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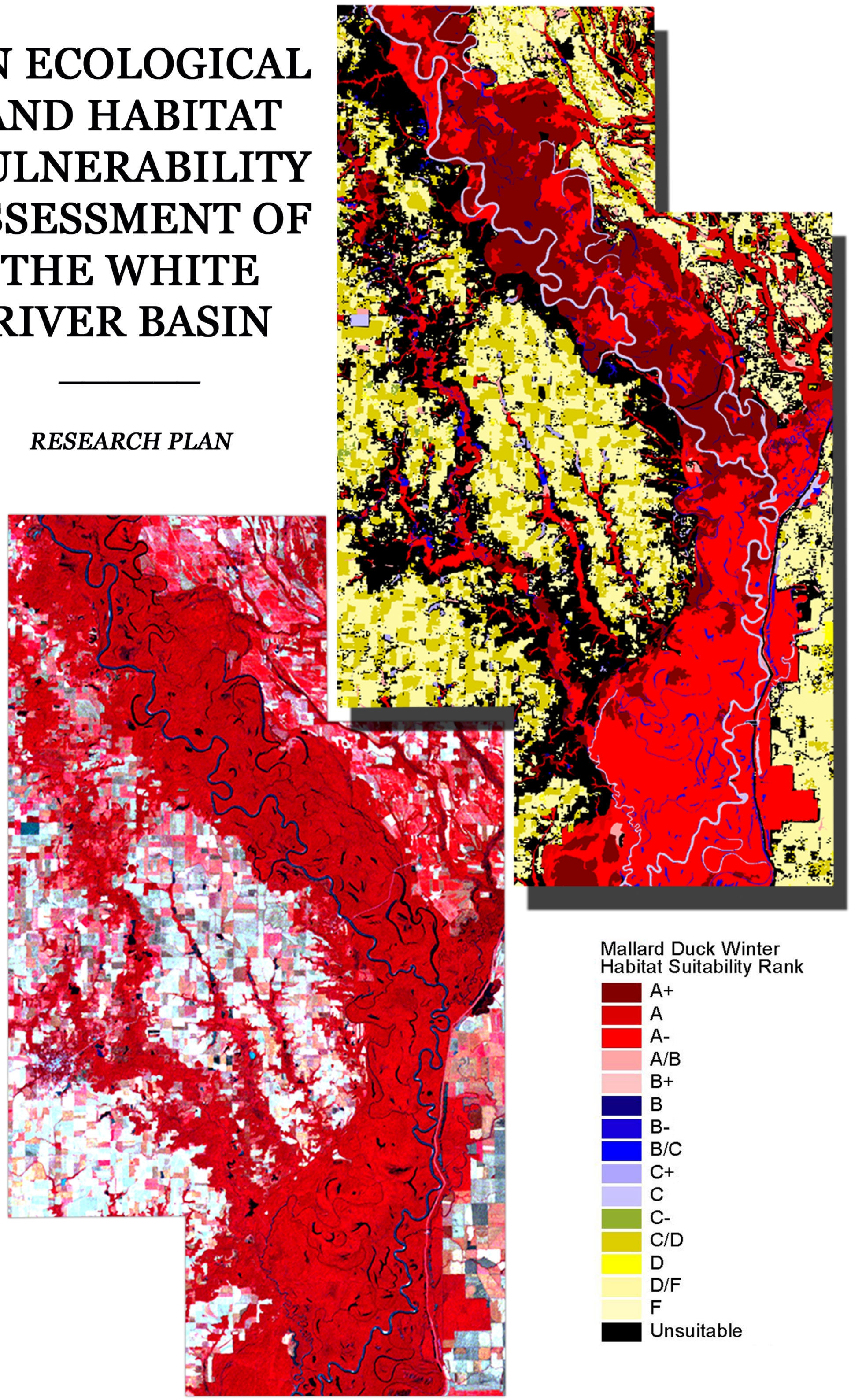
AN ECOLOGICAL AND HABITAT VULNERABILITY ASSESSMENT OF THE WHITE RIVER BASIN

RESEARCH PLAN



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Cover Images: A southern portion of the White River National Wildlife Refuge (Arkansas) and vicinity: (left) a 1992 "false color" Landsat MultiSpectral Scanner image, highlighting vegetated areas in shades of red; (right) a preliminary winter habitat suitability model (assuming current landscape conditions) for mallard duck in the same region.

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BACKGROUND

The White River begins in northwest Arkansas, flows through south-central Missouri, reenters Arkansas, and then flows southeast to its confluence with the Mississippi River (Figure 1). The White River Basin extends from the Ozark Mountains to the Mississippi Alluvial Plain, and drains from a wide range of landscapes that contain farmland, upland forests, wetlands, lakes, small streams, and urban development. Along the mainstem and tributaries of the White River there are seven reservoirs, and within the White River Basin there are two National Wildlife Refuges, a National Scenic River, and two National Forests. The lower White River,

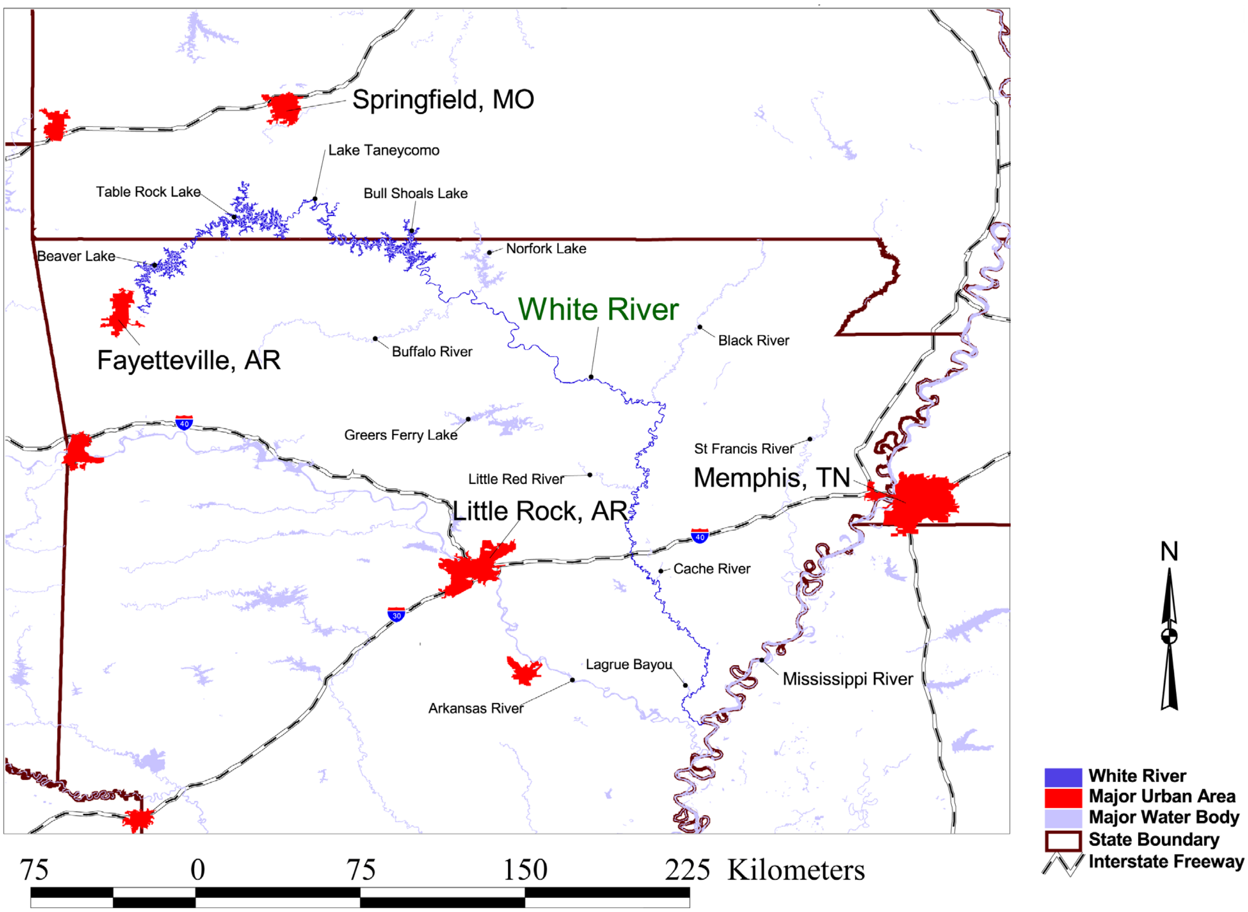

Figure 1. The White River (Arkansas and Missouri) and surrounding landscape.

which flows through the Mississippi Alluvial Plain, is one of the most important bottomland hardwood wetlands in the world (Figure 2) and has been designated as a Ramsar Wetland of International Importance (Ramsar 2000). The streams and wetlands in the lower White River Basin are unique in that they support the largest winter concentration of mallard ducks in North America and also provide critical habitat for plant species and animals, such as black bear and migratory birds (Twedt et al. 1999). The river system also supports an important riverine fishery, including sturgeon and paddlefish. The aquatic plant communities within bottomland hardwood swamps of this region are among the most biologically diverse and productive systems in the world (summarized by Mitsch and Gosselink 1993). The White River Basin is an especially valuable resource for the people of Arkansas because they directly depend upon it for surface water, flood control, agricultural products, commercial transport, numerous forms of outdoor recreation, commercial shelling industries, commercial fishing industries, tourism industries, and for their enjoyment of its plants and wildlife.

Figure 2. A remnant bottomland hardwood swamp (Burnt Lake) with wetland-adapted cypress trees and other wetland vegetation, within the boundaries of the White River National Wildlife Refuge, Arkansas.

RESEARCH RATIONALE AND NEED

The Lower Mississippi River, its tributaries, and the landscapes within these watersheds have undergone tremendous alteration in the past (Dahl 1990), which has resulted in the loss of natural wetland vegetation and hydrologic characteristics of the landscape that are unique to wetlands (Mitsch and Gosselink 1993). Since the 1970s the most extensive loss of wetlands has included those in Arkansas, Mississippi, and Louisiana (Dahl and Johnson 1991, Kress et al. 1996). These changes are likely to affect change in the biological diversity (Gosselink and Turner 1978, Ewel 1990), the capacity of the land to attenuate flood events (Hopkinson and Day 1980a, Hopkinson and Day 1980b, Brown 1984), and downstream water quality (Kitchens et al. 1975, Day et al. 1977, Hupp and Morris 1990, Hupp and Bazemore 1993). This study is an important first step toward a determination of how such landscape alterations are correlated with changes in the hydrologic, chemical, and biological characteristics of the White River Basin and how the influences of potential alterations may affect change in the future water quality and the biological integrity of the ecosystem. Quantifying these relationships could improve the decision-making processes for future land use planning in the White River and the Mississippi River watershed.

Recent detailed studies of the landscape in and around the remnant bottomland hardwood wetlands of the Cache River (Figure 1) show that the relationships between landscape change and wetland function in the region are complex and require a thorough understanding of impact history (Kress et al. 1996), water quality (DeLaune et al. 1996, Dortch 1996, Kleiss 1996), hydrology (Long and Nestler 1996, Walton et al. 1996a, Walton et al. 1996b, Wilber et al. 1996), and habitat characteristics (Kilgor and Baker 1996, Smith 1996, Wakeley and Roberts 1996). The White River, a major tributary to the Mississippi River, has not undergone a comprehensive assessment of this kind. A fundamental assessment of the landscape history, resource rarity, and ecological functions of the White River Basin is necessary to continue the efforts to better understand how the remaining bottomland hardwood wetlands, and other inter-linked ecosystems, of the Mississippi River Valley are impacted by future development. This need is urgent because approximately 70% of Arkansas' wetlands have been converted to other land cover types since the late nineteenth century (Dahl 1990), a loss of approximately 2.8 million hectares (Figure 3), and over 400 thousand acres of this loss occurred in the mid-twentieth century (Shaw and Fredine, 1956).

One of the land cover changes that predominates in this region of the United States is the conversion of forest to agricultural areas (Heggem et al., 1999). Conversely, in recent years some human-use areas (e.g., agricultural land) have been restored to their former 'natural' cover types (e.g., forest) through the U.S. Department of Agriculture Wetland Reserve Program (WRP). Information about the WRP can be found at the Internet web site: http://www.wl.fb-net.org/. Both types of land cover change will be assessed in this study. The observed relationships between land cover change and the status of ecosystems of the region will then be used to determine how: (a) future change in vegetation cover may impact habitat suitability of the basin; (b) future change in vegetation cover may impact water quality of rivers, lakes, and wetlands; and (c) river and wetland hydrology and vegetation change are related. These relationships will be used to predict potential habitat and water quality/quantity conditions of the future. Thus, the potential future scenarios can be used to assess the vulnerability of the ecosystems to future land cover change and land use change in the region.

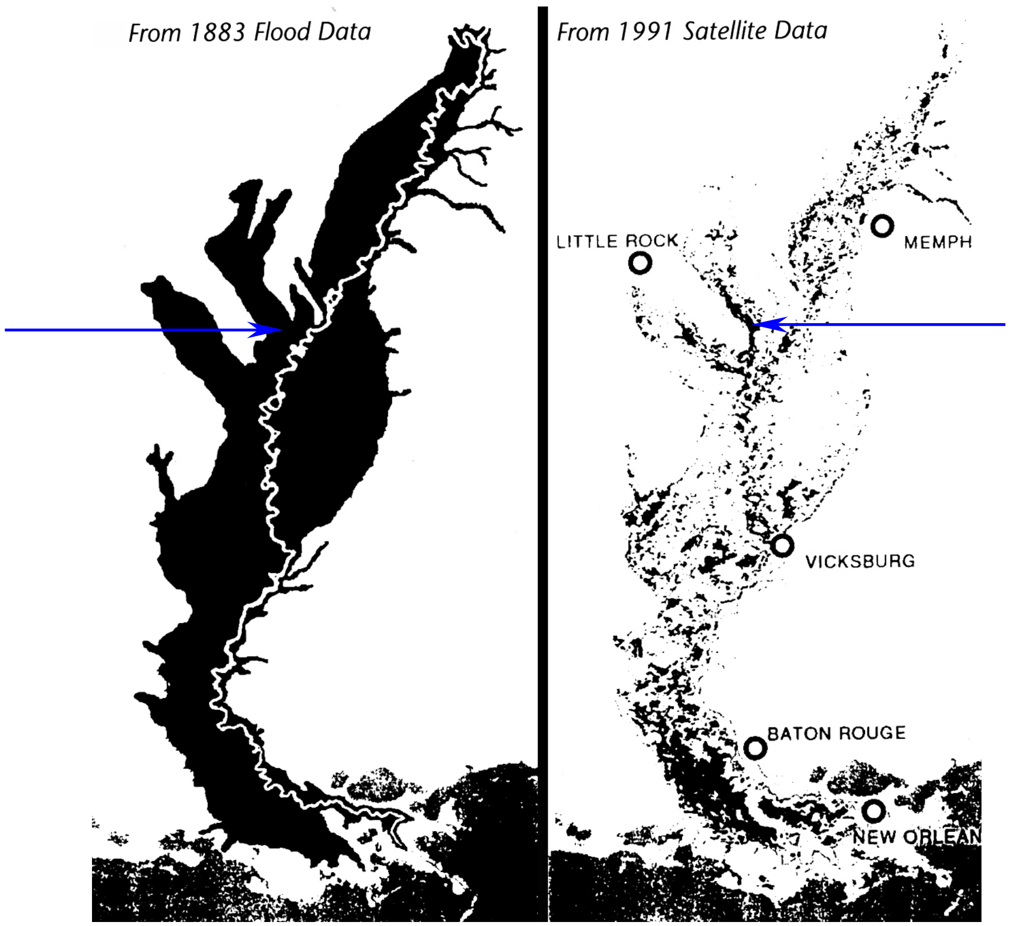

Figure 3. Wetland loss in the Mississippi Alluvial Valley (1883 – 1991). Most of the remaining wetlands (black areas north of "New Orleans") are included in this study. [adapted from Nature Conservancy 1992]. Arrows point to the approximate location of the southern end of the White River National Wildlife Refuge in the late twentieth century (right), and the same location in the late nineteenth century (left).

There are many projects currently under review for implementation in the White River Basin, each of which has the potential to alter a substantial proportion of the remaining forested areas of the landscape in the White River Basin. The planned projects include a navigation project that requires river channel alterations and may affect the hydrology of riparian wetlands; agricultural irrigation projects that involve increasing the removal of surface water from the White River and modification of reservoir releases that may substantially change the hydrology of the basin; roadway and bridge construction projects, thus fragmenting habitat. This project will provide a method for determining how such projects may affect the water quality, quantity, and habitat characteristics of the basin. Future development has the potential to specifically alter the delicate hydrology of palustrine and riverine wetlands, which may directly affect water quality and the suitability of habitat for wetland organisms of the region. Thus, this project will focus on the wetland areas of the White River Basin and the plant/animal communities of those areas. Specifically, the current extent of roads and future road projects in the White River Basin has great potential for causing forested wetland fragmentation, and may result in ecosystem degradation. Fragmentation of forests and other land cover types is likely to have ecological impacts on the region because White River watershed contains over 131,000 km of roads, of which approximately 11,000 km are within 15 km of the White River/Cache River/Bald Knob Wildlife Refuges, and 537 km of roads are inside the White River National Wildlife Refuge boundary.

As a result of projected development pressures on the ecology of the lower Mississippi River region, the Mississippi River Alluvial Plain and the White River Basin are currently the focus of heightened U.S. EPA concern. Of particular concern is the ecological vulnerability of the lower White River and the potential for loss of ecological function, given the plans for future development. Thus, this study will specifically focus on habitat functions as part of an overall assessment of ecological integrity of the White River ecosystem. In an effort to maintain an effective balance between navigation, flood control, and resource protection along the Mississippi River, EPA Regional Administrators have also committed to protect and restore the environmental resources of its tributaries, such as those in the White River Basin. Additionally, the loss of riparian vegetation in the White River Basin may be a contributing factor to the overall load of nutrients in the Mississippi River and the Gulf of Mexico, and contribute to the lack of habitat for plants, migratory birds, and other animals. Accordingly, they are committed to a systems approach to improve and protect water and habitat quality within the Mississippi River Basin, and those ecosystems in the Gulf of Mexico that are closely tied to the upstream habitat and water quality (e.g., the U.S. EPA St. Louis Compact of 1998). This study will help to fulfill this commitment by quantifying the potential impacts of nutrient loading and the loss of habitat within the lower Mississippi River watershed. The St. Louis Compact may be viewed on the U.S. EPA's Office of Wetlands, Oceans, and Watersheds Internet web site: http://www.epa.gov/OWOW/watershed/compact.html. The successful completion of this project will help to develop a protocol capable of determining the potential ecological and habitat vulnerability of the White River and the Mississippi Alluvial Valley, and may be useful as a protocol for larger regions of the United States, such as the entire Mississippi River watershed.

STUDY AREA BOUNDARIES

The ecological vulnerability of water bodies to land cover change will be assessed and reported for the lower White River, bounded by the USGS Hydrologic Unit Code (HUC) 0802 (Figure 4). The same attributes will be assessed and reported for the upper White River region (HUC 1101) because this watershed is hydrologically connected to the lower White River. The ecological vulnerability of habitat to land cover change will be assessed and reported for the region defined as the Mississippi Alluvial Valley Ecoregion (Omernik 1987), which includes the lower White River hydrologic boundary (HUC 0802). The habitat in the Mississippi Alluvial Valley Ecoregion (Figure 4) is important to include because it is connected to the existing habitat of the lower White River (e.g., the White River National Wildlife Refuge and the Cache River National Wildlife Refuge). A "fine-scale" sub-region (Figure 5) of the White River Basin has been selected to test the habitat vulnerability methodologies, which will be applied to the Mississippi Alluvial Valley Ecoregion study area. The fine-scale study area includes the White River National Wildlife Refuge, Cache River National Wildlife Refuge, and Bald Knob National Wildlife Refuge. An intended benefit of this project is that the results (e.g., from the fine-scale study area) will be directly applicable to the management practices of the wildlife refuge professionals of the region.

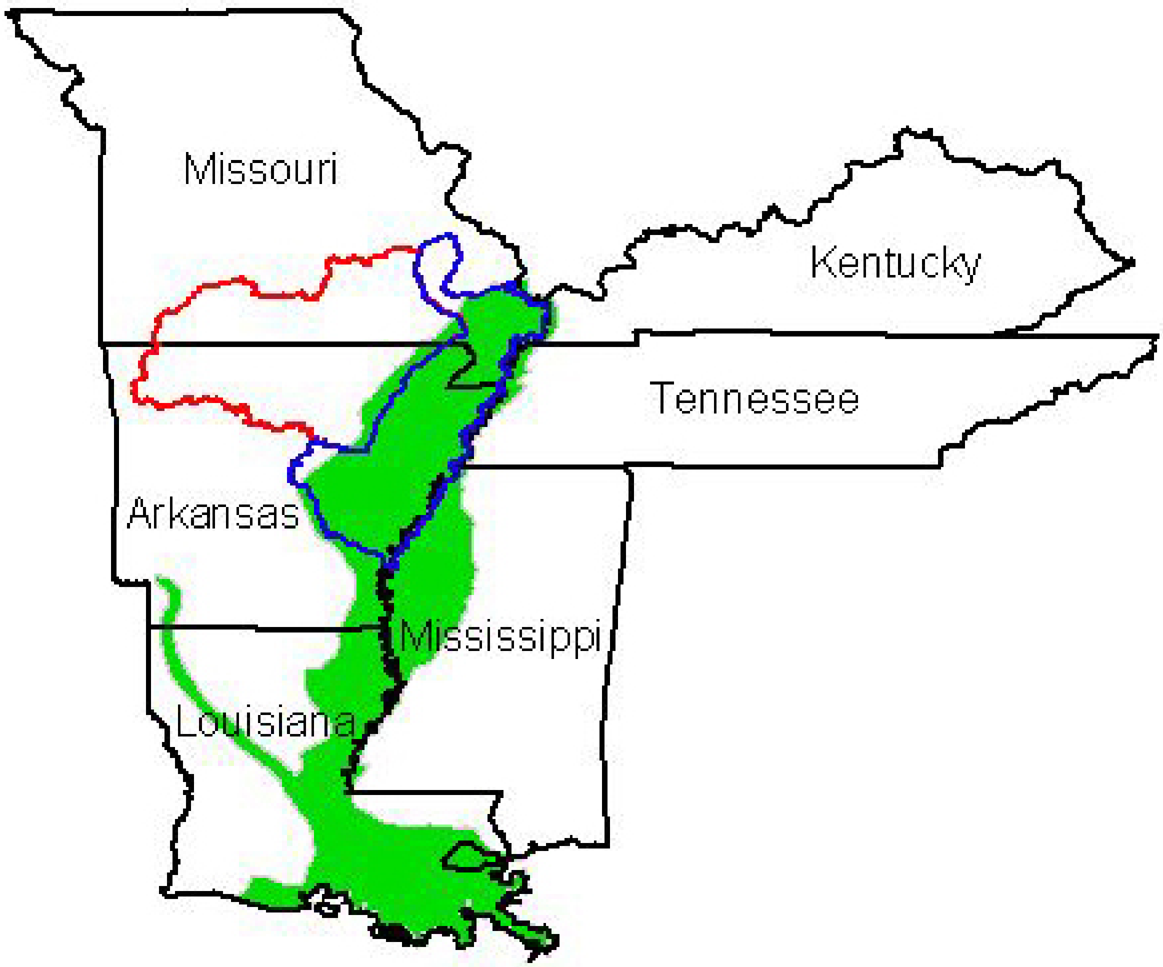

Figure 4. Study area utilized for habitat analyses is the (green-shaded) Mississippi Alluvial Valley Ecoregion (Omernik 1987). Study areas utilized for water quality analyses are the USGS Hydrologic Unit Code (HUC) regions 0802 (blue boundary) and 1101 (red boundary).

RESEARCH OBJECTIVES

A) Within the fine-scale and ecoregion study areas, five fundamental landscape ecology hypotheses (state here as questions) will be addressed by this study:
   1. What are the ranges (i.e., what are the gradients) of conditions in the landscape?
   2. How are the landscape gradients related to the habitat suitability for plant and animal species?
   3. What changes in current habitat suitability are predicted, given hypothetical changes in the future landscape?
   4. What will be the consequences of predicted changes on plants and animals of the region?
   5. How do the gradients of landscape change, thus the predicted habitat suitability, change at different spatial scales?

B) Within the USGS hydrologic units, five fundamental landscape ecology hypotheses (state here as questions) will be addressed by this study:
   1. What are the ranges (i.e., what are the gradients) of conditions in the landscape?
   2. How are the landscape gradients related to surface water quality/quantity?
   3. What changes in surface water quality/quantity are predicted, given hypothetical changes in the future landscape?
   4. What will be the consequences of predicted changes on water quality/quantity?
   5. How do the gradients of landscape change, thus the predicted water quality/quantity, change at different spatial scales?

This project is a component of the 10-year research strategy for the Landscape Sciences Program (Jones et al. 2000a). The three primary areas of the research strategy to be addressed by this study are: (a) change detection by comparing thematic data sets in a geographic information system (GIS) environment; (b) investigation and development of landscape indicators; and (c) assessment and quantification of landscape change. An overall objective of this study is to improve the understanding of ecological relationships between potential landscape stressors, habitat suitability/vulnerability, and water quality/quantity of the study areas. Our results may parallel efforts and techniques of the ORD Regional Vulnerability Assessment (REVA) and the U.S. EPA Region 6 Cumulative Risk Index of Analysis (CRIA), and may result in collaborative use of data layers and information for the ecological models. The research efforts of the White River Basin project will therefore be coordinated with the REVA and CRIA projects to best accomplish the above-mentioned research goals.

RESEARCH APPROACH

The models to be developed in this study could be constructed for other areas or by measuring other parameters, given the availability of sufficient ecological data. The specific plants and animals used in the habitat models of this study will be based upon a combination of selection criteria, in the order listed: (a) availability of habitat suitability information in the literature for a species and geographic coverage of these data; (b) plants or animals that are indicators of ecological conditions; (c) plants or animals that have undergone a decline in the region; (d) species that are listed as endangered or threatened at the state or national level; and (e) species of special interest, as expressed by the local or regional stakeholders. The selected ecological parameters should also provide guidance for subsequent researchers that perform similar studies and may have data of improved quality in the future.

The research approach is to:

A) Examine the relationships between landscape condition and ***habitat suitability*:**

1) Determine habitat requirements for plant and animal species or guilds (see criteria, above), using habitat suitability indexes and other natural history information available in the literature.
2) Use the habitat requirements of species or guilds, in combination with habitat characteristics (e.g., wetland type) from the 1980s and 1990s, entered into a GIS, to produce a habitat suitability model for the study areas under current landscape conditions.
3) Utilize historical trends in combination with prior ecological research results to hypothesize potential landscape stressor gradients that may be relevant to changes in habitat suitability (e.g., conversion of forest to agricultural land). The selection of potential stressor gradients will be based on current knowledge of the habitat requirements for particular species or guilds and may be based on a combination of habitat parameters (e.g., vegetation cover requirement and home range requirements). An initial analysis of general habitat requirements may help to focus efforts on other more detailed habitat-stressor relationships, for example the loss of core forest areas as a stressor for plants and animals.

B) Examine the relationships between landscape condition and ***water quality/quantity***:

1) Obtain water chemistry and hydrologic data (e.g., National Water Quality Assessment data, staff gauge measurements, and stream flow measurements) for the hydrologic study areas (HUC's 0802, 1101). Because prior research has demonstrated that landscape characterization results are scale dependent (Jones et. al 1997) the hydrologic study area will be analyzed at several different spatial scales: (i) as a complete river ecosystem (HUC 0802 and 1101, combined); (ii) as a mixture of lotic and lentic ecosystems containing major impoundments and steep terrain (HUC 1101); (iii) as a predominantly lotic ecosystem, flowing through the alluvial flood plain (HUC 0802); and (iv) at finer scales (e.g., 8-digit HUC sub-basins), where appropriate.
2) Determine and delineate land cover types (e.g., forest) and determine spatial gradients of land cover in the 1990s for the hydrologic study areas (e.g., using land cover derived for the Arkansas GAP, see *Methodology* and Figure 6).

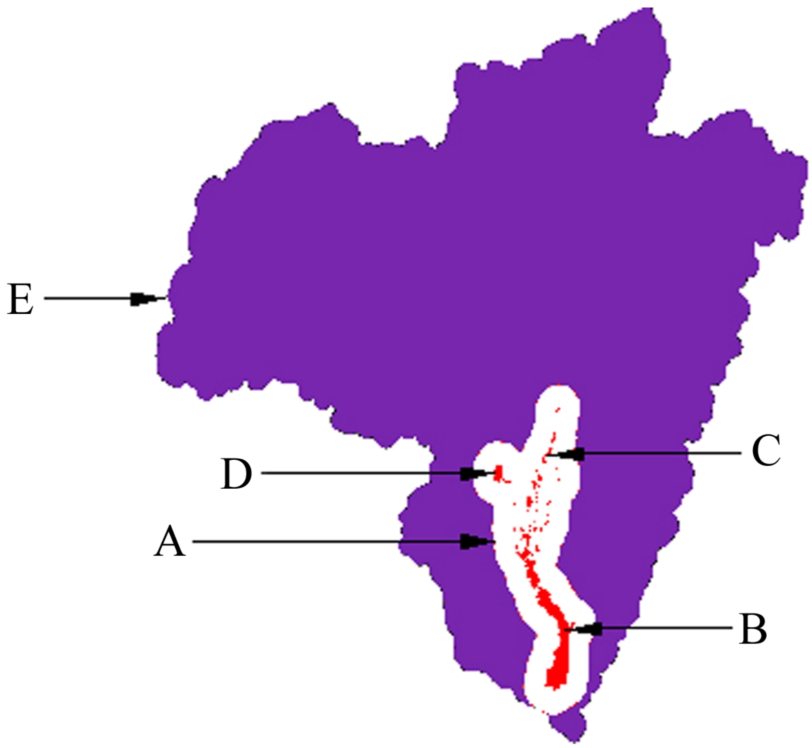

Figure 5. Approximate fine-scale study area (A), used to test some of the habitat suitability/vulnerability methodologies. The fine-scale study area includes the White River National Wildlife Refuge (B), Cache River Wildlife Refuge (C), and the Bald Knob National Wildlife Refuge (D). The hydrologic study area boundary (E) is included for reference (see Figure 4 for detail).

3) Utilize the land cover change gradient in the White River hydrologic study areas to hypothesize potential land cover stressor gradients, that are relevant to surface water quality (e.g., surface water concentration of nitrate+nitrite or phosphorus). The potential stressor gradients will also be based on prior research results that indicate a relationship between landscape condition and water quality or hydrology. Many of the mechanisms of the relationships between land cover and surface water chemistry are known. For example, prior studies in agricultural areas have demonstrated an inverse relationship between the presence of riparian vegetation and nutrient loading to nearby streams, because of nutrient uptake by the plants in the riparian zone (Peterjohn and Correll 1984). Other research suggests that, in general, there is a strong positive correlation between the improvement of water quality and the presence of wetland soil conditions and vegetation (Hey et al. 1989, Poiani et al. 1996, Fennessy and Cronk 1997, Giese et al. 2000). Thus, the loss of riparian vegetation (e.g., narrowing of riparian vegetation width) will be tested as a potential water quality stressor in the White River hydrologic study areas.

C) Model ***future*** landscape change scenarios and predict the ecological/habitat ***vulnerability*:** Using the gradient trends and relationships (determined in step A and B, above) or specific development plans for the future (e.g., road construction plans), develop several future landscape change scenarios. For example, a future scenario for a study area may be a result of a hypothetical 10% decrease in wooded riverine wetland along a segment of the White River, given specific information of similar change from a development plan or historical trends. Future impacts on plant and animal habitat, and future impacts on water quality/quantity will be estimated by implementing similar hypothetical changes in the land cover of those models. The future scenario models for habitat and water quality/quantity could be used to estimate the vulnerability of these resources to impacts, and to minimize the potential negative impacts of development.

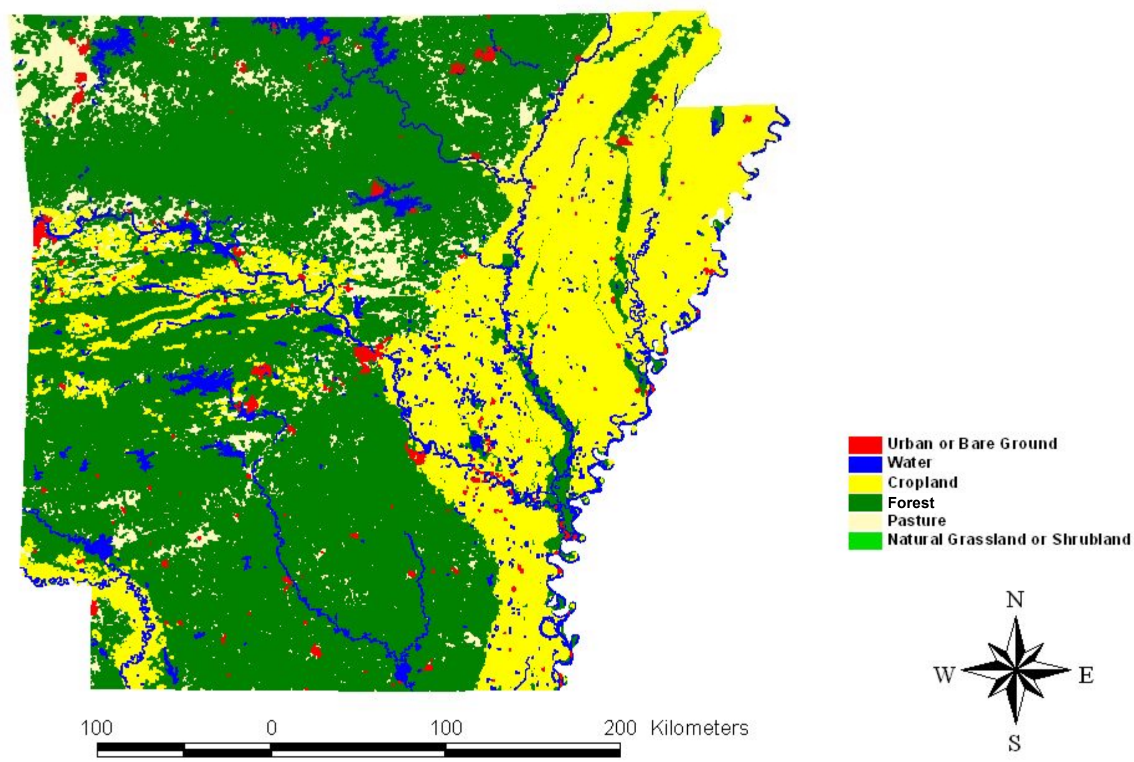

Figure 6. 'Arkansas GAP' land cover in the 1990s, derived from Landsat TM imagery (USGS 1998)

METHODOLOGY

Conceptual framework for modeling ecological/habitat vulnerability:

1. Develop habitat suitability models (i.e., based on current condition) for plant and animal species using the habitat requirements of each species (or guild) and available land cover data (see Table 1 and *Data* section, below)
2. Develop a water quality/quantity model for the current conditions in the White River hydrologic study areas using available water quality/quantity data and available land cover data (see *Data* section, below)
3. Estimate the trends in the historical land cover change for the study areas using gradient analyses, landscape indicators (Table 2), and a GIS.
4. Apply potential future landscape change scenarios to models in framework steps 1 and 2, based upon: (a) extending the trends observed in framework step 3 into the future; (b) expected ecosystem responses to environmental stress (Odum, 1985), for example the loss of facultative wetland vegetation in the riparian zone given hypothetical alterations in the hydrology of the study areas; and (c) application of known projects or development plans to the "current condition" landscape (established in framework steps 1 and 2), for example hypothesizing an increase in forest land cover at specific WRP restoration sites.

Landscape indicators

An ecological indicator is a measurement of change in ecological resources (Bromberg 1990, Hunsaker and Carpenter 1990, Hunsaker et al. 1990). When measured at the landscape-scale (Forman 1995) ecological indicators are called "landscape indicators", and are defined as measurable characteristics of the environment, both abiotic and biotic, that can provide quantitative information about ecological resources (Jones et al. 1997). Because it is currently impossible to measure all of these characteristics, in this study we selected landscape indicators (Table 2) that have demonstrated a correlation between landscape conditions and ecosystem integrity (Lopez 1999, Jones et al. 2000b, and Jones et al. 2000c). The use of GIS mapping techniques to determine correlations between indicators and response enables the determination of change in ecological resources because it allows for more rapid analyses of correlations between hypothesized landscape indicators and response parameters (Scott et al. 1993, Jones et al. 1997).

Gradient and statistical analyses

A fundamental component of a landscape-ecological study design is the selection of a sufficient number of study sites to account for the full range of disturbance conditions (Green 1979, Karr and Chu 1997). To examine gradients of landscape change in the study areas (ranging from least-impacted to impaired) complete available data coverage of the study areas

and a stratified random sampling design within each study area will be used. Prior knowledge of local experts, a preliminary review of the history, and a review of the current land cover of the study areas indicate that there is sufficient variability within each study area to successfully perform gradient analyses. Table 1 lists the minimum modified-Anderson (1976) "Level 1" land-cover classes to be used for the analysis of the land-cover gradients.
The relationships between land cover parameters, water quality/quantity, and habitat characteristics will be tested using multi-variate statistical techniques (e.g., multiple regression or multiple analyses of variance) to determine ecologically relevant and statistically significant correlations. Because one or both of the assumptions of parametric statistics tests (normality and equality of variance) may be violated in the data, a non-parametric analogue may be used (e.g., Spearman Rank Correlation, Kruskal Wallis test), $\alpha = 0.05$ [Zar 1984]. All analyses will be completed with Statview statistical software (SAS Institute, v.5.0.1).

Table 1.
Non-exclusive list of land cover classes that will be used to examine potential changes in habitat suitability and water quality (i.e., habitat and ecological vulnerability) in the White River Basin study areas (after Anderson et al. 1976)

Land cover class name(s)	Regional example(s)
Urban or Built-Up Land	Shopping center, parking areas, sub-urban area
Grassland	Grassy 'old field'
Forest Land	Forest
Water	Pond, lake, stream
Agricultural Land	Rice, soybean, cotton row crop
Barren Land	Gravel pit, beach
Wetland	Oxbow, hardwood swamp, emergent marsh

Watershed determination

A set of watersheds, corresponding to pour point water sampling locations, will be determined using a GIS and the National Elevation Dataset (NED). Watershed sizes will range from approximately 10 km^2 to 400 km^2 and may differ from the USGS hydrologic units described in the site description section, above. Watershed boundaries will be produced within Arc/Info Grid using water sample (point) locations and elevation model produced from the NED. Hydrologic sinks in the digital elevation model will be filled to ensure that a continuous drainage network, flow accumulations, and flow direction grids are created. Subsequently, drainage channels will be generated using cells with flow accumulations with greater than approximately 1000 grid cells (i.e., cells into which at least 10 hectares of watershed area are drained). If water sample (point) coordinates are inaccurate, sample points will be manually moved using location descriptions.

Table 2.

Non-exclusive list of landscape indicators that will be used to examine potential changes in habitat suitability and water quality (i.e., habitat and ecological vulnerability) in the White River Basin study areas (after Lopez 1999, Jones et al., 2000b, and Jones et al. 2000c)

Name of Indicator	Explanation of Indicator	Hypothesized Response Parameters
Forest land cover	Percent of support area that has forest land cover	Habitat suitability and water quality/quantity
Agricultural land cover	Percent of support area that has agricultural land cover	Habitat suitability and water quality/quantity
Urban land cover	Percent of support area with urban land cover	Habitat suitability and water quality/quantity
Wetland land cover	Percent of support area with wetland land cover	Habitat suitability and water quality/quantity
Inter-wetland distance	Mean distance between wetlands in support area	Habitat suitability and water quality/quantity
Wetland density	Number of wetland patches within a support area	Habitat suitability and water quality/quantity
Riparian agriculture	Percent of support area with agricultural land cover adjacent to stream edge	Habitat suitability and water quality/quantity
Riparian forest	Percent of support area with forest land cover adjacent to stream edge	Habitat suitability and water quality/quantity
Forest fragmentation	Percent of forested areas that join a forested area to a non-forested area	Habitat suitability and water quality/quantity
Road density	Mean number of kilometers of roads per km2 of support area	Habitat suitability and water quality/quantity
Roads near streams	Proportion of total stream length having roads within 30 meters	Habitat suitability and water quality/quantity

Non-exclusive list of data used in this study:
Aerial Photographs: These data will vary by region and by availability. Color infrared photographs as stereo-pairs will be the ideal selection criteria but final selection will depend upon availability. These data are available from a variety of sources and will be searched at the EROS Data Center in Sioux Falls, SD. The ideal range of scales is from approximately 1:6000 to 1:24,000, however scales up to 1:40,000 may be used if finer scales are unavailable. These data will be used to validate land cover, such as forest or agriculture, for the purpose of determining the habitat suitability for plants and animals, and the impact on water quality/quantity.

Landsat Thematic Mapper (TM) Data: These data are available from the EROS Data Center, Sioux Falls, SD, and are acquired from earth orbit. Digital image data are available in three visible bands (Red, Green, and Blue), one near-infrared band, and two mid-infrared bands with a spatial resolution of 30 meters. These data will be used to estimate area of land cover, specifically sandy shore habitat, urban areas, herbaceous vegetation, and woody vegetation, for the purpose of determining the habitat suitability for plants and animals, and the impact on water quality/quantity.

Landsat MultiSpectral Scanner (MSS) Data: These data are available from the joint EROS Data Center and the North American Landscape Characterization (NALC) database that is located at the U.S. EPA Landscape Ecology Branch (LEB) facility in Las Vegas, Nevada (see *Program Management*). These data are acquired from earth orbit and are processed to facilitate land cover change analyses (i.e., minimal cloud cover, co-registered decadal images). Digital image data are available in two visible bands (Red and Green), and two near-infrared bands, and have a nominal spatial resolution of approximately 80 meters, resampled to 60 meter resolution. These data will be used to estimate area of land cover, specifically sandy shore habitat, urban areas, herbaceous vegetation, and woody vegetation, for the purpose of determining the habitat suitability for plants and animals, and the impact on water quality/quantity.

National Wetland Inventory (NWI) Maps: (photo-interpretation mark-up of 7.5 minute USGS quadrangles): Where available in digital format, these maps will be ordered from the USFWS. If large-scale hard-copy maps will suffice, these data will be ordered in paper or Mylar format from the USFWS. These data will be used to estimate area of land cover, specifically wetland classes, for the purpose of determining the habitat suitability for plants and animals, and the impact on water quality/quantity.

Gap Analysis Program (GAP) Data: These data are available from USGS and estimate the current land cover of the study areas (1990s data). The purpose of the program is to provide regional assessments of the conservation status of native vertebrate species and natural land cover types, and to facilitate the application of this information to land management activities. These data will be used to estimate area of land cover, specifically plant species, vegetation type, and agriculture, for the purpose of determining the habitat suitability for plants and animals and the impact on water quality/quantity. The habitat models in the GAP dataset will also be used for comparison to the habitat suitability models developed in this study.

USFWS – NBS Land Cover Data: These data are available from the U.S. Fish and Wildlife Service and National Biological Service. These land cover data were classified from two-season (spring/fall) 1992 TM data at 30m resolution. Forest and some agricultural lands were classified using supervised classification. Remaining agricultural lands classifications are from independent classification of 1992 TM data by USDA and University of Arkansas Center for Advanced Spatial Technologies. These data will be used to estimate area of land cover, specifically agriculture crop type, for the purpose of determining the habitat suitability for animals, and the impact on water quality/quantity.

1950s Forest Cover Data: These data were made available by The Nature Conservancy. These data include a digital file depicting forest cover in the late 1950s, as determined by aerial photograph interpretation. These data will be used to estimate area of forest cover in the 1950s, for the purpose of estimating the presence of mature forest stands in the study areas.

Digital Raster Graphics (DRG): These data are available from the USGS and are scanned images of USGS topographic maps. The image inside the map neatline is georeferenced to the surface of the earth and fit to the Universal Transverse Mercator projection. These data (scale=1:24,000) will be used as supplementary information for estimating the area of land cover, specifically human activity (roads and urban areas), for the purpose of determining the habitat suitability for plants and animals, and the impact on water quality/quantity.

National Land Cover Data (NLCD): These data are sponsored by the Multi-Resolution Land Characteristics (MRLC) Consortium and are a product that contains land-cover data for the conterminous United States. NLCD land cover was mapped using general land cover classes (see http://www.epa.gov/mrlc/classes.html). These data will be used to estimate area of land cover, specifically wetland, upland, water, residential, commercial, and industrial, for the purpose of determining the habitat suitability for plants and animals, and the impact on water quality/quantity.

National Elevation Dataset (NED): These data have been developed by merging the highest-resolution, best-quality elevation data available across the United States into a seamless raster format, and are available from the USGS. NED is the result of the maturation of the USGS effort to provide 1:24,000-scale Digital Elevation Model (DEM) data for the conterminous United States and 1:63,360-scale DEM data for Alaska. These data will be used to develop a DEM and a watershed model of the study areas.

National Water-Quality Assessment (NAWQA) Data: These data are available from the USGS and are designed to describe the status and trends in the quality of the Nation's ground- and surface-water resources. As part of the NAWQA program, investigations will be conducted in

59 areas, called study units, two of which correspond with the White River Basin hydrologic study areas (the Mississippi Embayment NAWQA study unit and the Ozark Plateau NAWQA study unit). These data will be used to estimate current water quality/quantity in the White River Basin, for the purpose of determining the relationships between land cover gradients and water quality/quantity.

Storage and Retrieval (StoRet) System Data: These data are available from the U.S. EPA Office of Water. The system is a repository for water quality, biological, and physical data. These data will be used as a supplement to the NAWQA data to estimate current and historical water quality/quantity in the White River Basin, for the purpose of determining the relationships between land cover gradients and water quality/quantity.

Breeding Bird Survey (BBS) Data: The BBS is a large-scale survey of North American birds. It is a roadside survey, primarily covering the continental United States and southern Canada, although survey routes have recently been initiated in Alaska and northern Mexico. The BBS was started in 1966, and the over 3,500 routes are surveyed in June by experienced birders. Some of these routes are within the White River study areas. These data will be used to spot-check the results of the bird models, although there are insufficient BBS data at the scale of this study to perform statistical analyses.

Habitat Suitability Index (HSI) and Natural History Information: These indexes and information will be used for selected plant and animal species to construct a GIS-based model of habitat suitability. These suitability models (based upon current conditions) will then be re-run under a variety of future landscape change scenarios for the purpose of estimating ecological and habitat vulnerability.

SCHEDULE, MILESTONES

2000 Mar. - Apr.	RARE funding awarded. Determined MSS data coverage for general study area, ordered new satellite data (including "leaf-off" scenes).
2000 May	LEB completion of contract work assignment. Initial LEB team member meetings to develop study boundaries, potential indicators
2000 June	RARE funding received and committed. Contractor completion of Technical Work Assignment, preliminary meetings with contractor regarding study boundaries and data coverage, completion of Draft Research Plan, preliminary meeting with U.S. EPA Region 6 regarding indicator parameter selection, GIS data coverage collection
2000 July	U.S. EPA Region 6 and stakeholder meeting in Little Rock, Arkansas to discuss parameter selection and other issues, study area reconnaissance
2000 Oct.	Completion of quarterly report on study progress to Region 6

2000 Nov.- Mar.	Peer review of U.S. EPA research plan, completion of quarterly report on study progress to Region 6, preliminary habitat suitability model for the fine scale study area completed
2001 Apr.	Completion of quarterly report on study progress to Region 6
2001 July	Completion of all habitat suitability models, collection of remote sensing and GIS data, model development for water quality analyses, completion of quarterly report on study progress to Region 6
2001 Oct.	Completion of habitat vulnerability - future scenario analyses, completion of quarterly report on study progress to Region 6
2002 Jan.	Preliminary water quality models for hydrologic study area, completion of quarterly report on study progress to Region 6
2002 Mar.	Completion of water quality - future scenario analyses
2002 Apr.	Completion of quarterly report on study progress to Region 6
2002 Sept.	Publication of U.S. EPA report, preparation of manuscripts for refereed journal articles #1 - #3 (see *Major Project Deliverables*)

MAJOR PRODUCTS

A) Project report: *An Ecological and Habitat Vulnerability Assessment of the White River Basin* (hard-copy text and digital format)

B) Refereed journal articles:
- #1 *Utilizing landscape-ecological relationships of the past to model ecological scenarios of the future: a remote-sensing and GIS approach*
- #2 *The landscape-ecological relationships between land-cover change and habitat suitability in the Mississippi Alluvial Valley*
- #3 *The landscape-ecological relationships between land-cover change and water quality in the White River Basin*

C) Images/data from study areas
D) Land cover maps
E) Ecological models

PROJECT BUDGET OVERVIEW

U.S. EPA Region 6 RARE funding - Land cover maps, consistency assessment, and implementation of habitat models

In-kind support from the Landscape Ecology Branch - Processing and interpretation of satellite data and derived products; technical expertise in remote sensing and image processing; analyses using geographic information systems; multi-variate statistical analyses; ecological model development; map production; presentation of results; data set management and archiving, final report and refereed journal article production

PROJECT MANAGEMENT

The Landscape Ecology Branch

U.S EPA's Landscape Ecology Branch (LEB) is located on the campus of the University of Nevada, Las Vegas and is under the U.S. EPA's Office of Research and Development, Environmental Sciences Division. The LEB employs 33 professionals, including biologists, research ecologists, engineers, statisticians, GIS specialists, remote sensing specialists, photo-interpreters, data management specialists, graphic artists, technical writers, and procurement specialists. The LEB has robust hardware and software capabilities (e.g., ESRI-Arc/Info, ESRI-ArcView, ERDAS-Imagine, RSI-ENVI) that enable the efficient processing and analysis of data. The Branch employs 6 full-time Ph.D. researchers and possesses a modern laboratory, supported by the resources and facilities of the Environmental Sciences Division and the U.S. EPA Environmental Photographic Interpretation Center in Reston, Virginia.

The LEB conducts research in the field of landscape ecology and related disciplines, develops landscape assessment and characterization applications, and develops tools and methods for solving regional environmental problems. Many of these projects involve the analysis of ecosystem and watershed vulnerability to human-induced stresses. The primary goal of the LEB is to develop tools for: (1) understanding and forecasting ecosystem trends; (2) assessing the ability of an ecological resource to provide desired benefits; (3) anticipating emergency environmental problems; and (4) monitoring and documenting progress in maintaining and restoring ecosystems. LEB research includes developing ecologically-meaningful indicators of landscape condition and trends related to endpoints of importance to the EPA; developing, applying, and transferring tools for measurement, assessment, and prediction of the sustainability and vulnerability of landscapes at multiple spatial and temporal scales; and maintaining pace with rapidly developing science and technology of remote sensing. Current LEB projects include applied research in Arizona, Arkansas, California, Colorado, Delaware, Georgia, Idaho, Illinois, Indiana, Kentucky, Louisiana, Maryland, Michigan, Minnesota, Mississippi, Missouri, Nevada, New Jersey, New Mexico, New York, North Carolina, North Dakota, Ohio, Oregon, Pennsylvania, South Carolina, South Dakota, Tennessee, Vermont, Virginia, Washington, West Virginia, and Wisconsin.

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