Area x Export Coef;
   *WetlandEffect  = (FloodLoad + NonfloodLoad)*&&&Seg.Soybean&FluxVar.WFF&seasx;
   *Soybeankg      = FloodLoad + NonFloodLoad + WetlandEffect;

   *PASTURE LOAD;
   FloodLoad      = Pasturehm3*&&&seg.Pasture&fluxVar.C&seasx;*Vol x Conc;
   NonFloodLoad   = 0.5 * &&&Seg.Pasture&FluxVar.X&seasx*(PastureHA); *Area x Export Coef;
   WetlandEffect  = (FloodLoad + NonfloodLoad)*&&&Seg.Pasture&FluxVar.WFF&seasx;
   Pasturekg      = FloodLoad + NonFloodLoad + WetlandEffect;
   *Pasturekg     = Pasturehm3   *&&&seg.Pasture&FluxVar.X&seasx   *&&&seg.Pasture&FluxVar.WFF&seasx;

   *MIXED AG LOAD;
  * FloodLoad      = MixedAghm3*&&&seg.MixedAg&fluxVar.C&seasx;*Vol x Conc;
  * NonFloodLoad   = 0.5 * &&&Seg.MixedAg&FluxVar.X&seasx*(MixedAgHA); *Area x Export Coef;
  * WetlandEffect  = (FloodLoad + NonfloodLoad)*&&&Seg.MixedAg&FluxVar.WFF&seasx;
  * MixedAgkg        = FloodLoad + NonFloodLoad + WetlandEffect;
  * MixedAgkg     = MixedAghm3   *&&&seg.MixedAg&FluxVar.X&seasx   *&&&seg.MixedAg&FluxVar.WFF&seasx;

   *URBAN LOAD;
   FloodLoad      = URBANhm3*&&&seg.URBAN&fluxVar.C&seasx;*Vol x Conc;
   NonFloodLoad   = 0.5 * &&&Seg.URBAN&FluxVar.X&seasx*(URBANHA); *Area x Export Coef;
   WetlandEffect  = (FloodLoad + NonfloodLoad)*&&&Seg.URBAN&FluxVar.WFF&seasx;
   URBANkg        = FloodLoad + NonFloodLoad + WetlandEffect;
   *Urbankg       = Urbanhm3     *&&&seg.Urban&FluxVar.X&seasx     *&&&seg.Urban&FluxVar.WFF&seasx;

   *TOTAL LOADS;
   Totalkg        = Sum(Forestkg,Rowcropkg,Pasturekg,urbankg);
   TotKgPerHA     = Totalkg/MaxHa;
 Year = Year(date); *Need to join seasons by water year!;
*if (&PeakVar ne . )then;
 output;
RUN;

proc sort data=&OutData; by date; run;
* Do not need to delete ForMerge because we create it fresh each time
* proc datasets lib=work;
*  delete forMerge;
*  run;

%Mend getExports;


*=================================================================;
*USE Single MACRO CALL TO PERFORM ALL THE CALCULATIONS for One Basin ;
*=================================================================;



%MACRO RunExports(BasinID,LoadVar1);
%Let OutSet1 = &BasinID&LoadVar1;

* FIRST, GET THE "WITHOUT" CONDITION;
%GetExports(&BasinID,&LoadVar1,&OutSet1._WO1,PeakWO,1); *season 1;
%GetExports(&BasinID,&LoadVar1,&OutSet1._WO2,PeakWO,2); *season 2;

*Prepare to Merge Season1 and Season2 results;
proc sort data=&OutSet1._wo1; by year season; run;
proc sort data=&OutSet1._wo2; by year season; run;
Data ExportWo;
  merge &Outset1._wo1 &Outset1._wo2; by year season;
  run;

*Now Sum across the two seasons;
proc sort data=ExportWo; by year;

proc means data=ExportWo noprint;
var totalkg ;*totkgperHa;
by year ;
output out=Mean_ExportWo  sum = totalkgWo;
```

```
run;


*Second, GET THE "WITH PROJECT" ALTERNATIVE CONDITION for two seasons;
%GetExports(&BasinID,&LoadVar1,&OutSet1._W1,PeakW,1);*number is season;
%GetExports(&BasinID,&LoadVar1,&OutSet1._W2,PeakW,2);

*Prepare to Merge Season1 and Season2 results;
proc sort data=&OutSet1._w1; by year season; run;*Season 1;
proc sort data=&OutSet1._w2; by year season; run;*Season 2;
Data ExportW;
  merge &OutSet1._w1 &OutSet1._w2; by year season;
  run;

*Now Sum Across the Two Seasons;
proc sort data=ExportW; by year;
proc means data=ExportW noprint;
var totalkg ;*totkgperHa;
by year ;
output out=Mean_ExportW
  sum = totalkgW;
run;

* Combine With and Without into One;
proc sort data=Mean_ExportW; by year; run;
proc sort data=Mean_ExportWo; by year; run;
Data Mean_Export&OutSet1;
  merge Mean_exportW Mean_ExportWo;
  by year;
  drop _type_ _freq_;
  if totalkgwo = . then totalkgwo=0;
  run;

Title1 "Summary of Annual Mean &LoadVar1 Export from &BasinID";
Title2 "With and Without Alternative (&&&BasinID.Proj_Elev)";
proc means min max mean n data=mean_export&outset1;run;
*proc insight data=Mean_Export&Outset1;
*run;
%Mend RunExports;
```

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```
* CALL MACRO AS:  %RunExports(NM,&LoadName);*TP,TN,SED,TOC;
Options pageno=1;
%RunExports(NM,TP);
%RunExports(NM,TN);
%RunExports(NM,SED);
%RunExports(NM,TOC);
```

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Appendix B: Export Coefficients, Concentrations, and Wetland Function Factors.

In this revision to the Ashby et al. (2000) effort, we have used SAS software code and Macro variables to perform the calculations. This allows us to localize all the variables that can be readily altered (coefficients) into single listings as input files. The advantage to this approach over the original spreadsheet is that these values are all now listed explicitly, in a readable form, and in a single, accessible location. Values that are changed once in the one "master" list will be reflected in all calculations in the code (and the output).

The listing that follows is the actual SAS program code (a sequence of %Let statements) imported by SAS software as %Include files to perform the calculations in this report. The listings include export coefficients, flood water concentrations, and Wetland Function Factors for each of the export constituents of interest (i.e., total phosphorus, total nitrogen, organic carbon, and sediment), for each of two flood seasons, and each of the two sub-areas in the project (New Madrid Floodway and St. Johns Bayou). The SAS code represents these various input values as MACRO variables and sets a substantial number of these (%LET) that are then used in the calculations. The names of these macros (and hence the values they reference) follow this convention:

<Basin ID> <Land Cover><Constituent><Value Type><Season Number>

Basin Id = NM or STJ
Land Cover = One of eight (Forest, Wetland, RowCrop, NonRowCrop, Soybean,Pasture, MixedAg, or Urban)
Constituent = TP, TN, TOC, or SED.
Value Type = Concentration (c, mg/L), Export (x, kg/ha/season), Wetland Function Factor (WFF)
Season = 1 (fall winter) or 2 (late winter- spring).

For example NMForestTPC1 is New Madrid, Forest, Total Phosphorus Concentration, Season 1;

```
* SAS CODE STARTS HERE FOR PHOSPHORUSCOEFS.TXT;
```

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Background. We regroup the LC into the effective classes Ashby et al. (2000) used as follows:

LC class	Ashby Class
Corn	RowCrop
Cotton	RowCrop
Rice	RowCrop
Soybeans	Soybeans + XX to allow N behavior.
Wwheat	RowCrop
WwheatSoy	Mixed_Ag
Other_Ag	Mixed_Ag??
Fallow	Pasture
Forest	Forest
Woody_Wet	Forest
Developed	Urban
Grass	Pasture
HerbWetlands	Water
Wetlands	Water
Open_Water	Water
ShrubLand	Forest
Pasture	Pasture

==========

Forest = sum(forest, woody_wet, HerbWetlands, shrubland) = tupelo

RowCrop = sum(Corn,Cotton,WWheat,Rice)

NonRowCrop = Other_Ag

Soybean = Soybeans

Pasture = Sum(Pasture,Grass)

MixedAg = WWheatSoy = cotton/soy corn/soy

Urban = Developed

;

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```
*Flood Concentration ;

 %let NMforestTpC1       = 0.21; *B19;

 %let NMWetlandTpC1      = 0.21;

 %let NMrowcroptpC1      = 0.21; *B19;

 %let NMNonRowCropTPC1   = 0.21; *B19;

 %let NMSoybeanTPC1      = 0.21; *B19;

 %let NMPastureTPC1      = 0.21; *B19;

 %let NMMixedAgTPC1      = 0.21; *B19;

 %let NMUrbanTPC1        = 0.21; *B19;


*Dry Land Export Coef kg/ha/season - adjusted for length of flood-free period;

 %let NMforestTpX1       = 0.0; *Zero in Ashby sheet;

 %let NMWetlandTpX1      = 0.0;

 %let NMrowcroptpX1      = 1.1; *J19;

 %let NMNonRowCropTPX1   = 0.1; *o19 = herbaceous veg = other ag;

 %let NMSoyBeanTPX1      = 1.1; *L19;

 %let NMPastureTPX1      = 0.04;*P19;

 %let NMMixedAgTPX1      = 0.5; *M19;

 %let NMUrbanTPX1        = 1.5; *J19+ Not in Ashby, not significant;


 %let NMforestTpWFF1     = -0.4;

 %let NMWetlandTpWFF1    = -0.4;

 %let NMrowcroptpWFF1    = 1.0;

 %let NMNonRowCropTPWFF1 = 1.0;

 %let NMSoyBeanTPWFF1    = 1.0;

 %let NMPastureTPWFF1    = 1.0;

 %let NMMixedAgTPWFF1    = 1.0;
```

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```
%let NMUrbanTPWFF1      = 1.0;


*Season 2 - Winter Spring  = backwater flooding only, B20;

%let NMforestTpC2       = 0.15; *B20;

%let NMWetlandTpC2      = 0.21;

%let NMrowcroptpC2      = 0.15; *B20;

%let NMNonRowCropTPC2   = 0.15; *B20;

%let NMSoybeanTPC2      = 0.15; *B20;

%let NMPastureTPC2      = 0.15; *B20;

%let NMMixedAgTPC2      = 0.15; *B20;

%let NMUrbanTPC2        = 0.15; *B20;


*Ashby had NO dry land export during season2 in NM -backwater flooding only;

%let NMforestTpX2       = 0.0; *N/A;

%let NMWetlandTpX2      = 0.0;

%let NMrowcroptpX2      = 0.0; *N/A;

%let NMNonRowCropTPX2   = 0.0; *N/A;

%let NMSoybeantpX2      = 0.0; *N/A;

%let NMPastureTPX2      = 0.0; *N/A;

%let NMMixedAgTPX2      = 0.0; *N/A;

%let NMUrbanTPX2        = 0.0; *N/A;


*Ashby uses ONE WWF for both seasons;

%let NMforestTpWFF2     = -0.4;

%let NMWetlandTpWFF2    = -0.4;

%let NMrowcroptpWFF2    = 1.0;

%let NMNonRowCropTPWFF2 = 1.0;

%let NMSoybeanTPWFF2    = 1.0;
```

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```
%let NMPastureTPWFF2    = 1.0;

%let NMMixedAgTPWFF2    = 1.0;

%let NMUrbanTPWFF2      = 1.0;



*========  St. Johns Bayou ========;

*FALL and WINTER (season 1);

%let STJforestTpC1       = 0.21; *B19;

%let STJWetlandTpC1      = 0.21; *;

%let STJrowcroptpC1      = 0.21; *B19;

%let STJNonRowCropTPC1   = 0.21; *B19;

%let STJSoybeanTPC1      = 0.21; *B19=d19;

%let STJPastureTPC1      = 0.21; *B19;

%let STJMixedAgTPC1      = 0.21; *B19;

%let STJUrbanTPC1        = 0.21; *B19;


%let STJforestTpX1       = 0.0; *Season1 export = zero;

%let STJWetlandTpX1      = 0.0; *;

%let STJrowcroptpX1      = 1.1; *J19;

%let STJNonRowCropTPX1   = 0.1; *o19;

%let STJSoybeanTPX1      = 1.1; *L19;

%let STJPastureTPX1      = 0.04;*p19;

%let STJMixedAgTPX1      = 0.5; *M19;

%let STJUrbanTPX1        = 1.5; *J19+ Not in Ashby;


%let STJforestTPWFF1     = 1.0;

%let STJWetlandTPWFF1    = 1.0; *????;

%let STJrowcropTPWFF1    = 1.0;
```

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```
%let STJNonRowCropTPWFF1 = 1.0;

%let STJSoybeanTPWFF1    = 1.0;

%let STJPastureTPWFF1    = 1.0;

%let STJMixedAgTPWFF1    = 1.0;

%let STJUrbanTPWFF1      = 1.0;


*WINTER and SPRING = season2;

*Ashby had NO dry land export during season2 in STJ;

%let STJforestTpC2       = 0.15; *B20;

%let STJWetlandTpC2      = 0.15; *H20;

%let STJrowcroptpC2      = 0.15; *B20;

%let STJNonRowCropTPC2   = 0.15; *B20;

%let STJSoybeanTPC2      = 0.15; *B20;

%let STJPastureTPC2      = 0.15; *B20;

%let STJMixedAgTPC2      = 0.15; *B20;

%let STJUrbanTPC2        = 0.15; *B20;


%let STJforestTPX2       = 0.0;

%let STJWetlandTPX2      = 0.0;

%let STJrowcropTPX2      = 0.0;

%let STJNonRowCropTPX2   = 0.0;

%let STJSoybeanTPX2      = 0.0;

%let STJPastureTPX2      = 0.0;

%let STJMixedAgTPX2      = 0.0;

%let STJUrbanTPX2        = 0.0;


%let STJforestTpWFF2     = 1.0;

%let STJWetlandTpWFF2    = 1.0;
```

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```
  %let STJrowcroptpWFF2    = 1.0;

  %let STJNonRowCropTPWFF2 = 1.0;

  %let STJSoybeanTPWFF2    = 1.0;

  %let STJPastureTPWFF2    = 1.0;

  %let STJMixedAgTPWFF2    = 1.0;

  %let STJUrbanTPWFF2      = 1.0;


* SAS CODE STARTS HERE FOR NITROGENCOEFS.TXT;

* NEW MADRID

*Flood Concentration   (row 19) ;

  %let NMforestTNC1       = 1.5; *b19;

  %let NMWetlandTNC1      = 1.5; *h19;

  %let NMrowcropTNC1      = 1.5; *b19;

  %let NMNonRowCropTNC1   = 1.5; *b19 = herb. veg = other ag;

  %let NMSoybeanTNC1      = 1.5; *b19;

  %let NMSoyMixTNC1       = 1.5; *b19 wwheat+soy;

  %let NMPastureTNC1      = 1.5; *b19;

  %let NMMixedAgTNC1      = 1.5; *b19;

  %let NMUrbanTNC1        = 1.5; *b19 not in ashby;


*Dry Land Export Coef kg/ha/season adjusted for length of flood-free period;

  %let NMforestTNX1       = 0.10; *Zero in Ashby;

  %let NMWetlandTNX1      = 0.00; *B19;

  %let NMrowcropTNX1      = 6.75; *J19;

  %let NMNonRowCropTNX1   = 1.87; *o19 = herbaceous veg = other ag;

  %let NMSoybeanTNX1      =15.00; *L19;

  %let NMSoyMixTNX1       = 9.75; *M19;
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```
  %let NMPastureTNX1      = 3.75; *P19;

  %let NMMixedAgTNX1      = 9.75; *K19 = cotton/soy corn/soy;

  %let NMUrbanTNX1        = 7.00; *Not in Ashby;


*WetLand Function;

  %let NMforestTNWFF1     = -0.4;

  %let NMWetlandTNWFF1    = -0.8;*h21;

  %let NMrowcropTNWFF1    = 1.0;

  %let NMNonRowCropTNWFF1 = 1.0;

  %let NMSoybeanTNWFF1    = 1.0;

  %let NMPastureTNWFF1    = 1.0;

  %let NMMixedAgTNWFF1    = 1.0;

  %let NMUrbanTNWFF1      = 1.0;


*Season 2 - Winter Spring (Row 20);

  %let NMforestTNC2       = 1.2;

  %let NMWetlandTNC2      = 1.2;

  %let NMrowcropTNC2      = 1.2;

  %let NMNonRowCropTNC2   = 1.2;

  %let NMSoybeanTNC2      = 1.2;

  %let NMPastureTNC2      = 1.2;

  %let NMMixedAgTNC2      = 1.2;

  %let NMUrbanTNC2        = 1.2;


*Ashby had NO dry land export during season2 in NM;

  %let NMforestTNX2       = 0.0;
```

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```
%let NMWetlandTNX2      = 0.0;

%let NMrowcropTNX2      = 0.0;

%let NMNonRowCropTNX2   = 0.0;

%let NMSoybeanTNX2      = 0.0;

%let NMPastureTNX2      = 0.0;

%let NMMixedAgTNX2      = 0.0;

%let NMUrbanTNX2        = 0.0;


*Ashby uses ONE WWF for both seasons;

%let NMforestTNWFF2     = -0.8; *B21;

%let NMWetlandTNWFF2    = -0.8;

%let NMrowcropTNWFF2    = 1.0;

%let NMNonRowCropTNWFF2 = 1.0;

%let NMSoybeanTNWFF2    = 1.0;

%let NMPastureTNWFF2    = 1.0;

%let NMMixedAgTNWFF2    = 1.0;

%let NMUrbanTNWFF2      = 1.0;



*========  St. Johns Bayou ========;

*FALL and WINTER (season 1);


*Flood Concentration   (row 19) ;

%let STJforestTNC1       = 1.5; *b19;

%let STJWetlandTNC1      = 1.5; *b19;

%let STJrowcropTNC1      = 1.5; *b19;
```

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```
%let STJNonRowCropTNC1   = 1.5; *b19 = herb. veg = other ag;

%let STJSoybeanTNC1      = 1.5; *b19;

%let STJSoyMixTNC1       = 1.5; *b19= wwheat+soy;

%let STJPastureTNC1      = 1.5; *b19;

%let STJMixedAgTNC1      = 1.5; *b19;

%let STJUrbanTNC1        = 1.5; *not in ashby;


*Dry Land Export Coef kg/ha/season adjusted for length of flood-free period;

%let STJforestTNX1       = 0.10; *Zero in Ashby;

%let STJWetlandTNX1      = 0.00;

%let STJrowcropTNX1      = 6.75; *J19;

%let STJNonRowCropTNX1   = 1.87; *o19 = herbaceous veg = other ag;

%let STJSoybeanTNX1      =15.00; *L19;

%let STJSoyMixTNX1       = 9.75; *M19;

%let STJPastureTNX1      = 3.75; *P19;

%let STJMixedAgTNX1      = 9.75; *K19 = cotton/soy corn/soy;

%let STJUrbanTNX1        = 7.00; *Not in Ashby;



%let STJforestTNWFF1     = -.8;

%let STJWetlandTNWFF1    = -.8;

%let STJrowcropTNWFF1    = 1.0;

%let STJNonRowCropTNWFF1 = 1.0;

%let STJSoybeanTNWFF1    = 1.0;

%let STJPastureTNWFF1    = 1.0;

%let STJMixedAgTNWFF1    = 1.0;
```

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```
%let STJUrbanTNWFF1      = 1.0;


*WINTER and SPRING;

*Ashby had NO dry land export during season2 in STJ;


*Flood Concentration   (row 20) ;

%let STJforestTNC2       = 1.2; *b20;

%let STJWetlandTNC2      = 1.2;

%let STJrowcropTNC2      = 1.2;

%let STJNonRowCropTNC2   = 1.2; *b20 = herb. veg = other ag;

%let STJSoybeanTNC2      = 1.2; *b20;

%let STJSoyMixTNC2       = 1.2; *b20= wwheat+soy;

%let STJPastureTNC2      = 1.2; *b20;

%let STJMixedAgTNC2      = 1.2; *b20;

%let STJUrbanTNC2        = 1.2; *not in ashby;


%let STJforestTNX2       = 0.0;

%let STJWetlandTNX2      = 0.0;

%let STJrowcropTNX2      = 0.0;

%let STJNonRowCropTNX2   = 0.0;

%let STJSoybeanTNX2      = 0.0;

%let STJPastureTNX2      = 0.0;

%let STJMixedAgTNX2      = 0.0;

%let STJUrbanTNX2        = 0.0;


%let STJforestTNWFF2     = -.8;
```

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```
  %let STJWetlandTNWFF2    = -.8;

  %let STJrowcropTNWFF2    = 1.0;

  %let STJNonRowCropTNWFF2 = 1.0;

  %let STJSoybeanTNWFF2    = 1.0;

  %let STJPastureTNWFF2    = 1.0;

  %let STJMixedAgTNWFF2    = 1.0;

  %let STJUrbanTNWFF2      = 1.0;

* SAS CODE STARTS HERE FOR CarbonCOEFS.TXT;


Forest     = sum(forest, woody_wet, HerbWetlands, shrubland) = tupelo

RowCrop    = sum(Corn,Cotton,WWheat,Rice)

NonRowCrop = Other_Ag =

Soybean    = Soybeans = Cotton Soy

Pasture    = Sum(Pasture,Grass)

MixedAg    =

Urban      = Developed

Concentrations are mg/L, Exports are kg/ha/season

;

*NEW MADRID

SEASON 1

*Flood Concentration ;

  %let NMforestTOCC1       = 4.0;*b19;

  %let NMWetlandTOCC1      = 4.0;

  %let NMrowcropTOCC1      = 4.0;

  %let NMNonRowCropTOCC1   = 4.0;

  %let NMSoybeanTOCC1      = 4.0;
```

```
%let NMSoyMixTOCC1       = 4.0;*b19 wwheat+soy;

%let NMPastureTOCC1      = 4.0;

%let NMMixedAgTOCC1      = 4.0;

%let NMUrbanTOCC1        = 4.0;


*Dry Land Export Coef kg/ha/season - adjusted for length of flood-free period;

%let NMforestTOCX1       = 0.0;

%let NMWetlandTOCX1      = 0.0;

%let NMrowcropTOCX1      = 3.6;

%let NMNonRowCropTOCX1   = 3.6; *= herbaceous veg = other ag;

%let NMSoybeanTOCX1      = 3.6;

%let NMSoyMixTNX1        = 3.6; *M19;

%let NMPastureTOCX1      = 3.6;

%let NMMixedAgTOCX1      = 3.6;

%let NMUrbanTOCX1        = 3.6;


%let NMforestTOCWFF1     = 0.8;

%let NMWetlandTOCWFF1    = 0.8;

%let NMrowcropTOCWFF1    = 1.0;

%let NMNonRowCropTOCWFF1 = 1.0;

%let NMSoybeanTOCWFF1    = 1.0;

%let NMSoyMixTOCWFF1     = 1.0;

%let NMPastureTOCWFF1    = 1.0;

%let NMMixedAgTOCWFF1    = 1.0;

%let NMUrbanTOCWFF1      = 1.0;
```

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```
*Season 2 - Winter Spring;

%let NMforestTOCC2       = 4.0;*b20;

%let NMWetlandTOCC2      = 4.0;

%let NMrowcropTOCC2      = 4.0;

%let NMNonRowCropTOCC2   = 4.0;

%let NMSoybeanTOCC2      = 4.0;

%let NMSoyMixTOCC2       = 4.0;

%let NMPastureTOCC2      = 4.0;

%let NMMixedAgTOCC2      = 4.0;

%let NMUrbanTOCC2        = 4.0;


*Ashby had NO dry land export in season2 in NM, but we use SAME as season 1;

%let NMforestTOCX2       = 0.0;

%let NMWetlandTOCX2      = 0.0;

%let NMrowcropTOCX2      = 3.6;

%let NMNonRowCropTOCX2   = 3.6;

%let NMSoybeanTOCX2      = 3.6;

%let NMSoyMixTOCX2       = 3.6;

%let NMPastureTOCX2      = 3.6;

%let NMMixedAgTOCX2      = 3.6;

%let NMUrbanTOCX2        = 3.6;


*Ashby uses ONE WWF for both seasons;

%let NMforestTOCWFF2     = 0.8;

%let NMWetlandTOCWFF2    = 0.8;

%let NMrowcropTOCWFF2    = 1.0;
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```
%let NMNonRowCropTOCWFF2 = 1.0;

%let NMSoybeanTOCWFF2    = 1.0;

%let NMSoyMixTOCWFF2     = 1.0;

%let NMPastureTOCWFF2    = 1.0;

%let NMMixedAgTOCWFF2    = 1.0;

%let NMUrbanTOCWFF2      = 1.0;



*========  St. Johns Bayou ========;

*FALL and WINTER (season 1);


*Flood Concentration   (row 19) ;

%let STJforestTOCC1       = 4.0; *b19;

%let STJWetlandTOCC1      = 4.0; *b19;

%let STJrowcropTOCC1      = 4.0; *b19;

%let STJNonRowCropTOCC1   = 4.0; *b19 = herb. veg = other ag;

%let STJSoybeanTOCC1      = 4.0; *b19;

%let STJSoyMixTOCC1       = 4.0; *b19= wwheat+soy;

%let STJPastureTOCC1      = 4.0; *b19;

%let STJMixedAgTOCC1      = 4.0; *b19;

%let STJUrbanTOCC1        = 4.0; *not in ashby;


*Dry Land Export Coef kg/ha/season adjusted for length of flood-free period;

%let STJforestTOCX1       = 0.10; *Zero in Ashby;

%let STJWetlandTOCX1      = 0.00;

%let STJrowcropTOCX1      = 3.6; *J19;
```

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```
%let STJNonRowCropTOCX1   = 3.6; *o19 = herbaceous veg = other ag;

%let STJSoybeanTOCX1      = 3.6; *L19;

%let STJSoyMixTOCX1       = 3.6; *M19;

%let STJPastureTOCX1      = 3.6; *P19;

%let STJMixedAgTOCX1      = 3.6; *K19 = cotton/soy corn/soy;

%let STJUrbanTOCX1        = 3.6; *Not in Ashby;


%let STJforestTOCWFF1     = 0.8;

%let STJWetlandTOCWFF1    = 0.8;

%let STJrowcropTOCWFF1    = 1.0;

%let STJNonRowCropTOCWFF1 = 1.0;

%let STJSoybeanTOCWFF1    = 1.0;

%let STJPastureTOCWFF1    = 1.0;

%let STJMixedAgTOCWFF1    = 1.0;

%let STJUrbanTOCWFF1      = 1.0;


*Season 2, WINTER and SPRING;

*Ashby had NO dry land export in season2 in STJ;


*Flood Concentration   (row 20) ;

%let STJforestTOCC2       = 4.0; *b20;

%let STJWetlandTOCC2      = 4.0;

%let STJrowcropTOCC2      = 4.0;

%let STJNonRowCropTOCC2   = 4.0; *b20 = herb. veg = other ag;

%let STJSoybeanTOCC2      = 4.0; *b20;

%let STJSoyMixTOCC2       = 4.0; *b20= wwheat+soy;
```

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```
%let STJPastureTOCC2      = 4.0; *b20;

%let STJMixedAgTOCC2      = 4.0; *b20;

%let STJUrbanTOCC2        = 4.0; *not in ashby;


%let STJforestTOCX2       = 0.1; *No Season 2 export in Ashby, but we use season 1;

%let STJWetlandTOCX2      = 0.0;

%let STJrowcropTOCX2      = 3.6;

%let STJNonRowCropTOCX2   = 3.6;

%let STJSoybeanTOCX2      = 3.6;

%let STJPastureTOCX2      = 3.6;

%let STJMixedAgTOCX2      = 3.6;

%let STJUrbanTOCX2        = 3.6;


%let STJforestTOCWFF2     = 0.8;

%let STJWetlandTOCWFF2    = 0.8;

%let STJrowcropTOCWFF2    = 1.0;

%let STJNonRowCropTOCWFF2 = 1.0;

%let STJSoybeanTOCWFF2    = 1.0;

%let STJPastureTOCWFF2    = 1.0;

%let STJMixedAgTOCWFF2    = 1.0;

%let STJUrbanTOCWFF2      = 1.0;


* SAS CODE STARTS HERE FOR SedimentCOEFS.TXT;


*NEW MADRID

*Flood Concentration ;
```

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```
%let NMforestSEDC1       = 150.0;*B19;

%let NMWetlandSEDC1      = 150.0;

%let NMrowcropSEDC1      = 150.0;

%let NMNonRowCropSEDC1   = 150.0;

%let NMSoybeanSEDC1      = 150.0;

%let NMSoyMixSEDC1       = 150.0;

%let NMPastureSEDC1      = 150.0;

%let NMMixedAgSEDC1      = 150.0;

%let NMUrbanSEDC1        = 150.0;


*Dry Land Export Coef kg/ha/season - adjusted for length of flood-free period;

%let NMforestSEDX1       = 0.0;  * natural areas have zero sed exp in season 1 or 2;

%let NMWetlandSEDX1      = 0.0;

%let NMrowcropSEDX1      = 130.0; *J19;

%let NMNonRowCropSEDX1   = 130.0; *= herbaceous veg = other ag;

%let NMSoybeanSEDX1      = 130.0;

%let NMSoyMixSEDX1       = 130.0;

%let NMPastureSEDX1      = 130.0;

%let NMMixedAgSEDX1      = 130.0;

%let NMUrbanSEDX1        = 130.0;


%let NMforestSEDWFF1     = -0.8;

%let NMWetlandSEDWFF1    = -0.8;*Minus in Ashby for NM only???;

%let NMrowcropSEDWFF1    = 1.0;

%let NMNonRowCropSEDWFF1 = 1.0;

%let NMSoybeanSEDWFF1    = 1.0;
```

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```
%let NMSoyMixSEDWFF1     = 1.0;

%let NMPastureSEDWFF1    = 1.0;

%let NMMixedAgSEDWFF1    = 1.0;

%let NMUrbanSEDWFF1      = 1.0;


*Season 2 - Winter Spring;

%let NMforestSEDC2       = 260; *B20 = MS flood water;

%let NMWetlandSEDC2      = 260;

%let NMrowcropSEDC2      = 260;

%let NMNonRowCropSEDC2   = 260;

%let NMSoybeanSEDC2      = 260;

%let NMSoyMixSEDC2       = 260;

%let NMPastureSEDC2      = 260;

%let NMMixedAgSEDC2      = 260;

%let NMUrbanSEDC2        = 260;


*Ashby had NO dry land export for season 2 in NM, but we use Season 1;

%let NMforestSEDX2       = 0.0;

%let NMWetlandSEDX2      = 0.0;

%let NMrowcropSEDX2      = 130.0;*same as season 1 in this analysis;

%let NMNonRowCropSEDX2   = 130.0;

%let NMSoybeanSEDX2      = 130.0;

%let NMSoyMixSEDX2       = 130.0;

%let NMPastureSEDX2      = 130.0;

%let NMMixedAgSEDX2      = 130.0;

%let NMUrbanSEDX2        = 130.0;
```

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```
*Ashby uses ONE WWF for both seasons;

%let NMforestSEDWFF2     = -0.8;

%let NMWetlandSEDWFF2    = -0.8;*negative in Ashby;

%let NMrowcropSEDWFF2    = 1.0;

%let NMNonRowCropSEDWFF2 = 1.0;

%let NMSoybeanSEDWFF2    = 1.0;

%let NMSoyMixSEDWFF2     = 1.0;

%let NMPastureSEDWFF2    = 1.0;

%let NMMixedAgSEDWFF2    = 1.0;

%let NMUrbanSEDWFF2      = 1.0;



*========  St. Johns Bayou ========;

*FALL and WINTER (season 1);

%let STJforestSEDC1       = 150;

%let STJWetLandSEDC1      = 150;

%let STJrowcropSEDC1      = 150;

%let STJNonRowCropSEDC1   = 150;

%let STJSoybeanSEDC1      = 150;

%let STJSoyMixSEDC1       = 150;

%let STJPastureSEDC1      = 150;

%let STJMixedAgSEDC1      = 150;

%let STJUrbanSEDC1        = 150;
```

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```
%let STJforestSEDX1       = 0.0;

%let STJWetLandSEDX1      = 0.0;

%let STJrowcropSEDX1      = 130;

%let STJNonRowCropSEDX1   = 130;

%let STJSoybeanSEDX1      = 130;

%let STJSoyMixSEDX1       = 130;

%let STJPastureSEDX1      = 130;

%let STJMixedAgSEDX1      = 130;

%let STJUrbanSEDX1        = 130;


%let STJforestSEDWFF1     = 1.0;

%let STJWetLandSEDWFF1    = 1.0;

%let STJrowcropSEDWFF1    = 1.0;

%let STJNonRowCropSEDWFF1 = 1.0;

%let STJSoybeanSEDWFF1    = 1.0;

%let STJSoyMixSEDWFF1     = 1.0;

%let STJPastureSEDWFF1    = 1.0;

%let STJMixedAgSEDWFF1    = 1.0;

%let STJUrbanSEDWFF1      = 1.0;


*WINTER and SPRING;

*Ashby had NO dry land export during season2 in STJ;

%let STJforestSEDC2       = 260;

%let STJWetLandSEDC2      = 260;

%let STJrowcropSEDC2      = 260;

%let STJNonRowCropSEDC2   = 260;
```

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```
%let STJSoybeanSEDC2      = 260;

%let STJSoyMixSEDC2       = 260;

%let STJPastureSEDC2      = 260;

%let STJMixedAgSEDC2      = 260;

%let STJUrbanSEDC2        = 260;


%let STJforestSEDX2       = 0.0;*Ashby has zero dry land export in season2;

%let STJWetLandSEDX2      = 0.0;

%let STJrowcropSEDX2      = 130;

%let STJNonRowCropSEDX2   = 130;

%let STJSoybeanSEDX2      = 130;

%let STJSoyMixSEDX2       = 130;

%let STJPastureSEDX2      = 130;

%let STJMixedAgSEDX2      = 130;

%let STJUrbanSEDX2        = 130;


%let STJforestSEDWFF2     = -0.8;

%let STJWetLandSEDWFF2    = -0.8;

%let STJrowcropSEDWFF2    = 1.0;

%let STJNonRowCropSEDWFF2 = 1.0;

%let STJSoybeanSEDWFF2    = 1.0;

%let STJSoyMixSEDWFF2     = 1.0;

%let STJPastureSEDWFF2    = 1.0;

%let STJMixedAgSEDWFF2    = 1.0;

%let STJUrbanSEDWFF2      = 1.0;
```

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Appendix C: Land cover, Land use for the Project Areas.

Table C1. Land cover under alternatives 1 through 3 (no reforestation). Table lists cumulative acres of each land cover type below one-foot contours in the New Madrid Floodway provided by the Memphis District in 2011.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	Elev_cuml	Corn	Cotton	Rice	Soybeans	Wwheat	WwheatSoy	Other_Ag	Fallow	Forest	Woody_Wet	Developed	Grass	HerbWetlands	Wetlands	Open_Water	Shrubland	Pasture	Total
2	281	4.76902	0	2.78377	139.011	0.306429	0.28508	0	6.01038	10.1079	374.7612041	1.56894333	0	4.676031251	220.776	64.03604	0	0.27558	829.367
3	282	5.59432	0	6.38679	316.633	0.407295	0.2463538	0.00057	6.41954	14.0048	456.032727	2.49424255	0.0251	6.824161562	458.946	74.345843	0	0.40406	1348.76
4	283	8.93995	0	8.96029	606.639	0.473366	0.683709	0.226002	7.19516	20.579	522.870112	5.65104479	1.54775	7.144257243	531.47	85.301987	0	0.51168	1808.19
5	284	12.2828	0	9.15393	1058.52	0.516189	1.1926994	0.643929	8.57121	31.1938	618.7989626	10.0160249	1.54775	8.010984018	543.236	147.17825	0	0.62134	2451.49
6	285	16.6694	0	11.0128	1647.95	0.534648	2.6765719	1.334101	19.2596	49.7715	831.466932	23.2632403	1.54775	8.312065941	547.024	196.77268	0.22638	0.74311	3358.56
7	286	29.4371	0.04689	26.514	2879.11	0.553466	3.9707245	3.732088	98.7943	102.507	1447.883887	42.9871261	1.54775	24.23923637	559.065	348.81797	0.69956	0.87194	5570.78
8	287	43.6512	0.06517	66.9739	4766.82	0.562072	6.9648218	5.199456	165.387	158.375	2528.108591	74.8407436	1.54775	43.85524714	578.581	494.8647	1.00615	1.04947	8937.85
9	288	63.7716	0.84174	148.923	7547.48	0.584751	12.613357	9.025834	189.117	214.615	3433.827428	120.041087	1.553933	50.19945737	615.229	547.25179	1.52991	1.34868	12958
10	289	109.03	2.38062	155.684	11539.5	0.596072	20.590611	16.68487	194.425	258.041	4337.245654	173.664658	1.660463	55.92311007	623.791	583.61898	1.53651	1.66074	18076
11	290	201.521	3.73777	196.958	15958.2	0.608698	28.284203	27.71062	198.964	291.411	4994.524551	218.342408	1.702737	64.21511556	627.442	610.27292	1.53967	2.25208	23427.7
12	291	353.16	83.595	230.514	20727	0.62713	208.52313	204.6967	201.386	332.834	5362.143194	302.388663	1.718568	68.93454072	632.432	618.71713	1.61191	4.50187	29334.8
13	292	412.275	93.2233	423.543	25110.6	1.367827	282.08174	494.9287	202.967	372.366	5706.567136	416.12274	1.735212	74.79148104	635.433	629.1742	1.62975	6.85336	34865.6
14	293	641.605	132.34	512.955	29487.9	4.30725	428.71875	761.297	204.236	414.201	6212.161394	584.875123	1.754796	80.70879046	642.15	634.62317	1.64128	9.69355	40755.2
15	294	1114.48	148.885	524.711	33916.7	8.32405	819.91205	1114.829	206.136	488.962	6613.466933	763.620865	1.772731	85.84684907	652.549	663.57853	1.65281	14.0021	47139.4
16	295	1408.16	163.671	533.711	37248.6	8.779375	1553.3001	1287.57	207.425	544.117	6902.704913	978.200301	1.801877	88.79533567	654.649	679.73828	1.70535	21.826	52284.7
17	296	3261.63	180.733	549.978	41718.1	62.78888	4012.0697	1515.974	209.347	617.604	7351.114658	1650.57743	1.859445	93.06169257	655.591	685.50073	1.84699	76.8352	62644.6
18	297	3788.24	190.966	557.041	44115.4	64.31979	5666.5902	1638.633	210.076	655.506	7618.332684	2001.50149	1.905082	94.05523446	659.708	692.92608	6.11045	89.125	68050.4
19	298	4440.3	206.814	561.662	45840.6	65.1494	6766.1979	1788.804	210.522	687.565	7830.187653	2190.88339	1.937823	103.6906311	660.744	697.83487	9.28223	100.029	72162.2
20	299	5227.74	238.867	565.328	48205.1	66.59093	7918.6889	2067.047	212.193	721.616	8058.920586	2419.3891	1.967976	106.3087762	660.958	706.1742	9.28223	114.257	77300.4
21	300	5976.06	252.717	567.248	50324.7	72.876	8676.0423	2257.165	212.589	785.809	8241.22391	2639.85858	1.972319	109.470987	661.375	712.61124	9.28223	128.189	81629.2

Table C2. Land cover under alternatives 4.2 (reforestation) in the New Madrid Floodway only. Table lists the cumulative acres of each land cover type below one-foot contours in the New Madrid Floodway provided by the Memphis District in 2012.

	A	B	C	D	E	F	G	H	I	J
1	Elev_Cuml	Agriculture	Fallow	Forest	Developed	Herbaceous	Open Water	Scrub/Shrub	Pasture	Total
2	280	0.0000	5.6944	341.6648	0.6892	101.9704	68.8053	0.0000	0.0875	518.9115
3	281	0.0000	6.0094	486.6749	1.5687	263.5505	81.9844	0.0000	0.2756	840.0635
4	282	0.0000	6.4176	680.1204	2.4981	504.4533	106.9405	0.0000	0.4041	1300.8339
5	283	0.0000	7.2088	934.3465	5.6487	685.0802	131.6995	0.0000	0.5117	1764.4954
6	284	0.0000	10.4549	1325.5117	10.1123	870.0565	202.0407	0.0262	0.6213	2418.8237
7	285	0.0000	30.0915	1973.4250	22.9254	1047.9265	274.3473	0.2216	0.7431	3349.6804
8	286	0.0000	91.4263	3473.3873	41.9880	1307.0746	370.7959	0.6426	0.8712	5286.1858
9	287	0.0000	154.5966	6190.4936	71.6164	1569.2754	489.1008	0.9504	1.0487	8477.0819
10	288	0.0000	183.7912	9667.7479	117.0636	1946.1262	588.9216	1.5174	1.3387	12506.5067
11	289	0.0000	192.0888	13901.8613	170.1901	2349.2723	633.3565	1.5365	1.6571	17249.9627
12	290	0.0000	197.0750	18348.8921	214.5861	2720.3600	668.3494	1.5397	2.2348	22153.0372
13	291	4320.1661	200.3281	18807.0932	280.2049	2740.4700	683.8358	1.6119	3.6509	27037.3610
14	292	9499.6139	202.4977	19229.6610	392.0078	2756.0521	698.7625	1.6298	6.0490	32786.2738
15	293	14817.4489	203.9203	19767.9395	552.2536	2776.5150	708.9605	1.6413	8.8913	38837.5704
16	294	20112.5699	205.5956	20301.7279	730.4029	2801.7414	722.1563	1.6528	13.1230	44888.9697
17	295	25051.8760	207.0862	20702.4723	946.6277	2809.6863	738.0952	1.7053	20.1839	50477.7329
18	296	29621.4816	207.9863	21030.2187	1177.9015	2816.2449	765.7787	1.8412	28.0496	55649.5024
19	297	34521.4528	208.9828	21411.1436	1432.2626	2822.3287	774.3570	5.8603	40.6818	61217.0698
20	298	39106.6925	209.4241	21725.8558	1718.8947	2834.6830	780.9870	9.0618	63.0279	66448.6269
21	299	44601.9270	210.9984	22011.5775	2046.1470	2839.4044	789.0727	9.1571	83.1194	72591.4035
22	300	50064.2471	211.6936	22276.4359	2410.9104	2843.4149	794.9174	9.1827	104.6428	78715.4448

Table C3. Land cover under all alternatives addressed (land use changes are not considered) for the St. Johns Bayou project area. Cumulative acres of each land cover type below one-foot contours Bayou as provided by the Memphis District in 2011.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	Elev_cuml	Corn	Cotton	Rice	Soybeans	Wwheat	WwheatSoy	Other_Ag	Fallow	Forest	Woody_Wet	Developed	Grass	HerbWetlands	Wetlands	Open_Water	Shrubland	Pasture	Total
2	281	0	0	1.21069	245.213	0	3.84952491	0	0.0287	17.2372	318.65875	13.0909009	0	10.61023526	0	100.2179	0	0	710.117
3	282	0.12316	0	1.32904	261.45	0	4.12460932	0	0.08909	19.3491	367.8913	15.3581499	0	11.0017082	1.04686	100.2179	0	0.00012	781.981
4	283	0.52133	0	1.75354	280.889	0	4.12559852	0	0.90186	24.0857	418.40358	17.01959	0	11.54813944	1.26746	100.2179	0	0.12589	860.859
5	284	4.13886	0	5.35991	1566.53	0	5.81339027	0	5.59145	75.7357	791.87993	31.73898	0	34.93431091	5.65228	157.2591	0	0.48142	2685.11
6	285	5.5987	0	18.8719	1622.67	0	6.40566644	0	11.0989	85.6194	901.27675	33.95205	0	35.68224431	6.05106	158.4164	0	0.5645	2886.21
7	286	14.9079	0.05722	42.4808	1788.6	0	7.444706	1.66901	38.9125	112.031	1341.9673	41.83514	0	46.70244716	17.9361	187.4483	0	0.83708	3642.83
8	287	41.5957	0.18623	76.4534	2337.84	0	10.702473	15.5431	88.6785	165.648	1965.9984	56.79897	0	64.39894142	31.7637	244.4653	0	1.09947	5101.17
9	288	62.257	0.30161	116.886	2623.92	0	14.8975099	26.1372	152.209	193.224	2315.1985	65.35781	0	70.95372578	40.6145	259.6819	0	1.22902	5942.86
10	289	84.0769	0.59012	171.603	2964.2	0	19.5238603	36.4942	195.548	217.091	2602.3227	84.68511	0	78.04028764	47.9423	270.3363	0	1.42654	6773.88
11	290	134.527	4.01247	277.373	3865.61	0	27.5161152	46.8302	233.169	267.744	3068.2874	126.2018	0	83.54591724	53.0996	291.0613	0	2.86113	8481.84
12	291	250.108	4.06376	910.694	5809.61	0	50.9260244	85.5271	287.12	308.595	3513.5431	211.8649	0	97.20117073	69.2931	298.3148	0	7.41077	11904.3
13	292	349.409	4.9069	1645.66	8293.67	0.3974	84.1057207	115.959	304.996	350.321	3929.7742	330.0897	0	108.9930235	74.6332	306.9947	0	12.9198	15912.8
14	293	414.044	14.8271	1912.39	9863.49	0.55993	133.880191	133.383	313.519	375.797	4150.3872	417.2404	0	122.5301267	76.8525	309.8125	0	23.4761	18262.2
15	294	479.649	18.331	2130.83	11125.8	0.83561	221.026372	150.04	316.678	399.249	4293.4988	479.2179	0	128.6220153	77.144	309.9852	0	44.6081	20175.5
16	295	593.245	27.7974	2324.41	12650.9	2.02612	353.344247	172.863	319.171	422.743	4442.9622	548.3106	0	130.3249801	78.7104	310.3681	0	111.277	22488.5
17	296	1158.92	41.7272	2727.06	17277.7	4.30111	920.442657	335.771	321.446	490.04	4824.7099	840.3831	0	134.9909713	89.9317	310.7694	0	483.202	29961.4
18	297	1878.93	79.323	3094.04	22831.3	9.17949	2013.73599	492.428	325	558.927	5245.6202	1336.553	0	140.0211174	118.232	312.1073	0	938.91	39374.3
19	298	2148.86	100.428	3170.74	24345.9	13.6432	2619.80196	513.191	327.725	595.871	5481.395	1515.923	0	143.3252661	119.529	312.264	0.01647	1073.83	42482.5
20	299	2439.42	129.268	3204	25359.1	19.165	3236.8897	543.526	329.599	628.007	5646.0696	1676.249	0	144.3264053	119.923	312.5108	0.28756	1194.43	44982.8
21	300	2810.53	188.345	3222.32	26257.7	24.5803	3925.12069	581.848	333.294	651.859	5789.1551	1852.064	0	144.7580661	119.968	313.1251	0.77339	1273.93	47489.4

DRAFT

Appendix J

Biological Assessment

U.S. Army Corps of Engineers
Memphis District

DEPARTMENT OF THE ARMY
MEMPHIS DISTRICT CORPS OF ENGINEERS
167 NORTH MAIN STREET B-202
MEMPHIS, TENNESSEE 38103-1894

Reply to
Attention of:

October 06, 2011

Regional Planning and
Environmental Division South

Mr. Charlie Scott
U.S. Fish and Wildlife Service
Missouri Ecological Services Field Office Supervisor
101 Park DeVille Drive, Suite A
Columbia, MO 65203-0057

Dear Mr. Scott:

The Memphis District, U.S. Army Corps of Engineers, is submitting the enclosed biological assessment on the potential effects of the St. Johns Bayou and New Madrid Floodway Project, Missouri, on federally threatened and endangered species. The biological assessment concludes that the project may affect, but is not likely to adversely affect the federally endangered interior least tern (*Sterna antillarum*), pallid sturgeon (*Scaphirhynchus albus*), or their critical habitats.

Pursuant to Section 7 of the Endangered Species Act, as amended, we are requesting your concurrence with this determination. If you have any questions concerning this submittal, please contact Mike Thron at (901) 544-0708 or e-mail at john.m.thron@usace.army.mil.

Sincerely,

Edward P. Lambert

Edward P. Lambert
Chief, Environmental Compliance Branch
Regional Planning and Environmental Division South

Enclosure

ENDANGERED SPECIES
BIOLOGICAL ASSESSMENT

INTRODUCTION

This Biological Assessment (BA) is submitted to the U.S. Fish and Wildlife Service (USFWS) by the U.S. Army Corps of Engineers (USACE) to evaluate the potential impacts to federally listed threatened and endangered species from the proposed construction of the St. Johns Bayou and New Madrid Floodway Flood Control Project, Missouri (Phase 1), in accordance with the Endangered Species Act of 1973, as amended. Correspondence from the USFWS dated December 13, 2010, stated that two federally listed species should be included in this assessment: the interior population of the least tern (*Sterna antillarum*) and pallid sturgeon (*Scaphirhynchus albus*). Additionally, the correspondence noted that the bald eagle (*Haliaeetus leucocephalus*) is known to occur within the project area and although it was removed from the endangered species list, it remains protected by the Bald and Golden Eagle Act and the Migratory Bird Treaty Act.

PROJECT DESCRIPTION

An environmental impact statement (EIS) is being prepared for the proposed project analyzing the authorized project alternatives and several avoid and minimization measures. The following is a description of the authorized project alternative. The authorized project as presented in this biological assessment describes the potential project that would have the greatest environmental impact to the ecological resources in the project area. Any avoid and minimization measures recommended in the EIS would decrease environmental impacts. Therefore, this BA encompasses the greatest potential impact to the resource, and revisions are not needed in the event of a selection of an avoid-and-minimize alternative detailed in the EIS.

St. Johns Bayou Basin

The authorized project alternative consists of channel enlargement and drainage improvements along the lower 4.5 miles of St. Johns Bayou, beginning at New Madrid, Missouri, continuing along the Birds Point New Madrid Setback Levee Ditch, and ending with 10.8 miles along St. James Ditch. Selective clearing and snagging has already been completed along a 4.3-mile reach of the Setback Levee Ditch beginning at it confluence with St. James Ditch. In addition, a 1,000 cubic feet per second (cfs) pumping station would be constructed a few hundred feet east of the existing gravity outlet at the lower end of St. Johns Bayou.

The lower 4.5 miles of St. Johns Bayou would be cleared and enlarged on both sides; bottom widths would be increased from approximately 80 feet to 200 feet. Approximately 2,485,000 cubic yards of material would be deposited along both banks creating a 220-foot wide

embankment on each side. Following construction, the embankments would be allowed to re-vegetate naturally as part of a conservation easement.

The lower 8.1 miles of the Birds Point New Madrid Setback Levee Ditch would be enlarged from approximately 40 feet to 50 feet. The work would take place along the left descending bank and approximately 675,000 cubic yards of material would be placed in a 120-foot wide embankment located along the left descending bank. The area would be allowed to re-vegetate naturally as part of a conservation easement.

St. James Ditch would be enlarged along the left descending bank. The bottom width along the lower 3.5 miles would be enlarged from 35 feet to 45 feet. No changes to bottom width are anticipated along the remaining 7.8 miles of channel. However, top width along the left descending bank would be widened to an 80-foot average. Approximately 630,000 cubic yards of excavated material would be placed on a 100-foot wide embankment along the left descending bank. The area would be allowed to re-vegetate naturally as part of a conservation easement.

A 1,000 cfs pumping station would be constructed several hundred feet to the east of the existing gravity outlet structure on St. Johns Bayou. The pumping station would discharge interior impounded runoff over the levee during high Mississippi River stages. Pumping would commence when water in the sump area reached an elevation of 279.0 feet National Geodetic Vertical Datum (NGVD) and would continue until the sump elevation dropped to 277.0 feet NGVD. The gravity outlet structure gates would remain closed when river stages are greater than the sump elevation, thus preventing Mississippi River backwater flooding. The gates would remain open when the sump elevation is greater than the Mississippi River elevation, which would allow drainage through the St. Johns Bayou gravity outlet structure.

During waterfowl season (1 December to 31 January) the gates would be closed to impound interior runoff in the lower St. Johns Bayou Basin for the benefit of waterfowl. Impounded water would be managed to an elevation of 285.0 NGVD by gravity drainage or by turning on pumps in the event that impounded interior runoff elevations exceed an elevation of 285.0 feet NGVD.

New Madrid Floodway

The 1,500-foot levee gap at the lower end of the New Madrid Floodway between setback levee miles 35 and 37 would be closed with the construction of a levee and associated gated culverts. The closure levee would be constructed of approximately 233,000 cubic yards of material, have a crown elevation of 317.0 feet NGVD, top width of 16 feet, base width of approximately 302 feet, and have side slopes of 4.5:1. The footprint would be approximately 9 acres.

Four 10 by 10-foot gated box culverts would be constructed in Mud Ditch to maintain drainage in the New Madrid Floodway. The gates would be managed in a similar fashion as the existing St. Johns Bayou gravity outlet structure. The gates would be closed when the river elevation is

higher than the sump elevation. Subsequently, the gates would be opened when the sump elevation is greater than the river elevation.

A 1,500 cfs pump station would be constructed in the New Madrid Floodway. Within the New Madrid Floodway, pumping would normally commence when the water in the sump reached 278.0 feet NGVD and would continue until sump elevation dropped to 275.0 feet NGVD. Should river stages drop during pumping to levels below the sump elevation, pumping operations would cease and the floodgates would be opened to allow for gravity drainage.

During waterfowl season (1 December to 31 January) the gates would be closed to impound interior runoff in the lower New Madrid Floodway for the benefit of waterfowl. Impounded water would be managed to an elevation of 284.4 NGVD. This would be accomplished by partially closing the gates to impede drainage through the structure. The pumping station would be used to maintain the elevation of 284.4 feet NGVD in the event that the Mississippi River elevation is greater than 284.4 feet NGVD.

Closing the levee gap at the lower end of the New Madrid Floodway would reduce the conveyance for flood water passage when the floodway is operated. To maintain the authorized 3-foot freeboard above the project design flood, a 14.1-mile section of the Setback Levee would require a grade raise to ensure flood protection in the St. Johns Bayou Basin at the authorized level of protection. Setback Levee grade raises range from 0.1 feet to three feet (average 1.28 feet) and would require 2.4 million cubic yards of material. Material would be obtained from adjacent borrow areas.

SPECIES ASSESSMENTS

INTERIOR LEAST TERN (*Sterna antillarum)*

Description

The interior population of the least tern, *Sterna antillarum*, was listed as a federally endangered species on 27 June 1985 (USFWS 1985). The recovery plan for the species was approved on 19 September 1990 (USFWS 1990), but no critical habitat has been designated. Least terns are the smallest of the American terns, measuring from 8.5 inches to 9.75 inches long and having a wingspan of approximately 20 inches. Least terns have a black-capped crown, white forehead, a black-tipped yellow bill, gray back and dorsal wings, white belly, and orange legs. The sexes are mostly identical. Juveniles tend to have a darker, mottled, brownish plumage and bill compared to adults, with a dark band behind the eye and a dark shoulder patch.

Taxonomic Status

Lesson first described the least tern species as *Sterna antillarum* in 1847. During the 1940s, this bird was classified as a subspecies of the European little tern (*Sterna albifrons*) (Burleigh and Lowery 1942). As a result of more recent studies on vocalizations, behavior, and limited morphology, Old and New World least/little terns are now considered separate species and the species name for the least tern was returned to *Sterna antillarum*. The American Ornithologists Union (AOU) currently recognizes the least tern under a previously published name *Sternula antillarum* (Banks et al. 2006) based on mitochondrial DNA and molecular phylogeny (Bridge et al. 2005). The USFWS however currently retains use of *Sterna antillarum* (pers. com. Lindsey Lewis). The AOU also recognizes three subspecies of least tern in North America; the California Least Tern, *S. a. browni*, the coastal least tern, *S. a. antillarum* and the inland least tern, *S. a. athalassos*. The three subspecies are virtually indistinguishable morphologically and are distinguished by the separation of their breeding ranges. Due to taxonomic difficulties, the USFWS is uncertain if the interior least tern qualifies as a separate subspecies. However, the Endangered Species Act allows for the listing of vertebrate subspecies as a discrete population.

Historical Range and Population Level

The interior least tern is a migratory, colonial shorebird that breeds and rears its young on islands along much of the Mississippi, Missouri, Arkansas, and Ohio River systems. Downing (1980) performed a partial survey on the lower Mississippi River in 1975 and estimated there were about 1,200 adult birds in the total interior population of the United States and 750 least terns from Cairo, IL to below Osceola, AR. At the time of the Federal listing in 1985, approximately 1,400 to 1,800 terns were believed to be remaining in the total United States population (USFWS 1985). In 1990, census data estimated approximately 5,000 interior least terns, with half of these occurring along the lower Mississippi River (USFWS 1990). Past census surveys concentrated on where terns had been found historically and did not seek possible new locations. Hardy (1957) was the first to attempt a census over the entire lower Mississippi River but was limited by time, money and equipment. Recent, more comprehensive surveys indicate the terns move to the first available sandy nesting sites in response to habitat changes. USACE and many state agencies have attempted to standardize survey techniques and data recording methods (Lott 2006). These coordinated surveys have shown a greater range and much larger population numbers than expected. The first coordinated range-wide survey for the interior least tern was conducted in 2005 with a count of 17,591 interior least terns with 62% being found on the lower Mississippi River (Lott 2006). Interior least terns are most abundant along the lower Mississippi River; and presently, more than 10,000 individuals are commonly observed there each year (Figure 1, USACE 1986-2010). Small boat surveys along the lower Mississippi River have documented between 28 colony locations in 1986 to as many as 107 in 2006 (USACE 1986 - 2010).

Least tern reproductive behavior corresponds to the Mississippi River hydrograph. Although high river elevations can take place during any time of the year, the river typically is at its highest stages during March and April and at its lowest stages in August and September. Least terns typically arrive on the Mississippi River nesting areas from late April through mid May and spend approximately 4 to 5 months at the breeding sites. Soon after arriving in the breeding area, least terns form colonies ranging from less than a dozen to several hundred birds. Courtship and nesting begin in late May and early June through late July. Reproduction takes place from late May through early August, dependent on specific yearly river stages. Courtship and breeding are followed by nest excavation and egg laying. The shallow nest scrapes are generally on the highest parts of the sandbars, the first parts to become exposed when river stages fall, and located a few yards apart or else widely scattered over the ground. Nest colonies can be from several hundred feet to nearly 3/4 mile long, depending upon the sand bar configuration.

Fall departure from colony sites varies according to the geographic location and the time of nesting. Generally, fall departure is no later than early September. Late season high river stages (*i.e.*, June floods), which periodically delay nesting into early August, prevent least tern migration until fledglings are mature enough to survive migration. Least terns of the Lower Mississippi River Valley migrate through and winter along the northern and eastern coast of South America, the eastern and western coasts of Central America and the Caribbean Islands, mixing with other least tern subspecies of North America. Exact wintering locations are largely undocumented (Whitman 1988).

Habitat and Reason for Decline

Interior least terns on the lower Mississippi River choose nest colony sites on large, isolated, mostly bare sandbars or on the upstream and high downstream sandy points of islands. A colony can cover from several hundred square feet to several acres. Almost all colony sites are on land that is separated from the riverbank during the breeding season. Terns do not use grassland or woodland habitat. On the older or larger sandbars, colonies are usually located several hundred yards away from large trees. The specific colony site is almost always on the highest part of the sandbar; the first part to become exposed as high spring river stages recede. Nest sites are well drained and usually set back from or high above the waterline. Individual nests are shallow depressions scraped out in the bare sand or gravel, usually next to a small piece of driftwood, among the debris wrack lines, or often within short, sparsely scattered vegetation (Smith and Renken 1991, USACE 1986-2010). On sandbars without driftwood, nests are in bare sand or gravel and often placed on the sand-ripple edges.

The primary reason cited in the literature for the decline in the least tern population is habitat loss. The loss is attributed to channelization, river stabilization structures, navigation structures, and dam construction for flood control, hydropower, and recreation (Hardy 1957, Downing 1980, USFWS 1985 and 1990, Smith and Stucky 1988, Whitman 1988). Increasing river

development for industrial and recreational uses, in addition to increased irrigation water withdrawal from some rivers in the upper Midwest have caused a decline in available habitat. Least tern habitat may be available in those areas but it is often too short-lived to benefit the terns with a fully successful year class. However, in the Lower Mississippi River Valley, large sediment loads coupled with 40-ft. fluctuations in water level indicate that river conditions would allow for many sandbars to be made available to least terns as nesting habitat. USACE conducted a BA in 1999 evaluating effects on the interior least tern and its habitat due to channel improvement structures of the Mississippi River and Tributaries Project (USACE 1999a). The BA analyzed temporal and spatial relationships of sandbar habitat and usage according to the Low Water Reference Plane (LWRP), taking into account the slope of the river. Throughout many reaches of the lower Mississippi River, sandbars were shown to be dynamic in nature, including changes in size and elevation of some sandbars, degradation of other sandbars, and formation of new sandbars; however, little net change in total habitat area was observed. The BA found that the net effect of dike and revetment construction and related long term channel responses on total bare sandbar habitat for the interior least tern appears to have been comparatively small in the lower Mississippi River and that significant quantities of bare sandbar habitat remain present and would continue to remain present in the lower Mississippi River for the species. Much of the sandbar habitat utilized by least terns in the lower Mississippi River is associated within dike fields (USACE 1986-2010, USACE 1999a). Interagency meetings are held annually by the USACE to discuss proposed channel improvement work along the lower Mississippi River with various wildlife agencies and to incorporate habitat improvement features for the interior least tern into the USACE channel improvement program. Dike notches are a common feature placed within dike fields to increase aquatic habitat diversity and protect sandbars used by the interior least terns by isolating the colony with a back channel. The Recovery Plan goal for the lower Mississippi River was for a population between 2,200 and 2,500 adult least terns to remain stable for 10 years (USFWS 1990). Annual surveys conducted by USACE from 1985 to the present, have shown numbers exceeding 2,500 adult terns for more than twenty years in the lower Mississippi River with numbers exceeding 10,000 individuals in recent years (Figure 1).

Little is known about the interior least tern during its migration or on its winter range. Migration habitat characteristics have not been described in literature. However, it appears likely that least terns use habitat similar to that used for nesting, resting, and foraging during the regular breeding season. Significant habitat problems occurring in wintering areas and along migration routes could impact least tern populations (Whitman 1988).

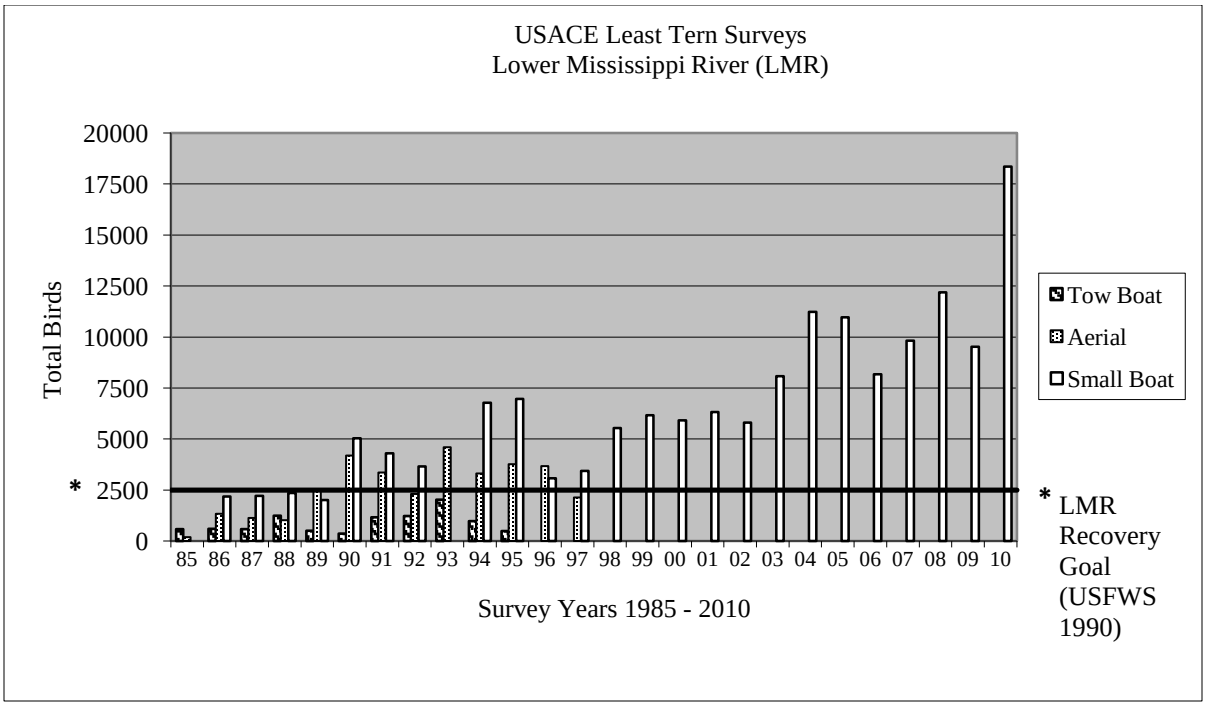

Figure 1. Interior least tern population data from U.S. Army Corps of Engineers surveys on the lower Mississippi River from 1985 to the present.

Food Habits

Least terns are almost exclusively piscivorous and plunge-dive to capture small fish near the surface of the water. Prey size seems to be more important than a preference for a particular species to the terns, feeding on fish up to approximately 3.5 inches in size (Moseley 1976, Whitman 1988, Smith and Renken 1990, USACE 1986-2010). Dominant prey species in the lower Mississippi River include shad (*Dorosoma spp.*), river carpsucker (*Carpiodes carpio*), *Notropis* minnows, white bass (*Morone chrysops*), largemouth bass (*Micropterus salmoides*), freshwater drum (*Aplodinotus grunniens*), and bluegill (*Lepomis macrochirus*) (Smith and Renken 1990, USACE 1986-2010). Observations of forage-sized bighead carp (*Hypophthalmichthys nobilis*) and silver carp (*Hypophthalmichthys molitrix*) dropped on sandbars at colony locations have also increased in the past few years (USACE 2004–2010). Fishing occurs close to the colony locations. Most of the least tern colony locations in the lower Mississippi River are associated with dike fields, and least terns are commonly observed among these and surrounding habitats (USACE 1986-2010). Tibbs and Galat (1998) showed that both availability and taxa richness of forage sized fish were greater in the shallow areas between sandbars (*i.e.*, colony locations) and the contiguous river channel than in deep water. Other foraging habitats observed in the lower Mississippi River include natural and revetted riverbanks on the opposite side of the river from a colony, over current divergences (boils) in the main river channel, at the mouths of "outlets" of floodplain lakes and tributary streams, turbulent water around dikes, backwater chutes, and occasionally ponds and lakes near the river (Dugger 1997,

USACE 1986-2010). On population surveys conducted by USACE, least terns were regularly observed fishing along the opposite revetted river bank, often 0.75 to 1 mile away, and distances up to 2.5 miles upstream and downstream from nesting colonies. The fishing area itself could be 0.75 miles in length (USACE 1986-2010). This contrasts with foraging distances on smaller rivers in Nebraska, where terns rarely ventured farther than 0.10 miles from their nesting colony (Faanes 1983).

Evaluation of Potential Impacts

Interior least terns do not typically nest within the project area. Record flooding in late April and early May 2011 resulted in operation of the Birds Point – New Madrid Floodway for the first time since the flood of 1937. Explosives were used to create an Inflow/Outflow Crevasse on the frontline levee near Big Oak Tree State Park resulting in a large quantity of sand being deposited in agricultural fields landside of the levee. Additionally, high river stages extended into the 2011 least tern breeding season and very few sandbars were exposed in the lower Mississippi River. A least tern colony of approximately 40 to 50 individuals was observed nesting in this sand deposit in late June 2011. As the river stages dropped and sandbars became exposed, the terns utilizing the sand deposit departed. By the middle of August 2011, vegetation had encroached onto the sand deposit, and all individuals had departed from that location. Coordination with the USFWS associated with this observed least tern colony was conducted during the Birds Point – New Madrid Floodway Repair Project, and it was determined that the proposed actions were not likely to adversely affect least terns. Since this time the majority of the sand deposit has been removed from the agricultural fields. Additionally, the land connection between this colony location and the forested Big Oak Tree State Park, increases the likelihood of predation by coyotes, owls, and other predators. Thus, future use of this location by least terns is extremely unlikely.

The closest regularly used colony location to the project area is associated with the Kentucky Point Dike Field a few miles downstream of New Madrid, Missouri (Figure 2). The proposed project would not impact sandbar habitat, thus no impacts to nesting habitat is expected.

The proposed project would reduce the duration and frequency of seasonal flooding in the project area. The impacts associated with the reduction in flood frequencies and durations have been assessed by a series of environmental models, including EnviroFish that quantifies fish spawning and rearing habitat. The proposed project is not likely to adversely affect least tern foraging because least terns forage on ubiquitous forage fish throughout the Lower Mississippi River, and there is ample remaining spawning and rearing habitat for these species.

Sheehan et al. (1998) sampled the tributaries within the proposed project area and found the most dominant taxon to be mosquitofish (*Gambusia affinis*), common carp (*Cyprinus carpio*), channel catfish (*Ictalurus punctatus*), and gizzard shad (*Dorosoma cepedianum*). Killgore et al. (unpublished data) sampled St. Johns Basin, New Madrid Basin, and Mud Ditch to the

confluence with the Mississippi River during 2007-2008. Over 4,000 individual fish representing 65 species were collected (Table 1). Similar to Sheehan et al. (1998), dominant taxa were mosquitofish, cyprinids, suckers, sunfish and shad. All of these species are found in various densities and habitats in the lower Mississippi River (Baker et al. 1991). The closest colony location is associated with the Kentucky Point Dike Field. The Kentucky Point Dikes are at various elevations ranging from 24 feet above the Low Water Reference Plane (LWRP) to 14 feet above the LWRP with several dike notches and both revetted and natural banks present throughout the dike field. This mosaic of habitats would undoubtedly provide spawning and rearing habitat for potential forage fish at intermediate river stages during appropriate times of the year. Dike field pools have been shown to contain similar larval fish compositions compared to other backwater habitats (*e.g.*, abandoned chutes and oxbow lakes) during slack-water conditions, consistently dominated by dense populations of shads, *Lepomis* spp. and inland silversides (Beckett and Pennington 1986). Additionally, Kentucky Point, located immediately across from New Madrid and adjacent to the closest least tern colony, is low in elevation and contains numerous abandoned channels and other fish spawning and rearing habitat (Figure 3). Other significant areas of batture land near the project area include Donaldson Point (Figure 3).

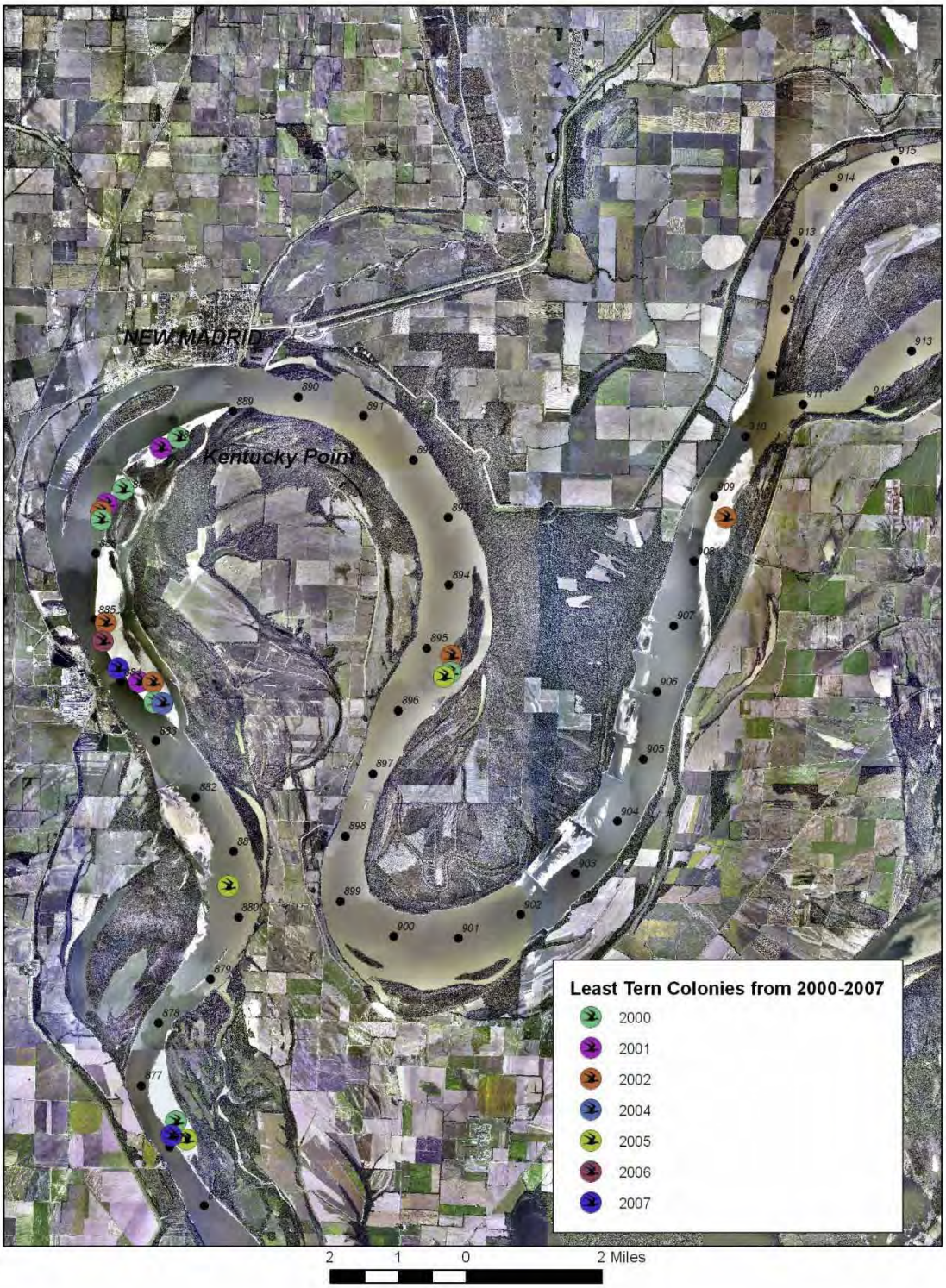

Figure 2. Locations of interior least tern colonies on the Mississippi River from USACE surveys conducted from 2000 to 2007 near New Madrid, Missouri, shown on a 2007 low-water aerial photograph.

Table 1. Fishes of the St. Johns/New Madrid project area collected in 2007-2008 by seines (n=18), hoopnets (n=32), electroshocking (n=4), and gill nets (n=6).

Family and Species	Number
Lepisosteidae	
Spotted gar (*Lepisosteus oculatus*)	53
Shortnose gar (*L. platostomus*)	57
Longnose gar (*L. osseus*)	8
Clupeidae	
Skipjack herring (*Alosa chrysochloris*)	2
Gizzard shad (*Dorosoma cepedianum*)	137
Threadfin shad (*D. petenense*)	3
Hiodontidae	
Goldeye (*Hiodon alosoides*)	9
Esocidae	
Grass pickerel (*Esox americanus*)	7
Cyprinidae	
Grass carp (*Ctenopharyngodon idella*)	3
Red shiner (*Cyprinella lutrensis*)	5
Blacktail shiner (*C. venusta*)	442
Common carp (*Cyprinus carpio*)	21
Silver carp (*Hypophthalmichthys molitrix*)	76
Bighead carp (*H. nobilis*)	6
Ribbon shiner (*Lythrurus fumeus*)	193
Speckled chub (*Macrhybopsis aestivalis*)	1
Golden shiner (*Notemigonus crysoleucas*)	1
Emerald shiner (*Notropis atherinoides*)	114
Ghost shiner (*N. buchanani*)	20
Ironcolor shiner (*N. chalybaeus*)	195
Weed shiner (*N. texanus*)	18
Mimic shiner (*N. volucellus*)	16
Pugnose minnow (*Opsopoeodus emiliae*)	23
Bullhead minnow (*Pimephales vigilax*)	173
Bluntnose minnow (*P. notatus*)	107
Catostomidae	
River carpsucker (*Carpiodes carpio*)	42
Highfin carpsucker (*Carpiodes velifer*)	1
Smallmouth buffalo (*Ictiobus bubalus*)	307
Bigmouth buffalo (*I. cyprinellus*)	58
Black buffalo (*I. niger*)	41
Spotted sucker (*Minytrema melanops*)	
Ictaluridae	
Black bullhead (*Ameiurus melas*)	1
Yellow bullhead (*A. natalis*)	1
	7

Blue catfish (*Ictalurus furcatus*)	40
Channel catfish (*I. punctatus*)	102
Tadpole madtom (*Noturus gyrinus*)	10
Freckled madtom (*N. nocturnus)*	1
Flathead catfish (*Pylodictis olivaris*)	10
Aphredoderidae	
Pirate perch (*Aphredoderus sayanus*)	30
Cyprinodontidae	
Golden topminnow (*Fundulus chrysotus*)	54
Blackstripe topminnow (*F. notatus*)	37
Blackspotted topminnow (*Fundulus olivaceus*)	23
Poeciliidae	
Western mosquitofish (*Gambusia affinis*)	1168
Atherinidae	
Brook silverside (*Labidesthes sicculus*)	180
Percichthyidae	
White bass (*Morone chrysops*)	13
Striped bass (*M. saxatilis*)	1
Centrarchidae	
Green sunfish (*Lepomis cyanellus*)	47
Warmouth (*L. gulosus*)	16
Orangespotted sunfish (*L. humilis*)	90
Bluegill (*L. macrochirus*)	58
Longear sunfish (*L. megalotis*)	29
Redspotted sunfish (*L. miniatus*)	27
Spotted bass (*M. punctulatus*)	13
Largemouth bass (*M. salmoides)*	12
White crappie (*Pomoxis annularis*)	4
Black crappie (*P. nigromaculatus*)	
Elassomatidae	
Banded pygmy sunfish (*Elassoma zonatum*)	148
Percidae	
Mud darter (*Etheostoma asprigene*)	1
Bluntnose darter (*E. chlorosomum*)	12
Slough darter (*E. gracile*)	3
Harlequin darter (*E. histrio*)	2
Cypress darter (*E. proeliare*)	31
Saddleback darter (*Percina ouachitae*)	5
Dusky darter (*P. sciera*)	5
Sciaenidae	
Freshwater drum (*Aplodinotus grunniens*)	120
Total	4,341

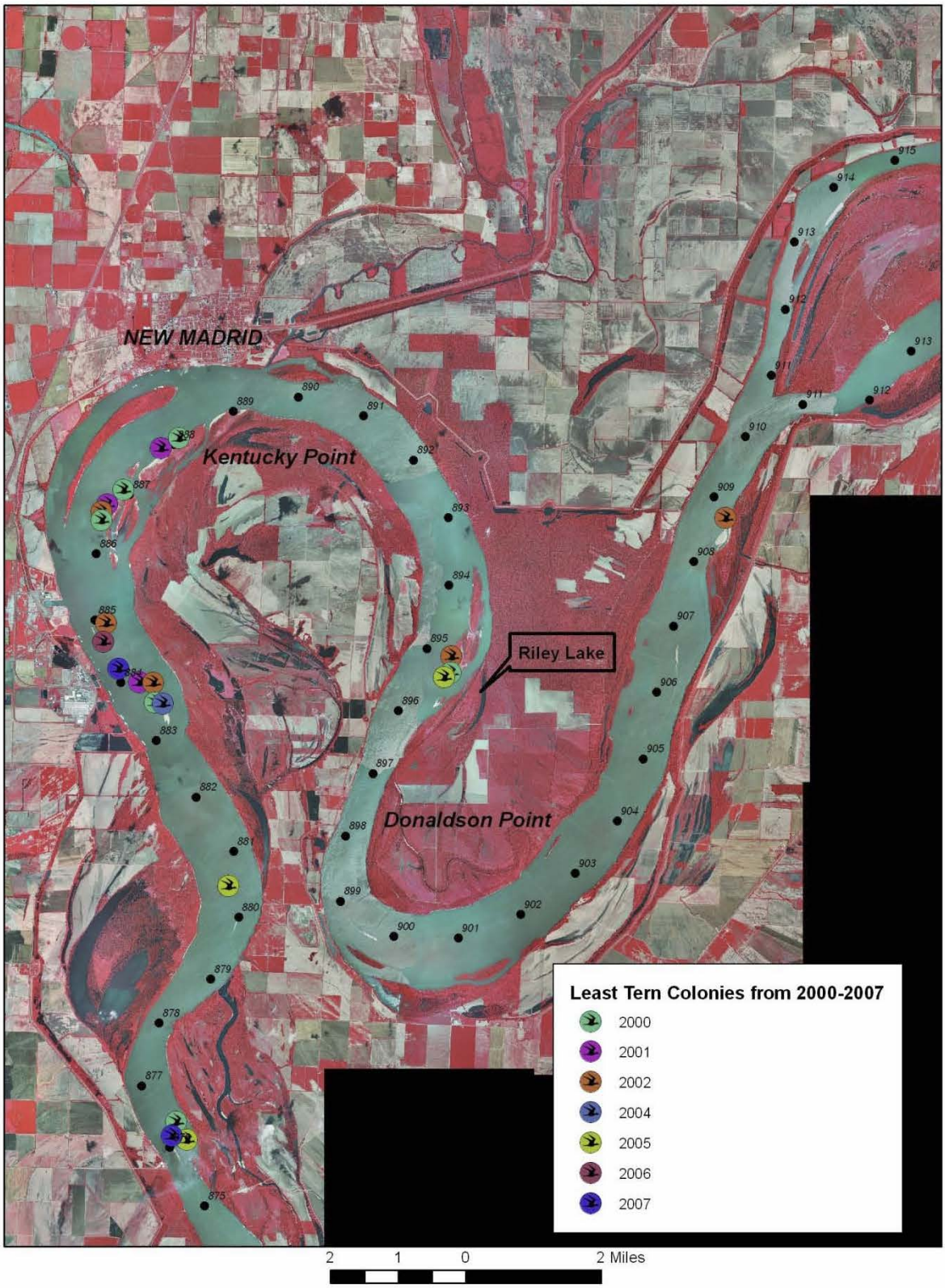

Figure 3. Interior least tern colonies in the vicinity of New Madrid, Missouri, shown on a 2009 high-water infrared aerial photograph.

Although no significant impacts to least tern foraging is expected as a result of the project, the proposed project would compensate for significant unavoidable impacts to fish spawning and rearing habitat. Since over 80% of the project area is devoted to agriculture production, the vast majority of impacts would be to agricultural lands. Agriculture fields provide sub-optimal habitat for fish when compared to bottomland hardwoods or floodplain lakes. However, flooded ag fields do provide good shorebird habitat. Moreover, several avoid and minimize measures are being developed that would reduce the overall impact of the project, including impacts to fish spawning and rearing habitat.

A range of compensatory mitigation measures were considered. They include but are not limited to wetland/bottomland hardwood restoration, restoration of hydrology to Big Oak Tree State Park, and restoring floodplain lake habitat. All of these measures would compensate for fish spawning and rearing habitat. However, mitigation measures that provide optimum fish habitat in foraging areas would directly benefit least terns. For example, the EIS is analyzing the restoration of Riley Lake, a floodplain lake that is located on Donaldson Point, immediately east of a least tern colony that was last observed in 2005 (see Figure 3). Attempts were made to drain the lake for agricultural purposes in the past. A preliminary mitigation measure being investigated is to construct a weir in the outlet channel to raise the lake to historic levels. Although this would provide optimum spawning and rearing habitat for fish, it would also likely be actively utilized by least terns while foraging. Mitigation measures that compensate for significant project impacts and would provide additional benefits to least terns would be investigated. This can include, but not be limited to, additional floodplain lake creation/restoration/rehabilitation, borrow pit construction, notching dike fields, reconnection/establishment of Mississippi River secondary channels, and other associated batture land compensatory mitigation measures.

PALLID STURGEON (*Scaphirhynchus albus)*

Much of the following information on pallid sturgeon was taken from the BA prepared for the Mississippi River Mainline Levees Enlargement and Seepage Control Project (USACE 1998b) by Dr. Jack Killgore and Dr. Jan Hoover, fishery biologists with the Engineer Research and Development Center, USACE.

Description

The pallid sturgeon was listed federally as an endangered species on 6 September 1990 (*Federal Register 55: 36647, USFWS 1994*), and a recovery plan was approved 7 November 1993 (USFWS 1993). Prior to this, it was listed as a threatened or endangered species by 9 of the 13 states in which it occurred (Kallemeyn 1983). It was also listed as threatened, later endangered,

throughout its range by the Endangered Species Committee of the American Fisheries Society (Deacon et al. 1979, Williams et al. 1989). The USFWS conducted a 5-year review of this species' endangered status in 2007 and determined that no status change was needed at that time (USFWS 2007). Imperilment of this species is attributed to "destruction, modification, or curtailment of its habitat or range" and "other natural or manmade phenomena" (Williams et al. 1989). To date, no critical habitat has been designated for this species.

The pallid sturgeon is one of only three species of river sturgeons (*Scaphirhynchus* spp.), an ancient group of fishes that inhabit large, turbid rivers of the central United States. The recently described Alabama sturgeon (*Scaphirhynchus suttkusi*) is endemic to the Mobile Basin. The pallid sturgeon occurs sympatrically with the shovelnose sturgeon (*Scaphirhynchus platorynchus*) in parts of the Mississippi-Missouri River Basin (Lee 1980a, 1980b). However, the shovelnose sturgeon occurs over a wider geographic range than the pallid sturgeon, inhabiting the upper Mississippi River, Ohio River and tributaries, and formerly inhabiting the Rio Grande Basin from which the pallid sturgeon is unknown.

Taxonomic Status

Fishes characteristic of swift, turbid rivers with high temporal variation in discharge share several morphological features (Cross and Moss 1987). They are ventrally flattened and possess small eyes, hyper-developed cutaneous sense organs, and crowded, embedded scales. Sturgeon, however, are exceptional. They are large, elongate fishes with a pronounced rostrum (hard, forward-projecting snout), five rows of bony plates (one dorsal, two lateral, and two ventrolateral), a muscular extension of the body into the upper lobe of the tail fin, and an inferior protrusible mouth immediately posterior to four fleshy barbels (Robison and Buchanan 1988). River sturgeon differ from other sturgeons by lacking spiracles (small openings into the gill chamber anterior to the operculum) and by possessing a long filament on the upper lobe of the tail fin and a flat, spadelike rostrum. Both structures have hydrodynamic functions. The caudal filament probably provides sensory input allowing young sturgeon to stay aligned in current and avoid displacement by high velocities (Weisel 1978). The rostrum generates "lift" during swimming and "resistance" during station-holding (Aleev 1963).

The three species of river sturgeons are very similar in appearance and early biologists did not distinguish them from each other. Unusually pale river sturgeons were observed by commercial fisherman; and in 1905, these were recognized as a distinctive form (Forbes and Richardson 1905). Originally described as a new species belonging to a new genus (*Parascaphirhynchus albus*), the pallid sturgeon was later reevaluated taxonomically based on larger numbers of specimens and reassigned to the same genus as the shovelnose sturgeon (Bailey and Cross 1954).

Pallid sturgeon have been described as differing from shovelnose sturgeon by their conspicuously lighter coloration and in several morphomeristic characters (Bailey and Cross 1954, Robison and Buchanan 1988, Keenlyne, et al. 1994a). Pallid sturgeon often have a greater

number of rays in the dorsal fin (37-42 versus 30-36) and anal fin (24-28 versus 18-23). Scales on the belly are often absent or reduced compared with those of shovelnose sturgeon. In pallid sturgeon, the bases of the barbels are often arranged in an arc with the outer barbels substantially (1.72-3.54 times) longer than the inner barbels. In shovelnose sturgeon the bases of the barbels are often aligned with the outer barbels only slightly (1.05-1.78 times) longer than the inner barbel.

Although pallid and shovelnose sturgeons are considered "readily separable...well-marked species" (Bailey and Cross 1954), physical differences between the two species can be difficult to determine due to geographic variation, allometric growth, and hybridization between pallid and shovelnose sturgeon (Kuhajda et al. 2007, Murphy et al. 2007). When morphomeristic measurements fail to separate the two species and their hybrids, genetic testing is another tool to identify pallid from shovelnose sturgeon and their hybrids. Genetic testing has been performed on populations of pallid sturgeon from the Missouri, middle Mississippi, and Atchafalaya Rivers but no comprehensive assessment has been performed range-wide, and specifically on the lower Mississippi River.

Due to the difficulty in separating the rare pallid sturgeon from the darker, more common, and commercially harvested shovelnose sturgeon, a Similarity of Appearance (SOA) rule was passed in 2010 (75 FR 53598-53606) making it illegal to harvest shovelnose sturgeon in areas where it occurs sympatrically with pallid sturgeon. The SOA was supported by higher mortality rates of pallid sturgeon where commercial fishing for shovelnose sturgeon was allowed (Columbo et al. 2007, Killgore et al. 2007b), and documented take of pallid sturgeon by commercial fishers (Bettoli et al. 2008). Recreational fishing for shovelnose sturgeon was not affected by this ruling.

Historic Range and Population Level

Pallid sturgeon are found throughout the Missouri River, the middle and lower Mississippi River, and in several larger tributaries including the Yellowstone, Platte, Kansas, St. Francis, Yazoo, Big Sunflower, and Atchafalaya Rivers (Lee et al. 1980a, Kallemeyn 1983, Ross and Brenneman 1991). Historically, pallid sturgeon populations were considered higher in the Missouri and Atchafalaya Rivers than in the Mississippi River (USFWS 1993, Etnier and Starnes 1993, Constant et al. 1997), but were "nowhere common" (Bailey and Cross 1954, Kallemeyn 1983). However, more recent sampling indicates significant pallid sturgeon populations exist in the lower Mississippi River (Killgore et al. 2007a).

Rarity of the pallid sturgeon is indicated by the paucity of records in the early scientific literature. The original taxonomic description was based on nine specimens collected near the mouth of the Illinois River (Forbes and Richardson 1905). In the next half-century, it was "definitively reported" only from the mouth of the Missouri River and the Mississippi River at Keokuk, Iowa. Re-description of the species was based on 17 specimens from 8 localities

(Bailey and Cross 1954). Occurrences in regional fish references are typically based on anecdote (Harland and Speaker 1951), sporadic occurrence (Cross and Collins 1975), or fewer than 5 voucher specimens (Cook 1959, Douglas 1974, Robison and Buchanan 1988, Ross and Brenneman 1991, Etnier and Starnes 1993).

Earlier collection records compiled for a 70-year period totaled only 250 observations (Kallemeyn 1983). Approximately 76 percent of those were from the Missouri River in Montana and the Dakotas, and most were from reservoirs constructed during the 1950's and 1960's. Only 13 specimens were confirmed from the lower Mississippi River prior to 1983. Since then, a relatively large population (over 100 specimens) has been documented in the Atchafalaya (Constant et al. 1997). More recent sampling efforts in the middle and lower Mississippi River indicate the presence of a significant population of pallid sturgeon with a substantial number of wild (non-hatchery origin) fish. Hatchery cultured pallid sturgeon have been released into the Missouri and Mississippi Rivers since 1994 and have been found inhabiting the middle and lower Mississippi River. Since 1997, more than 200 pallid sturgeon have been collected from more than 100 sites in the Mississippi River from its confluence with the Missouri River to New Orleans, Louisiana (Killgore et al. 2007a). When listed, there were only 28 recognized records of pallid sturgeon from the Mississippi River, with no recognized records from the Atchafalaya River (USFWS 2009).

Habitat and Reasons for Decline

Pallid sturgeon, like shovelnose sturgeon, inhabit comparatively large flowing rivers; but pallid sturgeon occur over a narrower range of conditions. They prefer greater turbidity (Bailey and Cross 1954, Lee 1980a; 1980b), finer substrates, and deeper, wider channels. They are more likely than shovelnose sturgeon to occur in sinuous reaches and near long-established islands and alluvial bars (Bramblett 1996). Pallid sturgeon typically inhabit thalwegs and channels of relatively low slope (Constant et al. 1997). Characteristic depths inhabited by pallid sturgeon vary among populations and with river morphometry, but fish typically avoid shallow waters. In the Atchafalaya River, pallid sturgeon inhabited depths of 23 to 69 feet (Constant et al. 1997). In the Middle Mississippi River, trawling studies indicated that young-of-year sturgeon (*Scaphirhynchus* spp.) may prefer low velocity habitats adjacent to the Main Channel (*e.g.*, dikes, side channels), whereas, larger sturgeon use a broader range of habitats (Phelps et al. 2010).

Rarity of the pallid sturgeon makes it difficult to document habitat-related declines in populations. However, declining populations and range reductions of paddlefish and shovelnose sturgeon suggest that populations of pallid sturgeon are similarly impacted (Kallemeyn 1983). Reduced numbers and possible extirpations are indicated in Kansas and in Missouri and are attributed to anthropogenic regulation of river flows (Cross and Moss 1987, Pflieger and Grace 1987). Dams block movements of pallid sturgeon, which may have home ranges greater than 185 miles; and populations become segregated and fragmented (Keenlyne et al. 1994, Bramblett

1996). Impoundments also create lentic environments, which are avoided by pallid sturgeon (Constant et al. 1997). Impoundments also reduce discharge, variation in discharge, erosion, turbidity, and presence of fine substrates, all of which are habitat factors to which the pallid sturgeon is specifically adapted (Bailey and Cross 1954, Cross and Moss 1987).

Reduced turbidity of water and a prevalence of coarse substrates are believed to reduce feeding efficiency of the pallid sturgeon. Population declines may be attributed to lowland rivers that have become more like upland rivers, resulting in possible competition with more adaptable, but biologically similar species (Pflieger and Grace 1987, Ruelle and Keenlyne 1994). Length-weight relationships for pallid sturgeon in the upper Missouri River suggest that fish of a given size were heavier prior to completion of reservoirs than after the reservoirs were established (Keenlyne and Maxwell 1993).

Water pollution may also have impacted pallid sturgeon populations. Long-lived, bottom-feeding fishes can bioaccumulate heavy metals and organic pesticides in their tissues. In the Missouri River, pallid sturgeon with high concentrations of mercury, cadmium, selenium, PCB's, DDT's, chlordane, and dieldrin are documented (Ruelle and Keenlyne 1993). These substances accumulate in multiple organ systems including the kidney, liver, and ovaries. High concentrations are associated with lower growth rates and decreased standing crops of fish. Several of these contaminants are concentrated in egg tissues and may impair successful reproduction.

Altered habitats reduce isolating mechanisms of sympatric species, and abundance of the two sturgeon species are disparate. Both factors reduce likelihood of intraspecific matings of pallid sturgeon and increase the likelihood of interspecific hybridization. Although some estimates of relative abundance of pallid to shovelnose sturgeon are as high as 1:5 (Etnier and Starnes 1993), most estimates are much lower, 1:20 to 1:400 (Kallemeyn 1983, Carlson et al. 1985). Killgore et al. (2007a) collected more than 6,200 sturgeon in the middle and lower Mississippi River with an average ratio of approximately 1 pallid for every 27 shovelnose sturgeon.

Recent studies have shown evidence of hybridization between pallid and shovelnose sturgeon in the lower and middle Mississippi River (Campton et al. 2000, Tranah et al. 2004, Schrey et al. 2007). Values for morphological and meristic characters of the hybrids are intermediate between those of shovelnose and pallid sturgeon. Hybrids also demonstrate intermediate growth rates and levels of piscivory when compared with those of the parent species. Historically, the documented percentage of sturgeon hybrids has varied considerably (Keenlyne et al. 1994b). More recent studies (Schrey at al. 2007) indicate these hybrids are not intermediate in all morphomeristic characters suggesting that they are not F1 hybrids (*i.e.*, first generation offspring of two different species).

Commercial fishing may also impact pallid sturgeon. Historically, river sturgeon were occasionally targeted by commercial fishermen and were frequently obtained as bycatch. Large

specimens, including pallid sturgeon, were exploited for caviar, and smaller specimens, including shovelnose sturgeon, were discarded as nuisances (Carlander 1969, Moos 1978). Commercial fishing is believed to have contributed to declines of both species since the early 20th century (Colombo et al. 2007). To eliminate potential impacts to pallid sturgeon from commercial fishing, a Similarity of Appearance rule was passed in 2010 (75 FR 53598-53606) making it illegal to harvest shovelnose sturgeon in areas where it occurs sympatrically with pallid sturgeon. This rule eliminates the chance of any pallid sturgeon being mis-identified and harvested as a shovelnose sturgeon.

Life History

Pallid sturgeon are large, long-lived, and slow to mature. They attain sizes of 65 inches total length and 68 pounds, although adult sizes of 23 to 35 inches total length are probably typical (Carlander 1969, Lee 1980a, Kallemeyn 1983). The age of one individual (approximately 59 inches total length) and 37 pounds was estimated at 41 years. Pallid sturgeon probably attain greater ages than this (Keenlyne et al. 1992). Age of sexual maturity is 5 to 7 years for males and 9 to 12 years for females, but first spawning may not begin until age 15 to 17 years or later (Keenlyne and Jenkins 1993). Sex ratios may be skewed. Females outnumbered males 2:1 throughout the Missouri and Mississippi Rivers (Carlson et al. 1985), but 13 specimens collected in the middle Mississippi River consisted of 12 males and 1 undetermined individual (R. Sheehan, personal communication). Fecundity, however, is high. One very large female contained 170,000 eggs, approximately 11 percent of her body weight (Keenlyne et al. 1992).

Age and growth of pallid sturgeon in the middle and lower Mississippi River has been examined by Killgore et al. (2007b). Pallid sturgeon in the middle Mississippi River grew faster for a given age compared to populations in the lower Mississippi River. However, higher mortality rates and little to no recruitment of pallid sturgeon was found in the middle Mississippi River while in the lower Mississippi River mortality rates were low and recruitment was evident due to the presence of young sturgeon not of hatchery origin.

Pallid sturgeon spawning in the wild has never been observed (Kallemeyn 1983), but they are suspected to scatter their adhesive eggs over coarse gravel or rocky substrates in shallow areas of rivers like all other freshwater sturgeon (Wildhaber et al. 2007). Based on apparent reproductive conditions of adults, the spawning season is believed to be during spring, initiation dependent upon latitude and timing of proximate cues like spring runoff. It is presumed to take place during high water. Spawning probably begins in March in the lower Mississippi and Atchafalaya Rivers, late April or early May in the lower Missouri and middle Mississippi Rivers, and late May or early June in the upper Missouri River (Keenlyne and Jenkins 1993).

Only a few pallid sturgeon larvae have been collected in the wild, but advances in telemetry technology and techniques for collecting eggs, embryos, and larvae in the field have afforded researchers with many new insights into reproductive behavior (DeLonay et al. 2007; Hrabik et

al. 2007; Simpkins and LaBay 2007). Radio tagged shovelnose sturgeon that showed gonadal development and physiological characteristics which indicated that they were ready to spawn, moved upstream, spawned, and moved downstream (DeLonay et al. 2007). Also, benthic sampling at the downstream ends of sand bars in the Mississippi River has captured pallid, shovelnose, and suspected hybrid sturgeon larvae (Hrabik et al. 2007). In the Missouri River, egg mats have been used to successfully collect sturgeon eggs from locations where reproductively mature shovelnose sturgeon were tracked using radio telemetry (Simpkins and LaBay 2007). In the middle Mississippi River, shovelnose sturgeon fecundity averages 29,573 eggs per female, and it was documented that age at maturity was 8 years for males and 9 years for females, spawning occurs every 2-3 years, and larvae grow rapidly up to 1.7mm/day (Tripp et al. 2009).

Growth during the first year is rapid. At one year of age, pallid sturgeon are approximately 11 inches total length and weigh just over 1 ounce. They grow an additional 4 inches per year during the following 3 years, and 1.2 to 2.4 inches per year after age 5 (Kallemeyn 1983). From approximately age 2 to 6, weight increases 2.1 to 8.8 ounces per year; in larger (>26.4 inches total length), older fish, weight increases more than 12.3 ounces per year (Keenlyne and Maxwell 1993). Several studies have estimated growth rates from pallid sturgeon captured in the wild (Carlander 1969; Kallemeyn 1983; Yerk and Baxter 2002; Killgore et al. 2007b). Growth rates of pallid sturgeon have been documented in hatcheries (Bollig 1998; USFWS 2007). The recapture of Passive Integrated Transponder (PIT)-tagged individuals is providing data for following growth of stocked fish in the wild (Peters and Parham 2008).

Pallid sturgeon, like shovelnose sturgeon, feed on aquatic insects, but unlike shovelnose sturgeon, also consume significant quantities of fishes (Carlson et al. 1985, Gerrity et al. 2005, Gerrity et al. 2006, Wanner 2007, Hoover et al. 2007). Also, as pallid sturgeon grow, fish become a progressively more important food item (Wanner 2007, Grohs 2008). One of the most common groups of fish prey for pallid sturgeon are river chubs belonging to the *Macrhybopsis* genus. These fish are bottom-oriented fishes occupying swift currents over sand and gravel substrates in medium to large, turbid rivers, which is very similar to habitat preferred by pallid sturgeon. Plant material is also frequently ingested but in small quantities.

Additional Data

General and project specific permits issued by the USACE recognize potential dredging-related risks to spawning pallid sturgeon. Dredging is prohibited during presumed "windows" of pallid sturgeon reproduction, 1 April through 30 June in Memphis, Vicksburg, and New Orleans districts.

Observations support previous studies demonstrating that pallid sturgeon occupy midchannels and deeper water more frequently than do shovelnose sturgeon, which are more likely to occur in shallower, near-shore waters (Moos 1978, Bramblett 1996, Constant et al. 1997). However,

neither species of sturgeon are likely to occur in Mud Ditch, which empties into the Mississippi River, or upstream tributaries. Surveys conducted in the New Madrid Floodway during the summer and fall of 1997 and spring of 1998 (Sheehan et al. 1998) did not produce any adult or larval pallid sturgeon. Similarly, no sturgeon were collected in 2007-2008 (Killgore et al., unpublished data) in Mud Ditch, St. Johns Basin, and New Madrid Basin using gill nets, hoop nets, electroshocking, and seines (Table 1).

Evaluation of Potential Impact

Project-related impacts to the pallid sturgeon population in the lower Mississippi River are not anticipated for any habitats typically utilized by pallid sturgeon. Pallid sturgeon are a main channel species avoiding backwaters and small tributaries, although one pallid was recaptured in the Obion River (Killgore et al. 2007a). They inhabit deep thalwegs with hard-packed, sandy substrate, or channel border areas with steep shorelines near fast water, including dikes. Spawning occurs over gravel bars or possibly other hard substrates (*e.g.*, riprap stones) in fast-flowing waters. These habitats do not coincide with any locations in the project area. No sturgeon were collected in the New Madrid Floodway ditches or inundated land during surveys in the summer and fall of 1997 and spring of 1998 (Sheehan et al. 1998). As mentioned previously, during multiple sampling efforts from 2007-2008, shovelnose or pallid sturgeon were not collected in the lowermost reaches of Mud Ditch, which contains a direct connection to the Mississippi River, or in any other tributary in the St. Johns-New Madrid Basin. Despite the apparent absence of pallid sturgeon in the project area and lack of suitable spawning habitat, sturgeon could enter the mouth of Mud Ditch for feeding purposes. However, sturgeon are rarely documented in tributaries, and one of the primary forage items eaten by pallid sturgeon are river chubs belonging to the *Macrhybopsis* genus. Chubs are bottom-oriented fishes occupying swift currents over sand and gravel substrates in medium to large, turbid rivers similar to habitats preferred by pallid sturgeon (Pflieger 1997). Although an occasional *Macrhybopsis* may be found in the ditches within the project area (Table 1), these ditches are not suitable spawning habitat as they are mostly straight and sediment-laden, with little flow most of the year.

CONCLUSION

Based on currently available biological and ecological data, a review of published and unpublished literature and studies, communications with experts, and findings of recent USACE investigations, USACE has determined that the proposed actions may affect, but are not likely to adversely affect the federally endangered species of interior least tern and pallid sturgeon as well as sensitive species such as the bald eagle. Although no surveys were conducted specifically for bald eagle nests, multiple habitat assessments were conducted for the EIS and did not reveal any nests in the proposed construction footprint. If any active bald eagle nests are discovered in the

proposed footprint prior to construction, avoidance measures and minimum work distances would be adhered to in accordance with the National Bald Eagle Management Guidelines.

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Appendix K

Hazardous, Toxic and Radioactive Waste

U.S. Army Corps of Engineers
Memphis District

Appendix K

HAZARDOUS, TOXIC AND RADIOACTIVE WASTE (HTRW)

Introduction

The U.S. Army Corps of Engineers (USACE), Memphis District, is considering levee closures to provide flood control in the New Madrid Floodway and St. Johns Bayou Basin in southeastern Missouri. The Memphis District conducted a Hazardous, Toxic and Radioactive Waste (HTRW) review pursuant to Corps of Engineers Regulation ER 1165-2-132, *Water Resources and Authorities for Hazardous, Toxic and Radioactive Waste for Civil Works Projects,* 26 June 1992, which requires identification and evaluation of potential and/or existing items of environmental concern in the project areas, particularly within the vicinity of the proposed flood protection levee footprints. In order to characterize environmental conditions of the project areas in accordance with the applicable portions of ER 1165-2-132 and the relevant American Society for Testing and Materials (ASTM) Standards, USACE:

- Reviewed Department of the Army records and federal, state and local databases;
- Conducted historical site search; and
- Interviewed pertinent site personnel.

Purpose

The purpose of this environmental site assessment (ESA) is to gather and evaluate data regarding the existence or potential for encountering HTRW in the project area. Specific requirements for this ESA included:

1. A brief review of the project area environmental setting;
2. Federal, state and local agency environmental database research in accordance with appropriate standards;
3. Interviews with pertinent personnel knowledgeable of environmental conditions in the project area; and
4. Documenting any HTRW problems and items of interest.

The ultimate goal is to provide a reasonable assessment of areas of concern so that project management and local sponsors can make decisions on property transfers or future testing requirements.

Methodology

This following report was prepared in accordance with the applicable requirements contained in the following references:

U.S. Army Corps of Engineers Regulation ER 1165-2-132, *Water Resources Policies and Authorities for Hazardous, Toxic and Radioactive Waste Guidance for Civil Works Projects, 26 June 1992*;

U.S. Army Corps of Engineers, Lower Mississippi Valley Regulation 1165-2-9, *Water Resources Policies and Authorities for Hazardous, Toxic and Radioactive Waste Guidance for Civil Works Projects, 14 June 1996*; and

American Society of Testing and Materials Standard (ASTM) E1527-00, *Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process.*

Historical Use Information

In accordance with ASTM E1527-00 Section 7.3 *Historical Use Information*, Gulf Engineers & Consultants (GEC) conducted a thorough historical record review in order to ascertain previous uses and occupants of the project area and surrounding areas. For this project, GEC reviewed U.S. Geological Survey (USGS) historical topographic quadrangle maps and a previous HTRW report prepared for the project area. Attachment 1 contains a list of the references consulted.

Local Interviews

The East Prairie and New Madrid fire departments were contacted (Attachment 2) in December 2010 and consulted as to whether sites of potential HTRW concern were located in the project area. There have been no incidents involving HTRW for the project area.

Agency Coordination/Historical Records Search

USACE conducted an environmental database search (Attachment 3) for the project area. The USACE search, combined with the June 2002 report conducted by Vista Information Soultions, Inc. (Vista), ensured all applicable and reasonably ascertainable Federal, state and local government environmental records specified by ASTM E1527-00 were reviewed for the project and adjacent properties.

Significant Findings

There appear to be no known sites of potential HTRW located in the project area.

Conclusion

Based on the data reviewed and information gathered during this, and previous, assessments, it appears unlikely that incidents or sites involving HTRW have occurred or are located in the project area.

Attachment 1

REFERENCES

American Society for Testing and Materials (ASTM) Standard E1527-00, Standard Practice for Environmental Site Assessment: Phase I Environmental Site Assessment Process.

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7.5-Minute Series Quadrangle, U.S. Geological Survey, New Madrid, Missouri, 1996.

7.5-Minute Series Quadrangle, U.S. Geological Survey, Henderson Mound, Missouri, 1996.

7.5-Minute Series Quadrangle, U.S. Geological Survey, Bayouville NE, Missouri, 1996.

Attachment 2

POINTS OF CONTACT

FEDERAL

Environmental Protection Agency, Region VII

Used incident query at website:
http://www.epa.gov/emefdata/em4ef.home

Superfund Division (913) 551-7733
Cecilia Topic (December 21, 2010)

STATE

Missouri Department of Natural Resources

Used incident query at website:
http://www.dnr.mo.gov/env/hwp/downloads/index.htm

Hazardous Waste Program (573) 751-3176
Jeff Heisler (December 17, 2010)

LOCAL

East Prairie Fire Department

Chief's Office (573)649-3511
Chief Danny Laferty (December 17, 2010)

New Madrid Fire Department

Chief's Office (573) 748-2866
Chief Jim Morris (December 21, 2010)

Attachment 3

ENVIROMAPPER DATA

UNDERGROUND STORAGE TANKS

http://oaspub.epa.gov/enviro/fii_master.fii_retrieve?county_name=mississippi&state_code=MO&all_programs=YES&program_search=1&report=1&page_no=1&output_sql_switch=TRUE&database_type=PCS

Water Discharge Permits (PCS)

Last updated on Friday, December 17, 2010

You are here: EPA Home Envirofacts PCS Query Results

Query Results

Report an Error

PCS

Consolidated facility information (from multiple EPA systems) was searched to select facilities

County Name: mississippi
State Abbreviation: MO

Results are based on data extracted on DEC-14-2010

Note: Click on the underlined CORPORATE LINK value for links to that company's environmental web pages.
Click on the underlined MAPPING INFO value to obtain mapping information for the facility.
Click on the underlined NPDES value to view detailed reports on the facility.

Go To Bottom Of The Page

Facility Information

NPDES ID	Facility Information	FACILITY NAME	ADDRESS	COUNTY NAME	PERMIT ISSUED DATE	PERMIT EXPIRED DATE	SIC CODE	SIC DESC	MAPPING INFO	USGS HUC
MO0114928	View Facility Information	ANNISTON WWTP	305 TERRY DRIVE ANNISTON, MO 63820	MISSISSIPPI	SEP-16-2005	SEP-15-2010	4952	SEWERAGE SYSTEMS	MAP	
MO0100111	View Facility Information	BERTRAND WWTF	405 EAST CEDAR BERTRAND, MO 63823	MISSISSIPPI	AUG-01-2008	JUL-31-2013	4952	SEWERAGE SYSTEMS	MAP	08020201
MO0120081	View Facility Information	CHARLESTON LAGOON	401 NORTH LOCUST CHARLESTON, MO 63834	MISSISSIPPI	JAN-23-2009	JAN-22-2014	4952	SEWERAGE SYSTEMS	MAP	
MOG140055	View Facility Information	CHEERS! TRAVEL CENTER	2460 EAST HIGHWAY 60 CHARLESTON, MO 63834	MISSISSIPPI	NOV-20-2009	DEC-23-2013	1629	HEAVY CONSTRUCTION, NOT ELSEWHERE CLASSIFIED	MAP	
MOR10B601	View Facility Information	CLINTON MATERIALS - DELTA	CHARLESTON, MO	MISSISSIPPI	FEB-26-2008	FEB-07-2012	1629	HEAVY CONSTRUCTION, NOT ELSEWHERE CLASSIFIED	MAP	
MOG822131	View Facility Information	DARK CYPRESS ENTERPRISES	HWY AB CHARLESTON, MO 63834	MISSISSIPPI	JUN-23-2006	JUN-08-2011	1629	HEAVY CONSTRUCTION, NOT ELSEWHERE CLASSIFIED	MAP	
MOR240152	View Facility Information	DELTA GROWERS ASSOCIATION	600 EAST IRONBANKS ROAD CHARLESTON, MO 63834	MISSISSIPPI	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MOR240175	View Facility Information	DELTA GROWERS ASSOCIATION	313 SOUTH HIGHWAY 105 CHARLESTON , MO 63834	MISSISSIPPI	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MO0021750	View Facility Information	EAST PRAIRIE WWTP	1.4 MILE EAST SHELBY ROAD EAST PRAIRIE, MO 63845	MISSISSIPPI	NOV-20-2009	NOV-19-2014	4952	SEWERAGE SYSTEMS	MAP	08020201
MOR80C021	View Facility Information	FARM PRODUCTS COMPANY INC	HWY 105 EAST PRAIRIE, MO 63845	MISSISSIPPI	AUG-14-2009	OCT-04-2012	1629	HEAVY CONSTRUCTION, NOT ELSEWHERE CLASSIFIED	MAP	
MOG491086	View Facility Information	FLYNN COMPANY INC	908 S CHESTNUT CHARLESTON, MO 63834	MISSISSIPPI	SEP-21-2007	OCT-05-2011	1422	CRUSHED AND BROKEN LIMESTONE	MAP	
			1300 SOUTH							

MOR23D066	View Facility Information	GATES RUBBER COMPANY	PLANT ROAD CHARLESTON, MO 638340345	MISSISSIPPI	SEP-30-2005	SEP-22-2010	3052	RUBBER AND PLASTICS HOSE AND BELTING	MAP	
MOG350140	View Facility Information	MFA BULK PLANT-EAST PRAIR	718 WEST WASHINGTON EAST PRAIRIE, MO 63845	MISSISSIPPI	JUN-22-2007	JUN-14-2012	5171	PETROLEUM BULK STATIONS AND TERMINALS	MAP	
MOR240477	View Facility Information	MRM AG SERVICE INCORPORATED	3468 WEST HIGHWAY 80 EAST PRAIRIE, MO 63845	MISSISSIPPI	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MOG140046	View Facility Information	PILOT TRAVEL CENTER #359	2071 MAIN ST CHARLESTON, MO 63834	MISSISSIPPI	FEB-27-2009	DEC-23-2013	5541	GASOLINE SERVICE STATIONS	MAP	
MOG821119	View Facility Information	ROBERT COFFER	HWY CC & HWY B EAST PRAIRIE, MO 63845	MISSISSIPPI	JAN-28-2004	OCT-03-2007	4971	IRRIGATION SYSTEMS	MAP	
MO0091936	View Facility Information	ROLLING MEADOWS INC	ROUTE 1, BOX 189 CHARLESTON, MO 63834	MISSISSIPPI	DEC-05-2008	DEC-04-2013	6515	OPERATORS OF RESIDENTIAL MOBILE HOME SITES	MAP	08020201
MOR240249	View Facility Information	ROLWING-MOXLEY AG, INC	1 MILL ST CHARLESTON, MO 63834	MISSISSIPPI	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MOR241002	View Facility Information	ROLWING-MOXLEY CO	CHARLESTON, MO 63834	MISSISSIPPI	MAY-13-2010	FEB-18-2015			MAP	
MOG010275	View Facility Information	TIM & CALVIN ARNOLD	2791 HWY O BERTRAND, MO 63823	MISSISSIPPI	APR-27-2007	FEB-23-2011	0251	BROILER, FRYER, AND ROASTER CHICKENS	MAP	
MOR240537	View Facility Information	WOLF ISLAND FARMS	9101 S HWY 77 WOLF ISLAND, MO 63881	MISSISSIPPI	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MO0088536	View Facility Information	WYATT WWTF	WYATT WYATT, MO 63882	MISSISSIPPI	SEP-28-2007	SEP-27-2012	4952	SEWERAGE SYSTEMS	MAP	08020201

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Total Number of Facilities Displayed: 22

_master_fii_retrieve?
_code=MO&all_programs=YES&program_search=2&report=1&page_no=1&output_sql_switch=TRUE&database_type=TRIS

Last updated on Friday, December 17, 2010

Toxics Release Inventory (TRI)

You are here: EPA Home Envirofacts TRI Query Results

Query Results

Report an Error

TRI

Only TRI facility information was searched to select facilities

County Name: mississippi
State Abbreviation: MO

Results are based on data extracted on SEP-27-2010

Note:
Click on the underlined TRI_FACILITY_ID value to view a detailed report on the facility.
Click on "View Facility Information" to view EPA Facility information for the facility.
Click on the underlined SUBMISSIONS value to view the list of DCN's for each of the TRI Reporting Year.

Go To Bottom Of The Page

List of EPA-Regulated Facilities in TRI

TRI FACILITY ID	FACILITY INFORMATION	FACILITY NAME	ADDRESS	COUNTY NAME	SUBMISSIONS
63834BRWNSSEVEN	View Facility Information	BROWN SHOE CO.	7TH & E. MARSHALL CHARLESTON, MO 63834	MISSISSIPPI	10
63834GTSRB1300S	View Facility Information	GATES CORP - CHARLESTON	1300 S PLANT RD CHARLESTON, MO 638340345	MISSISSIPPI	48
63834STRKM1200P	View Facility Information	STARK MANUFACTURING INC.	1200 PLANT RD. CHARLESTON, MO 63834	MISSISSIPPI	14

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Total Number of Facilities Displayed: 3

Superfund (CERCLIS)

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Go

You are here: EPA Home Envirofacts CERCLIS Query Results

Query Results

Report an Error

CERCLIS **Site ID:** Equal To: MON000705325

Results are based on data extracted on DEC-13-2010

Note: Click on the underlined CORPORATE LINK value for links to that company's environmental web pages.
Click on the underlined MAPPING INFO value to obtain mapping information for the facility.
Click on the underlined RECORD OF DECISION value for a RODS Site Report.
Click on the underlined "View Facility Information" link to view EPA Facility information for the facility.

Go To Bottom Of The Page

CERCLIS EPA ID:	MON000705325	**SITE NAME:**	MERCURY-ODDFELLOWS LODGE #84
STREET ADDRESS:	105 SOUTH FRANKLIN	**FACILITY INFORMATION**	View facility information
CITY NAME:	CHARLESTON		
STATE ABBR:	MO	**FEDERAL FACILITY:**	N
ZIP CODE:	63834	**NPL STATUS:**	Not on the NPL
COUNTY NAME:	MISSISSIPPI		
CORPORATE LINK:	No	**RECORD OF DECISION (ROD) INFO:**	No
LATITUDE:		**EPA REGIONAL LINK:**	No
LONGITUDE:		**MAPPING INFO:**	MAP
SITE SMSA:			

Enforcement and Cleanup Actions

Action	Action ID	Actual Start Date	Actual End Date	Responsibility	Planned Outcome	Urgency
REMOVAL	001	02/24/2006	04/13/2006	EPA Fund-Financed	Cleaned up	Emergency

Site Description

There were no Site Descriptions reported for this site.

Below is additional information for CERCLIS sites:

This information resource is not maintained, managed, or owned by the Environmental Protection Agency (EPA) or the Envirofacts Support Team. Neither the EPA nor the Envirofacts Support Team is responsible for their content or site operation. The Envirofacts Warehouse provides this reference only as a convenience to our Internet users.

- National Library of Medicine (NLM) EXIT EPA TOXMAP

Go To Top Of The Page

Total Number of Facilities Displayed: 1

e3
grams=YES&program_search=1&report=1&page_no=1&output_sql_saved=1&osh_data_source=1&p_date=12/17/2010

Resource Conservation and Recovery Act (RCRAInfo)

You are here: EPA Home Envirofacts RCRAInfo Query Results

Query Results

Report an Error

RCRAInfo

Data Disclaimer

Consolidated facility information (from multiple EPA systems) was searched to select facilities

County Name: mississippi
State Abbreviation: MO

Results are based on data extracted on DEC-10-2010

Note: Click on the underlined CORPORATE LINK value for links to that company's environmental web pages.
Click on the underlined MAPPING INFO value to obtain mapping information for the facility.
Go To Bottom Of The Page

HANDLER NAME:	AMERENUE CHARLESTON WHQ	HANDLER ID:	MOR000519488
STREET:	799 W MARSHALL	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
BARBARA MILLER	CHOUTEAU PO BOX 66149 MC602	ST LOUIS	MO	63166	3145542194	Public
BARBARA MILLER	CHOUTEAU PO BOX 66149 MC602	ST LOUIS	MO	63166	3145542194	Permit
BARBARA MILLER	1901 CHOUTEAU	ST LOUIS	MO	63166	3145542194	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION

221122	ELECTRIC POWER DISTRIBUTION

There was an error with the database tables.
Please send a report to enviromail_group@epamail.epa.gov telling us what criteria you used in the selection along with this error message:
ORA-06502: PL/SQL: numeric or value error: character string buffer too small

HANDLER NAME:	BROWN SHOE COMPANY	HANDLER ID:	MOD985774165
STREET:	7TH AND EAST MARSHALL	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
M SCOTT	PO BOX 354	ST LOUIS	MO	63166	5736834649	Public
M SCOTT	PO BOX 354	ST LOUIS	MO	63166	5736834649	Permit

HANDLER NAME:	BUFFALO ISLAND ELEVATOR	HANDLER ID:	MO0000048173
STREET:	758 HIGHWAY N	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF

						CONTACT
CHESTER GUNN	HWY N	CHARLESTON	MO	638348251	3146821527	Public
CHESTER GUNN	HWY N	CHARLESTON	MO	638348251	3146821527	Permit
JIM STUART	8 MI N ON HWY N	CHARLESTON	MO	63834	5736833358	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
49313	FARM PRODUCT WAREHOUSING AND STORAGE

HANDLER NAME:	CASEYS GENERAL STORE #1560	HANDLER ID:	MOR000016519
STREET:	308 E MARSHALL	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
GLENN NORGART	PO BOX 3001	ANKENY	IA	500218045	5159656238	Public
GLENN NORGART	PO BOX 3001	ANKENY	IA	500218045	5159656238	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
4471	GASOLINE STATIONS
44711	GASOLINE STATIONS WITH CONVENIENCE STORES

HANDLER NAME:	CASEYS GENERAL STORE #1711	HANDLER ID:	MOR000017830
STREET:	1202 S MAIN ST	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
GLENN NORGART	PO BOX 3001	ANKENY	IA	500218045	5159656238	Public
GLENN NORGART	PO BOX 3001	ANKENY	IA	500218045	5159656238	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
4471	GASOLINE STATIONS

HANDLER NAME:	CASEYS GENERAL STORE #1749	HANDLER ID:	MOR000017533
STREET:	605 W WASHINGTON	FACILITY INFORMATION:	View Facility Information
CITY:	EAST PRAIRIE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63845	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
GLENN NORGART	PO BOX 3001	ANKENY	IA	500218045	5159656238	Public
GLENN NORGART	PO BOX 3001	ANKENY	IA	500218045	5159656238	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
4471	GASOLINE STATIONS

HANDLER NAME:	CUSTOM FUEL SERVICES INC	HANDLER ID:	MOR000518985
STREET:	HWY 80 RT BANK OF MISS RIVER	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
R C HALL	S 3RD ST	PADUCAH	KY	42002	2708325494	Public
JASON ADAMS	1 WASHINGTON ST PO BOX 2756	PADUCAH	KY	42002	2704154457	Permit
R HALL	S 3RD ST	PADUCAH	KY	42002	2708325494	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
42512	WHOLESALE TRADE AGENTS AND BROKERS

HANDLER NAME:	DELTA EMERGENCY SERVICES INC	HANDLER ID:	MOP000038778
STREET:	814 S 8TH ST	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP

EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
DARRELL PULLEN	303 S MAIN ST	SIKESTON	MO	63801	5734717041	Public
DARRELL PULLEN	303 S MAIN ST	SIKESTON	MO	63801	5734717041	Permit

HANDLER NAME:	DRINKWATER PUMPING STATION	HANDLER ID:	MOR000507673
STREET:	INTER HWY AB & COUNTY RD 214	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
TOMMY LONG	706 TRUMAN RD	CARUTHERSVILLE	MO	63830	5733331043	Public
TOMMY LONG	706 TRUMAN RD	CARUTHERSVILLE	MO	63830	5733331043	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
92119	OTHER GENERAL GOVERNMENT SUPPORT

HANDLER	EASTSIDE CONVENIENCE	HANDLER ID:	MOR000511360

NAME:	STORE		
STREET:	901 W HWY 80	FACILITY INFORMATION:	View Facility Information
CITY:	EAST PRAIRIE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63845	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
JEFF HEDGES	901 W HWY 80	EAST PRAIRIE	MO	63845	5736499911	Public
JEFF HEDGES	901 W HWY 80	EAST PRAIRIE	MO	63845	5736499911	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
44711	GASOLINE STATIONS WITH CONVENIENCE STORES

HANDLER NAME:	EG & G TECHNICAL SERVICES	HANDLER ID:	MOP000515353
STREET:	100 BEASLEY RD	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
SHARON ROLWING	PO BOX 401 I-57 & HWY 105	CHARLESTON	MO	63834	5736836108	Public
SHARON ROLWING	PO BOX 401 I-57 & HWY 105	CHARLESTON	MO	63834	5736836108,	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
42392	TOY AND HOBBY GOODS AND SUPPLIES MERCHANT WHOLESALERS

HANDLER NAME:	EUGENE T BARNES	HANDLER ID:	MOD076967124
STREET:	HWY 80W 1 MI W OF CITY LIMIT	FACILITY INFORMATION:	View Facility Information
CITY:	EAST PRAIRIE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63845	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
NA NA	RR STAR BOX 138	EAST PRAIRIE	MO	63845	NA	Public
NA NA	HWY 80W 1 MI W OF CITY LIMIT	EAST PRAIRIE	MO	63845		Permit
NA NA	RR STAR BOX 138	EAST PRAIRIE	MO	63845	NA	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
115112	SOIL PREPARATION, PLANTING, AND CULTIVATING

HANDLER NAME:	FITZGERALD MARINE & REPAIR INC	HANDLER ID:	MOR000524272
STREET:	13600 E HWY 80	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP

EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
RILEY FITZGERALD	PO BOX 368	WYATT	MO	63882	5736495003	Public
RILEY FITZGERALD	PO BOX 368	WYATT	MO	63882	5736495003,	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
336611	SHIP BUILDING AND REPAIRING

HANDLER NAME:	GATES RUBBER COMPANY	HANDLER ID:	MOD056008352
STREET:	1300 SOUTH PLANT ROAD	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	638340345	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
BRUCE CHAPMAN	PO BOX 345	CHARLESTON	MO	63834	5736833704	Public
MICHAEL MURPHY	1300 S PLANT RD	CHARLESTON	MO	63834	5736833704	Permit
BRUCE CHAPMAN	PO BOX 345	CHARLESTON	MO	63834	5736833704	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
32622	RUBBER AND PLASTICS HOSES AND BELTING MANUFACTURING

HANDLER NAME:	GATES RUBBER COMPANY - CHARLESTON DISTRIBUTION CENTER	HANDLER ID:	MOR000020404
STREET:	701 EAST MARSHALL	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
SHARON PRUETT	PO BOX 345	CHARLESTON	MO	638340345	5736833704	Public
SHARON PRUETT	PO BOX 345	CHARLESTON	MO	638340345	5736833704	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
42184	INDUSTRIAL SUPPLIES WHOLESALERS

HANDLER NAME:	H & H OIL RECOVERY INC	HANDLER ID:	MOR000505107
STREET:	CORNER OF SINNEY & CLEVELAND	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
WILLIAM	25903 S					

KENNEDY	RIDGELAND AVE	MONEE	IL	60449	7085349300	Public
WILLIAM FOSTER	3580 S HWY 641	CAMDEN	TN	38320	7315842043	Permit
WILLIAM KENNEDY	25903 S RIDGELAND AVE	MONEE	IL	60449	7085349300	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
324191	PETROLEUM LUBRICATING OIL AND GREASE MANUFACTURING
42393	RECYCLABLE MATERIAL MERCHANT WHOLESALERS

HANDLER NAME:	HEARTLAND TRAILER SALES MFG INC	HANDLER ID:	MOD985811918
STREET:	HWY 105 E	FACILITY INFORMATION:	View Facility Information
CITY:	EAST PRAIRIE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63845	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
LARRY SMITH	HWY 105 E	EAST PRAIRIE	MO	63845	5736495637	Public
LARRY SMITH	HWY 105 E	EAST PRAIRIE	MO	63845	5736495637	Permit

HANDLER NAME:	HOGAN FARM & HOME CENTER	HANDLER ID:	MOD062420484
STREET:	722 EAST WASHINGTON STREET	FACILITY INFORMATION:	View Facility Information

CITY:	EAST PRAIRIE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63845	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
MARY HOGAN	PO BOX 160	EAST PRAIRIE	MO	63845	5736493589	Public
MARY HOGAN	PO BOX 160	EAST PRAIRIE	MO	63845	5736493589	Permit

HANDLER NAME:	HUBBARD MUFFLER CO INC	HANDLER ID:	MOD006305916
STREET:	HWY 105 AT HWY 102	FACILITY INFORMATION:	View Facility Information
CITY:	EAST PRAIRIE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63845	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
						Public

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
336399	ALL OTHER MOTOR VEHICLE PARTS MANUFACTURING

HANDLER NAME:	INTER RAIL SYSTEMS INC	HANDLER ID:	MOR000505198

STREET:	812 W MARSHALL ST	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
ROBERT JANOTA	PO BOX 526	CAPE GIRARDEAU	MO	63702	5733349437	Public
ROBERT JANOTA	PO BOX 526	CAPE GIRARDEAU	MO	63702	5733349437	Permit

HANDLER NAME:	JACKEL INC	HANDLER ID:	MOR000040089
STREET:	309 MILL RD	FACILITY INFORMATION:	View Facility Information
CITY:	EAST PRAIRIE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63845	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
JAMES HARTLIEB	400 BROADWAY	HIGHLAND	IL	62249	6186542371	Public
JAMES HARTLIEB	400 BROADWAY	HIGHLAND	IL	62249	6186542371	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
335312	MOTOR AND GENERATOR MANUFACTURING

HANDLER NAME:	MEDLIN EQUIPMENT CO	HANDLER ID:	MOR000024505
STREET:	2000 OUTER RD	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
GREG NICHELL	PO BOX 506	CHARLESTON	MO	63834	5736832601	Public
GREG NICHELL	PO BOX 506	CHARLESTON	MO	63834	5736832601	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
42182	FARM AND GARDEN MACHINERY AND EQUIPMENT WHOLESALERS

HANDLER NAME:	MID AMERICA MFG INC	HANDLER ID:	MOD985799089
STREET:	CTY RD 532 4 MI NW	FACILITY INFORMATION:	View Facility Information
CITY:	BERTRAND	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63823	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
TOM MOCK	RT 1 BOX 875	BERTRAND	MO	63823	5734719241	Public
TOM MOCK	RT 1 BOX 875	BERTRAND	MO	63823	5734719241	Permit

HANDLER NAME:	MO DEPT OF TRANSPORTATION	HANDLER ID:	MOP000000851
STREET:	HWY 80 .6 MI E OF HWY 105	FACILITY INFORMATION:	View Facility Information
CITY:	EAST PRAIRIE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63845	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
JOHN JURGENSMEYER	PO BOX 270	JEFFERSON CITY	MO	65102	5735264453	Public
JOHN JURGENSMEYER	PO BOX 270	JEFFERSON CITY	MO	65102	5735264453	Permit

HANDLER NAME:	MOORES LANDING FLEET	HANDLER ID:	MOD985799816
STREET:	1200 N COUNTY RD 303	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
WILLIE MILAM	1200 N COUNTY RD 303	CHARLESTON	MO	63834	5736753257	Public
WILLIE MILAM	1200 N COUNTY RD 303	CHARLESTON	MO	63834	5736753257	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION

483211	INLAND WATER FREIGHT TRANSPORTATION

HANDLER NAME:	ODDFELLOWS LODGE #84 % EPA R7	HANDLER ID:	MOP000514992
STREET:	105 S FRANKLIN ST	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
HEATH SMITH	97 N OUTER RD	EUREKA	MO	63025	5737834526	Public
HEATH SMITH	97 N OUTER RD	EUREKA	MO	63025	5737834526,	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
81341	CIVIC AND SOCIAL ORGANIZATIONS

HANDLER NAME:	PONDER CHEV & BUICK	HANDLER ID:	MOD029725710
STREET:	HWY 77 S	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT

GERALD BORDERS	PO BOX 186	CHARLESTON	MO	63834	5736833341	Public
GERALD BORDERS	PO BOX 186	CHARLESTON	MO	63834	5736833341	Permit

HANDLER NAME:	SAM AMOCO	HANDLER ID:	MOD985802024
STREET:	HWY 105 & 57TH ST	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
SAMUEL HOWARD	HWY 105 & 57TH ST	CHARLESTON	MO	63834	5736836285	Public
SAMUEL HOWARD	HWY 105 & 57TH ST	CHARLESTON	MO	63834	5736836285	Permit

HANDLER NAME:	STANLEY MUFFLER CO INC	HANDLER ID:	MOD985813088
STREET:	HWY 80W 1\2 M W OF CITY LIMIT	FACILITY INFORMATION:	View Facility Information
CITY:	EAST PRAIRIE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63845	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP	PHONE	TYPE OF

				CODE		CONTACT
STANLEY HUBBARD	W HWY 80 1/2 M W OF CITY LIMIT	EAST PRAIRIE	MO	63845	5736495151	Public
STANLEY HUBBARD	W HWY 80 1/2 M W OF CITY LIMIT	EAST PRAIRIE	MO	63845	5736495151	Permit
STANLEY HUBBARD	HWY 80W 1\2 M W OF CITY LIMIT	EAST PRAIRIE	MO	63845	5736495151	Permit

HANDLER NAME:	STARK MANUFACTURING	HANDLER ID:	MOD080008477
STREET:	1200 PLANT ROAD	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
TONI BEAVERS	1200 PLANT RD	CHARLESTON	MO	638342333	5736833321	Public
THOMAS E ROEMPAGEL					3146833321	Permit
TONI BEAVERS	1200 PLANT RD	CHARLESTON	MO	638342333	5736833321	Permit
DEREK K FARMER					3146833321	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
332999	ALL OTHER MISCELLANEOUS FABRICATED METAL PRODUCT MANUFACTURING
332112	NONFERROUS FORGING

HANDLER NAME:	SUTHERLAND OIL CO	HANDLER ID:	MOD985802156
STREET:	1110 E MARSHALL ST	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
KELLY BUTLER	1110 E MARSHALL ST	CHARLESTON	MO	63834	5736836573	Public
KELLY BUTLER	1110 E MARSHALL ST	CHARLESTON	MO	63834	5736836573	Permit

HANDLER NAME:	WOODS AVIATION INCORPORATED	HANDLER ID:	MOD990865867
STREET:	207 WASHINGTON ST	FACILITY INFORMATION:	View Facility Information
CITY:	EAST PRAIRIE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63845	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
						Public

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
115112	SOIL PREPARATION, PLANTING, AND CULTIVATING

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Total Number of Facilities Displayed: 32

http://oaspub.epa.gov/enviro/fii_master.fii_retrieve?county_name=new%20madrid&state_code=MO&all_programs=YES&program_search=1&report=1&page_no=1&output_sql_switch=TRUE&database_type=PCS

Last Updated on Friday, December 10, 2010

Water Discharge Permits (PCS)

You are here: EPA Home Envirofacts PCS Query Results

Query Results

Report an Error

Consolidated facility information (from multiple EPA systems) was searched to select facilities

PCS

County Name: new madrid
State Abbreviation: MO

Results are based on data extracted on DEC-14-2010

Note: Click on the underlined CORPORATE LINK value for links to that company's environmental web pages.
Click on the underlined MAPPING INFO value to obtain mapping information for the facility.
Click on the underlined NPDES value to view detailed reports on the facility.
Go To Bottom Of The Page

Facility Information

NPDES ID	Facility Information	FACILITY NAME	ADDRESS	COUNTY NAME	PERMIT ISSUED DATE	PERMIT EXPIRED DATE	SIC CODE	SIC DESC	MAPPING INFO	USGS HUC
MOR109BS7	View Facility Information	ADM GRAIN COMPANY-NEW MAD	NEW MADRID COUNTY PORT NEW MADRID, MO 63869	NEW MADRID	JAN-10-2008	MAR-07-2012	1629	HEAVY CONSTRUCTION, NOT ELSEWHERE CLASSIFIED	MAP	
MOR240498	View Facility Information	AG DISTRIBUTORS, INC.	3724 STATE HWY D CATRON, MO 63833	NEW MADRID	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MOR109DU4	View Facility Information	AGRIUM ADVANCED TECHNOLOG	500 COUNTY HWY 406 MARSTON, MO 63866	NEW MADRID	MAY-05-2009	MAR-07-2012	1629	HEAVY CONSTRUCTION, NOT ELSEWHERE CLASSIFIED	MAP	
MOR240021	View Facility Information	AGRO DISTRIBUTION, LLC	HWY 61 SOUTH PORTAGEVILLE, MO 63873	NEW MADRID	JUN-02-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MOR203375	View Facility Information	ALLOY RESEARCH INCORPORATED	1 HOPE WAY NEW MADRID, MO 63869	NEW MADRID	NOV-23-2005	MAR-04-2009	3743	RAILROAD EQUIPMENT	MAP	
MOG490599	View Facility Information	BROWN SAND & GRAVEL (DBA HEARTLAND ASPHALT MATERIALS)	297 SOUTH HWY 61 NEW MADRID, MO 63869	NEW MADRID	OCT-27-2006	OCT-05-2011	1422	CRUSHED AND BROKEN LIMESTONE	MAP	
MOR10A486	View Facility Information	CARGILL INC	LEVEE RD NEW MADRID, MO 63869	NEW MADRID	APR-30-2007	FEB-07-2012	1629	HEAVY CONSTRUCTION, NOT ELSEWHERE CLASSIFIED	MAP	
MOR240177	View Facility Information	CARGILL SERVICE CENTER INCORPORATED NEW MADRID FERTILIZER	250 LEVEE ROAD NEW MADRID, MO 63869	NEW MADRID	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MOR109DD0	View Facility Information	CPS	701 T PORT MARSTON, MO 63866	NEW MADRID	NOV-06-2008	MAR-07-2012	1629	HEAVY CONSTRUCTION, NOT ELSEWHERE CLASSIFIED	MAP	
MOR240500	View Facility Information	CROP PRODUCTION SERVICES	1661 US HWY 61 N PORTAGEVILLE, MO 63873	NEW MADRID	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MOG490641	View Facility Information	DELTA ASPHALT NEW MADRID	HIGHWAY 61 SOUTH NEW MADRID, MO 63869	NEW MADRID	OCT-27-2006	OCT-05-2011	1422	CRUSHED AND BROKEN LIMESTONE	MAP	
MOR60A014	View Facility Information	DELTA AUTO PARTS AND SALV	1519 US HIGHWAY 61 PORTAGEVILLE, MO 63873	NEW MADRID	JUN-27-2008	MAY-29-2013	5015	MOTOR VEHICLE PARTS, USED	MAP	
		DELTA	504 STATE							

MOR240544	View Facility Information	GROWERS ASSOCIATION	HIGHWAY W KEWANEE, MO 63860	NEW MADRID	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MOR240030	View Facility Information	DELTA GROWERS ASSOCIATION	500 SOUTH RAILROAD STREET MATTHEWS, MO 63867	NEW MADRID	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MOG140003	View Facility Information	FLYING J TRAVEL PLAZA	703 STATE HIGHWAY 80 MATTHEWS , MO 63867	NEW MADRID	FEB-27-2009	DEC-23-2013	5541	GASOLINE SERVICE STATIONS	MAP	
MO0021423	View Facility Information	GIDEON WWTF	HIGHWAY 162 GIDEON, MO 63848	NEW MADRID	MAY-28-2004	MAY-27-2009	4952	SEWERAGE SYSTEMS	MAP	08020204
MO0115339	View Facility Information	GOOD HUMOR BREYERS ICE CREAM	1010 COUNTY LINE ROAD SIKESTON, MO 63801	NEW MADRID	JUL-07-2006	JUL-06-2011	2024	ICE CREAM AND FROZEN DESSERTS	MAP	
MOR23E002	View Facility Information	GREAT RIVER SOY PROCESSIN	813 CO RD 641 LILBOURN, MO 63862	NEW MADRID	JUN-20-2008	MAY-22-2013	2869	INDUSTRIAL ORGANIC CHEMICALS, NOT ELSEWHERE CLASSIFIED	MAP	
MOR23A128	View Facility Information	GREAT RIVER SOY PROCESSING LLC	813 COUNTY RD 641 LILBOURN, MO 63862	NEW MADRID	AUG-17-2007	FEB-03-2010	2833	MEDICINAL CHEMICALS AND BOTANICAL PRODUCTS	MAP	
MOR240558	View Facility Information	HELENA CHEMICAL COMPANY	618 US HIGHWAY 61 NEW MADRID, MO 63869	NEW MADRID	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MO0092321	View Facility Information	HOWARDVILLE	HWY 61 HOWARDVILLE, MO 63869	NEW MADRID	JAN-19-2007	JAN-18-2012	4952	SEWERAGE SYSTEMS	MAP	08020204
MOR60A101	View Facility Information	JAMES ARTHUR MONTGOMERY	203 EAST RAILROAD STREET GIDEON, MO 63848	NEW MADRID	JUN-27-2008	MAY-29-2013	5015	MOTOR VEHICLE PARTS, USED	MAP	
MOG010270	View Facility Information	JIM GOINS	RT 1, BOX 99AA MATTHEWS, MO 63867	NEW MADRID	DEC-19-2008	FEB-23-2011	0251	BROILER, FRYER, AND ROASTER CHICKENS	MAP	
MO0048178	View Facility Information	LILBOURN WWTF	PO BOX 643 LILBOURN, MO 63862	NEW MADRID	JUL-26-2002	JUL-25-2007	4952	SEWERAGE SYSTEMS	MAP	08020204
MO0036200	View Facility Information	MARSTON	MARSTON MARSTON, MO 63866	NEW MADRID	NOV-30-2001	NOV-29-2006	4952	SEWERAGE SYSTEMS	MAP	08020204
MO0127175	View Facility Information	MATTHEWS	HWY AE MATTHEWS, MO 63867	NEW MADRID	MAY-13-2005	MAY-12-2010	4952	SEWERAGE SYSTEMS	MAP	
MOG140044	View Facility Information	MATTHEWS TRAVEL CENTER	I-55 & HWY 80 MATTHEWS, MO 63867	NEW MADRID	FEB-27-2009	DEC-23-2013	5541	GASOLINE SERVICE STATIONS	MAP	
MOR240550	View Facility Information	MCCORD GIN COMPANY	300 EAST 4TH STREET GIDEON, MO 63848	NEW MADRID	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MOG350120	View Facility Information	MFA OIL CO-BULK PET STOR	HWY D LILBOURN, MO 63862	NEW MADRID	JUN-22-2007	JUN-14-2012	5171	PETROLEUM BULK STATIONS AND TERMINALS	MAP	
MO0030821	View Facility Information	MOREHOUSE WASTE WATER TREATMENT FACILITY C/O CITY HALL	113 EAST BEECH STREET MOREHOUSE, MO 63868	NEW MADRID	NOV-20-2009	NOV-19-2014	4952	SEWERAGE SYSTEMS	MAP	08020204
MO0001171	View Facility Information	NEW MADRID POWER PLANT	41 SAINT JUDE INDUSTRIAL PARK MARSTON, MO 63866	NEW MADRID	MAY-02-2003	MAY-01-2008	4911	ELECTRIC SERVICES	MAP	08010100
MO0022845	View Facility Information	NEW MADRID WASTE WATER TREATMENT PLANT	LEVEE ROAD NEW MADRID, MO 63869	NEW MADRID	JUL-09-2004	JUL-08-2009	4952	SEWERAGE SYSTEMS	MAP	08020201
MOG640162	View Facility Information	NEW MADRID WTP	1 KOSKY LANE NEW MADRID, MO 63869	NEW MADRID	OCT-24-2008	OCT-23-2013	4941	WATER SUPPLY	MAP	
			391 SAINT					FABRICATED		

MO0105732	View Facility Information	NORANDA ALUMINUM INC	JUDE INDUSTRIAL PARK NEW MADRID , MO 63869	NEW MADRID	APR-03-2009	APR-02-2014	3499	METAL PRODUCTS, NOT ELSEWHERE CLASSIFIED	MAP	08010100
MOG490477	View Facility Information	NOVA BRIK MIDAMERICA, LLC	830 ROTH STREET SIKESTON, MO 63801	NEW MADRID	OCT-27-2006	OCT-05-2011	1422	CRUSHED AND BROKEN LIMESTONE	MAP	
MO0039900	View Facility Information	PARMA	CITY HALL, PO BOX 668 PARMA, MO 63870	NEW MADRID	MAR-30-2007	MAR-29-2012	4952	SEWERAGE SYSTEMS	MAP	08020204
MOG140043	View Facility Information	PILOT TRAVEL CENTERS LLC	917 E. ELM ST MARSTON, MO 63866	NEW MADRID	FEB-27-2009	DEC-23-2013	5541	GASOLINE SERVICE STATIONS	MAP	
MO0025275	View Facility Information	PORTAGEVILLE	PO DRAWER B PORTAGEVILLE, MO 63873	NEW MADRID	MAR-25-2005	MAR-24-2010	4952	SEWERAGE SYSTEMS	MAP	08020204
MOR240604	View Facility Information	QMI FERTILIZER AND GRAIN IN	109 MAIN ST PARMA, MO 63870	NEW MADRID	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MOR12A094	View Facility Information	RICELAND FOODS	918 NEW MADRID COUNTY MARSTON, MO 63866	NEW MADRID	AUG-04-2006	JUL-27-2011	2048	PREPARED FEEDS AND FEED INGREDIENTS FOR ANIMALS AND FOWLS, EXCEPT DOGS AND CATS	MAP	
MO0025852	View Facility Information	RISCO	HIGHWAY 62 RISCO, MO 63874	NEW MADRID	MAR-13-2009	MAR-12-2014	4952	SEWERAGE SYSTEMS	MAP	08020204
MOR240442	View Facility Information	SOUTHEAST COOP SERVICE CO	701 Z HIGHWAY MOREHOUSE, MO 63868	NEW MADRID	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MOG140032	View Facility Information	SOUTHWESTERN POWER ADMIN	NEW MADRID NEW MADRID, MO 63869	NEW MADRID	FEB-27-2009	DEC-23-2013	5541	GASOLINE SERVICE STATIONS	MAP	
MO0001180	View Facility Information	SRG GLOBAL PORTAGEVILLE	101 MEATTE STREET SUITE A PORTAGEVILLE, MO 63873	NEW MADRID	OCT-08-1999	OCT-07-2004	3089	PLASTICS PRODUCTS, NOT ELSEWHERE CLASSIFIED	MAP	08020204
MOG010719	View Facility Information	TILLER COHEN FARM LP	PO BOX 517 GIDEON, MO 63848	NEW MADRID	MAR-27-2009	FEB-23-2011	0241	DAIRY FARMS	MAP	
MOR109E37	View Facility Information	U.S. ARMY ENGINEER DISTRI	1 MI E OF NEW MADRID NEW MADRID, MO 63869	NEW MADRID	MAR-26-2007	MAR-07-2012	1629	HEAVY CONSTRUCTION, NOT ELSEWHERE CLASSIFIED	MAP	

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Total Number of Facilities Displayed: 46

v/enviro/fii_master.fii_retrieve?county_name=new%
=MO&all_programs=YES&program_search=2&report=1&page_no=1&output_sql_switch=TRUE&database_type=TRIS

Last updated on Friday, December 17, 2010

Toxics Release Inventory (TRI)

You are here: EPA Home Envirofacts TRI Query Results

Query Results

Report an Error

TRI

Only TRI facility information was searched to select facilities

County Name: new madrid
State Abbreviation: MO

Results are based on data extracted on SEP-27-2010

Note:
Click on the underlined TRI_FACILITY_ID value to view a detailed report on the facility.
Click on "View Facility Information" to view EPA Facility information for the facility.
Click on the underlined SUBMISSIONS value to view the list of DCN's for each of the TRI Reporting Year.

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List of EPA-Regulated Facilities in TRI

TRI FACILITY ID	FACILITY INFORMATION	FACILITY NAME	ADDRESS	COUNTY NAME	SUBMISSIONS
63801LNWRC830SO	View Facility Information	ALAN WIRE CO INC	830 SOUTHWEST ST SIKESTON, MO 63801	NEW MADRID	21
63869NWMDRSTJUD	View Facility Information	ASSOCIATED ELECTRIC COOPERATIVE INC NEW MADRID POWER PLANT	41 ST JUDE RD MARSTON, MO 63866	NEW MADRID	143
63869KCHMTHWY61	View Facility Information	BROWN SAND & GRAVEL (DBA HEARTLAND ASPHALT MATERIALS)	297 HWY 61 S NEW MADRID, MO 638690277	NEW MADRID	4
63862GRTRV813CU	View Facility Information	GREAT RIVER SOY PROCESSING LLC	813 COUNTY RD 641 LILBOURN, MO 63862	NEW MADRID	1
63801NTNLL104KE	View Facility Information	NATIONAL LOCK CORP	104 KEYSTONE DR SIKESTON, MO 63801	NEW MADRID	41

63869NRNDLSTJUD	View Facility Information	NORANDA ALUMINUM INC	391 ST JUDE INDUSTRIAL PARK NEW MADRID, MO 638690070	NEW MADRID	140
63801LDCST959SC	View Facility Information	OLDCASTLE LAWN & GARDEN	959 SCHOOL ST SIKESTON, MO 63801	NEW MADRID	1
63873SRFNS122MA	View Facility Information	S-R FINISHING	122 MARY ST. PORTAGEVILLE, MO 63873	NEW MADRID	9
63869LLYRSONEHO	View Facility Information	SPECIALLOY METALS CO.	1 HOPE WAY NEW MADRID, MO 63869	NEW MADRID	39
63873PLSTN101ME	View Facility Information	SRG GLOBAL PORTAGEVILLE	101 MEATTE ST PORTAGEVILLE, MO 63873	NEW MADRID	228

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Total Number of Facilities Displayed: 10

Resource Conservation and Recovery Act (RCRAInfo)

Query Results

Report an Error

RCRAInfo

Data Disclaimer

Consolidated facility information (from multiple EPA systems) was searched to select facilities

County Name: new madrid
State Abbreviation: MO

Results are based on data extracted on DEC-10-2010

Note: Click on the underlined CORPORATE LINK value for links to that company's environmental web pages.
Click on the underlined MAPPING INFO value to obtain mapping information for the facility.
Go To Bottom Of The Page

HANDLER NAME:	ALLOY RESEARCH INCORPORATED	HANDLER ID:	MOD985794858
STREET:	1 HOPE WAY	FACILITY INFORMATION:	View Facility Information
CITY:	NEW MADRID	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63869	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
BILLIE GRAY	HOPE WAY	NEW MADRID	MO	638691306	5737489000	Public
BILL GRAY	PO BOX 214	FINGER	TN	38334	5737489000	Permit
DANA LANCASTER	1 HOPE WAY	NEW MADRID	MO	63869	5737485501	Permit
BILLIE GRAY	HOPE WAY	NEW MADRID	MO	638691306	5737489000	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
331525	COPPER FOUNDRIES (EXCEPT DIE-CASTING)
331492	SECONDARY SMELTING, REFINING, AND ALLOYING OF NONFERROUS METAL (EXCEPT COPPER AND ALUMINUM)

HANDLER NAME:	ALS QUICK SACK	HANDLER ID:	MOP000031526
STREET:	102 W FRONT ST	FACILITY INFORMATION:	View Facility Information
CITY:	MOREHOUSE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63868	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
AL STOFFREGEN	HWY 114 BOX 277	MOREHOUSE	MO	63869	5736679998	Public
AL STOFFREGEN	HWY 114 BOX 277	MOREHOUSE	MO	63869	5736679998	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
44511	SUPERMARKETS AND OTHER GROCERY (EXCEPT CONVENIENCE) STORES

HANDLER NAME:	ASGROW SEED CO	HANDLER ID:	MOD122609910
STREET:	HWY 80 EAST OUTER RD V	FACILITY INFORMATION:	View Facility Information
CITY:	MATTHEWS	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63867	MAPPING INFO:	MAP

EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
WILLIAM SEXTON	PO BOX 109	MATTHEWS	MO	63867	5734715606	Public
WILLIAM SEXTON	PO BOX 109	MATTHEWS	MO	63867	5734715606	Permit

There was an error with the database tables.
Please send a report to enviromail_group@epamail.epa.gov telling us what criteria you used in the selection along with this error message:
ORA-06502: PL/SQL: numeric or value error: character string buffer too small

HANDLER NAME:	AWG NEW MADRID GATE STATION	HANDLER ID:	MOP000028381
STREET:	400 FT SOUTH OF HIGHWAY 61 ON	FACILITY INFORMATION:	View Facility Information
CITY:	NEW MADRID	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63869	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
RON CARVER	PO BOX 1288	FAYETTEVILLE	AR	727021288	5015828666	Public
RON CARVER	PO BOX 1288	FAYETTEVILLE	AR	727021288	5015828666	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
2212	NATURAL GAS DISTRIBUTION

There was an error with the database tables.
Please send a report to enviromail_group@epamail.epa.gov telling us what criteria you used in the selection along with this error message:
ORA-06502: PL/SQL: numeric or value error: character string buffer too small

HANDLER NAME:	AWG SIKESTON GATE STATION	HANDLER ID:	MOP000028399
STREET:	400 FT NORTH OF NORTH STREET O	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
RON CARVER	PO BOX 1288	FATETTEVILLE	AR	727021288	5015828666	Public
RON CARVER	PO BOX 1288	FATETTEVILLE	AR	727021288	5015828666	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
2212	NATURAL GAS DISTRIBUTION

HANDLER NAME:	BROWN SAND & GRAVEL (DBA HEARTLAND ASPHALT MATERIALS)	HANDLER ID:	MOR000019844
STREET:	297 SOUTH HWY 61	FACILITY INFORMATION:	View Facility Information
CITY:	NEW MADRID	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63869	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
KEVIN FAULKNER	PO BOX 277	NEW MADRID	MO	63869	5737482587	Public
DARRYL DARNELL	PO BOX 277	NEW MADRID	MO	63869	5737482587	Permit
KEVIN FAULKNER	PO BOX 277	NEW MADRID	MO	63869	5737482587	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
324121	ASPHALT PAVING MIXTURE AND BLOCK MANUFACTURING

HANDLER NAME:	C P S FARM CENTER MATTHEWS	HANDLER ID:	MOD064659956
STREET:	SOUTH MILLER ST	FACILITY INFORMATION:	View Facility Information
CITY:	MATTHEWS	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63867	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
J.L. DEHNER	PO BOX 577	MATTHEWS	MO	63867	8163324332	Public
J.L. DEHNER	PO BOX 577	MATTHEWS	MO	63867	8163324332	Permit

HANDLER NAME:	C R BREEDEN ENTERPRISES INC	HANDLER ID:	MOD985792191
STREET:	HWY Z	FACILITY INFORMATION:	View Facility Information
CITY:	MOREHOUSE	CORPORATE LINK:	No

STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63868	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
CHARLES BREEDEN	P O BOX 136	MOREHOUSE	MO	63868	5736675213	Public
CHARLES BREEDEN	P O BOX 136	MOREHOUSE	MO	63868	5736675213	Permit

HANDLER NAME:	CALGON	HANDLER ID:	MOP000010934
STREET:	1.5 MI E OF HWY 61 CTY RD 806	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
KAREN STADNIK	PO BOX 1346	PITTSBURGH	PA	15230	4124948384	Public
KAREN STADNIK	PO BOX 1346	PITTSBURGH	PA	15230	4124948384	Permit

HANDLER NAME:	CARGILL SERVICE CENTER INCORPORATED NEW MADRID FERTILIZER	HANDLER ID:	MOD980323216

HANDLER NAME:	MEDLIN EQUIPMENT CO	HANDLER ID:	MOR000024505
STREET:	2000 OUTER RD	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
GREG NICHELL	PO BOX 506	CHARLESTON	MO	63834	5736832601	Public
GREG NICHELL	PO BOX 506	CHARLESTON	MO	63834	5736832601	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
42182	FARM AND GARDEN MACHINERY AND EQUIPMENT WHOLESALERS

HANDLER NAME:	MID AMERICA MFG INC	HANDLER ID:	MOD985799089
STREET:	CTY RD 532 4 MI NW	FACILITY INFORMATION:	View Facility Information
CITY:	BERTRAND	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63823	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
TOM MOCK	RT 1 BOX 875	BERTRAND	MO	63823	5734719241	Public
TOM MOCK	RT 1 BOX 875	BERTRAND	MO	63823	5734719241	Permit

HANDLER NAME:	MO DEPT OF TRANSPORTATION	HANDLER ID:	MOP000000851
STREET:	HWY 80 .6 MI E OF HWY 105	FACILITY INFORMATION:	View Facility Information
CITY:	EAST PRAIRIE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63845	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
JOHN JURGENSMEYER	PO BOX 270	JEFFERSON CITY	MO	65102	5735264453	Public
JOHN JURGENSMEYER	PO BOX 270	JEFFERSON CITY	MO	65102	5735264453	Permit

HANDLER NAME:	MOORES LANDING FLEET	HANDLER ID:	MOD985799816
STREET:	1200 N COUNTY RD 303	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
WILLIE MILAM	1200 N COUNTY RD 303	CHARLESTON	MO	63834	5736753257	Public
WILLIE MILAM	1200 N COUNTY RD 303	CHARLESTON	MO	63834	5736753257	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION

483211	INLAND WATER FREIGHT TRANSPORTATION

HANDLER NAME:	ODDFELLOWS LODGE #84 % EPA R7	HANDLER ID:	MOP000514992
STREET:	105 S FRANKLIN ST	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
HEATH SMITH	97 N OUTER RD	EUREKA	MO	63025	5737834526	Public
HEATH SMITH	97 N OUTER RD	EUREKA	MO	63025	5737834526,	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
81341	CIVIC AND SOCIAL ORGANIZATIONS

HANDLER NAME:	PONDER CHEV & BUICK	HANDLER ID:	MOD029725710
STREET:	HWY 77 S	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT

GERALD BORDERS	PO BOX 186	CHARLESTON	MO	63834	5736833341	Public
GERALD BORDERS	PO BOX 186	CHARLESTON	MO	63834	5736833341	Permit

HANDLER NAME:	SAM AMOCO	HANDLER ID:	MOD985802024
STREET:	HWY 105 & 57TH ST	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
SAMUEL HOWARD	HWY 105 & 57TH ST	CHARLESTON	MO	63834	5736836285	Public
SAMUEL HOWARD	HWY 105 & 57TH ST	CHARLESTON	MO	63834	5736836285	Permit

HANDLER NAME:	STANLEY MUFFLER CO INC	HANDLER ID:	MOD985813088
STREET:	HWY 80W 1\2 M W OF CITY LIMIT	FACILITY INFORMATION:	View Facility Information
CITY:	EAST PRAIRIE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63845	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP	PHONE	TYPE OF

				CODE		CONTACT
STANLEY HUBBARD	W HWY 80 1/2 M W OF CITY LIMIT	EAST PRAIRIE	MO	63845	5736495151	Public
STANLEY HUBBARD	W HWY 80 1/2 M W OF CITY LIMIT	EAST PRAIRIE	MO	63845	5736495151	Permit
STANLEY HUBBARD	HWY 80W 1\2 M W OF CITY LIMIT	EAST PRAIRIE	MO	63845	5736495151	Permit

HANDLER NAME:	STARK MANUFACTURING	HANDLER ID:	MOD080008477
STREET:	1200 PLANT ROAD	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
TONI BEAVERS	1200 PLANT RD	CHARLESTON	MO	638342333	5736833321	Public
THOMAS E ROEMPAGEL					3146833321	Permit
TONI BEAVERS	1200 PLANT RD	CHARLESTON	MO	638342333	5736833321	Permit
DEREK K FARMER					3146833321	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
332999	ALL OTHER MISCELLANEOUS FABRICATED METAL PRODUCT MANUFACTURING
332112	NONFERROUS FORGING

HANDLER NAME:	SUTHERLAND OIL CO	HANDLER ID:	MOD985802156
STREET:	1110 E MARSHALL ST	FACILITY INFORMATION:	View Facility Information
CITY:	CHARLESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63834	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
KELLY BUTLER	1110 E MARSHALL ST	CHARLESTON	MO	63834	5736836573	Public
KELLY BUTLER	1110 E MARSHALL ST	CHARLESTON	MO	63834	5736836573	Permit

HANDLER NAME:	WOODS AVIATION INCORPORATED	HANDLER ID:	MOD990865867
STREET:	207 WASHINGTON ST	FACILITY INFORMATION:	View Facility Information
CITY:	EAST PRAIRIE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	MISSISSIPPI
ZIP CODE:	63845	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
						Public

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
115112	SOIL PREPARATION, PLANTING, AND CULTIVATING

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Total Number of Facilities Displayed: 32

http://oaspub.epa.gov/enviro/fii_master.fii_retrieve?county_name=new%20madrid&state_code=MO&all_programs=YES&program_search=1&report=1&page_no=1&output_sql_switch=TRUE&database_type=PCS

Last Updated on Friday, December 10, 2010

Water Discharge Permits (PCS)

You are here: EPA Home Envirofacts PCS Query Results

Query Results

Report an Error

Consolidated facility information (from multiple EPA systems) was searched to select facilities

PCS

County Name: new madrid
State Abbreviation: MO

Results are based on data extracted on DEC-14-2010

Note: Click on the underlined CORPORATE LINK value for links to that company's environmental web pages.
Click on the underlined MAPPING INFO value to obtain mapping information for the facility.
Click on the underlined NPDES value to view detailed reports on the facility.
Go To Bottom Of The Page

Facility Information

NPDES ID	Facility Information	FACILITY NAME	ADDRESS	COUNTY NAME	PERMIT ISSUED DATE	PERMIT EXPIRED DATE	SIC CODE	SIC DESC	MAPPING INFO	USGS HUC
MOR109BS7	View Facility Information	ADM GRAIN COMPANY-NEW MAD	NEW MADRID COUNTY PORT NEW MADRID, MO 63869	NEW MADRID	JAN-10-2008	MAR-07-2012	1629	HEAVY CONSTRUCTION, NOT ELSEWHERE CLASSIFIED	MAP	
MOR240498	View Facility Information	AG DISTRIBUTORS, INC.	3724 STATE HWY D CATRON, MO 63833	NEW MADRID	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MOR109DU4	View Facility Information	AGRIUM ADVANCED TECHNOLOG	500 COUNTY HWY 406 MARSTON, MO 63866	NEW MADRID	MAY-05-2009	MAR-07-2012	1629	HEAVY CONSTRUCTION, NOT ELSEWHERE CLASSIFIED	MAP	
MOR240021	View Facility Information	AGRO DISTRIBUTION, LLC	HWY 61 SOUTH PORTAGEVILLE, MO 63873	NEW MADRID	JUN-02-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MOR203375	View Facility Information	ALLOY RESEARCH INCORPORATED	1 HOPE WAY NEW MADRID, MO 63869	NEW MADRID	NOV-23-2005	MAR-04-2009	3743	RAILROAD EQUIPMENT	MAP	
MOG490599	View Facility Information	BROWN SAND & GRAVEL (DBA HEARTLAND ASPHALT MATERIALS)	297 SOUTH HWY 61 NEW MADRID, MO 63869	NEW MADRID	OCT-27-2006	OCT-05-2011	1422	CRUSHED AND BROKEN LIMESTONE	MAP	
MOR10A486	View Facility Information	CARGILL INC	LEVEE RD NEW MADRID, MO 63869	NEW MADRID	APR-30-2007	FEB-07-2012	1629	HEAVY CONSTRUCTION, NOT ELSEWHERE CLASSIFIED	MAP	
MOR240177	View Facility Information	CARGILL SERVICE CENTER INCORPORATED NEW MADRID FERTILIZER	250 LEVEE ROAD NEW MADRID, MO 63869	NEW MADRID	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MOR109DD0	View Facility Information	CPS	701 T PORT MARSTON, MO 63866	NEW MADRID	NOV-06-2008	MAR-07-2012	1629	HEAVY CONSTRUCTION, NOT ELSEWHERE CLASSIFIED	MAP	
MOR240500	View Facility Information	CROP PRODUCTION SERVICES	1661 US HWY 61 N PORTAGEVILLE, MO 63873	NEW MADRID	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MOG490641	View Facility Information	DELTA ASPHALT NEW MADRID	HIGHWAY 61 SOUTH NEW MADRID, MO 63869	NEW MADRID	OCT-27-2006	OCT-05-2011	1422	CRUSHED AND BROKEN LIMESTONE	MAP	
MOR60A014	View Facility Information	DELTA AUTO PARTS AND SALV	1519 US HIGHWAY 61 PORTAGEVILLE, MO 63873	NEW MADRID	JUN-27-2008	MAY-29-2013	5015	MOTOR VEHICLE PARTS, USED	MAP	
		DELTA	504 STATE							

MOR240544	View Facility Information	GROWERS ASSOCIATION	HIGHWAY W KEWANEE, MO 63860	NEW MADRID	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MOR240030	View Facility Information	DELTA GROWERS ASSOCIATION	500 SOUTH RAILROAD STREET MATTHEWS, MO 63867	NEW MADRID	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MOG140003	View Facility Information	FLYING J TRAVEL PLAZA	703 STATE HIGHWAY 80 MATTHEWS , MO 63867	NEW MADRID	FEB-27-2009	DEC-23-2013	5541	GASOLINE SERVICE STATIONS	MAP	
MO0021423	View Facility Information	GIDEON WWTF	HIGHWAY 162 GIDEON, MO 63848	NEW MADRID	MAY-28-2004	MAY-27-2009	4952	SEWERAGE SYSTEMS	MAP	08020204
MO0115339	View Facility Information	GOOD HUMOR BREYERS ICE CREAM	1010 COUNTY LINE ROAD SIKESTON, MO 63801	NEW MADRID	JUL-07-2006	JUL-06-2011	2024	ICE CREAM AND FROZEN DESSERTS	MAP	
MOR23E002	View Facility Information	GREAT RIVER SOY PROCESSIN	813 CO RD 641 LILBOURN, MO 63862	NEW MADRID	JUN-20-2008	MAY-22-2013	2869	INDUSTRIAL ORGANIC CHEMICALS, NOT ELSEWHERE CLASSIFIED	MAP	
MOR23A128	View Facility Information	GREAT RIVER SOY PROCESSING LLC	813 COUNTY RD 641 LILBOURN, MO 63862	NEW MADRID	AUG-17-2007	FEB-03-2010	2833	MEDICINAL CHEMICALS AND BOTANICAL PRODUCTS	MAP	
MOR240558	View Facility Information	HELENA CHEMICAL COMPANY	618 US HIGHWAY 61 NEW MADRID, MO 63869	NEW MADRID	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MO0092321	View Facility Information	HOWARDVILLE	HWY 61 HOWARDVILLE, MO 63869	NEW MADRID	JAN-19-2007	JAN-18-2012	4952	SEWERAGE SYSTEMS	MAP	08020204
MOR60A101	View Facility Information	JAMES ARTHUR MONTGOMERY	203 EAST RAILROAD STREET GIDEON, MO 63848	NEW MADRID	JUN-27-2008	MAY-29-2013	5015	MOTOR VEHICLE PARTS, USED	MAP	
MOG010270	View Facility Information	JIM GOINS	RT 1, BOX 99AA MATTHEWS, MO 63867	NEW MADRID	DEC-19-2008	FEB-23-2011	0251	BROILER, FRYER, AND ROASTER CHICKENS	MAP	
MO0048178	View Facility Information	LILBOURN WWTF	PO BOX 643 LILBOURN, MO 63862	NEW MADRID	JUL-26-2002	JUL-25-2007	4952	SEWERAGE SYSTEMS	MAP	08020204
MO0036200	View Facility Information	MARSTON	MARSTON MARSTON, MO 63866	NEW MADRID	NOV-30-2001	NOV-29-2006	4952	SEWERAGE SYSTEMS	MAP	08020204
MO0127175	View Facility Information	MATTHEWS	HWY AE MATTHEWS, MO 63867	NEW MADRID	MAY-13-2005	MAY-12-2010	4952	SEWERAGE SYSTEMS	MAP	
MOG140044	View Facility Information	MATTHEWS TRAVEL CENTER	I-55 & HWY 80 MATTHEWS, MO 63867	NEW MADRID	FEB-27-2009	DEC-23-2013	5541	GASOLINE SERVICE STATIONS	MAP	
MOR240550	View Facility Information	MCCORD GIN COMPANY	300 EAST 4TH STREET GIDEON, MO 63848	NEW MADRID	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MOG350120	View Facility Information	MFA OIL CO-BULK PET STOR	HWY D LILBOURN, MO 63862	NEW MADRID	JUN-22-2007	JUN-14-2012	5171	PETROLEUM BULK STATIONS AND TERMINALS	MAP	
MO0030821	View Facility Information	MOREHOUSE WASTE WATER TREATMENT FACILITY C/O CITY HALL	113 EAST BEECH STREET MOREHOUSE, MO 63868	NEW MADRID	NOV-20-2009	NOV-19-2014	4952	SEWERAGE SYSTEMS	MAP	08020204
MO0001171	View Facility Information	NEW MADRID POWER PLANT	41 SAINT JUDE INDUSTRIAL PARK MARSTON, MO 63866	NEW MADRID	MAY-02-2003	MAY-01-2008	4911	ELECTRIC SERVICES	MAP	08010100
MO0022845	View Facility Information	NEW MADRID WASTE WATER TREATMENT PLANT	LEVEE ROAD NEW MADRID, MO 63869	NEW MADRID	JUL-09-2004	JUL-08-2009	4952	SEWERAGE SYSTEMS	MAP	08020201
MOG640162	View Facility Information	NEW MADRID WTP	1 KOSKY LANE NEW MADRID, MO 63869	NEW MADRID	OCT-24-2008	OCT-23-2013	4941	WATER SUPPLY	MAP	
			391 SAINT					FABRICATED		

MO0105732	View Facility Information	NORANDA ALUMINUM INC	JUDE INDUSTRIAL PARK NEW MADRID , MO 63869	NEW MADRID	APR-03-2009	APR-02-2014	3499	METAL PRODUCTS, NOT ELSEWHERE CLASSIFIED	MAP	08010100
MOG490477	View Facility Information	NOVA BRIK MIDAMERICA, LLC	830 ROTH STREET SIKESTON, MO 63801	NEW MADRID	OCT-27-2006	OCT-05-2011	1422	CRUSHED AND BROKEN LIMESTONE	MAP	
MO0039900	View Facility Information	PARMA	CITY HALL, PO BOX 668 PARMA, MO 63870	NEW MADRID	MAR-30-2007	MAR-29-2012	4952	SEWERAGE SYSTEMS	MAP	08020204
MOG140043	View Facility Information	PILOT TRAVEL CENTERS LLC	917 E. ELM ST MARSTON, MO 63866	NEW MADRID	FEB-27-2009	DEC-23-2013	5541	GASOLINE SERVICE STATIONS	MAP	
MO0025275	View Facility Information	PORTAGEVILLE	PO DRAWER B PORTAGEVILLE, MO 63873	NEW MADRID	MAR-25-2005	MAR-24-2010	4952	SEWERAGE SYSTEMS	MAP	08020204
MOR240604	View Facility Information	QMI FERTILIZER AND GRAIN IN	109 MAIN ST PARMA, MO 63870	NEW MADRID	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MOR12A094	View Facility Information	RICELAND FOODS	918 NEW MADRID COUNTY MARSTON, MO 63866	NEW MADRID	AUG-04-2006	JUL-27-2011	2048	PREPARED FEEDS AND FEED INGREDIENTS FOR ANIMALS AND FOWLS, EXCEPT DOGS AND CATS	MAP	
MO0025852	View Facility Information	RISCO	HIGHWAY 62 RISCO, MO 63874	NEW MADRID	MAR-13-2009	MAR-12-2014	4952	SEWERAGE SYSTEMS	MAP	08020204
MOR240442	View Facility Information	SOUTHEAST COOP SERVICE CO	701 Z HIGHWAY MOREHOUSE, MO 63868	NEW MADRID	MAR-27-2009	FEB-19-2014	5191	FARM SUPPLIES	MAP	
MOG140032	View Facility Information	SOUTHWESTERN POWER ADMIN	NEW MADRID NEW MADRID, MO 63869	NEW MADRID	FEB-27-2009	DEC-23-2013	5541	GASOLINE SERVICE STATIONS	MAP	
MO0001180	View Facility Information	SRG GLOBAL PORTAGEVILLE	101 MEATTE STREET SUITE A PORTAGEVILLE, MO 63873	NEW MADRID	OCT-08-1999	OCT-07-2004	3089	PLASTICS PRODUCTS, NOT ELSEWHERE CLASSIFIED	MAP	08020204
MOG010719	View Facility Information	TILLER COHEN FARM LP	PO BOX 517 GIDEON, MO 63848	NEW MADRID	MAR-27-2009	FEB-23-2011	0241	DAIRY FARMS	MAP	
MOR109E37	View Facility Information	U.S. ARMY ENGINEER DISTRI	1 MI E OF NEW MADRID NEW MADRID, MO 63869	NEW MADRID	MAR-26-2007	MAR-07-2012	1629	HEAVY CONSTRUCTION, NOT ELSEWHERE CLASSIFIED	MAP	

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Total Number of Facilities Displayed: 46

v/enviro/fii_master.fii_retrieve?county_name=new%
=MO&all_programs=YES&program_search=2&report=1&page_no=1&output_sql_switch=TRUE&database_type=TRIS

Last updated on Friday, December 17, 2010

Toxics Release Inventory (TRI)

You are here: EPA Home Envirofacts TRI Query Results

Query Results

Report an Error

TRI

Only TRI facility information was searched to select facilities

County Name: new madrid
State Abbreviation: MO

Results are based on data extracted on SEP-27-2010

Note:
Click on the underlined TRI_FACILITY_ID value to view a detailed report on the facility.
Click on "View Facility Information" to view EPA Facility information for the facility.
Click on the underlined SUBMISSIONS value to view the list of DCN's for each of the TRI Reporting Year.

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List of EPA-Regulated Facilities in TRI

TRI FACILITY ID	FACILITY INFORMATION	FACILITY NAME	ADDRESS	COUNTY NAME	SUBMISSIONS
63801LNWRC830SO	View Facility Information	ALAN WIRE CO INC	830 SOUTHWEST ST SIKESTON, MO 63801	NEW MADRID	21
63869NWMDRSTJUD	View Facility Information	ASSOCIATED ELECTRIC COOPERATIVE INC NEW MADRID POWER PLANT	41 ST JUDE RD MARSTON, MO 63866	NEW MADRID	143
63869KCHMTHWY61	View Facility Information	BROWN SAND & GRAVEL (DBA HEARTLAND ASPHALT MATERIALS)	297 HWY 61 S NEW MADRID, MO 638690277	NEW MADRID	4
63862GRTRV813CU	View Facility Information	GREAT RIVER SOY PROCESSING LLC	813 COUNTY RD 641 LILBOURN, MO 63862	NEW MADRID	1
63801NTNLL104KE	View Facility Information	NATIONAL LOCK CORP	104 KEYSTONE DR SIKESTON, MO 63801	NEW MADRID	41

63869NRNDLSTJUD	View Facility Information	NORANDA ALUMINUM INC	391 ST JUDE INDUSTRIAL PARK NEW MADRID, MO 638690070	NEW MADRID	140
63801LDCST959SC	View Facility Information	OLDCASTLE LAWN & GARDEN	959 SCHOOL ST SIKESTON, MO 63801	NEW MADRID	1
63873SRFNS122MA	View Facility Information	S-R FINISHING	122 MARY ST. PORTAGEVILLE, MO 63873	NEW MADRID	9
63869LLYRSONEHO	View Facility Information	SPECIALLOY METALS CO.	1 HOPE WAY NEW MADRID, MO 63869	NEW MADRID	39
63873PLSTN101ME	View Facility Information	SRG GLOBAL PORTAGEVILLE	101 MEATTE ST PORTAGEVILLE, MO 63873	NEW MADRID	228

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Total Number of Facilities Displayed: 10

Resource Conservation and Recovery Act (RCRAInfo)

Query Results

Report an Error

RCRAInfo

Data Disclaimer

Consolidated facility information (from multiple EPA systems) was searched to select facilities

County Name: new madrid
State Abbreviation: MO

Results are based on data extracted on DEC-10-2010

Note: Click on the underlined CORPORATE LINK value for links to that company's environmental web pages.
Click on the underlined MAPPING INFO value to obtain mapping information for the facility.
Go To Bottom Of The Page

HANDLER NAME:	ALLOY RESEARCH INCORPORATED	HANDLER ID:	MOD985794858
STREET:	1 HOPE WAY	FACILITY INFORMATION:	View Facility Information
CITY:	NEW MADRID	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63869	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
BILLIE GRAY	HOPE WAY	NEW MADRID	MO	638691306	5737489000	Public
BILL GRAY	PO BOX 214	FINGER	TN	38334	5737489000	Permit
DANA LANCASTER	1 HOPE WAY	NEW MADRID	MO	63869	5737485501	Permit
BILLIE GRAY	HOPE WAY	NEW MADRID	MO	638691306	5737489000	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
331525	COPPER FOUNDRIES (EXCEPT DIE-CASTING)
331492	SECONDARY SMELTING, REFINING, AND ALLOYING OF NONFERROUS METAL (EXCEPT COPPER AND ALUMINUM)

HANDLER NAME:	ALS QUICK SACK	HANDLER ID:	MOP000031526
STREET:	102 W FRONT ST	FACILITY INFORMATION:	View Facility Information
CITY:	MOREHOUSE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63868	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
AL STOFFREGEN	HWY 114 BOX 277	MOREHOUSE	MO	63869	5736679998	Public
AL STOFFREGEN	HWY 114 BOX 277	MOREHOUSE	MO	63869	5736679998	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
44511	SUPERMARKETS AND OTHER GROCERY (EXCEPT CONVENIENCE) STORES

HANDLER NAME:	ASGROW SEED CO	HANDLER ID:	MOD122609910
STREET:	HWY 80 EAST OUTER RD V	FACILITY INFORMATION:	View Facility Information
CITY:	MATTHEWS	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63867	MAPPING INFO:	MAP

EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
WILLIAM SEXTON	PO BOX 109	MATTHEWS	MO	63867	5734715606	Public
WILLIAM SEXTON	PO BOX 109	MATTHEWS	MO	63867	5734715606	Permit

There was an error with the database tables.
Please send a report to enviromail_group@epamail.epa.gov telling us what criteria you used in the selection along with this error message:
ORA-06502: PL/SQL: numeric or value error: character string buffer too small

HANDLER NAME:	AWG NEW MADRID GATE STATION	HANDLER ID:	MOP000028381
STREET:	400 FT SOUTH OF HIGHWAY 61 ON	FACILITY INFORMATION:	View Facility Information
CITY:	NEW MADRID	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63869	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
RON CARVER	PO BOX 1288	FAYETTEVILLE	AR	727021288	5015828666	Public
RON CARVER	PO BOX 1288	FAYETTEVILLE	AR	727021288	5015828666	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
2212	NATURAL GAS DISTRIBUTION

There was an error with the database tables.
Please send a report to enviromail_group@epamail.epa.gov telling us what criteria you used in the selection along with this error message:
ORA-06502: PL/SQL: numeric or value error: character string buffer too small

HANDLER NAME:	AWG SIKESTON GATE STATION	HANDLER ID:	MOP000028399
STREET:	400 FT NORTH OF NORTH STREET O	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
RON CARVER	PO BOX 1288	FATETTEVILLE	AR	727021288	5015828666	Public
RON CARVER	PO BOX 1288	FATETTEVILLE	AR	727021288	5015828666	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
2212	NATURAL GAS DISTRIBUTION

HANDLER NAME:	BROWN SAND & GRAVEL (DBA HEARTLAND ASPHALT MATERIALS)	HANDLER ID:	MOR000019844
STREET:	297 SOUTH HWY 61	FACILITY INFORMATION:	View Facility Information
CITY:	NEW MADRID	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63869	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
KEVIN FAULKNER	PO BOX 277	NEW MADRID	MO	63869	5737482587	Public
DARRYL DARNELL	PO BOX 277	NEW MADRID	MO	63869	5737482587	Permit
KEVIN FAULKNER	PO BOX 277	NEW MADRID	MO	63869	5737482587	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
324121	ASPHALT PAVING MIXTURE AND BLOCK MANUFACTURING

HANDLER NAME:	C P S FARM CENTER MATTHEWS	HANDLER ID:	MOD064659956
STREET:	SOUTH MILLER ST	FACILITY INFORMATION:	View Facility Information
CITY:	MATTHEWS	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63867	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
J.L. DEHNER	PO BOX 577	MATTHEWS	MO	63867	8163324332	Public
J.L. DEHNER	PO BOX 577	MATTHEWS	MO	63867	8163324332	Permit

HANDLER NAME:	C R BREEDEN ENTERPRISES INC	HANDLER ID:	MOD985792191
STREET:	HWY Z	FACILITY INFORMATION:	View Facility Information
CITY:	MOREHOUSE	CORPORATE LINK:	No

STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63868	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
CHARLES BREEDEN	P O BOX 136	MOREHOUSE	MO	63868	5736675213	Public
CHARLES BREEDEN	P O BOX 136	MOREHOUSE	MO	63868	5736675213	Permit

HANDLER NAME:	CALGON	HANDLER ID:	MOP000010934
STREET:	1.5 MI E OF HWY 61 CTY RD 806	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
KAREN STADNIK	PO BOX 1346	PITTSBURGH	PA	15230	4124948384	Public
KAREN STADNIK	PO BOX 1346	PITTSBURGH	PA	15230	4124948384	Permit

HANDLER NAME:	CARGILL SERVICE CENTER INCORPORATED NEW MADRID FERTILIZER	HANDLER ID:	MOD980323216

STREET:	250 LEVEE ROAD	FACILITY INFORMATION:	View Facility Information
CITY:	NEW MADRID	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63869	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
JOHN HARTNESS	PO BOX 307	NEW MADRID	MO	63869	5737485576	Public
JOHN HARTNESS	PO BOX 307	NEW MADRID	MO	63869	5737485576	Permit

HANDLER NAME:	CASEYS GENERAL STORE #1883	HANDLER ID:	MOR000016204
STREET:	200 MAIN ST	FACILITY INFORMATION:	View Facility Information
CITY:	GIDEON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63848	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
GLENN NORGART	PO BOX 3001	ANKENY	IA	500218045	5159656238	Public
GLENN NORGART	PO BOX 3001	ANKENY	IA	500218045	5159656238	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
4471	GASOLINE STATIONS

HANDLER NAME:	CASEYS GENERAL STORE #1884	HANDLER ID:	MOR000016246
STREET:	INTERSECTON OF HWY D & HWY U	FACILITY INFORMATION:	View Facility Information
CITY:	LILBOURN	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63862	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
GLENN NORGART	PO BOX 3001	ANKENY	IA	500218045	5159656238	Public
GLENN NORGART	PO BOX 3001	ANKENY	IA	500218045	5159656238	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
4471	GASOLINE STATIONS

HANDLER NAME:	CASEYS GENERAL STORE #1919	HANDLER ID:	MOR000015891
STREET:	HWY 162 E	FACILITY INFORMATION:	View Facility Information
CITY:	PORTAGEVILLE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63873	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF

						CONTACT
GLENN NORGART	PO BOX 3001	ANKENY	IA	500218045	5159656238	Public
GLENN NORGART	PO BOX 3001	ANKENY	IA	500218045	5159656238	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
4471	GASOLINE STATIONS

HANDLER NAME:	CHRISTIAN SALVESEN TRANSPORT	HANDLER ID:	MOD985801547
STREET:	119 HARLENE ST	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
DON HURST	119 HARLENE ST	SIKESTON	MO	63801	5734715633	Public
DON HURST	119 HARLENE ST	SIKESTON	MO	63801	5734715633	Permit

HANDLER NAME:	CROP PRODUCTION SERVICES INC	HANDLER ID:	MOR000535963
STREET:	500 COUNTY RD 406	FACILITY INFORMATION:	View Facility Information
CITY:	MARSTON	CORPORATE LINK:	No

STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63866	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
LINDA HENDRICKSON	W 4TH ST	GREELEY	CO	80634	9703471652	Public
LINDA HENDRICKSON	W 4TH ST	GREELEY	CO	80634	9703471652	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
42491	FARM SUPPLIES MERCHANT WHOLESALERS

There was an error with the database tables.
Please send a report to enviromail_group@epamail.epa.gov telling us what criteria you used in the selection along with this error message:
ORA-06502: PL/SQL: numeric or value error: character string buffer too small

HANDLER NAME:	DEKALB CORPORATION	HANDLER ID:	MOP000012112
STREET:	7 MILES SOUTH HIGHWAY 61	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
NICHOLAS ARRIGO	3100 SYCAMORE RD	DEKALB	IL	60115	8157589194	Public
NICHOLAS ARRIGO	3100 SYCAMORE RD	DEKALB	IL	60115	8157589194	Permit

HANDLER NAME:	DRURY INDUSTRIES	HANDLER ID:	MOP000001345
STREET:	HWY 55 & HWY 162	FACILITY INFORMATION:	View Facility Information
CITY:	PORTAGEVILLE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63873	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
LARRY WESTRICH	PO BOX 910	CAPE GIRARDEAU	MO	63702	5733353134	Public
LARRY WESTRICH	PO BOX 910	CAPE GIRARDEAU	MO	63702	5733353134	Permit

HANDLER NAME:	DUCKETT TRUCK CENTERS INC	HANDLER ID:	MOR000520452
STREET:	307 LYNUAL ST	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	638019361	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
SHIRLEY WATSON	LYNUAL ST	SIKESTON	MO	638019361	8004557453	Public
PETE CANTRELL	307 LYNUAL RD	SIKESTON	MO	638019361	8004557453, 3733	Permit
SHIRLEY WATSON	LYNUAL ST	SIKESTON	MO	638019361	8004557453	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
81111	AUTOMOTIVE MECHANICAL AND ELECTRICAL REPAIR AND MAINTENANCE
81112	AUTOMOTIVE BODY, PAINT, INTERIOR, AND GLASS REPAIR

HANDLER NAME:	ESSEX CHEMICAL CORP	HANDLER ID:	MOP000001043
STREET:	HWY U & HOPE WY	FACILITY INFORMATION:	View Facility Information
CITY:	NEW MADRID	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63869	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
BEN BAKER	BROAD ST	CLIFTON	NJ	07015	5176360787	Public
BEN BAKER	BROAD ST	CLIFTON	NJ	07015	5176360787	Permit

HANDLER NAME:	GIDEON 37 SCHOOL DISTRICT	HANDLER ID:	MOR000530311
STREET:	400 MAIN ST	FACILITY INFORMATION:	View Facility Information
CITY:	GIDEON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	638489186	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
DAVID	PO BOX	GIDEON	MO	63848	5734483911	Public

HOLLINGSHEAD	227					
DAVID HOLLINGSHEAD	PO BOX 227	GIDEON	MO	63848	5734483911	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
61111	ELEMENTARY AND SECONDARY SCHOOLS

HANDLER NAME:	GIDEON ANDERSON LUMBER CO INC	HANDLER ID:	MOD070343538
STREET:	MAIN & 2ND ST	FACILITY INFORMATION:	View Facility Information
CITY:	GIDEON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63848	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
RONALD RANDEN	P O BOX 197	GIDEON	MO	63848	5734483518	Public
RONALD RANDEN	P O BOX 197	GIDEON	MO	63848	5734483518	Permit

HANDLER NAME:	GREAT RIVER SOY PROCESSING LLC	HANDLER ID:	MOR000536904
STREET:	813 COUNTY RD 641	FACILITY INFORMATION:	View Facility Information
CITY:	LILBOURN	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63862	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
SAM HUNTER	PO BOX 10	NEW MADRID	MO	638690010	5737485551	Public
SAM HUNTER	PO BOX 10	NEW MADRID	MO	638690010	5737485551	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
56291	REMEDIATION SERVICES

HANDLER NAME:	HG RHODES AUTO SALES	HANDLER ID:	MOP000514778
STREET:	401 N 3RD ST	FACILITY INFORMATION:	View Facility Information
CITY:	LILBOURN	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63862	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
KEVIN KNIGHT	PO BOX 170	LILBOURN	MO	63862	5737859621	Public
KEVIN KNIGHT	PO BOX 170	LILBOURN	MO	63862	5737859621	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
44111	NEW CAR DEALERS

HANDLER NAME:	IVIE OIL CO	HANDLER ID:	MOD985802461
STREET:	1ST & BAKER	FACILITY INFORMATION:	View Facility Information
CITY:	PORTAGEVILLE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63873	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
RICHARD IVIE	PO BOX 219	PORTAGEVILLE	MO	63873	5733793668	Public
RICHARD IVIE	PO BOX 219	PORTAGEVILLE	MO	63873	5733793668	Permit

HANDLER NAME:	KONTEK INDUSTRIES	HANDLER ID:	MOR000534032
STREET:	1200 DAWSON ROAD	FACILITY INFORMATION:	View Facility Information
CITY:	NEW MADRID	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63869	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
ALLEN NOLTE	PO BOX 98	NEW MADRID	MO	63869	5737485561	Public
ALLEN NOLTE	PO BOX 98	NEW MADRID	MO	63869	5737485561	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
332311	PREFABRICATED METAL BUILDING AND COMPONENT MANUFACTURING

HANDLER NAME:	MCCRATE EQUIPMENT CO	HANDLER ID:	MOD981705742
STREET:	421 E MAIN ST	FACILITY INFORMATION:	View Facility Information
CITY:	PORTAGEVILLE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63873	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
L T FERRELL	421 E MAIN ST	PORTAGEVILLE	MO	63873	5733795455	Public
L T FERRELL	421 E MAIN ST	PORTAGEVILLE	MO	63873	5733795455	Permit

HANDLER NAME:	MFA OIL CO LILBOURN	HANDLER ID:	MOP000515296
STREET:	JCT HWY U & COUNTY RD 641	FACILITY INFORMATION:	View Facility Information
CITY:	LILBOURN	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63862	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
DANIEL CREEK	PO BOX 519	COLUMBIA	MO	65205	5732195785	Public
DANIEL CREEK	PO BOX 519	COLUMBIA	MO	65205	5732195785,	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
42471	PETROLEUM BULK STATIONS AND TERMINALS

HANDLER NAME:	MILLIKEN PUBLISHING CO	HANDLER ID:	MOD985796630
STREET:	309 LYNUAL ST	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
ROGER CRAFT	PO BOX 669	SIKESTON	MO	63801	5734721980	Public
ROGER CRAFT	PO BOX 669	SIKESTON	MO	63801	5734721980	Permit

HANDLER NAME:	MO DOT KEWANEE MAINTENANCE SHED	HANDLER ID:	MOR000504001
STREET:	86 HWY W	FACILITY INFORMATION:	View Facility Information
CITY:	NEW MADRID	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63869	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP	PHONE	TYPE OF

				CODE		CONTACT
LANCE LIVESAY	PO BOX 270	JEFFERSON CITY	MO	65102	5735264764	Public
LANCE LIVESAY	PO BOX 270	JEFFERSON CITY	MO	65102	5735264764	Permit
LANCE LIVESAY	PO BOX 270	JEFFESON CITY	MO	65102	5735264764	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
23731	HIGHWAY, STREET, AND BRIDGE CONSTRUCTION

HANDLER NAME:	NEW MADRID POWER PLANT	HANDLER ID:	MOD053964862
STREET:	41 SAINT JUDE INDUSTRIAL PARK	FACILITY INFORMATION:	View Facility Information
CITY:	MARSTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63866	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
RUSSELL RICE	PO BOX 156	NEW MADRID	MO	63869	5736432211	Public
RUSSELL RICE	PO BOX 156	NEW MADRID	MO	63869	5736432211	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
2211	ELECTRIC POWER GENERATION, TRANSMISSION AND DISTRIBUTION

HANDLER NAME:	NEW MADRID TRACTOR CO	HANDLER ID:	MOD985807114
STREET:	HWY 61 N ONE MILE	FACILITY INFORMATION:	View Facility Information
CITY:	NEW MADRID	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63869	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
CHRIS CRYSLER	PO BOX 5	NEW MADRID	MO	63869	5733590141	Public
CHRIS CRYSLER	PO BOX 5	NEW MADRID	MO	63869	5733590141	Permit

HANDLER NAME:	NEW MADRID VO TECH SCHOOL	HANDLER ID:	MOD985804996
STREET:	310 US HWY 61	FACILITY INFORMATION:	View Facility Information
CITY:	NEW MADRID	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63869	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
JIMMY HARREL	310 US HWY 61	NEW MADRID	MO	63869	5736882161	Public
JIMMY HARREL	310 US HWY 61	NEW MADRID	MO	63869	5736882161	Permit

HANDLER NAME:	NORANDA ALUMINUM INC	HANDLER ID:	MOD093750966
STREET:	391 SAINT JUDE INDUSTRIAL PARK	FACILITY INFORMATION:	View Facility Information
CITY:	NEW MADRID	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63869	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
DON BACKFISCH	P O BOX 70	NEW MADRID	MO	63869	5736432361 2126	Public
DON E. BACKFISCH					5736432361, 2126	Permit
DON BACKFISCH					5736432361, 2126	Permit
ROBERT E HURT					3146432361, 2234	Permit
DON E BACKFISCH					3146432361, 2235	Permit
DAVID E HART					3146432361, 2234	Permit
DON BACKFISCH	PO BOX 70	NEW MADRID	MO	63869	5736432361, 2126	Permit
DON BACKFISCH	PO BOX 70	NEW MADRID	MO	63869	5736432361	Permit
DON E BACKFISCH					5736432361, 2235	Permit
DON BACKFISCH					5736432361, 2126	Permit
DON BACKFISCH	P O BOX 70	NEW MADRID	MO	63869	5736432361, 2126	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
331314	SECONDARY SMELTING AND ALLOYING OF ALUMINUM
331319	OTHER ALUMINUM ROLLING AND DRAWING
331312	PRIMARY ALUMINUM PRODUCTION

HANDLER NAME:	RISCO HIGH SCHOOL	HANDLER ID:	MOR000531095
STREET:	101 LOCUST	FACILITY INFORMATION:	View Facility Information
CITY:	RISCO	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	638741002	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
TISKA RODGERS	LOCUST	RISCO	MO	638741002	5733965568	Public
TISKA RODGERS	LOCUST	RISCO	MO	638741002	5733965568	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
61111	ELEMENTARY AND SECONDARY SCHOOLS

HANDLER NAME:	RITEWAY FULL SERVICE	HANDLER ID:	MOR000536086
STREET:	201 N HWY 61	FACILITY INFORMATION:	View Facility Information
CITY:	PORTAGEVILLE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	638731423	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
KEVIN KNIGHT	N HWY 61	PORTAGEVILLE	MO	638731423	5737859621	Public
KEVIN KNIGHT	N HWY 61	PORTAGEVILLE	MO	638731423	5737859621	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION

44711	GASOLINE STATIONS WITH CONVENIENCE STORES

HANDLER NAME:	S R FINISHING	HANDLER ID:	MO0000064550
STREET:	122 MARY AVENUE	FACILITY INFORMATION:	View Facility Information
CITY:	PORTAGEVILLE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63873	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
ROCKY DUNAVANT	122 MARY ST	PORTAGEVILLE	MO	63873	5733793857	Public
ROCKY D DUNAVANT					5733793857	Permit
ROCKY DUNAVANT	122 MARY ST	PORTAGEVILLE	MO	63873	5733793857	Permit
SHAWN SIMPSON					5733793857	Permit
ROCKY DUNAVANT					5733793857	Permit
STEVEN SHERRIFF	PO BOX 486	RIPLEY	TN	38063	9016353421	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
332813	ELECTROPLATING, PLATING, POLISHING, ANODIZING, AND COLORING

HANDLER NAME:	SIKESTON MOTOR	HANDLER ID:	MOD031128325
STREET:	1030 SOUTH MAIN STREET	FACILITY INFORMATION:	View Facility Information

CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
BILL TEETERS	PO BOX 728	SIKESTON	MO	63801	5734711255	Public
BILL TEETERS	PO BOX 728	SIKESTON	MO	63801	5734711255	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
44111	NEW CAR DEALERS

HANDLER NAME:	SIMMONS SERVICE STATION	HANDLER ID:	MOR000536094
STREET:	303 N HWY 61	FACILITY INFORMATION:	View Facility Information
CITY:	PORTAGEVILLE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	638731425	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
KEVIN KNIGHT	N HWY 61	PORTAGEVILLE	MO	638731425	5737859621	Public
KEVIN KNIGHT	N HWY 61	PORTAGEVILLE	MO	638731425	5737859621	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
44711	GASOLINE STATIONS WITH CONVENIENCE STORES

HANDLER NAME:	SINCLAIR PIPELINE COMPANY - NEW MADRID TERMINAL	HANDLER ID:	MOD980742399
STREET:	211 WATER STREET	FACILITY INFORMATION:	View Facility Information
CITY:	NEW MADRID	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63869	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
RANDY DANIELSON	OLD HWY 24	CARROLLTON	MO	64633	6605420206	Public
RANDY DANIELSON	OLD HWY 24	CARROLLTON	MO	64633	6605420206	Permit
RANDY DANIELSON	RTE 4 BOX 2A	CARROLLTON	MO	64633	6605420206	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
42271	PETROLEUM BULK STATIONS AND TERMINALS
42471	PETROLEUM BULK STATIONS AND TERMINALS

HANDLER NAME:	SMITHS AUTO SALES	HANDLER ID:	MOR000030395
STREET:	302 N MAIN ST	FACILITY INFORMATION:	View Facility Information
CITY:	GIDEON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63848	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
LEO SMITH	302 N MAIN ST	GIDEON	MO	63848	5734485189	Public
LEO SMITH	302 N MAIN ST	GIDEON	MO	63848	5734485189	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
811121	AUTOMOTIVE BODY, PAINT, AND INTERIOR REPAIR AND MAINTENANCE

HANDLER NAME:	SOLVENT RECLAIMING CO	HANDLER ID:	MOD980740351
STREET:	HWY 61 S IN TOWN	FACILITY INFORMATION:	View Facility Information
CITY:	PORTAGEVILLE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63873	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
EARL CROSS	6953 COLONIAL WOODS DR #47	ST. LOUIS,	MO	63129	5733792252	Public
EARL CROSS	6953 COLONIAL WOODS DR #47	ST. LOUIS,	MO	63129	5733792252	Permit

HANDLER NAME:	SRG GLOBAL PORTAGEVILLE	HANDLER ID:	MOD052612850
STREET:	101 MEATTE STREET SUITE A	FACILITY INFORMATION:	View Facility Information
CITY:	PORTAGEVILLE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	NEW MADRID
ZIP CODE:	63873	MAPPING INFO:	MAP

EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
JOHN A EWER	MEATTE ST	PORTAGEVILLE	MO	63873	5733793857 1045	Public
ROCKY K DUNAVANT					3143793857	Permit
ROCKY DUNAVANT					5733793857, 259	Permit
JOHN EWER	MEATTE ST	PORTAGEVILLE	MO	63873	5733793857, 1045	Permit
SHAWN SIMPSON					5733793857, 261	Permit
ROCKY DUNAVANT	101 MEATTE ST	PORTAGEVILLE	MO	63873	5733793857, 259	Permit
SHAWN SIMPSON					5733793857	Permit
ROCKY D DUNAVANT					5733793857	Permit
KEITH WILSON	101 MEATTE ST	PORTAGEVILLE	MO	63873	5733793857	Permit
JOHN EWER	MEATTE ST	PORTAGEVILLE	MO	638731652	5733793857, 1045	Permit
ROCKY DUNAVANT					5733793857, 1045	Permit
HOWARD RICE	101 MEATTE STREET	PORTAGEVILLE	MO	63873	5733793857	Permit
ROCKY DUNAVANT					5733793857	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
332813	ELECTROPLATING, PLATING, POLISHING, ANODIZING, AND COLORING

HANDLER NAME: TAP COOPERATIVE AG PESTICIDE 2001

HANDLER ID: MOP000044164

EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
CHARLES MCINTURFF	811 MAIN STREET ROOM 939	KANSAS CITY	MO	64141	8163912607	Public
CHARLES MCINTURFF	811 MAIN STREET ROOM 939	KANSAS CITY	MO	64141	8163912607	Permit

HANDLER NAME: ATMOS ENERGY CORP
HANDLER ID: MOP000515098
STREET: HWY 77 1.3 MI S
FACILITY INFORMATION: View Facility Information
CITY: ORAN
CORPORATE LINK: No
STATE: MO
COUNTY: SCOTT
ZIP CODE: 63771
MAPPING INFO: MAP
EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
STUART SCHULZ	810 CRESCENT CENTRE DR STE 600	FRANKLIN	TN	370676226	6157718405	Public
STUART SCHULZ	810 CRESCENT CENTRE DR STE 600	FRANKLIN	TN	370676226	6157718405,	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
22121	NATURAL GAS DISTRIBUTION

HANDLER NAME: AUTO TIRE & PARTS HANDLER ID: MOD092991991
STREET: HWY 61 N FACILITY INFORMATION: View Facility Information
CITY: SIKESTON CORPORATE LINK: No
STATE: MO COUNTY: SCOTT
ZIP CODE: 63801 MAPPING INFO: MAP
EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
GARY MCKOWN	N HWY 61	SIKESTON	MO	63801	5734712233	Public
GARY MCKOWN	N HWY 61	SIKESTON	MO	63801	5734712233	Permit

HANDLER NAME: B P AMOCO 8560 HANDLER ID: MOD985803105
STREET: 2525 E MALONE FACILITY INFORMATION: View Facility Information
CITY: SIKESTON CORPORATE LINK: No
STATE: MO COUNTY: SCOTT
ZIP CODE: 63801 MAPPING INFO: MAP
EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
CHUCK CLEMINS	400 S WOODS MILL RD STE 250	CHESTERFIELD	MO	63017	3144344059	Public
CHUCK CLEMINS	400 S WOODS MILL RD STE 250	CHESTERFIELD	MO	63017	3144344059	Permit

HANDLER NAME: BLAIR IND HANDLER ID: MOD985792357
STREET: 314 MADISON FACILITY INFORMATION: View Facility Information
CITY: SCOTT CITY CORPORATE LINK: No

STATE: MO COUNTY: SCOTT
ZIP CODE: 63780 MAPPING INFO: MAP
EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
DAVE REIMANN	314 MADISON	SCOTT CITY	MO	63780	5732642146	Public
DAVE REIMANN	314 MADISON	SCOTT CITY	MO	63780	5732642146	Permit

HANDLER NAME: BLAIR IND HANDLER ID: MOD985795665
STREET: 116 E MISSOURI ST FACILITY INFORMATION: View Facility Information
CITY: SCOTT CITY CORPORATE LINK: No
STATE: MO COUNTY: SCOTT
ZIP CODE: 63780 MAPPING INFO: MAP
EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
DENNIS MERTZ	116 E MISSOURI ST	SCOTT CITY	MO	63780	5732642146	Public
DENNIS MERTZ	116 E MISSOURI ST	SCOTT CITY	MO	63780	5732642146	Permit

HANDLER NAME: BOATMENS BANK HANDLER ID: MOP000001188
STREET: 3250 OUTER RD FACILITY INFORMATION: View Facility Information
CITY: SCOTT CITY CORPORATE LINK: No
STATE: MO COUNTY: SCOTT

ZIP CODE: 63780 MAPPING INFO: MAP
EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
GARY DIEBOLD	PO BOX 220	CAPE GIRARDEAU	MO	63702	5733347111	Public
GARY DIEBOLD	PO BOX 220	CAPE GIRARDEAU	MO	63702	5733347111	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
551111	OFFICES OF BANK HOLDING COMPANIES

HANDLER NAME: BOHANNON CLEANERS INC - BOHANNON CLEANERS INC
HANDLER ID: MOD985803972
STREET: 1500 MAIN STREET
FACILITY INFORMATION: View Facility Information
CITY: SCOTT CITY
CORPORATE LINK: No
STATE: MO
COUNTY: SCOTT
ZIP CODE: 63780
MAPPING INFO: MAP
EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
JEFFREY BOHANNON	1500 MAIN	SCOTT CITY	MO	63780	5732642325	Public
JEFFREY BOHANNON	1500 MAIN	SCOTT CITY	MO	63780	5732642325	Permit

HANDLER NAME:	BOOTHEEL DIESEL FUEL INJECTION	HANDLER ID:	MOD985817592
STREET:	HWY 62 E	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
DANNY BRICKELL	PO BOX 884E	SIKESTON	MO	63801	5734711039	Public
DANNY BRICKELL	PO BOX 884E	SIKESTON	MO	63801	5734711039	Permit

HANDLER NAME:	BORDEN INC	HANDLER ID:	MOP000000705
STREET:	3420 NASH RD	FACILITY INFORMATION:	View Facility Information
CITY:	SCOTT CITY	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63780	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
GEORGE DAVIS	PO BOX 532	CAPE GIRARDEAU	MO	63702	5733342414	Public
GEORGE DAVIS	PO BOX 532	CAPE GIRARDEAU	MO	63702	5733342414	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
44711	GASOLINE STATIONS WITH CONVENIENCE STORES

HANDLER NAME:	BROWN SHOE CO	HANDLER ID:	MOD985821909
STREET:	103 S ACRES	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
PATRICIA BROWN	103 S ACRES	SIKESTON	MO	63801	NA	Public
PATRICIA BROWN	103 S ACRES	SIKESTON	MO	63801	NA	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
49311	GENERAL WAREHOUSING AND STORAGE

HANDLER NAME:	BROWN SHOE COMPANY	HANDLER ID:	MOD980690408
STREET:	ROUTE 1 HIGHWAY 77	FACILITY INFORMATION:	View Facility Information
CITY:	BENTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63736	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
						Public
RICHARD WILLIAMS	BOX 354	ST LOUIS	MO	63166	5735453035	Permit

HANDLER NAME:	BUDS DISCOUNT CITY NO 4062	HANDLER ID:	MOR000009878
STREET:	205 SOUTHLAND	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
CHAD MILES	205 SOUTHLAND	SIKESTON	MO	63801	5734713931	Public
CHAD MILES	205 SOUTHLAND	SIKESTON	MO	63801	5734713931	Permit

HANDLER NAME:	C P S TRAILER CO	HANDLER ID:	MOD981723927
STREET:	500 ROSATI ST	FACILITY INFORMATION:	View Facility Information
CITY:	ORAN	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63771	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
DAVID A POBST	HWY 77	ORAN	MO	63771	5732622166 30	Public
LISA MILLS					5732622166	Permit
JEAN-PHILIPPE MONFET					4506414000, 3573	Permit

LISA MILLS	PO DRAWER K	ORAN	MO	63771	5732622166	Permit
DAVID POBST	HWY 77	ORAN	MO	63771	5732622166, 30	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
336212	TRUCK TRAILER MANUFACTURING
333518	OTHER METALWORKING MACHINERY MANUFACTURING

HANDLER NAME:	C R BREEDEN ENTERPRISES	HANDLER ID:	MOR000504910
STREET:	443 WESTERN DRIVE	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
BILLIE HEATON	PO BOX 822	SIKESTON	MO	63801	5734810362	Public
BILLIE HEATON	PO BOX 822	SIKESTON	MO	63801	5734810362	Permit

HANDLER NAME:	CANEDY SIGN CO INC	HANDLER ID:	MOD985803964
STREET:	700 KINGSHIGHWAY	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
TED MARTIN	PO BOX 648	SIKESTON	MO	63801	5734710121	Public
TED MARTIN	PO BOX 648	SIKESTON	MO	63801	5734710121	Permit

HANDLER NAME:	CARGILL INC - SIKESTON	HANDLER ID:	MOD985777432
STREET:	410 WEST MALONE AVE	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
STEVE WELLMAN	410 W MALONE	SIKESTON	MO	63801	5734722272	Public
STEVE WELLMAN	410 W MALONE	SIKESTON	MO	63801	5734722272	Permit

HANDLER NAME:	CARNELLS BODY SHOP	HANDLER ID:	MOD981723935
STREET:	117 NORTH WEST ST	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
DAVID CARNELL	N WEST ST	SIKESTON	MO	63801	5734720828	Public
DAVID CARNELL	N WEST ST	SIKESTON	MO	63801	5734720828	Permit

HANDLER NAME:	CASEYS GENERAL STORE #2151	HANDLER ID:	MOR000523407
STREET:	1110 MAIN ST	FACILITY INFORMATION:	View Facility Information
CITY:	SCOTT CITY	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	637802023	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
JILL REAMS-WIDDER	PO BOX 3001	ANKENY	IA	50021	5159656100	Public
JILL REAMS-WIDDER	PO BOX 3001	ANKENY	IA	50021	5159656100	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
44711	GASOLINE STATIONS WITH CONVENIENCE STORES

HANDLER NAME:	CASEYS GENERAL STORE 1528	HANDLER ID:	MOR000017848
STREET:	1207 W MALONE	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No

STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
GLENN NORGART	PO BOX 3001	ANKENY	IA	500218045	5159656238	Public
GLENN NORGART	PO BOX 3001	ANKENY	IA	500218045	5159656238	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
4471	GASOLINE STATIONS

HANDLER NAME:	CENTRAL STATES COCO COLA	HANDLER ID:	MOP000001071
STREET:	202 W FRONT ST	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
DALE CLARK	202 W FRONT ST	SIKESTON	MO	63801	5734715673	Public
DALE CLARK	202 W FRONT ST	SIKESTON	MO	63801	5734715673	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
312111	SOFT DRINK MANUFACTURING

HANDLER NAME:	CHAFFEE R2 SCHOOL DISTRICT	HANDLER ID:	MOR000531350
STREET:	517 W YOAKUM	FACILITY INFORMATION:	View Facility Information
CITY:	CHAFFEE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	637401825	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
KEN LATHAM	W YOAKUM	CHAFFEE	MO	637401825	5738873532	Public
KEN LATHAM	W YOAKUM	CHAFFEE	MO	637401825	5738873532	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
61111	ELEMENTARY AND SECONDARY SCHOOLS

HANDLER NAME:	CONSTRUCTION TRAILER SPECIALISTS INC - SIKESTON	HANDLER ID:	MOR000038661
STREET:	2535 ROSE PKWY	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
WADE RHODES	ROSE PKWY	SIKESTON	MO	63801	5734810941	Public

WESLEY GRAVIETT	2535 ROSE PKWY	SIKESTON	MO	63801	5734810941	Permit
WESLEY GRAVIETT					5734810941	Permit
WADE RHODES	ROSE PKWY	SIKESTON	MO	63801	5734810941	Permit
WILLIAM PALMER	PO BOX 159	SIKESTON	MO	63801	5734810941	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
336211	MOTOR VEHICLE BODY MANUFACTURING
336212	TRUCK TRAILER MANUFACTURING
53249	OTHER COMMERCIAL AND INDUSTRIAL MACHINERY AND EQUIPMENT RENTAL AND LEASING

HANDLER NAME:	CONTECH CONSTRUCTION PRODUCTS INC	HANDLER ID:	MOR000516294
STREET:	140 AIRPORT INDUSTRIAL DR	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
LEE MAYS	AIRPORT INDUSTRIAL DR	SIKESTON	MO	63801	5734716771 207	Public
LEE MAYS	PO BOX 1006	SIKESTON	MO	63801	5734716771	Permit
LEE MAYS	AIRPORT INDUSTRIAL DR	SIKESTON	MO	63801	5734716771, 207	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS	NAICS DESCRIPTION

CODE	
332322	SHEET METAL WORK MANUFACTURING
33121	IRON AND STEEL PIPE AND TUBE MANUFACTURING FROM PURCHASED STEEL

HANDLER NAME:	COONEY EQUIPMENT CO	HANDLER ID:	MOD031126253
STREET:	HWY 61 S	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
JOHN HOPER	PO BOX 357 HWY 61 S	SIKESTON	MO	63801	5734715260	Public
JOHN HOPER	PO BOX 357 HWY 61 S	SIKESTON	MO	63801	5734715260	Permit

HANDLER NAME:	CUMMINS GATEWAY INC	HANDLER ID:	MOD985770619
STREET:	101 KEYSTONE	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
BUD MEHNER	101 KEYSTONE	SIKESTON	MO	63801	5734720303	Public
BUD MEHNER	101 KEYSTONE	SIKESTON	MO	63801	5734720303	Permit

HANDLER NAME:	CURTIS H CLINE	HANDLER ID:	MOP000001149
STREET:	947 LAKE ST	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
CURTIS CLINE	947 LAKE ST	SIKESTON	MO	63801	5734721487	Public
CURTIS CLINE	947 LAKE ST	SIKESTON	MO	63801	5734721487	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
81411	PRIVATE HOUSEHOLDS

There was an error with the database tables.
Please send a report to enviromail_group@epamail.epa.gov telling us what criteria you used in the selection along with this error message:
ORA-06502: PL/SQL: numeric or value error: character string buffer too small

HANDLER NAME:	CUSTOM TRAILERS BY J A MAR MANUFACTURING	HANDLER ID:	MOD985801828

EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
CHARLES MCINTURFF	811 MAIN STREET ROOM 939	KANSAS CITY	MO	64141	8163912607	Public
CHARLES MCINTURFF	811 MAIN STREET ROOM 939	KANSAS CITY	MO	64141	8163912607	Permit

HANDLER NAME: ATMOS ENERGY CORP
HANDLER ID: MOP000515098
STREET: HWY 77 1.3 MI S
FACILITY INFORMATION: View Facility Information
CITY: ORAN
CORPORATE LINK: No
STATE: MO
COUNTY: SCOTT
ZIP CODE: 63771
MAPPING INFO: MAP
EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
STUART SCHULZ	810 CRESCENT CENTRE DR STE 600	FRANKLIN	TN	370676226	6157718405	Public
STUART SCHULZ	810 CRESCENT CENTRE DR STE 600	FRANKLIN	TN	370676226	6157718405,	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
22121	NATURAL GAS DISTRIBUTION

HANDLER NAME: AUTO TIRE & PARTS HANDLER ID: MOD092991991
STREET: HWY 61 N FACILITY INFORMATION: View Facility Information
CITY: SIKESTON CORPORATE LINK: No
STATE: MO COUNTY: SCOTT
ZIP CODE: 63801 MAPPING INFO: MAP
EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
GARY MCKOWN	N HWY 61	SIKESTON	MO	63801	5734712233	Public
GARY MCKOWN	N HWY 61	SIKESTON	MO	63801	5734712233	Permit

HANDLER NAME: B P AMOCO 8560 HANDLER ID: MOD985803105
STREET: 2525 E MALONE FACILITY INFORMATION: View Facility Information
CITY: SIKESTON CORPORATE LINK: No
STATE: MO COUNTY: SCOTT
ZIP CODE: 63801 MAPPING INFO: MAP
EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
CHUCK CLEMINS	400 S WOODS MILL RD STE 250	CHESTERFIELD	MO	63017	3144344059	Public
CHUCK CLEMINS	400 S WOODS MILL RD STE 250	CHESTERFIELD	MO	63017	3144344059	Permit

HANDLER NAME: BLAIR IND HANDLER ID: MOD985792357
STREET: 314 MADISON FACILITY INFORMATION: View Facility Information
CITY: SCOTT CITY CORPORATE LINK: No

STATE: MO COUNTY: SCOTT
ZIP CODE: 63780 MAPPING INFO: MAP
EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
DAVE REIMANN	314 MADISON	SCOTT CITY	MO	63780	5732642146	Public
DAVE REIMANN	314 MADISON	SCOTT CITY	MO	63780	5732642146	Permit

HANDLER NAME: BLAIR IND HANDLER ID: MOD985795665
STREET: 116 E MISSOURI ST FACILITY INFORMATION: View Facility Information
CITY: SCOTT CITY CORPORATE LINK: No
STATE: MO COUNTY: SCOTT
ZIP CODE: 63780 MAPPING INFO: MAP
EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
DENNIS MERTZ	116 E MISSOURI ST	SCOTT CITY	MO	63780	5732642146	Public
DENNIS MERTZ	116 E MISSOURI ST	SCOTT CITY	MO	63780	5732642146	Permit

HANDLER NAME: BOATMENS BANK HANDLER ID: MOP000001188
STREET: 3250 OUTER RD FACILITY INFORMATION: View Facility Information
CITY: SCOTT CITY CORPORATE LINK: No
STATE: MO COUNTY: SCOTT

ZIP CODE: 63780 MAPPING INFO: MAP
EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
GARY DIEBOLD	PO BOX 220	CAPE GIRARDEAU	MO	63702	5733347111	Public
GARY DIEBOLD	PO BOX 220	CAPE GIRARDEAU	MO	63702	5733347111	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
551111	OFFICES OF BANK HOLDING COMPANIES

HANDLER NAME: BOHANNON CLEANERS INC - BOHANNON CLEANERS INC
HANDLER ID: MOD985803972
STREET: 1500 MAIN STREET
FACILITY INFORMATION: View Facility Information
CITY: SCOTT CITY
CORPORATE LINK: No
STATE: MO
COUNTY: SCOTT
ZIP CODE: 63780
MAPPING INFO: MAP
EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
JEFFREY BOHANNON	1500 MAIN	SCOTT CITY	MO	63780	5732642325	Public
JEFFREY BOHANNON	1500 MAIN	SCOTT CITY	MO	63780	5732642325	Permit

HANDLER NAME:	BOOTHEEL DIESEL FUEL INJECTION	HANDLER ID:	MOD985817592
STREET:	HWY 62 E	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
DANNY BRICKELL	PO BOX 884E	SIKESTON	MO	63801	5734711039	Public
DANNY BRICKELL	PO BOX 884E	SIKESTON	MO	63801	5734711039	Permit

HANDLER NAME:	BORDEN INC	HANDLER ID:	MOP000000705
STREET:	3420 NASH RD	FACILITY INFORMATION:	View Facility Information
CITY:	SCOTT CITY	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63780	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
GEORGE DAVIS	PO BOX 532	CAPE GIRARDEAU	MO	63702	5733342414	Public
GEORGE DAVIS	PO BOX 532	CAPE GIRARDEAU	MO	63702	5733342414	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
44711	GASOLINE STATIONS WITH CONVENIENCE STORES

HANDLER NAME:	BROWN SHOE CO	HANDLER ID:	MOD985821909
STREET:	103 S ACRES	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
PATRICIA BROWN	103 S ACRES	SIKESTON	MO	63801	NA	Public
PATRICIA BROWN	103 S ACRES	SIKESTON	MO	63801	NA	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
49311	GENERAL WAREHOUSING AND STORAGE

HANDLER NAME:	BROWN SHOE COMPANY	HANDLER ID:	MOD980690408
STREET:	ROUTE 1 HIGHWAY 77	FACILITY INFORMATION:	View Facility Information
CITY:	BENTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63736	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
						Public
RICHARD WILLIAMS	BOX 354	ST LOUIS	MO	63166	5735453035	Permit

HANDLER NAME:	BUDS DISCOUNT CITY NO 4062	HANDLER ID:	MOR000009878
STREET:	205 SOUTHLAND	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
CHAD MILES	205 SOUTHLAND	SIKESTON	MO	63801	5734713931	Public
CHAD MILES	205 SOUTHLAND	SIKESTON	MO	63801	5734713931	Permit

HANDLER NAME:	C P S TRAILER CO	HANDLER ID:	MOD981723927
STREET:	500 ROSATI ST	FACILITY INFORMATION:	View Facility Information
CITY:	ORAN	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63771	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
DAVID A POBST	HWY 77	ORAN	MO	63771	5732622166 30	Public
LISA MILLS					5732622166	Permit
JEAN-PHILIPPE MONFET					4506414000, 3573	Permit

LISA MILLS	PO DRAWER K	ORAN	MO	63771	5732622166	Permit
DAVID POBST	HWY 77	ORAN	MO	63771	5732622166, 30	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
336212	TRUCK TRAILER MANUFACTURING
333518	OTHER METALWORKING MACHINERY MANUFACTURING

HANDLER NAME:	C R BREEDEN ENTERPRISES	HANDLER ID:	MOR000504910
STREET:	443 WESTERN DRIVE	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
BILLIE HEATON	PO BOX 822	SIKESTON	MO	63801	5734810362	Public
BILLIE HEATON	PO BOX 822	SIKESTON	MO	63801	5734810362	Permit

HANDLER NAME:	CANEDY SIGN CO INC	HANDLER ID:	MOD985803964
STREET:	700 KINGSHIGHWAY	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
TED MARTIN	PO BOX 648	SIKESTON	MO	63801	5734710121	Public
TED MARTIN	PO BOX 648	SIKESTON	MO	63801	5734710121	Permit

HANDLER NAME:	CARGILL INC - SIKESTON	HANDLER ID:	MOD985777432
STREET:	410 WEST MALONE AVE	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
STEVE WELLMAN	410 W MALONE	SIKESTON	MO	63801	5734722272	Public
STEVE WELLMAN	410 W MALONE	SIKESTON	MO	63801	5734722272	Permit

HANDLER NAME:	CARNELLS BODY SHOP	HANDLER ID:	MOD981723935
STREET:	117 NORTH WEST ST	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
DAVID CARNELL	N WEST ST	SIKESTON	MO	63801	5734720828	Public
DAVID CARNELL	N WEST ST	SIKESTON	MO	63801	5734720828	Permit

HANDLER NAME:	CASEYS GENERAL STORE #2151	HANDLER ID:	MOR000523407
STREET:	1110 MAIN ST	FACILITY INFORMATION:	View Facility Information
CITY:	SCOTT CITY	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	637802023	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
JILL REAMS-WIDDER	PO BOX 3001	ANKENY	IA	50021	5159656100	Public
JILL REAMS-WIDDER	PO BOX 3001	ANKENY	IA	50021	5159656100	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
44711	GASOLINE STATIONS WITH CONVENIENCE STORES

HANDLER NAME:	CASEYS GENERAL STORE 1528	HANDLER ID:	MOR000017848
STREET:	1207 W MALONE	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No

STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
GLENN NORGART	PO BOX 3001	ANKENY	IA	500218045	5159656238	Public
GLENN NORGART	PO BOX 3001	ANKENY	IA	500218045	5159656238	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
4471	GASOLINE STATIONS

HANDLER NAME:	CENTRAL STATES COCO COLA	HANDLER ID:	MOP000001071
STREET:	202 W FRONT ST	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
DALE CLARK	202 W FRONT ST	SIKESTON	MO	63801	5734715673	Public
DALE CLARK	202 W FRONT ST	SIKESTON	MO	63801	5734715673	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
312111	SOFT DRINK MANUFACTURING

HANDLER NAME:	CHAFFEE R2 SCHOOL DISTRICT	HANDLER ID:	MOR000531350
STREET:	517 W YOAKUM	FACILITY INFORMATION:	View Facility Information
CITY:	CHAFFEE	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	637401825	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
KEN LATHAM	W YOAKUM	CHAFFEE	MO	637401825	5738873532	Public
KEN LATHAM	W YOAKUM	CHAFFEE	MO	637401825	5738873532	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
61111	ELEMENTARY AND SECONDARY SCHOOLS

HANDLER NAME:	CONSTRUCTION TRAILER SPECIALISTS INC - SIKESTON	HANDLER ID:	MOR000038661
STREET:	2535 ROSE PKWY	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
WADE RHODES	ROSE PKWY	SIKESTON	MO	63801	5734810941	Public

WESLEY GRAVIETT	2535 ROSE PKWY	SIKESTON	MO	63801	5734810941	Permit
WESLEY GRAVIETT					5734810941	Permit
WADE RHODES	ROSE PKWY	SIKESTON	MO	63801	5734810941	Permit
WILLIAM PALMER	PO BOX 159	SIKESTON	MO	63801	5734810941	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
336211	MOTOR VEHICLE BODY MANUFACTURING
336212	TRUCK TRAILER MANUFACTURING
53249	OTHER COMMERCIAL AND INDUSTRIAL MACHINERY AND EQUIPMENT RENTAL AND LEASING

HANDLER NAME:	CONTECH CONSTRUCTION PRODUCTS INC	HANDLER ID:	MOR000516294
STREET:	140 AIRPORT INDUSTRIAL DR	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
LEE MAYS	AIRPORT INDUSTRIAL DR	SIKESTON	MO	63801	5734716771 207	Public
LEE MAYS	PO BOX 1006	SIKESTON	MO	63801	5734716771	Permit
LEE MAYS	AIRPORT INDUSTRIAL DR	SIKESTON	MO	63801	5734716771, 207	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS	NAICS DESCRIPTION

CODE	
332322	SHEET METAL WORK MANUFACTURING
33121	IRON AND STEEL PIPE AND TUBE MANUFACTURING FROM PURCHASED STEEL

HANDLER NAME:	COONEY EQUIPMENT CO	HANDLER ID:	MOD031126253
STREET:	HWY 61 S	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
JOHN HOPER	PO BOX 357 HWY 61 S	SIKESTON	MO	63801	5734715260	Public
JOHN HOPER	PO BOX 357 HWY 61 S	SIKESTON	MO	63801	5734715260	Permit

HANDLER NAME:	CUMMINS GATEWAY INC	HANDLER ID:	MOD985770619
STREET:	101 KEYSTONE	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
BUD MEHNER	101 KEYSTONE	SIKESTON	MO	63801	5734720303	Public
BUD MEHNER	101 KEYSTONE	SIKESTON	MO	63801	5734720303	Permit

HANDLER NAME:	CURTIS H CLINE	HANDLER ID:	MOP000001149
STREET:	947 LAKE ST	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
CURTIS CLINE	947 LAKE ST	SIKESTON	MO	63801	5734721487	Public
CURTIS CLINE	947 LAKE ST	SIKESTON	MO	63801	5734721487	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
81411	PRIVATE HOUSEHOLDS

There was an error with the database tables.
Please send a report to enviromail_group@epamail.epa.gov telling us what criteria you used in the selection along with this error message:
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HANDLER NAME:	CUSTOM TRAILERS BY J A MAR MANUFACTURING	HANDLER ID:	MOD985801828

HANDLER NAME:	JOHNSON-MATTHEWS CO	HANDLER ID:	MOD985801539
STREET:	1601 WEST MALONE AVENUE	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
JOHN JOHNSON	2405 E MALONE AVE	SIKESTON	MO	63801	5734716199	Public
JOHN JOHNSON	2405 E MALONE AVE	SIKESTON	MO	63801	5734716199	Permit

HANDLER NAME:	KELLER TRUCK SERVICE	HANDLER ID:	MOP000509893
STREET:	614 HWY H	FACILITY INFORMATION:	View Facility Information
CITY:	MINER	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
JOE KING	HWY H	MINER	MO	63801	5734713311	Public
JOE KING	HWY H	MINER	MO	63801	5734713311	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
44711	GASOLINE STATIONS WITH CONVENIENCE STORES

HANDLER NAME:	KELPRO	HANDLER ID:	MOD985799675
STREET:	2047 STATE HIGHWAY Z	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
LARRY KELLETT	PO BOX 834	SIKESTON	MO	63801	5734719512	Public
LARRY KELLETT	PO BOX 834	SIKESTON	MO	63801	5734719512	Permit

HANDLER NAME:	KINGS HIGHWAY RETAIL PROPERTY	HANDLER ID:	MOP000033019
STREET:	98-102 N KINGS HIGHWAY	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
HORACE WEAVER	901 MAIN ST TX1-492-11-07	DALLAS	TX	75202	2142092547	Public
HORACE WEAVER	901 MAIN ST TX1-492-11-07	DALLAS	TX	75202	2142092547	Permit

HANDLER NAME:	LAIDLAW EDUCATIONAL SERVICES	HANDLER ID:	MOR000524199
STREET:	3356 E OUTER RD REAR	FACILITY INFORMATION:	View Facility Information
CITY:	SCOTT CITY	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	637809700	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
JIM PULLEY	PERIMETER PARK STE E	KNOXVILLE	TN	37922	5733352510	Public
JIM PULLEY	PERIMETER PARK STE E	KNOXVILLE	TN	37922	5733352510,	Permit
MARKEL THURSTON	3356 E OUTER RD REAR	SCOTT CITY	MO	637809700	5733352169,	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
48541	SCHOOL AND EMPLOYEE BUS TRANSPORTATION

HANDLER NAME:	LARRYS PIT STOP	HANDLER ID:	MOR000529495
STREET:	2413 E MALONE	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	638013803	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

				ZIP		TYPE OF

NAME	STREET	CITY	STATE	CODE	PHONE	CONTACT
LYNN MCKINNIE	N KINGSHIGHWAY	SIKESTON	MO	63801	5734711456	Public
LYNN MCKINNIE	N KINGSHIGHWAY	SIKESTON	MO	63801	5734711456	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
44711	GASOLINE STATIONS WITH CONVENIENCE STORES

HANDLER NAME:	LOWES HOME CENTER INC #1209	HANDLER ID:	MOR000518431
STREET:	1240 S MAIN ST	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
ROB GASS	PO BOX 1000 MAILCODE: LPMO	MOORESVILLE	NC	28115	7047586033	Public
ROB GASS	PO BOX 1000 MAILCODE: LPMO	MOORESVILLE	NC	28115	7047586033,	Permit
DAMON CHAPPELL	W KENTON CIR STE 130	HUNTERSVILLE	NC	28078	7047586005	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
44413	HARDWARE STORES
44411	HOME CENTERS

HANDLER NAME:	MAIN STREET MOTORS	HANDLER ID:	MOR000009522
STREET:	1045 S MAIN	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
NANCY PEMBERTON	1045 S MAIN	SIKESTON	MO	63801	5734715108	Public
NANCY PEMBERTON	1045 S MAIN	SIKESTON	MO	63801	5734715108	Permit

HANDLER NAME:	MALONE & HYDE	HANDLER ID:	MOD985773514
STREET:	1500 W MALONE	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
ARTHUR SHORT	PO BOX 1785	SIKESTON	MO	63801	5734712262	Public
ARTHUR SHORT	PO BOX 1785	SIKESTON	MO	63801	5734712262	Permit

HANDLER NAME:	MCDOWELL FRANK J	HANDLER ID:	MOD055888465
STREET:	801 DAVIS BLVD	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
						Public

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
33711	WOOD KITCHEN CABINET AND COUNTERTOP MANUFACTURING

HANDLER NAME:	MEDIA PRESS	HANDLER ID:	MOG000004291
STREET:	835 WAKEFIELD	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
CHRISTY MOTHERSHEAD	PO BOX 1370	SIKESTON	MO	63801	5734719857	Public
CHRISTY MOTHERSHEAD	PO BOX 1370	SIKESTON	MO	63801	5734719857	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
323116	MANIFOLD BUSINESS FORMS PRINTING

HANDLER NAME:	MERCER AUTO REPAIR (FORMERLY NICKS AUTOMOTIVE)	HANDLER ID:	MOD985799824
STREET:	606 RUTH STREET	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
MICHAEL NICOSON	606 RUTH ST	SIKESTON	MO	63801	5734712097	Public
MICHAEL NICOSON	606 RUTH ST	SIKESTON	MO	63801	5734712097	Permit

There was an error with the database tables.
Please send a report to enviromail_group@epamail.epa.gov telling us what criteria you used in the selection along with this error message:
ORA-06502: PL/SQL: numeric or value error: character string buffer too small

HANDLER NAME:	MIDWEST TRAILERS	HANDLER ID:	MOD985796374
STREET:	200 NORTH INTERSTATE DRIVE	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
GAYLE RETTIG	200 N INTERSTATE DR	SIKESTON	MO	63801	5734718115	Public
GAYLE	200 N					

RETTIG	INTERSTATE DR	SIKESTON	MO	63801	5734718115	Permit

HANDLER NAME:	MILLENNIUM ENVIRONMENTAL MO DNR ENVIRON	HANDLER ID:	MOR000502096
STREET:	3100A INDUSTRIAL FUELS DR	FACILITY INFORMATION:	View Facility Information
CITY:	SCOTT CITY	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63780	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
DAN CAREY	PO BOX 176 % HWP	JEFFERSON CITY	MO	65102	5737513021	Public
DAN CAREY	PO BOX 176 % HWP	JEFFERSON CITY	MO	65102	5737513021,	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
92411	ADMINISTRATION OF AIR AND WATER RESOURCE AND SOLID WASTE MANAGEMENT PROGRAMS

HANDLER NAME:	MISSOURI DELTA COMMUNITY HOSPITAL	HANDLER ID:	MOD079911244
STREET:	1080 N MAIN ST	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
JOANIE DELISLE	N MAIN ST	SIKESTON	MO	63801	5734727675	Public
JOANIE DELISLE	N MAIN ST	SIKESTON	MO	63801	5734727675	Permit
JUDE WILLIAMS	1008 N MAIN ST	SIKESTON	MO	63801	3144711600	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
62211	GENERAL MEDICAL AND SURGICAL HOSPITALS

HANDLER NAME:	MISSOURI HIGHWAY & TRANSPORTATION DEPARTMENT	HANDLER ID:	MOD985801679
STREET:	111 EDWARD STREET	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
LANCE LIVESAY	P O BOX 270	JEFFERSON CITY	MO	65102	5735264764	Public
DON DAVIDSON	111 EDWARD ST	SIKESTON	MO	63801	5737514620	Permit
LANCE LIVESAY					5735264764	Permit
LANCE LIVESAY	P O BOX 270	JEFFERSON CITY	MO	65102	5735264764	Permit
LANCE LIVESAY	PO BOX 270	JEFFERSON CITY	MO	65102	5737514764	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
23731	HIGHWAY, STREET, AND BRIDGE CONSTRUCTION

HANDLER NAME:	MO DEPT OF TRANSPORTATION	HANDLER ID:	MOR000036657
STREET:	2675 N MAIN ST	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
JOE DAVIS	PO BOX 270	JEFFERSON CITY	MO	65102	5735264531	Public
JOE DAVIS	PO BOX 270	JEFFERSON CITY	MO	65102	5735264531,	Permit
JOE DAVIS	PO BOX 270	JEFFERSON CITY	MO	65102	5735264531	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
92119	OTHER GENERAL GOVERNMENT SUPPORT

HANDLER NAME:	MO HIGHWAY & TRANSPORTATION DEPT	HANDLER ID:	MOD981725906
STREET:	201 N MAIN	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP

EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
BILLY HAY	PO BOX 160	SIKESTON	MO	63801	5734725333	Public
BILLY HAY	PO BOX 160	SIKESTON	MO	63801	5734725333	Permit

HANDLER NAME: MODOT DISTRICT 10 HANDLER ID: MOR000537530
STREET: 201 N MAIN ST FACILITY INFORMATION: View Facility Information
CITY: SIKESTON CORPORATE LINK: No
STATE: MO COUNTY: SCOTT
ZIP CODE: 638014211 MAPPING INFO: MAP
EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
WILLIAM WILDER	PO BOX 270	JEFFERSON CITY	MO	651020270	5735262904	Public
WILLIAM WILDER	PO BOX 270	JEFFERSON CITY	MO	651020270	5735262904	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
23731	HIGHWAY, STREET, AND BRIDGE CONSTRUCTION

HANDLER NAME: MUNICIPAL POWER PLANT HANDLER ID: MOT300010840
STREET: 1400 COMPRESS RD FACILITY INFORMATION: View Facility Information
CITY: SIKESTON CORPORATE LINK: No

STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
E INMAN	CITY HALL	SIKESTON	MO	63801	5734713328	Public
E INMAN	CITY HALL	SIKESTON	MO	63801	5734713328	Permit

HANDLER NAME:	OHIO PACIFIC EXPRESS	HANDLER ID:	MOD115837320
STREET:	HWY 55 & 77	FACILITY INFORMATION:	View Facility Information
CITY:	BENTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63736	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
						Public
GARY TANKSLEY	HWY 55 & 77	BENTON	MO	63736	5735453100	Permit

HANDLER NAME:	ONE DAY CLEANERS	HANDLER ID:	MOD985794932
STREET:	112 SOUTH SCOTT STREET	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP

EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
ALIENE HILL	112 S SCOTT	SIKESTON	MO	63801	5734720098	Public
ALIENE HILL	112 S SCOTT	SIKESTON	MO	63801	5734720098	Permit

HANDLER NAME:	ORAN R3 SCHOOL DISTRICT	HANDLER ID:	MOR000530949
STREET:	310 CHURCH ST	FACILITY INFORMATION:	View Facility Information
CITY:	ORAN	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63771	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
BRIAN HUKEL	CHURCH ST	ORAN	MO	63771	5732623345	Public
BRIAN HUKEL	CHURCH ST	ORAN	MO	63771	5732623345	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
61111	ELEMENTARY AND SECONDARY SCHOOLS

HANDLER NAME:	PAVESTONE COMPANY	HANDLER ID:	MOR000501650
STREET:	2720 E OUTER RD	FACILITY INFORMATION:	View Facility Information
CITY:	SCOTT CITY	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT

ZIP CODE: 63780 MAPPING INFO: MAP
EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
PAUL KELLEY	2720 E OUTER RD	SCOTT CITY	MO	63780	5732641500	Public
PAUL KELLEY	2720 E OUTER RD	SCOTT CITY	MO	63780	5732641500	Permit

HANDLER NAME: PENSKE TRUCK LEASING CO LP
HANDLER ID: MOD981710148
STREET: NASH RD E 1000FT S
FACILITY INFORMATION: View Facility Information
CITY: SCOTT CITY
CORPORATE LINK: No
STATE: MO
COUNTY: SCOTT
ZIP CODE: 63780
MAPPING INFO: MAP
EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
JEFFREY FUHRMEISTER	2300 N LINDBERGH BLVD	ST LOUIS	MO	63114	5734293000	Public
FLOYD STEPHENS	PO BOX 1084	CAPE GIRARDEAU	MO	63701	5733354644	Permit
JEFFREY FUHRMEISTER	2300 N LINDBERGH BLVD	ST LOUIS	MO	63114	5734293000	Permit

HANDLER NAME:	PULLEN BROS INC	HANDLER ID:	MOD077137420
STREET:	1788 HWY HH	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	63801	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
TOM BOULNOIS	HWY HH	SIKESTON	MO	63801	5734717897	Public
TOM BOULNOIS	HWY HH	SIKESTON	MO	63801	5734717897	Permit
TOM BOULNOIS	BOX 6H	SIKESTON	MO	63801	5734717896	Permit

LIST OF NAICS CODES AND DESCRIPTIONS

NAICS CODE	NAICS DESCRIPTION
484121	GENERAL FREIGHT TRUCKING, LONG-DISTANCE, TRUCKLOAD

HANDLER NAME:	RELIABLE FREIGHT SYSTEMS INCORPORATED	HANDLER ID:	MOP000011825
STREET:	126 INDUSTRIAL DR	FACILITY INFORMATION:	View Facility Information
CITY:	SIKESTON	CORPORATE LINK:	No
STATE:	MO	COUNTY:	SCOTT
ZIP CODE:	638010000	MAPPING INFO:	MAP
EPA REGION:	7		

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
MICHAEL RICHARDS	PO BOX 144	SIKESTON	MO	63801	5734717457	Public
DAVID A RICHARDS					5734717457, 210	Permit
MICHAEL RICHARDS	PO BOX 144	SIKESTON	MO	63801	5734717457	Permit

HANDLER NAME: RETTIG ENTERPRISES HANDLER ID: MOR000036665
STREET: 1362 HWY H FACILITY INFORMATION: View Facility Information
CITY: SIKESTON CORPORATE LINK: No
STATE: MO COUNTY: SCOTT
ZIP CODE: 63801 MAPPING INFO: MAP
EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
ALLAN RETTIG	1362 HWY H	SIKESTON	MO	63801	5734725165	Public
ALLAN RETTIG	1362 HWY H	SIKESTON	MO	63801	5734725165	Permit

HANDLER NAME: ROADWAY EXPRESS HANDLER ID: MOR000010264
STREET: 1067 NASH RD FACILITY INFORMATION: View Facility Information
CITY: SCOTT CITY CORPORATE LINK: No
STATE: MO COUNTY: SCOTT
ZIP CODE: 63780 MAPPING INFO: MAP
EPA REGION: 7

CONTACT INFORMATION

NAME	STREET	CITY	STATE	ZIP CODE	PHONE	TYPE OF CONTACT
LORI LEONTI	GORGE BLVD	AKRON	OH	44309	5733841717	Public
LORI LEONTI	GORGE BLVD	AKRON	OH	44309	5733841717	Permit
LORI LEONTI	1077 GORGE BLVD	AKRON	OH	44309	5733841717	Permit

Active Underground Storage Tanks in SJNM Project Vicinity in Remediation

Facility ID	Owner ID	Rem ID	Name	Address	City	ZIP	County
ST0019910	OW00005	R007036	FFP #850	I55 & HWY 77	BENTON	63736	SCOTT
ST0010907	OW10466	R007875	FISCA OIL CO INC #74	HWY 60 W OF CAIRO	BIRDS POINT	63882	MISSISSIPPI
ST0008877	OW10498	R005077	PILOT TRAVEL CENTER #35	I-57 & HWY 105 S EX	CHARLESTON	63834	MISSISSIPPI
ST0020466	OW10595	R006817	HUCKS	203 WEST MARSHA	CHARLESTON	63834	MISSISSIPPI
ST0019121	OW09129	R007207	REEVES AMOCO STATION	HWY 105	CHARLESTON	63834	MISSISSIPPI
ST0012968	OW10215	R007264	BREAK TIME CONVENIECE	2630 E MARSHAL/I-	CHARLESTON	63834	MISSISSIPPI
ST0020376	OW09254	R007530	MISSISSIPPI COUNTY AIRPORT	HWY 105 SOUTH &	CHARLESTON	63834	MISSISSIPPI
ST0008877	OW10498	R008216	PILOT TRAVEL CENTER #35	I-57 & HWY 105 S EX	CHARLESTON	63834	MISSISSIPPI
ST3003360	OW99999	R008507	FLAG STOP, INC	211 SOUTH STORY	CHARLESTON	63834	MISSISSIPPI
ST0008078	OW03741	R005847	BIG OAK TREE	RT 2 BOX 343	EAST PRAIRIE	63845	MISSISSIPPI
ST3003357	OW99999	R007823	EASTSIDE STORE	901 W HWY 80	EAST PRAIRIE	63845	MISSISSIPPI
ST0021495	OW99999	R008029	DOGWOOD STORE	1586 STATE RT B	EAST PRAIRIE	63845	MISSISSIPPI
ST0019797	OW00861	R007274	DELTA GROWERS ASSN.	HWY W	KEWANEE	63860	NEW MADRID
ST3003532	OW99999	R008162	MFA BULK PLANT	HWY 61 & W (NW CRNR	KEWANEE	63860	NEW MADRID
ST0019911	OW00005	R007967	FFP #854	NE CRNR OF I55 @	MATTHEWS	63867	NEW MADRID
ST5800901	OW99999	R006574	FORMER BULK PLANT-HOM	HIGHWAY 60	MINER	63801	SCOTT
ST0021222	OW99999	R007720	WATER TREATMENT PLANT	HWY AA & HARRISON	MINER	63801	SCOTT
ST0012969	OW10215	R008350	BREAK TIME #3147	2823 E MALONE	MINER	63801	SCOTT
ST0012291	OW10226	R005415	SIKESTON MAINT SHED	RT 62 E	SIKESTON	63801	SCOTT
ST0019247	OW09236	R007566	KELLER TRUCK SERVICE, I	614 STATE HWY H	SIKESTON	63801	SCOTT
ST0008327	OW10189	R007815	HUCKS FOOD & FUEL STORE	823 E MALONE	SIKESTON	63801	SCOTT
ST0006425	OW04888	R008238	HOME OIL CO	838 E MALONE, PO	SIKESTON	63801	SCOTT
ST0021669	OW99999	R008239	JIM'S AUTO SALES	822 E MALONE AVE	SIKESTON	63801	SCOTT
ST0008665	OW20007	R008255	THE PIT STOP	2413 E MALONE	SIKESTON	63801	SCOTT
ST0012971	OW10314	R008502	FAST GAS	101 EAST ST	SIKESTON	63801	SCOTT
ST0006423	OW09667	R008504	DOWNTOWN TIRE & AUTO	309 E MALONE ST	SIKESTON	63801	SCOTT
ST0006423	OW21612	R008504	DOWNTOWN TIRE & AUTO	309 E MALONE ST	SIKESTON	63801	SCOTT
ST5018147	OW10466	R008099	FISCA OIL COMPANY (M R	9943 US HWY 60	WYATT	63882	MISSISSIPPI

Active Underground Storage Tanks in SJNM Project Vicinity in Remediation

Facility ID	Owner ID	Rem ID	Name	Address	City	ZIP	County
ST0019910	OW00005	R007036	FFP #850	I55 & HWY 77	BENTON	63736	SCOTT
ST0010907	OW10466	R007875	FISCA OIL CO INC #74	HWY 60 W OF CAIRO	BIRDS POINT	63882	MISSISSIPPI
ST0008877	OW10498	R005077	PILOT TRAVEL CENTER #35	I-57 & HWY 105 S EX	CHARLESTON	63834	MISSISSIPPI
ST0020466	OW10595	R006817	HUCKS	203 WEST MARSHA	CHARLESTON	63834	MISSISSIPPI
ST0019121	OW09129	R007207	REEVES AMOCO STATION	HWY 105	CHARLESTON	63834	MISSISSIPPI
ST0012968	OW10215	R007264	BREAK TIME CONVENIECE	2630 E MARSHAL/I-	CHARLESTON	63834	MISSISSIPPI
ST0020376	OW09254	R007530	MISSISSIPPI COUNTY AIRPORT	HWY 105 SOUTH &	CHARLESTON	63834	MISSISSIPPI
ST0008877	OW10498	R008216	PILOT TRAVEL CENTER #35	I-57 & HWY 105 S EX	CHARLESTON	63834	MISSISSIPPI
ST3003360	OW99999	R008507	FLAG STOP, INC	211 SOUTH STORY	CHARLESTON	63834	MISSISSIPPI
ST0008078	OW03741	R005847	BIG OAK TREE	RT 2 BOX 343	EAST PRAIRIE	63845	MISSISSIPPI
ST3003357	OW99999	R007823	EASTSIDE STORE	901 W HWY 80	EAST PRAIRIE	63845	MISSISSIPPI
ST0021495	OW99999	R008029	DOGWOOD STORE	1586 STATE RT B	EAST PRAIRIE	63845	MISSISSIPPI
ST0019797	OW00861	R007274	DELTA GROWERS ASSN.	HWY W	KEWANEE	63860	NEW MADRID
ST3003532	OW99999	R008162	MFA BULK PLANT	HWY 61 & W (NW CRNR	KEWANEE	63860	NEW MADRID
ST0019911	OW00005	R007967	FFP #854	NE CRNR OF I55 @	MATTHEWS	63867	NEW MADRID
ST5800901	OW99999	R006574	FORMER BULK PLANT-HOM	HIGHWAY 60	MINER	63801	SCOTT
ST0021222	OW99999	R007720	WATER TREATMENT PLANT	HWY AA & HARRISON	MINER	63801	SCOTT
ST0012969	OW10215	R008350	BREAK TIME #3147	2823 E MALONE	MINER	63801	SCOTT
ST0012291	OW10226	R005415	SIKESTON MAINT SHED	RT 62 E	SIKESTON	63801	SCOTT
ST0019247	OW09236	R007566	KELLER TRUCK SERVICE, I	614 STATE HWY H	SIKESTON	63801	SCOTT
ST0008327	OW10189	R007815	HUCKS FOOD & FUEL STORE	823 E MALONE	SIKESTON	63801	SCOTT
ST0006425	OW04888	R008238	HOME OIL CO	838 E MALONE, PO	SIKESTON	63801	SCOTT
ST0021669	OW99999	R008239	JIM'S AUTO SALES	822 E MALONE AVE	SIKESTON	63801	SCOTT
ST0008665	OW20007	R008255	THE PIT STOP	2413 E MALONE	SIKESTON	63801	SCOTT
ST0012971	OW10314	R008502	FAST GAS	101 EAST ST	SIKESTON	63801	SCOTT
ST0006423	OW09667	R008504	DOWNTOWN TIRE & AUTO	309 E MALONE ST	SIKESTON	63801	SCOTT
ST0006423	OW21612	R008504	DOWNTOWN TIRE & AUTO	309 E MALONE ST	SIKESTON	63801	SCOTT
ST5018147	OW10466	R008099	FISCA OIL COMPANY (M R	9943 US HWY 60	WYATT	63882	MISSISSIPPI