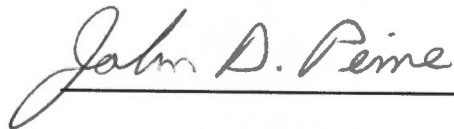


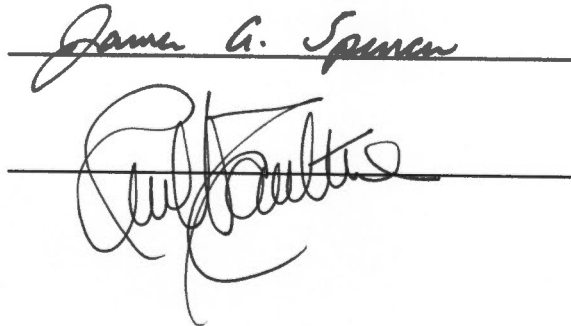
To the Graduate Council:

I am submitting herewith a thesis written by Jeffrey Carl Pfitzer entitled "A Methodology for Natural Resources Analysis Appropriate for County Level Planning." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science in Planning, with a major in Planning.

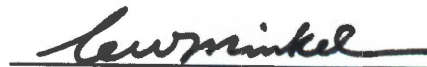


John D. Peine, Ph.D., Major Professor

We have read this thesis and
recommend its acceptance:



Accepted for the Council:



Associate Vice Chancellor and
Dean of the Graduate School

**A Methodology for Natural Resources Analysis
Appropriate for County Level Planning.**

A Thesis
Presented for the
Master of Science in Planning
Degree
The University of Tennessee, Knoxville

Jeffrey Carl Pfitzer
December, 1999

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Abstract

In this thesis a methodology for developing an integrated cumulative analysis of sensitive natural resources was developed. Themes of natural resources—waterways, wetlands, forested lands, prime agricultural soils, and steep slopes—were brought together in a GIS system, in a grid format, in a manner so that each cell of the grid accumulated value according to the increasing presence of resource themes. For example, an area (30 meter x 30 meter grid cell) containing only one of the above themes is given a value of “1,” whereas an area containing slopes, streams, and forests might, after weighting factors, have a value of “5.” The result is a map that demonstrates the cumulative value of sensitivity of a given area and its relative relation to the landscape under analysis. The methodology uses off-the-shelf GIS software and available GIS data sources, and is designed to require a minimum of technical and financial resources. This methodology is particularly useful for counties in Tennessee in meeting the requirements of Public Chapter 1101, the Growth Policy Act.

The case study for this thesis reveals that much development does, in fact, occur in sensitive natural areas and that, therefore, this tool could be well utilized by planners to inform the public and to assist in the development of policy aimed toward the protection of sensitive areas from activities that would reduce their capacity to serve their natural functions.

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**“Yet can the values which nature represents be weighed and measured so
that decent, prudent men can act in deference to them?” Ian McHarg, 1967**

Introduction

As the 20th century comes to a close and our ability and desire to alter our environment continues to increase, we are reminded of the cumulative effects of our actions on the environment. Conversion of forests and farmland into subdivisions continues at a rapid pace. Expanding development pressures have adverse impacts on wetlands, streams, drainage areas and wildlife habitat. The ecological balance of the landscape is disrupted by the continual increase in the amount of impervious surfaces. Air quality declines as annual vehicle miles of travel per person climb higher and the suburbs move steadily further and further out. Infrastructure investments demanded in new suburban growth areas deplete fiscal resources needed to maintain existing first ring suburbs and the urban core. Our natural economy is in a downward spiral. Across the nation the cries of alarm are rising (Time, March 22, 1999).

Nationally there is a growing interest in the management of the cumulative impacts of development on the environment. There were over 240 state and local ballot measures on conservation, parklands, and smart growth that went before voters in November 1998. Voters displayed their concern with the approval of 72% of these ballot measures (Myers, 1999). President Clinton and Vice President Gore recently announced a \$1 billion Lands Legacy Initiative that expands federal efforts to save America's natural treasures (<http://www1.whitehouse.gov/CEQ/landslegacy2.html>, January 12, 1999). This initiative provides significant new resources to states and communities to protect local green

spaces. There is no question that urban sprawl is a growing concern and that natural resource protection is on the minds of the American public.

At least one of the many pieces of legislation introduced in America in 1998 came as a surprise. Out of the General Assembly of the historically conservative state of Tennessee came Public Chapter 1101; otherwise known as the "Growth Boundary Bill." This new law was initially conceived as a response to problematic annexation laws. In addition to addressing annexation issues, the law that was passed proposed that at a county by county level, representatives of the respective legislative bodies present in each county come together with other specified representatives of the communities to form a coordinating committee. Among the duties of this committee is to consider the impacts of urban growth on core infrastructure, services, facilities, and environmentally sensitive areas and to set forth urban growth boundaries and designate rural areas.

This thesis will provide a readily applicable guideline for conservation-minded communities to more effectively address their growth-management needs as they relate to sensitive natural resources according to the spirit of Tennessee's latest planning law; public chapter 1101. It is important to develop a methodology for natural resource analysis in order to address the following problems:

1. Sensitive natural resources are increasingly subject to loss and degradation associated with some development. Public chapter 1101 identifies the county's

duty to manage natural resources. Proper management requires knowledge. An integrated analysis of sensitive natural resources will provide the needed knowledge base.

2. Many county planning agencies may lack resources necessary to develop an adequate natural resource analysis from scratch -- particularly predominantly rural counties. This methodology will provide a ready-made framework for such analysis.
3. The planning profession lacks a clearly defined methodology that unifies existing GIS data sources. This methodology will unify existing data sources and integrate them with local values.
4. The political climate surrounding growth management may be volatile. Attention to the ability to legally defend land use planning decisions is especially appropriate in the formation of growth boundaries. A clearly defined methodology increases the ability to defend any comprehensive planning effort.

The goal of this thesis is to provide a methodology for county level analysis of natural resource appropriate for land use planning, including determining growth boundaries and conservation areas in Tennessee. This method will help to identify areas of sensitive natural resources and to rank areas of sensitivity based on a cumulative valuation. It will accomplish this using existing data sources, off-the-shelf computer software, and minimum technical training.

The theoretical underpinnings for this methodology are derived from the overlay style of analysis popularized by Ian McHarg. His method was expertly applied using GIS technology in Hamilton County, Tennessee, in a direct response to the recommendations of Public Chapter 1101. Hamilton County's Resource Management Task Force, supported by the local Planning Agency, aptly demonstrated the type of objective, citizen driven, analytical foundation necessary for good land use planning. This methodology recommended in this thesis is largely based on their model, with modifications to bring it within the practical reach of counties and agencies on a limited planning budget.

The first chapter will review the planning literature on methods of natural resources analysis. In the second chapter, a methodology is developed to meet the needs outlined above. Chapter three discusses existing GIS data sources and their relevancy to this analysis. Then, in chapter four, a case study involving Sevier County is used to demonstrate the application of this methodology. Chapter five contains the author's conclusions regarding the usefulness of this methodology for land use planning.

Chapter One:

Review of Natural Resources Analysis Methods

Growing concern over protection of sensitive natural resources punctuates the need for more and better informed ecosystem management to minimize detrimental impacts of man on the environment. Management of natural resources requires analysis of the existing conditions of specific natural resources for any given location. Without appropriate analysis, it is difficult to direct resource management efforts in the most productive manner. It is important that analysis be suited to the need of the ecosystem manager.

Review of the literature reveals many methodologies for the analysis of natural resources. Most of these methods are computer-based, are developed around site-specific issues, and use data gathered specifically for use in the particular analysis. The chapter begins with a brief introduction to methods for analysis of natural resources in general, as demonstrated by Ian McHarg. Then it will progress to categorize some fundamental differences between several other methodologies and provide basic description of representative examples including discussion regarding relevancy for this thesis.

Any review of methods of natural resource analysis should begin with a look at *Design With Nature* (McHarg 1967). Ian McHarg set forth a method of identifying and mapping

social and natural processes as social values. His method is still respected and used today (Beatley and Manning 1997; Kaiser 1995; Westman 1985). His analysis involved the evaluation and ranking of the values of these processes in an integrative and cumulative manner. McHarg's work and the work of his students demonstrates a new method of planning that maximizes the social utility of these processes. Maximization requires that we understand the relationships of these processes. Decisions that affect these processes then can be made in a way that avoids, or at least minimizes damage to the most valuable lands and processes. Value, for McHarg, was not defined purely in economic terms reflected in a typical benefit/cost analysis. Instead, he extended value to include such categories as scenery and ecological processes. McHarg reinforced and brought to prominence the notion that social systems, natural resource systems, and aesthetics benefit society in ways that may not be readily converted into economic terms.

McHarg felt that laws pertaining to land use and development needed to be elaborated to reflect the public costs and the consequences of private action. Land use policy at that time neither recognized natural processes—as they relate to the public good in terms of flood control, water quality, agriculture, amenities and recreational potential—nor did it hold landowners or developers responsible for their actions. Since McHarg and his students completed their first study, we have made some progress in recognizing ecosystem sensitivity to disturbance. Legislation such as the National Environmental Policy Act (NEPA), the Comprehensive Response Compensation and Liability Act (CERCLA), the Environmental Protection Agency (EPA), and the Endangered Species

Act (ESA), all reflect a growing awareness of the importance of biodiversity and intact ecosystems. Nevertheless, land use decisions in this country are still largely predicated on Euclidean zoning laws. These laws are designed primarily to separate various classes of land use for preserving the economic value of land and have little or no consideration for social and ecological systems. Much work remains to be done to shift the focus of land use decision-making toward restoring and sustaining the performance of natural systems. McHarg's method provides a basic model for effective integrative analysis of existing conditions and for mapping change over time. This model provides critical information to be considered and respected as we evolve our land use policies to be more sustainable and environmentally responsible.

Overview

Design with Nature

The method developed by McHarg required gathering data on a variety of social and natural resource themes. Each theme was individually mapped and ranked based on a graduated scale. Ranking was based on social values and reflected the usefulness of the processes represented by each theme to the continued health and well-being of the human species. Man's dependency on ecological systems was implicit for McHarg. A rating of one was awarded to areas that were least sensitive to disturbance, and the highest rating to areas most sensitive to disturbance. Areas in each zone were coded in grey-tones on the map. Those of greatest sensitivity were coded with the darkest grey-tone shading, while areas with the least susceptibility to damage by disturbance were shaded the lightest grey-

tone or left unshaded. Each of the resultant maps was photographed and converted to transparencies. These transparencies were then layered one upon the other to provide an integrated analysis of the sensitivity of the region under study. Areas accumulating the greatest density of shading were deemed most sensitive and therefore in greatest need of conservation and protection. Areas left clear or lightly shaded were, by default, the areas preferred for activities of disturbance (i.e., development-related activities such as roads, buildings, etc.).

More than thirty years later, the method developed by McHarg is acknowledged as the precursor to most modern day systems of land use analysis that require cumulative analysis of spatially located events. Over the last thirty years, what has changed more than the basic analysis method is the technology with which we can execute the methodology. No longer are hand-drawn maps required to be photographed and transferred to transparencies. Precise digital mapping technologies allow disparate sources of spatially located data to be combined and analyzed in a myriad of fashions. They allow tabular data to be associated with spatial elements and manipulated mathematically to simulate cause and effect relations. The rapid advance of geographic information systems (GIS) applications in spatial data storage and manipulation have brought a new era of efficiency and expanded opportunities to land use planning and resource management.

Geographic Information Systems

A GIS is a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information with data identified according to their locations.

The complete GIS also includes operating personnel and data. Maximum utility of any GIS requires careful design that closely involves its end-users (ESRI 1999). GIS technology can be used for a large variety of geo-referenced data management tasks including scientific investigations, resource management, and development and land use planning.

GIS is useful for relating information from different sources. Maps and other data are stored as layers of information in a GIS, which makes it possible to perform such complex analyses as data integration and mathematical modeling. For example, using maps of wetlands, slopes, streams, land use, and soils, a GIS might produce a new map layer or overlay that ranks the wetlands according to their relative sensitivity to disturbance. In this way GIS can be used for multicriteria analysis (Eastman 1998).

Logical (Boolean) operators can be utilized, and weighted values can be assigned and calculated. A GIS can also recognize and analyze the spatial relationships among mapped phenomena. Conditions of adjacency (what is next to what), containment (what is enclosed by what), and proximity (how close something is to something else) can all be determined with a GIS (USGS 1997). Even at a casual glance, it is readily apparent that GIS is a powerful technological tool for data analysis in natural resources planning.

There are many commercially available GIS software programs for viewing geographic data. These programs provide the user the ability to view maps, to manipulate existing data, to create new data through statistical and mathematical analysis, and to generate corresponding maps. Individual GIS systems are built or manipulated according to the desired output data. As noted previously, it is up to the end-users and designers to provide or develop a methodology to determine precisely how the data is to be analyzed.

Unfortunately, many of these systems are not compatible with one another. The same holds true for differently formatted data. These problems must be resolved in the future if we are to maximize the utility of available geo-referenced data and unleash the full potential of GIS.

Overview of Methods of Analysis

Most modern methods of analysis can be placed into a simple matrix of types according to the scope of analysis in time and space and the level of detail and complexity (Table 1)¹. There are two basic distinctions between the methods that this table serves to clarify. The first is the scope of the analysis in level of detail. This is represented in the difference between comprehensive and focused analysis. The second is the scope of analysis in time. The time-dependent aspect of analysis breaks into two sub-groups based on the intended scope of the analysis. Is the analysis intended to demonstrate existing or historical conditions? Are we conducting the analysis to make logical inferences or are we attempting to make statistical predictions? A look at existing conditions provides a static

¹All maps and tables are found in the appendices.

analysis. Only the most recent data is needed for such an analysis. Trend analysis is time-dependent; data must be used that represents change over time. In the predictive models, on the other hand, we have both time dependent and static analysis. Time-dependent predictive models extend trends and relations into the future in order to predict an outcome based on occurrences of particular impacts or based on the continuation of the status quo or on various other inputs. Static predictive models extrapolate the likelihood, and spatial location of specific activities or relations of interest. These predictive models do not rely on change as a predicate for prediction, but rather on favorable conditions based on known occurrences of similar events. A static predictive model may aggregate data in an attempt to understand or demonstrate relationships based on logical assumptions. Of course this is a simplified matrix, and existing models cover a full range of varieties within the matrix. This matrix serves as a starting-point to understand some basic distinctions between differing types of GIS analysis methods being used in land use planning.

Comprehensive versus focused analysis

Analysis and inventorying can usefully be divided into two general categories: comprehensive and focused (Sargent 1991). The comprehensive planning approach promoted in urban planning (Kaiser 1995) theoretically gathers all relevant data regarding the area of study for publication in its own right, then, proceeds to the task of analysis and definition of problems. The database produced in such a planning effort can be drawn upon to answer most questions that may arise regarding the area of study. An exhaustive

gathering of data is often useful in ways not initially foreseen. Generally speaking, the more data the more comprehensive the analysis. Truly comprehensive planning methods are important and useful, but for many applications are often not practical due to time, technology and data constraints. Nor are they sometimes even necessary, due to the specific nature of the issues being addressed (Starfield 1988). Comprehensive inventory techniques are important for our methods. We want to be aware of as large a context as possible when addressing natural resource issues, even if we cannot integrate as much information into our analysis as we might prefer. When more comprehensive planning methods are called for, the compilation of data is often assembled categorically and then recalled in any number of varieties of combinations for analysis. One useful feature of GIS is its the ability to incorporate geo-referenced tabular data that is useful elaboration, but might be confusing if it were all present on a visual map. These data can be easily accessed by the user, and can also be referenced internally to the system for computational analysis.

Focused planning methods are generally used when there are constraints such as time, resources, or limited data but may also be called on to address a very specific issue. In a focused analysis the subject of study more specifically influences the type of data gathered and the method by which it is analyzed. This method is generally employed in situations where the hypothesis being tested or the phenomenon being studied is sufficiently narrowly defined to permit the analysis to be tailored exactly to the task at hand. An example of such a situation would be an analysis to study the effects of

clearcutting forestry practices on stream sedimentation. The exact location of historical churches in the area may be interesting, but probably is not terribly relevant. Limitations such as the availability of data may also be a problem. This problem is magnified by the caveats of each data set and inconsistencies in temporal and spacial resolution. One must be cautious in designing analysis to fit existing data and in recognizing the limitations of such an approach. Yet data collection can be both costly and time consuming, and sometimes, studying available data while recognizing the limitations of the results is more beneficial than not doing a study at all (Berry 1999).

Static system analysis versus active system analysis

Another distinction to be made regarding methods of analysis is that between the types of systems being studied according to their relation to time. This is a simple, but important distinction. Is the analysis of a given condition at a discrete time t , or is it time-dependent, i.e., requiring comparison of measures gathered at various times $t_1, t_2, t_3, \dots$ Static analysis can give us a snapshot of existing conditions and relations. For an active-system analysis, however, a change in data must be measured to gain understanding of dynamic relationships. Analysis of dynamic systems is generally more meaningful if it involves a study of change over time. This information can then be statistically analyzed to create formulae for projections. This type of analysis is used to create predictive models. One limitation of GIS, is that due to the relative newness of the technology, often historical data simply does not exist.

Applied Analysis Methodologies Utilizing GIS Technology

The following is a brief review of the methods of natural resource and land use planning analysis shown in the Applied Methodologies Matrix.

SAA

The Southern Appalachian Assessment (SAA), conducted by the Southern Appalachian Man and the Biosphere (SAMAB), is an excellent example of a regional comprehensive analysis. The SAA was compiled by a broad group of local, state, and federal agencies. The mission of SAMAB was to gather, generate and compile as much data as possible regarding the Southern Appalachian region, to analyze the data thoroughly, and to identify gaps in data that need to be filled. SAMAB sought to bring the best available knowledge about the land, air, water, and people together to provide a vision for a sustainable balance between biological diversity, economic uses, and cultural values (SAA 1996).

The method of analysis used by SAMAB began with dividing the data gathering and data development into four major resource groups: terrestrial, atmospheric, aquatic, and social/cultural/economic. Public meetings were held to solicit public concerns. The results of these meetings provided a framework for the scientific teams to conduct detailed analyses that addressed the identified concerns. Most information used in analysis came from existing sources. What made the SAA unique was the aggregation of such a broad range of information in GIS. The amassing of such a quantity of data helped

to assure a more comprehensive picture of the state of the region than previously had been available. SAMAB hoped to use the SAA to identify potentially serious problems *before* they threatened the well being of the natural resources of Southern Appalachia. Another reason that the SAA approach to analysis is particularly noteworthy is that it sought to focus on ecological rather than political boundaries. The final product of SAA was published in a five-part study with a companion set of all data used in the analysis on CD-Rom disks.

Gap Analysis (GAP)

The Gap Analysis approach to protection of biological diversity provides a quick overview of the distribution and conservation status of various indicators of biodiversity. Digital map overlays are used in a GIS to identify areas rich in species and vegetation variety, and to identify areas that may lack some unrepresented or underrepresented species. Gap Analysis seeks to identify gaps in the distribution and conservation of vegetation types and species that indicate fragmentation of ecosystems. It uses the distribution of actual vegetation types, mapped from satellite imagery, and vertebrate and butterfly species as well as other species, if data are available, as indicators of biodiversity and ecosystem integrity. Ecosystem gaps need to be identified so that they can be filled through conservation or other protective land management practices. Gap Analysis also organizes existing survey information to identify areas of high biodiversity that may need additional protection before they are further degraded. It functions as a preliminary step to the more detailed studies needed to establish actual boundaries for

potential biodiversity management areas. Gap Analysis is typically more useful than single-species methods of analysis for the identification of endangered habitats. This is largely because the Gap Analysis methodology uses a broad range of data and recognizes the interrelated nature of biological organization (Scott 1993).

Gap Analysis can be a useful first-step in a comprehensive land conservation planning program for any region. It provides baseline information of the amount and distribution of several components of biological diversity and of the relationship of those components to one another in the landscape. Gap Analysis provides a quick and efficient frame work for conservation-oriented land-use planning.

Resource Management Task Force (RMTF)

A Natural Resources Task Force was formed in Hamilton County, Tennessee, to provide information to the County's Coordinating Committee in support of compliance with Tennessee Public Chapter 1101. Their mission was to help in the development of local land use plans by identifying and quantifying sensitive natural and cultural resources. The Task Force held regularly scheduled meetings and invited a broad representation of interested parties to identified issues and gathered relevant data. The group worked closely with the Regional Planning Agency and utilized the Agency's GIS mapping technology and expertise in producing their assessment. The RMTF's primary products include resource maps that locate individual resource themes throughout the county, and an integrated map showing the relative categorization of the entire county to human

disturbance (Wood 1999). A sensitive area map was composed by overlaying the individual theme maps in a GIS. The map layers represented the following attributes: agriculturally used lands, forests, recreation areas, wildlife management areas, wetlands, floodplains, groundwater recharge, steep slopes, and historic and cultural sites. Each map layer was weighted according to resource values assigned by the task force. Weighting was based on the ability of the resource to perform certain socially beneficial functions. A list of the functions considered included wildlife habitat, recreation opportunity, floodwater control, filtering of pollutants, erosion reduction, conservation of agricultural lands and other areas required for consideration under law. Table 2 illustrates the weighting of themes according to utility.

This project is a typical example of an analytic method developed in response to a specific local issue. The data used for the analysis consisted of a combination of existing and some newly created data. Their method of analysis used overlays of the selected themes, providing a cumulatively integrated map of sensitive areas as a final product.

The Environmental Monitoring and Assessment Program EMAP

EMAP is a program developed by EPA's Office of Research and Development. EMAP was developed to monitor the condition of the Nation's ecological resources, to evaluate policies and programs, and to identify emerging environmental problems before they become widespread or irreversible.

The EMAP program was formed as a response to the understanding that "policies and programs that promote the preservation of ecosystem integrity and sustainable use of natural resources must be formulated from scientific knowledge of the environment." That knowledge is dependent on cooperation among programs at all levels of government. Unfortunately, "most state and local agencies do not have the information needed to manage meaningful environmental protection programs." The EMAP response to this situation is to help generate missing information in critical areas. The initial stage of EMAP's response is to find and fill the gap in knowledge of ecosystem functioning and human impacts on ecosystem functioning. Following an understanding of ecosystems, a framework is required to monitor important ecosystem characteristics and human actions that alter them. EMAP's mission is based on the hope that their effort to supply an "environmental report card" will help generate the social and political will to respond appropriately to their findings (U.S. EPA 1997).

The strategy for EMAP is based on three principles. The first is to create and establish a monitoring framework. The second, to focus on the research necessary to carry out the monitoring network. Third, build a national network from the bottom up, starting with effective existing networks and adding to them where needed. (U.S. EPA 1997).

EMAP strategy involves a four-tiered approach to environmental monitoring: (1) Use national landcover characterization based on remote sensing; (2) Locate data or generate estimates for important indicators of environmental condition; (3) Support more focused

studies of regions of special concern; and (4) Establish sites within the National Park system for intensive monitoring and research. EMAP's vision of holistic environmental monitoring and analysis is dependent on support from other federal agencies and with the cooperation of local agencies (U.S. EPA 1997).

EMAP's primary role in research is coordination. EMAP promotes research for the development of effective indicators, monitors local research designs to insure the compatibility of local research with regional analyses, and works toward the integration of different monitoring approaches to provide more complete answers to environmental management and regulation problems (U.S. EPA 1997). GIS provides the framework to bring the different local projects together into meaningful regional analysis.

As a whole, EMAP is a very comprehensive project in its scale. The individual projects at the local level that compose the heart of the EMAP strategy, however, are typically extremely focused. EMAP is an ambitious project that shows the potentials of GIS applications to integrate a wide range of information. As more comprehensive data bases are developed, methods of analysis are standardized and systematic updating procedures are established, the capabilities and opportunities for application of GIS such as those being explored by EMAP will increase.

Landsat and The North American Landscape Characterization (NALC)

NALC Project is a component of the National Aeronautics and Space Administration (NASA) Landsat Pathfinder Program. Pathfinder projects focus on the investigation of global change using remote sensing technologies. Landsat satellites have been collecting images of the Earth's land surface since 1972 (See Table 3 for dates and resolution of the seven satellites). The resultant data archive has played an important role in many disciplines. The Landsat imagery is very useful to further our understanding of the Earth's land surfaces and human impact on the environment.

The Landsat 7 system, launched in April of 1999, has the highest resolution of any of the Landsat satellites. It provides the capability to monitor important small-scale processes on a global scale, such as the cycles of vegetation growth; deforestation; agricultural land use; erosion and other forms of land degradation; snow accumulation and melt and the associated freshwater reservoir replenishment; and urbanization (USGS 1997).

Landsat data are used for a variety of studies, inventories, and analyses (Table 4). Some areas of application include crop acreage inventories, timber class identifications, soil association identification and mapping, range cover and forage production analysis, plant stress detection, regional land use classifications, photo-map generation, mineral and petroleum exploration, pollution monitoring, geological mapping and interpretation, areal snow extent assessments, sea ice movement monitoring, vegetation classification and

mapping, surface mining operations monitoring, flood/forest fire monitoring, and beach erosion detection (USGS, March 1999).

NALC is a collaborative effort between the EPA and the U.S. Geological Survey (USGS) that compiles Landsat imagery for the purposes of mapping land cover and documenting land cover change over time. This project is focused in purpose and ambitious in scope. The goal of the NALC project is to produce standardized digital data sets for the U.S. and Mexico. The project will develop standard data analysis methods to inventory land cover, quantify land cover change analyses, and produce digital data products in support of research programs. Changes in land cover over time is an important area of study. NALC provides spatial data to help in understanding the change in natural processes and the influences of human activities on ecological conditions. NALC acquires Landsat images with low cloud cover and assembles them to create overlapping triplicate data sets from 1973, 1986, and 1991. These triplicate scenes are georeferenced to a 60 x 60 meter coordinate grid and then used to generate land use and land cover categorizations. Each triplicate scene thus shows land use and land cover changes in three images over an eighteen-year period. NALC archives and distributes the image data and metadata to researchers and conducts ongoing research on related technical issues such as image categorization, change detection, and landscape indicators using the NALC data sets. NALC data are distributed on 8mm magnetic tape and CD-ROM. Data may also be ordered via the Internet (U.S. EPA 1993). The NALC triplicate data sets are available

from the USGS's Earth Resources Observation Systems (EROS) Data Center on the Internet at <http://edc.usgs.gov/landdaac/>.

The Metropolitan Landscape Planning Model (METLAND)

(METLAND) is a comprehensive approach to regional land use planning that has been developed since the 1970's by an interdisciplinary research team at the University of Massachusetts. It is designed to show the potential cause effect relationships of alternative land uses on various landscape, ecological and public service resources of prime concern in landscape planning.

METLAND research was in response to the incremental conversion of rural land that characterizes the growth of today's metropolises. The costs, negative effects and uncertainties generated by such processes are increasingly evident. To overcome these problems, it is essential that decision-makers understand the costs and benefits implicit in their land use decisions. The METLAND landscape planning process is an attempt to aid decision makers to overcome such problems by providing pertinent information about the landscape areas in which changes occur.

The philosophical notion underlying the METLAND vision of landscape planning is that land, like air and water, is essentially a public good whose efficient use is beneficial to all citizens. The benefits gained by resource conservation, developing land best suited for

development, and the costs avoided by restricting the development of poor or hazardous land, accrue to the population at large.

With efficient and equitable land use as its goal, landscape planning depends on valid knowledge about the functioning of landscape resources and hazards, and on the utilization of the tools available for interpreting that knowledge for planning purposes. In both of these areas, there has been a significant improvement in the state-of-the-art in recent years. These developments have made possible the effort to systematize landscape planning that the METLAND research represents. The rapid advance of computer applications in spatial data storage and manipulation have brought a new era of efficiency and opportunities to land use planning and resource management.

The primary procedures of METLAND respond to five basic landscape planning principles that have been formulated by the past research teams: (1) development should be discouraged in areas that are characterized by significant resource values; (2) development should also be discouraged in areas subject to natural or human hazards; (3) development should be encouraged in the areas best physically suited for it; (4) the ecological "carrying capacity" of a regional environment should not be exceeded; and (5) development should be guided to areas where public services are available at the highest quality and the least cost to the community (METLAND 1995).

Of the predictive models reviewed, the METLAND project model is one of the most comprehensive in scope. METLAND projects began with general landscape planning and

evaluation projects in Massachusetts. The original model required the work of forty people for seven years and cost hundreds of thousands of dollars. It is noted by early users of METLAND, however, that the data required to realize the full potential of this model are not available, and much "soft data" has been entered to run simulations. This practice leads to questions of the reliability of some results (Westman 1988). Again, we see that availability of data is a significant limiting factor in modeling and analysis. Further, what data was available often did not index well between sources, resulting in fuzzy and ill-defined boundaries and borders. Many ecological and social criteria that would be required according to the philosophical framework are not included in the model. Another problem of the METLAND model is the use of a monetary value for the computational standard—some processes and criteria are simply not appropriate to monetarize. So, although the beauty of the METLAND model lies in its complexity, so do many of its shortcomings. Early METLAND presented a rich picture of the subject area, but a more focused analysis, based on well-selected data, may provide more accurate results for more focused analysis.

More focused analysis is precisely where the METLAND model found its later application. Researchers took advantage of newer PC technology and powerful off-the-shelf software to apply the METLAND philosophy to a broad range of issues. Titles of more recent METLAND projects include "Evaluation of Landscape Plan Alternatives" (1987); "River Corridors: Present Opportunities for Computer Aided Landscape Planning" (1991); "Landscape Planning for Watershed Protection" (1992); "Septic

System Suitability Assessment for Rural Communities” (1992); “Suitability Assessment of Land Zoned for Industrial Use” (1993); and “A Management Plan to Balance Cultural and Natural Resources” (1993). The most recent analyses are ARC/INFO based and therefore require much less information system development than earlier METLAND projects (METLAND 1995).

LUCAS

The Land-Use Change Analysis System for Evaluating Landscape Management Decisions (LUCAS) was developed to study the effects of land use on landscape structure in regions such as the Little Tennessee River basin in western North Carolina and the Olympic Peninsula of Washington state. The map layers used by LUCAS are derived from remotely-sensed images, census and ownership maps, topographical maps, and outputs from econometric models. These map layers are stored, displayed, and analyzed using a public-domain Geographic Information System called GRASS. Simulations using LUCAS generate maps of land cover representing land-cover change. These maps are then used so that issues such as biodiversity conservation, assessing the importance of landscape elements to meet conservation goals, and long-term landscape integrity can be addressed. (Berry et al. 1995)

LUCAS is an integrated model that examines the impact of human activities on environmental and natural resource sustainability. The premise of the model is that landscape properties such as fragmentation, connectivity, spatial dynamics, and

dominance of habitat types are influenced by market processes, human institutions, landowner knowledge, and ecological processes. Therefore, modeling environmental sustainability of landscapes will benefit from the integration of human and ecological processes.

The structure adopted for LUCAS consists of three subject modules. The first LUCAS module contains the socioeconomic models used to compute probabilities of transition associated with changes in land cover. These probabilities are computed based on socioeconomic variables including (1) transportation networks (access and transportation costs); (2) slope and elevation (indicators of land-use potential); (3) ownership (land holder characteristics); (4) land cover (vegetation); and (5) population density.

Preliminary analysis of the Little Tennessee River Basin revealed that land-cover change is most likely to occur on private land, near a paved road, on flat low-elevation land, and close to the major urban center of the watershed (Berry et al. 1996).

Conversations with Dr. Mike Berry at UT Department of Computer Science, a key member of the LUCAS development team, confirmed that building computer models for analysis of natural processes is a very situation-specific task (1999). According to Dr. Berry the framework for LUCAS could be adapted for another application. The model itself (for LUCAS and other similar programs for environmental analysis) is built around the data and conditions for a specific location and thus is not directly transferrable. Data collection alone for LUCAS required three years. Dr. Berry suggested that for an analysis

program to be developed in a timely manner one should look to existing data bases for support and build the model around the available data.

Environmental Vulnerability Index (EVI)

EVI is risk assessment analysis developed by South Pacific Applied Geoscience Commission (SOPAC) in response to concerns regarding the vulnerability of small island developing states. This method of analysis is used to compare the relative vulnerability among regions, based on the risk of disturbance of natural systems. For this, EVI uses a single-digit index. Following is an overview of the theory behind EVI and the methodology used in its execution, paraphrased from the Executive Summary to "SOPAC Technical Report Number 275" by Ursula Kaly, et al., 1999.

Human systems and the environment are mutually dependent. Risks to the environment of a state will eventually translate into risks to humans because of their dependence on the natural environment for resources. In turn, the environment is susceptible to both natural events and appropriate management by humans. This means that estimation of the overall vulnerability of a state should include measures of both human and natural systems and the risks that affect them. Such a 'Composite Vulnerability Index' (CVI) was proposed to the United Nations by the Maltese Ambassador in 1990. The development of an Environmental Vulnerability Index (EVI) is an important step toward development of the CVI.

EVI analysis focuses on the vulnerability of the environment itself to both human and natural hazards. It includes effects on the physical and biological aspects of ecosystems, diversity, populations or organisms, communities and species. Long range plans for use of the EVI involve combining it with an economic vulnerability index to produce a composite index. This composite index will be a single figure that represents the environmental and economic concerns of a state. It is planned that the EVI and CVI would be recalculated every five years to examine changes through time and to rank the relative vulnerability of countries.

SOPAC developed the EVI for analysis of Pacific Small Island Developing States. The stated aims of the program included development of a logical framework and method of calculating an index for environmental vulnerability; identification and collection of data that would be used to calculate the environmental index; identification of gaps in the available data; and identification of future needs for the further development of an internationally acceptable environmental vulnerability index. It was determined that there has been no true measure of environmental vulnerability in past studies of this type. Previous studies on the subject had actually looked at the vulnerability of human systems to natural disasters, rather than at the vulnerability of the environment itself.

Ecosystem management—the maintenance of ecosystem or ecological integrity—is at the heart of the development of a vulnerability index for the environment. Ecosystem integrity is a sensitive balance commonly threatened by both natural and anthropogenic

hazards. The theory behind EVI includes the notion that ecosystem integrity is so complex that it cannot be expressed through a single indicator. Therefore, a useful EVI requires the composition of a set of indicators at different spatial, temporal and hierarchical levels of the ecosystem. Any events or processes that can cause damage to ecosystem integrity are considered as risks to the environment. These include natural and human events and processes such as 'the weather' and 'pollution'. The EVI methodology incorporates risk events that cause sudden and seemingly-negative impacts on natural systems as a way to evaluate vulnerability. Ecosystem integrity depends on biodiversity, ecosystem functioning and resilience, all of which are such interrelated variables. Factors that effect just one of these can have extensive ecosystem-wide consequences.

Although most identifiable risk events can cause damage, it is only the larger and more intense events that are likely to cause wholesale changes in the environment, at least in a short to mid-ranged time frame. Some of the more important risks that can have an impact on the environment include meteorological events such as cyclones, droughts, and heatwaves; geological events such as earthquakes, tsunamis, and volcanos; anthropogenic impacts such as mining, habitat destruction, and pollution; climate change; and sealevel rise.

Three aspects of environmental vulnerability were identified that would need to be incorporated into an EVI. These are the REI, IRI, and EDI. The Risk Exposure sub-Index (REI) examines the frequency and the intensity of risk events that may affect the

environment. These are based primarily on observations over the past 5-10 years, but for geological events may include data covering much longer periods. The REI is a measure of *potential* risk. The Intrinsic Resilience sub-Index (IRI) refers to characteristics of a country that would tend to make it more or less able to cope with natural and anthropogenic hazards. The IRI is a measure of *resiliency*. The Environmental Degradation sub-Index (EDI) describes the ecological integrity or level of degradation of ecosystems. The more degraded an ecosystem is, the more vulnerable it is likely to be to future risks. The EVI itself is a composite of these three sub-indices.

Because there are so many risks, and ecosystem resilience and integrity are complex in character, SOPAC decided that it is necessary to use indicators to characterize them. This means that not all aspects of risk and vulnerability are covered, but that a subset of variables is selected that best characterize environmental risks and vulnerability. The criteria for the selection of indicators chosen by SOPAC were that they should be applicable over the entire region of analysis, remain relevant in differing ecosystems, be relatively easy to understand, be well defined, have data available, and be as unrelated as possible (to limit redundancy).

A total of 57 indicators of environmental vulnerability were selected for inclusion in the index. This included 39 indicators of risk (REI), five indicators of resilience (IRI) and 13 indicators of environmental integrity or degradation (EDI). These indicators are listed in Appendix B. Many indicators were expressed as a fraction of area of land or coast rather

than simply absolute numbers because it is density or proportion of disturbance that is of interest from an environmental perspective.

Larger numbers of indicators provide a more accurate picture of risks, resilience and ecological integrity. More indicators were chosen than were finally used. Many indicators were discarded because there were either no data available and data were unlikely to be generated in the near future, or the information they represented was present in another indicator.

Data for calculating the EVI were collected for three countries (Fiji, Tuvalu and Australia) to provide initial testing of the model. These data were obtained from country reports, publications from international agencies, centers for risk assessment and management, local experts and government officers. Due to the inability of researchers to travel to the countries to train local researchers in the task of collecting or compiling the required data, some indicators were unavailable for the initial testing.

An overriding principle in constructing the EVI was to avoid introduction of unnecessary complexities into the model. Variables were mapped onto a 0-7 scale where 1-7 was used for the range of values and 0 or N was used for 'non-applicable' and 'no-data' responses. Measures of the indicators were set wherever possible using technical literature or consulting with experts. When other sources were unavailable, estimates were used.

Six of the 57 indicators were assigned an intrinsic weighting factor of five, while the remaining indicators were given the default weighting of one. This gave each of the six weighted indicators the equivalent value of five indicators. Weighting was applied to indicators considered most critical to measuring ecosystem vulnerability. The EVI and sub-indices were calculated using Microsoft's EXCEL.

A method for assessing the reliability of data was built into the EVI through the use of metadata. The metadata was reported alongside each index and was designed to be used with the EVI to reduce inaccurate readings of the results. The metadata includes the number of non-applicable indicators, the number with no data, the number of responses that were based on real data, and the number of responses based on 'best guess' or estimated by the operator and/or authorities.

One strength of the EVI is that it is based on a comprehensive theoretical framework that prompts researchers to find indicators for all identified aspects of vulnerability. Further, it is designed to incorporate quantitative and qualitative data on different response scales and identifies two types of vulnerability (Net and Gross) simultaneously. This allows for a worldwide comparison of states and for assessment of the real risks likely to affect individual states. It also identifies areas in which local environmental agencies could improve data collection. Although the initial application of EVI focuses on Oceania, it is universally transferrable by the identification and incorporation of appropriate indicators.

A major weakness of the EVI is that the index does not exclusively rely on published data. This results in omissions and a high cost of data collection. Another weakness is that there is some subjectivity in assigning weights to indicators. The mapping of data on a 7-point scale may result in a loss of detail compared with directly using numerical data. The EVI is also affected by the indicators chosen, and the results obtained may differ if different variables were chosen. All local variations, short and long term effects and other details cannot be incorporated into the model without making it too complex.

SOPAC analysis of the project determined that the environmental vulnerability index will require further refinement before it becomes fully operational. Their application of EVI shows that a great deal of the data previously thought to be difficult to obtain can be obtained. The methodology selected in the computation of the index can produce results that could be useful for ranking countries according to their environmental vulnerabilities. It would be particularly useful if the EVI was recalculated every five years to provide updates on the vulnerability status of countries and to identify trends. The index highlights the need for governments to upgrade their collection and collation of environmental statistics. In addition, the breakdown of results into meteorological, geological, anthropogenic, and other categories of risk highlights areas of concern for environmental action (Kaly 1999).

Further Discussion

Staff from four U.S. federal agencies were given a list of methods for analysis of natural resources and asked to indicate their use within the agency (Wathern 1988). The results show that the traditional techniques such as overlay mapping and habitat evaluation are used more often than predictive modeling. Almost one-third of the responses fell into the "other" category, showing that agencies often rely on their own approaches rather than existing techniques. This study is now 10 years old, and GIS has since grown much more user-friendly and is being applied in an increasing number of situations. Nevertheless, the conclusions reached then reflect the findings of this literature review. Due to the specificity of most natural resource analysis projects and the limited availability of standardized data, most analyses are conducted using methodologies constructed specifically, at least in detail if not in theory, for a singular application. GIS, descended in part directly from McHargian overlay techniques, has become an almost universal tool. In the future, it is hoped, digital data collected by different agencies will be more compatible. The Federal Geographic Data Committee is working to coordinate standards for spatial data through the development of the National Spatial Data Infrastructure (NSDI). The NSDI promotes policies, standards, and procedures for organizations to produce and share geographic data cooperatively (FGDC 1999).

Chapter Two:

Methods of Analysis

A Background of Planning Inventories and Natural Resources Themes

Comprehensive and Focused Inventories

As noted in the last chapter, there are two general categories of approaches to inventorying: comprehensive and focused (Sargent 1991). The comprehensive planning approach directs the planner to gather all relevant data for analysis. Results of analysis determine the direction of further study and planning. The database produced in such a planning effort can be maintained with regular updates to remain useful to ongoing analysis. Truly comprehensive planning methods such as this are important and useful, but not always practical. It is for purposes of brevity and manageability that we will exclude consideration for use of such an inventory for this methodology. A comprehensive perspective, however, is important for a focused inventory. We want to be aware of as large a context as possible when addressing natural resource issues, even if we cannot obtain all of the data or integrate such a vast range of information into our analysis. Sometimes, the context of a county is not sufficient for proper analysis; GAP analysis, to be effective, should regard an entire ecological region or regions.

In their seminal text, *Site Planning*, Kevin Lynch and Gary Hack compile a list of indicators important for site analysis that is predominantly analysis of natural resources at

the scale of an individual potential development project. Their list from *Site Planning*, appendix G is found in Appendix C of this thesis. Lynch and Hack's analytical framework is useful as a background to an actual analysis. The issues raised in their framework should prompt the planner to consider a broad context in conducting her analysis. A broad perspective serves to alert the planner to circumstances that may be relevant to a focused analysis.

General context issues for site analysis include many concerns such as geographic location, adjacent land use patterns, access systems, nearby destinations and facilities, and stability or change in development patterns. Other general context issues include political jurisdictions, social structures, population characteristics, ecological systems of the region, hydrographic systems of the region, and the nature of the area's economic structure. Sometimes, broad economic or social issues can have a tremendous impact on the conclusions of an analysis that cannot be foreseen from the particular data.

Lynch and Hack divide the physical data of a site and adjacent land into soils, water, climate, ecology, man-made structures, and something they call "sense qualities." Soils data includes underlying geology, soil type and depth, the value of soils as plant medium and as engineering material, areas of fill, and the presence of hazardous chemicals or contaminants. They also include ledges, liability of ground to slides or subsidence, and the usefulness of land for mining activity.

As stated previously, we are interested in a sufficiently efficient analysis that it can be conducted with respectable accuracy on a small budget. Therefore, we are interested in an inventory that is more focused than the one outlined by Lynch and Hack for conducting our natural resources analysis. Before proceeding with an analysis, compiling a listing of indicators used to represent the sensitivity of land and sustainability of land uses is necessary. Having determined appropriate indicators, the next logical step is to develop an analytic framework. In the next chapter, the list of indicators will be compared with available data sources for availability, compatibility, and reliability.

Focused Environmental Inventory

Experts in the field of environmental land use planning provide a less detailed set of factors for consideration in conducting analysis of natural resources. The factors listed below are commonly acknowledged as basic environmental land use planning criteria. They distill the full spectrum of relevant information into concise and manageable categories of critical elements: land, water, air, and habitats (Kaiser 1995). The next task then is to decide the particular elements from each of these four categories that will adequately represent sensitive aspects of natural resources. These must be elements for which data are available.

Fragmentation of environmental management can result from a focus on one element to the exclusion of others and from the failure to recognize interdependent relations. Avoidance of this problem requires that the planner consider as many themes as can be

accurately and reasonably represented. The following list of themes for data collection was created by comparison and compilation of natural resource analysis techniques described by Kaiser, (1995), McHarg (1969), Sargent (1991), and Wood (1999). Land resources data desirable for consideration in our analysis include soil types, geological features, topography, land cover, and areas characterized by toxic wastes. Hydrological data desirable for inclusion include areas of surface waters, underground aquifers and water recharge areas, floodplains, wetlands, and water quality measures, including concentration of pollutants in water systems and point sources of pollution. General air quality and concentrations and sources of airborne pollutants require consideration in the analysis. Habitat locations for humans, other animals, and threatened and endangered species are also important and should be included in the analysis to the extent that data are available. An integrative GIS-based analysis can show which areas are best suited for increasing human populations, and which areas are better suited for conservation of plant and animal habitats.

Some important development and environment interactions we should consider in our analysis include the following areas of concerns:

1. Areas of highly erodible soil: Maintenance of a maximum amount of vegetation cover on steep slopes will reduce disturbances associated with erosion and slope failure. Erosion is a significant cause for loss of topsoil, for diminished water quality, and for the ability of waterways to support aquatic life (NRCS 1992).

2. Prime agriculture land and topsoil: Preservation of land for agriculture should be encouraged. Prime agricultural soils in use for agriculture should be identified and methods for encouraging continuation of agriculture should be considered. Acceptable soil conservation practices should always be employed on all lands where the ground cover is disturbed. Activities that disturb the vegetative groundcover include agriculture, development, and timber harvesting (NRCS 1992).
3. Surface water sources and natural drainage and recharge systems: The functions that forests serve for rainwater filtration and diffusion should be protected. Protection of riparian zones and wetlands for habitat and water filtration should be enforced. Impervious surfaces increase contamination and quantities of stormwater runoff. Surface waters should also be monitored for other point and non-point pollution sources. Floodplains are important for temporary rainwater storage and recharge (Center for Watershed Protection 1998).
4. Air quality: Toxic releases of industry and automobiles should be monitored (Kaiser 1995). This dimension is linked directly to land use, and has strong correlation to human health threats.
5. Habitat protection and restoration: Prime wildlife habitat often coincides with other fragile resources such as wetlands, streams, riparian zones, and forested slopes. Other concerns for habitat protection include the presence of corridors of connectivity between larger habitat areas, creation of conservation areas and restoration of degraded landscapes. Provision of adequate habitat size and

configuration is important for genetic diversity and species sustainability (Peine 1999).

6. Sense of place: Public places and places associated with cultural identity are important. People need an appropriate habitat just as much as plants and other animals. We need access to green space and recreational corridors and access to naturally functioning ecosystems. Open spaces, developed areas, and naturally forested lands are all important to the diversity of land-uses which are necessary for a healthy and resilient ecosystem (Kaplan 1998).

Methodology

The purpose and limitations of the classification and evaluation system should be understood from the start. It is a rating system for land use *planning* purposes. As such, it is a *tool* for planning, not a rigid model for zoning. The information gained from this analysis will be at a scale useful for understanding the issues that need to be dealt with and the context of land use in the county. It is possible that the results alone will not contain sufficient detail for establishing policy. They will, however, certainly inform the policy-making process. Visual confirmation and ground truthing of results are important. As will be shown in the next chapter, this analysis does not require the generation of new data. It will be based on the best available data which will be used to generate a new form of *information*. This thesis will show how to objectively describe the cumulative level of sensitivity of natural resources to human impacts. Only one element recommended in this

method *requires* subjective input. The “sense of place” theme requires that inhabitants and users of the land express their opinions and preferences.

This methodology has been developed utilizing off-the-shelf GIS software (ESRI’s ArcView) in a way that requires a minimum amount of technical expertise. It is not exhaustive in scope or in detail, nor is it steeped in complexity. Simplicity is one of its assets. The methodology is constructed to provide a quick and focused perspective of natural resources conditions of a county under study. Budgetary constraints will be assumed to be high. The model will encompass enough data, thoughtfully integrated, to be helpful in providing guidance for general land use planning purposes.

Goal

As noted in the Introduction, the goal of this thesis is to provide a method for county level analysis of natural resource appropriate for land use planning, including determining growth boundaries and conservation areas in Tennessee. Our goal is the same as that of the Hamilton County Task Force. The difference between their methodology and ours is in the availability of data. Hamilton County has a GIS staff, and an ongoing GIS mapping program. Some data used in their analysis were created specifically for growth planning under Public Chapter 1101. That data could not have been created without a high level of technical resources. We are going to assume a limited budget, staff, and technical resources, and seek to create a similar analysis using existing GIS data from a variety of sources.

Objective

The primary objective of the methodology is to identify areas of sensitive natural resources and to rank areas of sensitivity based on a cumulative valuation. The secondary objectives of this methodology are as follows: to use existing data sources, to be implementable with readily available computer software and minimum technical training, and to integrate ecological, social and economic values.

Purpose

The purpose is to show the relative level of sensitivity of natural resources. It will indicate areas appropriate for conservation or protective measures. Conversely, the methodology will also identify areas that are appropriate for development-related activities. These areas should receive careful attention regarding their availability for development. Sensitivity of the natural resources under study will be expressed as a gradient range based on the smallest available level of resolution. This information can also be combined with data representing urbanization and human impact on the landscape to indicate areas that may be under pressure for near-future development. Areas identified as high-risk can then be given priority for mitigation or conservation.

Scope

The primary level of analysis for this project is the county. The methodology is applicable to any location where sufficient data are available. Sevier County will be the county used as a case study for the demonstration of the methodology.

General Method of Analysis

The method used for analysis will be as follows: 1) to define indicators representing natural resource themes; 2) to associate these themes with digitized data according to available data sources; 3) to consider weighting each theme (according to public input, or ecological, social, and economic utility); and 4) to combine the values of the chosen themes to create levels of sensitivity rating. The rating will be expressed as integer value and the indicated level of sensitivity will increase with its distance from zero. The sensitivity ratings will be associated with appropriate locations that, when viewed on a county base map, will show the specific areas of natural resource sensitivity in the county and their relative level of sensitivity. Natural resources will also be shown in relation to developed areas, existing infrastructure, and known pollution sources to develop a comprehensive natural resource analysis of the county.

Criteria

Criteria for analysis will be of two kinds: factors and constraints. A factor is a criterion (theme) that enhances or detracts from site sensitivity. Factors are cumulative and add or detract from ratings, while constraint serves to limit areas absolutely. Constraints are expressed in Boolean terms—appropriate OR inappropriate. They either exclude or include areas available for development accordingly, independent of other factors. A National Park would be a good example of an absolute constraint. Table 5 shows a matrix listing the primary themes considered in this analysis of natural resources (Kaiser 1995; Sargent 1991; Lynch 1984; Wood 1999).

Rational of Methodology

The ratings achieved by this method are relative. If our valuation is properly balanced, then it is expected that areas of land suitable for development and areas appropriate for conservation measures are logically distinguished. If one area is rated lower than another, it does not mean that the area is not sensitive or should not be protected. It means that there are not as many sensitive themes in that area. Habitat GAP analysis may reveal areas that are rated low, yet still provide critical linkages for contiguous wildlife corridors.

Besides this analysis, specific policies and performance controls should be used to decide the appropriateness of individual land use proposals and to mediate the impacts of human activity on the landscape. This methodology is designed to help communities to decide the location of areas most sensitive to disturbance based on ecological factors. It will help communities to determine where to act *first* for land protection and conservation measures and where to encourage growth and development. This information is critical for placement of appropriate growth boundaries as required under Tennessee Public Chapter 1101.

The model that was chosen for this methodology is adapted from that used by the Citizens Task Force on Natural Resources in Hamilton County, Tennessee—which includes the city of Chattanooga. The Task Force was assembled to gather and analyze data and to provide information to the Coordinating Committee. Discreet-theme mapping and

weighted McHargian-style overlays were used by the Task Force to develop their analysis of natural resources in Hamilton County. Their analysis was intended to be used by the Coordinating Committee in developing the growth boundaries required under Tennessee Public Chapter 1101².

Methodology

The first stage of this analysis is to identify the natural resource themes to be used in the analysis and to learn the spatial location of those themes. A list of natural resource themes will be compiled by consideration of the factors noted above and by the availability of data. Appropriate data will be gathered by researching the most current and most accurate existing GIS data sources. Data used for this thesis must be formatted for use on an ArcView-based GIS mapping and analysis system.

Some data required for this analysis are not scientific in nature. Where subjective data are required, local residents and primary users of areas should be consulted. Table 2 shows how analysis could be weighted based on ecological, social, and economic values.

Themes can just as easily be weighted using public input to decide the values used in a cumulatively integrated analysis. The incorporation of local values helps insure public ownership of the ensuing evaluation. Methods for incorporating public concerns and

²Note: In spite of the work done by the Task Force, resource protection was not even mentioned in the growth plan presented by Hamilton County at the required public hearing held on October 7, 1999.

preferences are included in Appendix D. Public input will not be sought for this thesis due to time and budgetary constraints. A list of desired data themes follows.

Ecological themes include forested lands and hydrological processes, represented by streams, recharge areas, wetlands, and floodplains (where data are available). Slope constraints will be categorized incrementally: 10-15% slope, 16-20%, and greater than 20% slope. Regional habitat GAP analysis would be included as an indicator of habitat fragmentation and overall habitat availability were that information available. GAP data will be discussed in chapter three.

Social themes are represented by areas identified as socially or culturally significant such as sites on the National Historic Register. Unique geological areas that provide a sense of place, including gorges, waterfalls, and scenic vistas should receive special protection. National, state, and local parks; lands held in trust; and wildlife management areas should be considered as absolute constraints and therefore off limits to development.

Prime agricultural lands should receive special consideration. Location, quantity, and importance to the economy should all be considered in determining the level of protection appropriate for agricultural lands. Commercial timber harvest areas and mineral extraction areas should be included in the inventory in a manner consistent with their level of social, economic and environmental impacts. Their status in the analysis should be determined according to context.

Areas of significant existing human impact are the counterparts to the natural resource themes. These are areas that show high level of disturbance. For the purposes of this analysis, disturbance is any alteration of natural systems or landscape. Such areas should be interpreted according to context. They may be areas indicative of urbanization and appropriate for further intensity of use, or they may be degraded areas with impaired natural function where remediation of some type is required. Examples of degraded areas include known point sources of pollution and areas characterized by toxic contamination. The above themes should be used to create a variety of output maps. Independent categories of themes such as land use and land cover, hydrological themes including riparian zone coverage, and pollution sources may be useful in their own right, independent of a cumulative analysis.

A simple overlay color-coded map showing unweighted resource relationships is useful for perspective of relationship of all of the themes. The following color scheme will be employed.

- Surface water: blue
- Wetlands: light blue
- Forest: green
- Cropland: tan
- Pasture: pale green
- Prime agricultural soils: brown crosshatch

- Slopes: shades of orange
- Known point pollution sources: pink
- Roads: black
- Developed areas: red

An integrated value map shows gradient tones incorporating all values to give a cumulative level of sensitivity analysis. The Hamilton County Task Force's method of analysis was to divide the cumulative sensitivity values into five categories of sensitivity and to map accordingly. The levels of sensitivity used in the Hamilton County, Tennessee, analysis include five zones: Zone I is an area of absolute exclusion from development. Zone II is the "Most Sensitive Areas" designation. These were areas they decided should be protected, but may not be under any current protection. Zone III is designated as "Areas of Some Sensitivity." These areas require approval for conditional, limited development. Zone IV is "Areas of Moderate Sensitivity." Normal restrictions apply, and best management and stewardship practices should be employed in zone IV. Zone V is the "Least Sensitive Areas," the preferred areas for development. Appropriate stewardship practices and principles should be employed for land use decisions in any zone.

The analysis in this thesis will not provide descriptive designation for the levels of sensitivity as was done by the Hamilton County Task Force. Instead the gradations of the analysis will be allowed to speak for themselves to demonstrate the *relative* levels of

sensitivity. Each area in the final analysis must be judged on its own merit in the context in which it exists. Categorically stated interpretation of an integrated analysis may only serve to increase the political challenges inherent to land use planning. The policies chosen to protect the identified themes will more specifically elucidate the nature of their sensitivity than will any attempt to define protection based solely on the findings of this analysis. The relation of this analysis to the formulation of policy will be briefly discussed in the final chapter.

Chapter Three:

Data

An analysis of natural resources depends on two fundamental elements: methodology and data. The first two chapters of this thesis dealt with methodology. This chapter and the following chapter deal with the data needed to execute the methodology. Included in this chapter are matters of availability, accuracy, compatibility, resolution, date of collection, and status of some current data projects. This is hardly intended to represent a complete survey of data sources. A quick search of the Internet reveals that there is a great deal of both public and private data available. What we attempt here, rather, is a brief survey of the most current, reliable and useful publicly available data—primarily that which we will use for the case study that follows. Several of the identified data sources are currently working on new data sets that will soon be available and are expected to be useful for our purposes. Table 5 presents us with a basic matrix of natural resource data themes, sources, and brief, pertinent notations regarding availability and quality.

General Data Issues

The first task of a natural resources analysis is to develop a methodology. This was outlined in the previous chapter. Having determined a methodology, it becomes necessary to locate sources for the data required to execute that methodology. In this chapter we will discuss various sources and availability of data, compatibility among data sets, and the

general status of GIS data today. Some of the data needed to complete a relevant natural resources assessment are not found in the scientific sources and should be gathered from inhabitants and primary users of the area. Methods of gathering subjective input are found in Appendix D.

Among the many issues confronting those interested in GIS analysis is data compatibility. Data is often created using different software applications, and sometimes by software created specifically for the task of one special application. In some instances conversion of various data sources to a common platform can be simple, but ease of conversion should not be assumed. Conversion of data to an applicable format sometimes requires technical expertise beyond that of a casual GIS user. Even data from within a single prepackaged collection of data (SAMAB's Southern Appalachian Assessment for example) is sometimes incompatible for integrated analysis under ArcView. For this thesis, when conversion to compatible formats was possible, it often involved a high degree of technical assistance, additional specialized software, and occasionally resulted in a significant loss of resolution. Data presented in otherwise compatible formats from differing sources was sometimes found in differing projections and/or spatially reference. Usually, these issues can be overcome with GIS software. ArcView GIS can convert a variety of data formats into shapefiles and into different projections, but at times these are still not suitable for integration. Even if data is brought into compatible formats, the level of detail of the original data may be reduced in conversions. Some data sets have unique spatial referencing. The result is that the data are digitally located in space at different

scales and physical locations. Three data sets of differing origins place Sevier County in different locations and at different scales in the same view (Map 1). Fortunately, the Southern Appalachian Man And the Biosphere (SAMAB) Southern Appalachian Assessment (SAA) provides a standardized set of data that can be used for the demonstration of this methodology. Unfortunately, some this data is old and some point data is inaccurately referenced. It was decided that for *demonstration* purposes, the SAA data would be sufficient. Most of these data are available in more current forms, but require adaptation to bring them into common reference and format. It should be noted that governmental data sources are rapidly advancing toward standardized, and user-friendly, forms of data dissemination and more timely updates of data. The EPA is currently offering some updated data on their website for downloading via the Internet, and SAMAB is seeking to employ someone to update their data sets for redistribution (U.S. EPA 1999). Another plus for data availability in the near future is the high level of interest in GIS analysis today. Most State and Federal agencies are working together to improve both the quality and accessibility of data including the use of national metadata standards.

An additional item of note is contained in a notice from U.S. FWS on their main GIS page on the Internet which warns that while there is an increasing amount of data available for free via the Internet, there may be times when one would be better off getting their data on a permanent storage media. According to the site, some offices that disseminate data have just one Internet phone connection, or perhaps have poor quality

phone lines. Data transmission of large files, and some of these are very large, can be extremely time consuming even if everything works right the first time. Data transmission on the Internet can also be interrupted by carriers or service providers and the resulting need to start again can be very frustrating. A permanent storage media like a CD-ROM disc not only avoids downloading problems, but also provides a good archive copy of the data. (U.S. FWS 1999). We received one data set via e-mail and some point data from the EPA via the Internet with no difficulty. TWRA sent us data on CD-ROM, and we purchased some commercial data based on the U.S. census and USDA Agricultural Census on CD-ROM. The SAA is available on CD-ROM and most of the SAA is also available via the Internet. In all cases, data on CD-ROM is assumed to be a more secure and reliable source of data with which to work. Of course, we hope that more frequent updates of some data will make the permanency of CD-ROM's useful for historical archives for use in time-series comparisons as well as for current working data. During our acquisition of data for the case study, at least one data file was lost due to computer hardware problems and a few more to operator error. If one does not utilize CD-ROM as a storage media, it is wise to backup all files on hard drive to floppy or ZIP discs to avoid the time-consuming necessity of reacquisition of data.

Overview of Primary Data Sources

This section will review agencies responsible for data collection and distribution including information of data quality and availability. Most of these data are or will soon be available via the Internet. It should be noted that most federal agencies cooperate in

varying degrees with one another on many GIS projects. NALC is a good example of a multi-agency program. SAMAB is another example of multi-agency cooperation.

Multiple agencies are credited where appropriate or useful for explanation of the origin of a particular data set. This chapter does not provide in-depth histories of all of the projects.

The purpose is to orient the reader with sources and issues, not to provide detailed histories of the various agency interactions.

The data available are considerable and varied. Following are the data sources which are most useful for this project. Some useful sources may have been missed, but all of the themes outlined in the chosen methodology are covered with the sources listed below.

U.S. Census Bureau TIGER Files

The TIGER/Line files are a digital database of geographic features, such as roads, railroads, rivers, lakes, political boundaries, and census statistical boundaries, covering the entire United States. They are the public product created from the Census Bureau's TIGER (Topologically Integrated Geographic Encoding and Referencing) data base of geographic information. TIGER was developed at the Census Bureau to support the mapping and related geographic activities required by the decennial census and sample survey programs. With GIS software a user can produce maps ranging in detail from a neighborhood street map to a map of the United States. These data are updated with each decennial census (U.S. Census Bureau 1999). Although the TIGER files are public record, several organizations have repackaged these data in various ways and combined

them with other census information to support a variety of analyses. These repackages of data are available for a fee from the various responsible companies.

SAMAB

SAMAB is a public/private partnership that focuses its attention on the Southern Appalachian Biosphere Reserve. The partnership encourages the use of ecosystem and adaptive management principles. The vision of the program is to promote the achievement of a sustainable balance between the conservation of biological diversity, compatible economic uses, and cultural values across the Southern Appalachians. Such a balance is expected to be achieved by collaboration among stakeholders, through information gathering and sharing, integrated assessments, and demonstration projects directed toward the solution of critical regional issues. To date, the primary product of the SAMAB project has been Southern Appalachian Assessment (SAA). The SAA is a cooperative, multi-agency effort with contributions from the U.S. Forest Service, EPA, North Carolina Department of Environment, Health, and Natural Resources, U.S. Geologic Survey, Appalachian Regional Commission, U.S. Army Corps of Engineers, Georgia Department of Natural Resources, Tennessee Valley Authority, National Park Service, U.S. Fish and Wildlife Services, National Biological Service, Tennessee Department of Environment and Conservation, and the U.S. Economic Development Administration. These agencies came together to assess the ecological condition of the Southern Appalachian region. GIS technology and data played a vital role in the assessment process. This data base was assembled primarily with publically available

data from those agencies. A great deal of effort was made in converting the data into a common, useable format and GIS provided the vehicle to accomplish this ambitious project (SAMAB 1996).

The SAA data set included environmental themes for the Southern Appalachian Biosphere Reserve region. Data are contained on a five-CD-ROM disc set and are partially available for downloading from the SAMAB website. This method of information distribution is both useful and innovative and demonstrates some potentials of rapidly advancing GIS technology. The data included in the SAA are outlined in Appendix F.

Plentiful, comprehensive, and organized though it may be, there are many limitations to use of the data gathered for the SAA. Some point data in the Assessment was spatially located inaccurately: the data points were placed incorrectly on the map. In map 2, the point is shown to be in Sevier County but the information in the accompanying theme table refers to a location many miles away in Cocke County. These particular data points were entered according to zip codes and are therefore only gross approximations of the locations they represent. Further, much of the data is simply old. For example, the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) data used in the SAA shows Sevier County to have six CERCLIS sites. The metadata shows these data to have been gathered in 1988 (Appendix F). All these sites have been delisted and are no longer on the EPA's CERCLIS list. In this case,

more current data are available through the EPA "Envirofacts" website on the Internet. Unfortunately, the EPA data have to be entered manually into the GIS and new theme tables created before it can be used for integrated analysis with the SAA data. The EPA point-data available for downloading is georeferenced differently from the SAA data. In consideration of these shortcomings it is fair to say that the SAA is a progressive *model* for regional data gathering for natural resources analysis but should not be used in actual analysis without close scrutiny and recognition of the dated nature of some data sets. In certain cases the metadata will alert us to the limitations of the SAA data. In other cases, metadata is either incomplete or nonexistent, so there can be no certainty as to the accuracy of the data. Researchers should look forward to future products from SAMAB as they progress in refinement of thoroughness in metadata collection, frequency of updates, and reliability of data.

The Multi-Resolution Land Characteristics (MRLC) Consortium

The MRLC Consortium is the core of the federal GIS data programs. Six Federal environmental monitoring programs, EMAP (EPA), GAP (USGS), NAWQA (USGS), C-CAP (NOAA), NALC (EPA/USGS), and the RSA Center (USFS) have formed a partnership with the EROS Data Center (USGS) to develop comprehensive land characteristics information for the United States. This partnership established the Multi-Resolution Land Characteristics Interagency Consortium. Each of the respective programs brings unique experience, expertise, and resources that help the Consortium to obtain, organize and coordinate data and information. The goals for the MRLC

Consortium include the generation of landcover data for the United States and the development of a land characteristics database to meet the needs of the participating programs and federal agencies, as well as those of other public and private interests. (U.S. EPA 1996). The National Aeronautics and Space Administration's (NASA) Landsat Program is the primary source for U.S. satellite imagery. It is used for the North American Landscape Characterization (NALC) project, and for the other MRLC project most relevant to data collection for this thesis: EPA's EMAP.

Landsat

As noted in a previous chapter, the Landsat Program is the longest running enterprise for acquisition of imagery of the earth from space. The first Landsat satellite was launched in 1972; the most recent, Landsat 7, was launched on April 15, 1999. The images gathered by the Landsat program are one of the primary resources for the research of global and regional landcover change (Sheffer 1996).

Landsat data are used for many kinds of studies, inventories, and analyses by governmental, commercial, industrial, civilian, and educational researchers. Some areas of application include crop acreage inventories, timber class identifications, soil association identification and mapping, range cover and forage production analysis, plant stress detection, regional land use classifications, photo-map generation, mineral and petroleum exploration, pollution monitoring, geological mapping and interpretation, sea ice movement monitoring, vegetation classification and mapping, surface mining

operations monitoring, flood/forest fire monitoring, and beach erosion detection. See table 4 for more descriptions of data uses. As this list shows, Landsat data is extremely useful for monitoring the conditions of the Earth's land surface. The images can also be used to map changes on the Earth's surface over periods from several months to several years to decades. Examples of changes that can be identified using the landsat data include agricultural development, deforestation, urbanization, and the development and degradation of water resources.

NALC

The North American Landscape Characterization (NALC) project is a collaborative effort between the EPA and the USGS which is compiling complete landsat data coverage of the U.S. and Mexico for the purposes of mapping land cover and land cover change. The NALC project is a component of the National Aeronautics and Space Administration (NASA) Landsat Pathfinder Program. The NALC project is a cooperative effort between the EPA, the USGS, and NASA to make Landsat data available to the widest possible group of users for scientific research and other interests. The objectives of the NALC project include the development of standardized remotely sensed data sets and standard analysis methods in support of investigations of changes in land cover (Lunetta and Sturdevant 1993; USGS 26 August 1999).

USGS's Earth Resources Observation Systems (EROS) Data Center (EDC) has primary responsibility for producing the NALC Landsat multispectral scanner (MSS) triplicate

data sets, as well as the responsibility for archiving, managing, and distributing data and information derived from the NALC triplicates. These data sets are useful for analysis related to land use/land cover changes. The NALC triplicates are processed using standardized methods to give users data sets that can be easily used with available digital image processing software, a plus for local or regional analysis on a small budget. The NALC Landsat MSS triplicates provide a valuable set of information that is useful for regional environmental assessments. In addition to the basic data sets and the NALC triplicates, the EROS Data Center also provides "higher level" data products which are processed for land cover classifications. (USGS 9 September 1996). It is these "higher level" data products that are most useful for this methodology, because they have already been processed to provide a picture of the landscape that is categorically defined according to land use.

According to Frank van Manen of the USGS Southern Appalachian Field Laboratory, current Landsat imagery (late 1990's) has recently been compiled and interpreted and is available for use but is in a projection not compatible with our other data. Therefore, this analysis will use land use/land cover data that incorporates an earlier NALC product used in the Southern Appalachian Assessment.

River Reach (EPA)

One of the simple base map themes provided by the EPA is their River Reach files. These files provide a series of databases portraying the surface waters of the continental United

States in ArcView shape files format. Reach codes uniquely identify, by watershed, the individual components of the Nation's rivers and lakes. These codes provide a common language for Federal and State reporting of surface water conditions as required under the Clean Water Act. In addition, the network defined within the Reach Files enables the modeling and visualization of waterborne pollution associated with both point and non-point sources. Integrating data from government organizations at all levels by linking them to this nationally consistent hydrologic network allows permit writers, emergency management personnel, and other environmental managers to better orient locations when assessing the causes or implications of pollution events. River Reach files are available via the EPA Internet site (EPA 1995).

BASINS (EPA)

EPA's water programs are increasingly emphasizing watershed and water quality-based assessment as an important management tool. EPA is also increasingly promoting interactive information systems for use on the Internet. Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) is an interactive Internet mapping program developed by EPA that can be used to access detailed watershed information which then can be used and manipulated in GIS analysis. BASINS is a system developed for the purpose of doing integrated analysis of point and nonpoint pollution sources at the watershed level. It integrates GIS, national watershed data, and state-of-the-art environmental assessment and modeling tools into an Internet based application. (USGS. 27 May 1999).

According to EPA, BASINS addresses three objectives: (1) to facilitate examination of environmental information, (2) to provide an integrated watershed and modeling framework, and (3) to support analysis of point and nonpoint pollution sources. The BASINS program allows analysis of total maximum daily loads (TMDLs) for a watershed. TMDL analysis integrates both point and nonpoint pollution sources for a comprehensive picture of the health of a watershed. TMDL analysis is important for watershed, county, or regional environmental planning to determine the cumulative load being placed on the water resources and the nature and location of sources of the impacts on water quality. BASINS provides a complete analytical framework for watershed and water quality analysis. (USGS. 27 May 1999)

Available data from the BASINS project includes land use/land cover; urbanized areas; location and boundaries of populated places; river "Reach Files"; State Soil Geographic (STATSGO) data; digital elevation models (DEM); major roads; USGS hydrologic unit boundaries; drinking water supply sites; dam sites; EPA regional, state, and county boundaries; Federal and Indian lands; and Bailey's ecoregions. BASINS also includes the following environmental monitoring data: water quality monitoring station summaries; water quality observation data; bacteria monitoring station summaries; weather station sites; USGS gaging stations; fish consumption advisories; national sediment inventory (NSI); shellfish classified areas; and Clean Water Needs Survey results (USGS. 27 May 1999). This data set is an excellent companion to the SAA for updated spatial

representation of pertinent environmental data available for use in a GIS environment. The data sets used for BASINS Internet mapping are especially useful for our purposes because of their availability for downloading as ArcView shapefiles and point data.

Envirofacts (EPA)

The EPA also hosts the Envirofacts Warehouse on the Internet. The mission of the Envirofacts program is to give the public direct access to the information contained in many EPA databases. Envirofacts is a useful companion to BASINS and can be used to retrieve more thorough information on the point source sites shown in BASINS.

Envirofacts allows the user to retrieve environmental information from EPA databases on air quality, chemicals, hazardous waste, superfund, toxic releases, water permits and drinking water supplies. Envirofacts also includes GIS point source data associated with the following data sets: Industrial Facilities Discharge (IFD) sites; Permit Compliance System (PCS) sites and loadings; Toxic Release Inventory (TRI) sites; CERCLIS-Superfund National Priority List (NPL) sites; Resource Conservation and Recovery Information System (RCRIS) sites; and Mineral Industry Locations (U.S. EPA 29 September 1999).

OIRM (EPA)

The EPA's Office of Information Resources Management (OIRM), along with the EPA GIS Work Group, developed the EPA Spatial Data Library System (ESDLS) as a repository for the Agency's geospatial data holdings. Users can access these data holdings

through various GIS applications. Data sets are contained in ESDLS for the county, state, and national levels. These data are available at a scale of 1:100,000 at the county level, 1:250,000 at the state level, and 1:2,000,000 for other data at the state and national level (U.S. EPA 28 May 1998).

County level spatial data for the United States currently includes: 1990 Census Block Boundaries; 1990 Census Block Centroids; 1990 Census Block Group Boundaries; 1990 Census Block Group Centroids; 1990 Census Block Group Boundaries with Zero Population; 1992 TIGER Roads Features Layer for Counties; 1992 TIGER Railway Features Layer for Counties; 1992 TIGER Miscellaneous Points Features Layer for Counties; 1992 TIGER Miscellaneous Lines Features Layer for Counties; 1992 TIGER Miscellaneous Areas/Polygons Features Layer for Counties; 1992 TIGER Visible and Nonvisible Political Boundaries Features Layer for Counties; 1992 TIGER Hydrography Features Layer for Counties; 1995 USGS Geographic Names Information System 2 (GNIS2) Data for Counties; EPA Metadata for ESDLS EF Layer; EPA Regulated Facilities Point Locations from Envirofacts; 1992 TIGER State Political Boundaries; 1992 TIGER County Political Boundaries; and Superfund National Priority List (NPL) Site Boundaries (U.S. EPA 28 May 1998). EPA is obviously a primary source of base map and environmental data.

U.S. Fish and Wildlife Services (USFWS)

USFWS, in cooperation with Department of Natural Resources (DNR) and USGS publishes Digital Orthophoto Quad maps (DOQ) (aerial photography). DOQs are available for most of the state of Tennessee. These maps are useful if one is setting up a GIS department that as an ongoing part of daily operations. Typically these are used as a base map showing buildings and infrastructure. When used as part of an ongoing GIS project, they need to be updated periodically to reflect changes in the built environment.

Knoxville Geographic Information Systems (KGIS) in Knoxville is a good example of such a comprehensive GIS system. KGIS provides GIS services to support a range of public and private information needs (Casey 1999). The cost, time and technical expertise required to develop this level of GIS is well beyond the scope of our analysis.

Digital Raster Graphics (DRGs) are also available for the entire state either through USGS or TVA. DRGs are made by directly scanning published paper maps and are not useful for integrated analysis because the features they contain are not differentiated as separate shapefiles and thus cannot be accessed individually for manipulation or analysis. There are methods to convert these maps to useful shapefiles, but these methods are beyond the scope of this thesis (U.S.FWS 21 July 1999).

Federal Emergency Management Agency (FEMA)

FEMA maps include Flood Insurance Rate Maps (FIRM) depicting 100 and 500 year floodways and corporate limits. No base map information is included on these paper

maps, only the waterways and floodplains. DFIRM maps are the digital (GIS) version of the FIRMs and are very limited in availability. Q3 maps are similar to DFIRM with slightly less data and are more widely available. Q3 data are adequate for our purpose but none of the FEMA digital data are available for Tennessee and are not scheduled for digitizing anytime soon (FEMA 1999).

Office of Surface Mining (OSM)

The OSM is in the process of mapping coal fields in the 73 map quadrangles that lie on the Cumberland Plateau. OSM expects to finish digital mapping of the coal fields in 1-2 years and will include boundaries for all mining permits issued in the U.S. on 1:24,000 Digital Raster Graph (DRG) maps (Card July 1999).

The National Wetlands Inventory (NWI) of the U.S. Fish and Wildlife Service produces information on the characteristics, extent, and status of the Nation's wetlands and deepwater habitats. All of TN has been mapped, but GIS ready digital quad maps available for Tennessee through the NWI are limited to Dyersburg, Nashville, Johnson City, Memphis, Columbia, Chattanooga, and Knoxville (U.S. FWS NWI Overview; U.S. FWS 21 July 1999). NWI data had been integrated into the SAMAB SAA land use/land cover themes in the SAA dataset of 1996. The SAA metadata describes a data compilation process that filters out small wetlands (which are rumored to be unreliably mapped anyway) but includes most wetland areas over 2 acres (SAMAB 1996). For more

information on the algorithm used for the SAA landcover data see the metadata in Appendix G.

Natural Resources Conservation Service (NRCS) Soils Data

NRCS has developed local lists of map units that contain all soils types for each county or parish in the United States with accompanying Soil Interpretations Records. These maps and records show and describe all local soils types in great detail and include prime agricultural soils and hydric soils classifications. These local lists are available at NRCS state offices and are the preferred lists for use in making preliminary wetland and other soils suitability determinations. Detailed lists and paper maps for soils in much of East Tennessee can be obtained at the Dixon Office of NRCS in Knoxville. Coarse classifications of soils types are included in the SAA in ArcView shapefiles. The theme for these shapefiles contain little data and require separate analysis of the NRCS Soils Interpretation Records for interpretation and determination of which soil classifications should be considered as environmental constraints.

Soil Survey Geographic (SSURGO) is NRCS's most detailed level of soil mapping. SSURGO digitizing duplicates the original soil survey maps. NRCS is in the process of making these digital soils maps for Tennessee, but the local mapping project is moving slowly. Currently SSURGO data is available for only a few counties in Tennessee. No

data are available that would be of use for this thesis. NRCS maintains an online map of the status of their mapping efforts at <http://www.ftw.nrcs.usda.gov/jpg/ssurgo.jpg> (McMillan July 1999).

The National Soil Information System (NASIS) is a tool to help create and maintain soil surveys to national standards. It takes advantage of the latest technologies to provide an automated means for storing all information about and for soil surveys. This is a good example of national data and metadata standards that will help standardize local mapping efforts to a common national standard which can then be compiled and used for larger scale analysis (NRCS 13 November 1997).

The State Soil Geographic (STATSGO) Database consists of map data, metadata and attribute data. Each map unit is linked to attribute data files containing soil properties and interpretive information. The data were designed primarily for regional resource planning, management, and monitoring. The map data are typical soil map unit data compiled and digitized from 1:250,000-scale maps, so they are not very detailed at a county level. This is similar to resolution available in the SAMAB SAA dataset.

The USDA Census of Agriculture provides a complete accounting of United States agricultural production, including county and zip code level statistics but containing no maps, and is available on the Internet at <http://www.nass.usda.gov/census>. These

statistical data can be useful to supplement map data for more detailed understanding of the dynamics of changes in agricultural practices and land use over time.

NRI

The USDA Natural Resources Conservation Service's National Resource Inventory data can also be utilized to supplement GIS data by providing trend statistics describing the natural resource condition of the study area.

Data collected in the 1982, 1987, 1992, and 1997 NRIs provide a basis for analysis of recent trends in resource conditions. In addition, the NRI is linked to the Natural Resources Conservation Service's (NRCS) Soil Interpretations Records to provide additional soils information where available, but not in East Tennessee.

NRI is continuously adding elements to its database. Consistent data for the years 1982, 1987, and 1992 include information about the following: farmstead, urban, and built-up areas; farmstead and field windbreaks; streams less than 1/8 mile wide and water bodies less than 40 acres; type of land ownership; soils information-soil classification, soil properties, and soil interpretations such as prime farmland; land cover/use-cropland, pasture land, rangeland, forest land, barren land, rural land, urban and built-up areas; cropping history; irrigation-type and source of water; erosion data-wind and water; wetlands-classification of wetlands and deepwater habitats in the U.S. (1982 and 1992 only); conservation practices and treatment needed; potential conversion to cropland;

rangeland condition, apparent trend of condition. New data elements added to the NRI database for the 1992 NRI are: streams greater than 1/8 mile wide and water bodies by kind and size greater than 40 acres; Conservation Reserve Program land under contract; type of earth cover-crop, tree, shrub, grass-herbaceous, barren, artificial, water; forest type group; primary and secondary use of land and water; wildlife habitat diversity; irrigation water delivery system; Food Security Act (FSA) wetland classification; for rangeland areas-range site name and number; woody canopy; noxious weeds; concentrated flow, gully, and streambank erosion; conservation treatment needed; type of conservation tillage. (NRCS 17 May 1999).

Tennessee Wildlife Resources Agency (TWRA)

TWRA has the distinction of having the first GIS in Tennessee state government. TWRA is a primary natural resources data source for all of Tennessee and also holds and distributes data for Tennessee Department of Environment and Conservation (Whitehead July 1999).

TWRA GIS data are available primarily through the Tennessee Biodiversity Program. Established by the Tennessee Conservation League, the Tennessee Biodiversity Program and TWRA's GIS division have been working together to provide planners and community leaders, landowners, natural resource professionals, and educators with information on Tennessee's natural resources. TWRA provides TN-GAP data and related GIS data layers as ArcView files to county planners and community leaders. Current

plans include presentation of the TN-GAP data as part of the TWRA web page. TWRA will also compile a CD-ROM of available GIS data for counties in ArcView format with an appropriate agency request and permissions from the various originators of data sets. Among the data sets available from TDEC are Land Use/Land Cover information from Landsat imagery, National Wetlands Inventory (NWI) data, public lands including most state and federal lands, USGS topographical quad base maps, county boundaries, roads, rails, rivers and streams from TIGER files and power lines right of ways. The mapping of home ranges for vertebrate species are presently being prepared for inclusion in the TWRA data set, but are not yet ready for release. TWRA staff are also working on biodiversity maps depicting species richness, and habitat GAP Analysis that should be available by the end of this year. New vegetation maps are completed, species distributions and species richness data have been produced but are not yet ready for release. A new land stewardship layer is completed as well, but not ready for release. All data sets will soon be available on TWRA website as well as on CD-ROM (Barrett July 1999).

Tennessee Parcel GIS

Tennessee Parcel GIS is a project under the Tennessee Department of Finance, led by Mark Tuttle. Tennessee Parcel GIS is compiling GIS versions of all existing tax maps in the state of Tennessee. The addition of parcel data will dramatically enhance our analysis capabilities. The added ability to analyze land ownership patterns along with the more traditional environmental assessment elements will help to discern trends in land use,

help demonstrate patterns of speculative land holdings, and show corporate vs. private land ownership. Parcel data are currently available for Sullivan, Hamilton, Montgomery, Maury and Lewis counties. The entire state is expected to be mapped in 4 years (Tuttle July 1999).

Other Projects

Tennessee Conservation League (TCL) has set up offices in Sewanee and Jackson, Tennessee to provide assistance for watershed level planning. Their current projects include the Elk River near Sewanee in Franklin County, and the Wolf and Hatchie Rivers near Memphis. TCL plans to provide GIS data from TWRA/ TVA to interested parties. No GIS technical services or analysis will be offered.

The future for GIS data.

Content Standard for Digital Geospatial Metadata: The June 1998 version of the Content Standard for Digital Geospatial Metadata is applicable to all geospatial data produced by the federal government. The Federal Geographic Data Committee (FGDC) also invites and encourages organizations from state, local, and tribal governments, the private sector and non-profit organizations to use the standard (FGDC June 1998). It is this type of cooperation and standardization that furthers the practical utility of government data for local and private analysis.

Chapter Four:

Sevier County: A Case Study

The first three chapters of this thesis dealt with selecting a methodology, and locating appropriate data sources. Chapter four is a case study in which we bring these together in an analysis of natural resources. Sevier County serves as the demonstration area for this analysis.

Sevier County was chosen for five reasons. First, it lies within the state of Tennessee and is thus subject to the mandates of Public Chapter 1101. Second, it lies within the southern Appalachian region—an area characterized by a richness of biodiversity unparalleled in the United States. Not only is the southern Appalachian region of East Tennessee rich in biodiversity, but it also is characterized by terrain at once both rugged and fragile. Third, it falls within the data coverage of the SAMAB's Southern Appalachian Assessment (SAA) which provides a generous assortment of compatible data. Fourth, it was selected because of its proximity to the Great Smoky Mountains National Park (GSMNP) and, therefore, its interest to those who study the interactions that occur as anthropocentric activities approach an internationally recognized bioserve. Finally, Sevier County is experiencing the fastest population growth of all counties adjacent to the GSMNP.

This chapter begins with an overview of the basic mapping data used. The base themes chosen from the SAA represent the natural resources under consideration. Metadata from all themes used in this analysis are included in the Appendix G. Initial presentation of the themes in separate maps gives perspective to the individual data layers used in the analysis. Map 3 shows the basic landcover interpretation from landsat remote sensing. This map is portrayed at 30 meter resolution, and distinguishes 17 different landcover classifications: northern hardwood forests, mixed mesophytic hardwood forests, oak-hickory forests, bottomland hardwood forests white pine-hemlock forests, montane spruce-fir forests, southern yellow pine forests, white pine-hemlock-hardwood forests, mixed pine-hardwood forests, herbaceous, barren, agricultural-pasture, agriculture-cropland, wetlands, developed, water, and indeterminate-clouds and shadow (Hermann 1996). The “developed” classification indicates areas where impervious surface dominates a grid cell. This is a significant indicator of anthropomorphic impact on the natural landscape. Impervious surfaces retain and reflect heat, hasten stormwater runoff, diminish water absorption and aquifer recharge capacity, and facilitate introduction of pollutants into waterways (Kendig 1980, Marsh 1997). Further details regarding these data, including the algorithm used to determine landcover classifications, are outlined in the landcover metadata in Appendix G. Map 4 shows the steepness of slopes as a percentage. Slope percentage is calculated by division of the vertical rise of land by the horizontal distance traveled to attain that rise. Thus a slope that rises one foot in two feet of horizontal travel would be a $\frac{1}{2}$ or 50% slope. In this map the slope is divided into five equal-area intervals. Map 5 shows the surface waters of the county. Map 6 shows primary

soils association types. The entire system of roads, for perspective of the areas which are most used by humans, appears on Map 7. Individually, the first four of these maps (Maps 3-6) provide the basic information concerning the location of natural resources. The themes represented by these separate maps are the base themes which will be used in the first composite map. The map showing the network of roads serves two purposes. It orients the reader, and it approximates the location of the source of the greatest threat to sensitive areas—humans and their alteration of the natural environment. Infrastructure is useful to approximate the location and density of environmental disruption and, in conjunction with landownership and landforms, is our best indicator of future development activity (Berry 1996). Because landowner information is not yet available to researchers in GIS format, this thesis will focus on the other two indicators.

The composite map of natural resources (Map 8) is produced by overlaying the landcover map (reclassified to show forest, herbaceous, pasture, crops, barren and developed, wetlands, and water), the slopes map (showing only slopes of 10-15%, 15-20%, and 20% and above), prime farmland soil associations (USDA 1980), surface waters, and roads. This map does not show levels of sensitivity *per se*. Instead, it shows the relation of the various resources themes and human impact themes. Adding the road network increases our understanding of the location of threats from anthropomorphic disturbance.

Comprehensive natural resource sensitivity analysis requires the incorporation of flood-frequency zones. Unfortunately, the SAA does not include floodplain data, and FEMA

data for Tennessee are not scheduled for digitizing anytime soon. It is possible to manually create shapefiles representing floodplains using paper flood maps as a guide, but, given the high level of budgetary and time constraints, this analysis will be conducted without the benefit of floodplain data.

Mapping Technique

The base maps were created from the SAA using ArcView's *Geoprocessing Wizard* and *Map Calculator*. Initially, the SAA shapefile containing all counties in the SAA (saa1/saa_100k/counties) was brought into an ArcView project view. Sevier County was identified and selected using the ArcView *Select Feature* tool. The county was then converted to a separate shapefile using the *Create Shapefile* tool. This shapefile was then used as a mask to "clip" other shapefiles using the *Geoprocessing Wizard*. Each of the desired themes was selected from the SAA and brought into the view.

The data used for these analyses were in two formats: vector and raster. Shapefiles are ArcView's format for storing location, shape, and attribute information. They are stored in a vector format utilizing x,y coordinates to represent points, lines, and polygons. Raster files are stored in a grid format in which each grid cell has discrete values. Vector files present smooth boundaries, require less storage space in computer memory, and are easy to query and manipulate in ArcView. Grid files, on the other hand, require large amounts of memory to store their detailed data, are thus slow to process, and are not readily viewed or manipulated in the basic ArcView program.

The SAA data files cover the entire SAA region. Ease of use and clarity of study area suggested that we clip shapefiles to the county size as described above. Clipping of the shapefiles was a simple procedure using ArcView's *Geoprocessing Wizard*. Hardware limitations made it necessary that we reduce grid files to county size as well. The computer hardware available for this analysis was very powerful by today's PC standards (A Dell computer with an Intel Pentium II 500 MHz CPU and 128 megabytes RAM), but would routinely "crash" when asked to process the entire SAA region of a grid file for printing, even if we only wanted to print a single county. The grid files, however, posed a greater problem to clip than the shapefiles because the format is not routinely handled by the basic ArcView program. Viewing the grid files required loading a program called *Spatial Analyst* created by the designers of ArcView to extend its basic capabilities. This program provided the capability to view grid data and to manipulate it with a *Map Calculator*. The *Map Calculator* was used to reduce the size and shape of the grid files using the county shape as an output mask. It was also used to perform the computations required for cumulative analysis.

Once the SAA themes were clipped to the study area, producing the base maps was an easier task. The shapefiles were suitable for use "as is." Grid files typically required editing or reclassification to communicate the information required for the base maps. Most modifications were simple and were accomplished with the ArcView *Legend Editor* tool. The real challenge arose when producing the cumulative analysis map.

The cumulative analysis computations were done with the *Map Calculator* tool. *Map Calculator* requires that all data used in computations be in grid format. At this point, all themes except slopes and landcover are still in the simpler vector format. Conversion of the vector files to grid files was accomplished using the *Convert to grid* function of the *Spatial Analyst* extension. Attention was given to insure that output grid size and output extent were consistent among the various maps and intermediate procedures.

Not only must all files used for the cumulative analysis be converted to raster format, but they must also contain a field in their attribute tables containing values appropriate for the cumulative analysis. Normal conversion of shapefiles to a grid creates a new file with two values: "1" and "no data." In the arithmetic calculation used for cumulative analysis, the *Map Calculator* does not compute an addition of "no value." To overcome this problem, a new file must be created with values of "1" and "0." The new file containing only numerical cell values can then be used to build cumulative values for the final analysis.

The conversion of the streams file provides a good example of this process. Because it is a line feature, that is, a feature with no volume, and we are working in a grid format with two dimensions, we must convert the line to a two-dimensional shape. To accomplish this, the shapefile is first converted to a grid with a large cell size (250).³ Then the grid is

³If a smaller cell size of 30 is used—which is required for the final product—the resultant grid will have gaps which will distort the analysis.

converted back into a shapefile. This produces a shapefile similar to the previous line feature, but with area. In other words we now have a stream with “banks” rather than a simple line. The theme table for this new shape is then edited to create field in which every segment of the stream feature is given a value of “1”. A field must then be created within the theme table of the county shapefile with the same name as the new field in the stream shapefile, but with a value of “0”. The new stream shapefile is then “unioned” with a county shape file using the *Geoprocessing Wizard*, designating the newly created fields of “1”s and “0”s as the common output field. The result of this union is a new shapefile which contains two classes of shapes which, when combined, comprise the entire study area. The new shapefile is then converted to a grid with a cell size the same as that for the other files to be used in the analysis (30). We now have a grid file with one of two values contained within every cell: “1” for grids cells containing the stream or “0” for those cells with no stream (Map 9).

Having created a useful stream grid file, now we must turn to preparation of the other, existing, grid files. Because we are working exclusively with the SAMAB dataset the files are already in the same projection and are appropriately georeferenced. The files have already been masked to the desired shape and size. We now must create valuation within these grids that we can use in arithmetic calculations with the stream file.

The landcover file must be prepared for calculation. A field is needed with values which can be used for arithmetic calculation. The *Reclassify* tool provides a method for creating

these values. In this case there exists a field called "value" which contains a numerical value, "1" through "16", for each landcover classification. When the Reclassify feature is employed, these values can be changed to correspond to the value we want assigned to each classification for cumulative analysis. For this analysis, the northern hardwood forests, mixed mesophytic hardwood forests, oak-hickory forests, bottomland hardwood forests white pine-hemlock forests, montane spruce-fir forests, southern yellow pine forests, white pine-hemlock-hardwood forests, and mixed pine-hardwood forests classifications were given a value of "1." The herbaceous, barren, agricultural-pasture, agriculture-cropland, developed, and indeterminate-clouds and shadow classifications were given a value of "0." The remaining classifications of wetlands and water were given values of "3." Because these last two themes represent high functioning ecological systems, it was decided that their visibility on the cumulative map needed to be assured. The weighted valuation of "3" assures that, when the cumulative valuation calculations are performed, the wetlands and water areas will reflect their ecological importance. In this manner, the output file created with the *Reclassify* tool will assign each grid cell a value of either a "0," a "1," or a "3" (Map 10).

The slopes file was then reclassified in a similar manner. The *Reclassify* tool was used to create a classification of four percentage ranges of slope: 0-10%, 11-15%, 16-20% and 21-50%. The slopes under 10% were given a value of "0." Slopes from 11-15% were given a value of "1." Slopes from 16-20% were given a value of "2." And slopes over

20% were given a value of “3.” This provided a cumulative value to slopes that was weighted according to increasing steepness (Map 11).

Next, the soil types were researched to determine which associations are considered “prime farmland” by USDA Soil Conservation Service (USDA, 1980). The appropriate soil associations were selected from the county soil types in the SAA. Shapefiles of these associations were clipped to the shape of the county. These files were again clipped to eliminate all areas with a slope of more than 6%—a criterion for these prime farmland soil associations (USDA 1980). The final shape file was then converted to a grid with values of “1” for prime farmland soils and “0” for all other soil associations. These values are appropriately placed in a field named to coincide with the valuation field in the other grids (Map 12).

Following the creation of all of the individual grid files is their assimilation into the cumulative analysis map. This is accomplished using the *Map Calculator* tool. Each grid file is brought into the calculator for a simple arithmetic operation where all of the grids are added together based on their valuation field. The output is a grid file with a cumulative value for each grid cell. This file is then classified using a graduated grey-scale based on the range of individual cell values. The resulting map is a cumulatively integrated analysis of sensitive natural resources (Map 13). Public input can be used to determine other features to be added to the analysis and also to determine additional weighted value to be assigned to any particular theme or feature (Appendix D). This

analysis can also be used as part of community “visioning,” or other agenda-setting, or for educational activities, to inform citizens of existing conditions. To demonstrate how different community values can produce different results, the same cumulative analysis was done excluding the prime farmland soils from the equation (Map 14).

Human Impact Themes

The analysis technique demonstrated above only addresses the presence of natural resources. It is also useful to consider the threats posed to those resources. Map 15 shows one example of human impacts on a sensitive natural resource. The map shows the relationship between riparian zone landcover, municipal water supply intakes, roads, developed areas, and point pollution data. The riparian zone theme was created by reclassifying the landcover grid to the seven primary classes used above, then using a grid mask of the stream coverage to 'clip' the land cover grid. This results in a new file that shows the landcover classification of the stream banks. Riparian zones serve many purposes, including wildlife habitat and migration corridors, stormwater runoff filtration (from sediments and other pollutants), stream bank erosion control, and water temperature moderation for sensitive aquatic species (Marsh 1997, PAS 1975). The pollution point data includes EPA's Toxic Release Inventory (TRI) points, Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) points (including Superfund Sites), and National Pollutant Discharge Elimination System (NPDES) points. As mentioned earlier, these data points are not 100% reliable and are shown here for demonstration purposes only. The relation of the

various riparian zones and pollution sources to water supply intake points can be visually interpreted for an idea of potential conflicts of interest.

Cost of Analysis

In real terms, what does it cost to perform the analysis described here? The answer to that question depends on many factors, such as existing equipment, desired output, and cost of labor. The two main components are a high-speed computer with sufficient memory and software. Environmental Systems Research Institute has been known to donate GIS software to some not-for-profit organizations, but for this purpose we will consider retail value of ArcView with necessary extensions. Then the question arises as to how one will present the analysis. Do you need a standard 8.5" x 11" color laser printer, or are you going to prepare 36" x 36" wall maps? Will you contract printing out to another agency? Maybe you will simply post your results to the Internet or distribute it on CD-ROM. PowerPoint presentations require special projection equipment that an organization may or may not have. To estimate costs, let us assume no equipment resources and a nominal budget.

ArcView is currently offering special promotional packages that combine Dell Precision Workstation computers with preloaded ArcView software for prices ranging from \$4,600 to \$5,300 (ESRI November 1999). They also offer Hewlett-Packard Design Jet 36" printers with ArcPress for ArcView software for prices ranging from \$7,800 to \$9,900

and 54" printer packages for \$11,500 to \$13,800 (ESRI November 1999). All of the data used for this analysis is available in the public domain at no charge.

Given appropriate hardware, software, and data, one needs to consider technical expertise. This can either be purchased or acquired. Experience cautions me to stress that labor costs are dependent on a wide range of variables. Anyone who has set out to learn a new computer system can attest to the frustration of the "unforeseen problems" factor. Assuming a familiarity with GIS, and the use of a data set that is already georeferenced (such as the SAMAB data), one might be able to complete this analysis within a 40-hour work week. For those unfamiliar with the basic operations of GIS, but proficient with other windows-based software, expect to double that time to allow for learning basic GIS skills. Obviously a skilled technician will command higher wages than someone teaching themselves how to use the software for the first time.

So, for approximately \$5,000, plus staff for a few weeks, one can conceivably set up to do the analysis (without mapping capability). For approximately \$13,000 to \$19,000, plus staff, one can obtain equipment to do analysis and print presentation-quality maps. Of course, one could contract the analysis to an independent consultant. The cost of equipment for a one-time analysis, or even for a periodic analysis, if that was the only use for setting up GIS, might present a high cost. In that case, it might be prudent to contract the analysis to a consultant or a GIS expert. Depending on the components of the analysis and the type of presentation, it would not be unreasonable to spend in the range of

\$4,000-\$5,000 for such an analysis. This is based on estimates to replicate the output of this thesis from scratch at the rate of \$100 per hour. To integrate public involvement into the analysis would necessarily increase the cost. These numbers are speculative, based on the experience gained writing this thesis.

Chapter Five:

Conclusion

As was pointed out in the introduction to this thesis, it is important that this methodology for analysis of the cumulative sensitivity of natural resources should address several problems in Tennessee.

1. Sensitive natural resources are increasingly subject to loss and degradation associated with some development. Public Chapter 1101 identifies the county's *duty* to manage the very natural resources which are being degraded. Proper management requires knowledge, and that knowledge is dependent on accurate information. This integrated analysis of sensitive natural resources provides the information needed to begin building that knowledge base.
2. Many county planning agencies may lack resources necessary to develop an adequate natural resource analysis, especially in predominantly rural counties. This methodology provides a ready-made framework for low-budget analysis.
3. There is no clearly defined methodology that unifies existing GIS data sources. Unification of existing data sources is at the heart of this method of analysis.
4. The political climate surrounding growth management may be volatile. Attention to the ability to defend land use planning decisions, both in the court of law and in the court of public opinion, is especially important in the formation of growth boundaries. A clearly defined methodology such as this one increases a county's

ability to defend comprehensive land use plans that include natural resource conservation measures.

5. Lack of political will can be a constraint to comprehensive land use planning. The prevailing political climate greatly influences the success or failure of many planning efforts. A resource analysis process that reflects local public opinion and values may help overcome political inertia. By using public input to determine the inclusion of themes or to weight their valuation, this methodology can readily integrate local values into the analysis.

Research Questions Answered

The question asked at the start of this thesis was: “What data are available on the spatial location of sensitive natural resources (on a county level) and how can that data be rendered useful for comprehensive land use planning?”

Research revealed that there is a great deal of data currently available for natural resource analysis in Tennessee, and even more in various stages of development. SAMAB’s SAA alone provided most of the necessary data to represent the basic themes for this analysis⁴. Many agencies are at work to increase the types of available data, to update existing data, and to standardize data formats. The cumulative results of these efforts are ushering in a new era of GIS capabilities in which one can readily organize and analyze an incredible

⁴ Analysis was performed without the benefit of floodplain data.

array of information using desktop computer hardware and over-the-counter software programs.

Implications

It is important to recognize that any form of analysis is simply a tool, part of a larger and more complex planning process. This methodology is a first step to informed land use decision-making. An equally important part of land use planning is policy. If analysis is a precursor to decision making, then policy is the result. This analysis makes matters of policy more clear, will allow for more defensible planning measures, and will encourage planners, citizens, and government officials, to appropriately address the critical issue of protecting sensitive natural resources.

It is interesting to note that most of the land in Sevier County that is not covered in forest or steeply sloped is considered prime farmland. Even though we don't have GIS data to represent floodplains, a glance at the FEMA Flood Insurance Rate Maps shows that a fair number of the main stream channels lie in flood zones. The inclusion of this theme to the analysis could lead one to conclude that most of Sevier County is sensitive to disturbance, the areas in the county which are well-suited to development are few, and most development occurs in a sensitive context.

A closer look at the Sevierville-Gatlinburg corridor in the center of the study clearly shows the context of the roadways in Sevier County (Map 16). While only closer ground-

truthing would reveal specific impacts of each parcel of land, study of this map clearly reveals certain relationships and conditions. One relationship of immediate importance revealed here is the proximity of roads to riparian zones. Due to the topography, most of the roads follow the waterways. Roads increase the amount of impervious surfaces, automotive pollutants, and development potential. All of these contribute to decline in water and habitat quality. Prudent planning would dictate that associated negative impacts and potential impacts must be mitigated proactively to protect this resource. Preservation of riparian zone landcover and treatment of rainwater runoff between the road surface and the water are two policy measures toward addressing this concern. The presence of slopes on the lower half of the map is a condition that indicates a high potential for erosion and stream siltation—another contributor to degraded water quality and another reason for proactive land use controls. Policy measures dictating the maximum percentage of impervious surfaces, minimum disturbance of native vegetation, and large minimum lot sizes help address this concern. Extensive contiguous areas of high sensitivity indicate areas where conservation, through acquisition or easements, might be appropriate. The results of this analysis make a strong visual argument for the encouragement of conservation measures, and the implementation of performance controls, to insure the continued functioning of natural ecosystem processes.

There are many policy measures available to the land use planner which address sensitive natural resource protection much more effectively than traditional euclidean, exclusionary, zoning. It is not the place of this thesis to explore these measures. The

American Planning Association's Planning Advisory Service Reports 307/308 (PAS 1975) offers numerous policy-oriented techniques to preserve sufficient private property rights while still protecting the natural functions of forests, riparian zones, wetlands, slopes, and other sensitive areas. Randall Arendt addresses the issue of appropriate development techniques in rural settings in his important how-to text, *Rural By Design* (1994). The not-for-profit organization, Trust for Public Lands, offers assistance with understanding and implementing voluntary conservation measures. The subject of managing and minimizing man's impact on natural systems is prevalent in current planning literature (Beatley 1994, 1997, Coble 1999, Peine 1999, Porter 1997, and Sargent 1991). Rather than responding to sensitive environments with myopic condemnation of all human activity, or encouragement of all development, planners have a responsibility to seek solutions, to develop and implement innovative measures to mitigate human impacts on the environment, and to look for new ways that we can truly "design *with* nature."

Ian McHarg was correct in his 1967 call for a new method of analysis reflecting a greater sensitivity toward natural resources in land use planning. This thesis demonstrates that, in 1999, planners can take his method of analysis to an even higher level. The concepts introduced by McHarg, when coupled with modern GIS capabilities, provide an opportunity for low-budget, high-yield, analysis. The method demonstrated in this thesis clearly shows that the data which is available can be readily analyzed in an integrative manner reflecting cumulative value based on the presence of sensitive natural resources.

What this means for planners is that even in the smallest planning offices we can now implement powerful, cost-effective, analysis of natural resources to guide land use planning toward a higher level of sustainability.

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Appendices

Appendix A

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Table 1: Applied Methodologies Matrix

	Comprehensive	Focused
Existing Conditions	SAA (SAMAB)	GAP Analysis RMTF (Chattanooga)
Historical Trends	EMAP (EPA)	NALC (USGS)
Predictive: Time-dependent: Static:	METLAND (Boston)	LUCAS EVI: Risk Assessment Analysis

Note: Projects are located in the matrix according to their primary associations. Categories are by no means exclusive, and particular methodologies often could easily be placed in multiple categories.

Table 2: Weighted Natural Resource Valuation

Ecological, Social, and Economic Values:	Wildlife habitat	Reduces Erosion	Pollution	Sense of Place	Flood Water Management	Water Supply	Market Utility	Recreation	Total Value Points
Forests	X	X	X	X	X	X	X	X	8
Wildlife Migration Corridors	X							X	2
Streams	X		X	X	X	X		X	6
Wetlands	X		X	X	X			X	5
Floodplains					X			X	2
Groundwater Recharge Areas			X		X	X			4
Agricultural Land				X			X		2
Steep Slopes	X	X		X	X				4
Protected Lands*	X			X				X	99
Built Environment									
Resource Impact Factors									
Infrastructure: Roads, Sewers	-X						-X		-2
Urbanized Areas	-X		-X				-X		-3
Pollution Sources	-X		-X			-X		-X	-4
Impaired Waterways	-X		-X			-X		-X	-4

Table 3: NASA Landsat Pathfinder Program Satellites

System	Launch (End of Service)	Resolution (meters)
Landsat 1	07/23/72	80
	(01/06/78)	80
Landsat 2	01/22/75	80
	(02/25/82)	80
Landsat 3	03/05/78	40
	(03/31/83)	80
Landsat 4	07/16/82	80
		30
Landsat 5	03/01/84	80
		30
Landsat 6	10/05/93	n.a.
	(10/05/93)	n.a.
Landsat 7	04/15/99	15 (pan)
		30 (ms)
		60 (ms)

Table 4: Landsat 7 Data Users and Applications

Agriculture, Forestry, and Range Resources	Land Use and Mapping	Geology	Water Resources	Environment
Discrimination of vegetative, crop, and timber types, and range vegetation	Classification of land uses	Mapping of major geologic units	Determination of water boundaries and surface water areas	Monitoring environmental effects of man's activities (lake eutrophication, defoliation, etc.)
Measurement of crop and timber acreage	Cartographic mapping and map updating	Revising geologic maps	Mapping of floods and flood plains	Mapping and monitoring of water pollution
Estimating crop yields	Categorization of land capability	Recognition of certain rock types	Determination of areal extent of snow and ice	Determination of effects of natural disasters
Forest harvest monitoring	Monitoring urban growth	Delineation of unconsolidated rocks and soils	Measurement of glacial features	Monitoring surface mining and reclamation
Determination of range readiness and biomass	Regional planning	Mapping recent volcanic surface deposits	Measurement of sediment and turbidity patterns	Assessing drought impact
Determination of soil conditions and associations	Mapping of transportation networks	Mapping landforms	Delineation of irrigated fields	Siting for solid waste disposal

Assessment of grass & forest fire damage	Mapping of land-water boundaries	Search for surface guides to mineralization	Inventory of lakes	Siting for power plants and other industries
Wildlife habitat assessment	Siting for transportation and power transmission routes	Determination of regional structures	Estimating snow melt runoff	
	Flood plain management			

U.S. Department of the Interior, U.S. Geological Survey.

Table 5: Natural Resources Themes

Theme	Source	Availability/Quality
Rivers, Streams	EPA SAA TIGER	readily available via Internet
Riparian Zones	EPA (SAA)	based on 1992 Landsat data
Wetlands	TWRA: NWI EPA/SAA	In process of digitizing. NALC
Flood plains	FEMA TVA	Limited availability in GIS format (DFIRM). Limited availability.
Aquifer Recharge Areas	Not Available	
Steep Slopes	SAA	
Elevation Features (Ridgelines, Peaks, and Bluffs)	SAA	
Forests	EPA/SAA	NALC
Grasslands/ Pastures	EPA/SAA	NALC
Lands in Agricultural Use	EPA /SAA USGS	NALC
Land in Timber Production	Tax maps Landsat The Center	Corporate Ownership Monoculture Conversions/ Clearcuts Southwings

Prime Farmland Soils Hydric Soils Highly Erodible Soils	NRCS SAA	Limited availability. In GIS format for West TN only at this time.
Wildlife Habitat	TWRA/TDEC: GAP Analysis SAA	Available in 2000 Crude.
Viewsheds	public input	
Protected Areas: national parks state and national forests trust lands wildlife management areas	SAA NPS TDEC TWRA TCL	
Polluted Areas	EPA	GIS point data and full tabular record on Internet includes CERCLIS, RICRA, TRI, and NPDES data.
Urban Areas	EPA/SAA Census data	NALC

Appendix B

EVI Indicators

EVI Vulnerability Indicators

Excerpted from *Environmental Vulnerability Index (EVI) to summarize national environmental vulnerability profiles*. By: Ursula Kaly et al. SOPAC Technical Report 275

These indicators provide a description, categorization and the response levels set for the questions used in this study to measure aspects of vulnerability. For many of the risk indicators, the observed value is expressed as a ratio in relation to the area of land or sea available. The reasoning behind this is that it is the *density* of risks, not the absolute number that affects the environment. The ability of ecosystems to tolerate impacts depends on how much of the ecosystem is affected at any one time and how much ecosystem is available to absorb the effects of a risk. For example 1 ton of a pollutant spread over 100 km² is expected to have a smaller detrimental effect than the same amount spread over 1 km² (all else being equal) because the concentration of the pollutant will be lower and any toxicity thresholds are less likely to be exceeded. A select representation of indicators are presented below.

Question number: 12

Sub-index: REI

Categorisation: Anthropogenic, Agriculture

Factor type: Risk Factor

Intrinsic weighting: 1

Percentage of agriculture land under subsistence / organic agriculture

Scoring levels:

1	2	3	4	5	6	7
80-100%	60-79%	40-60%	21-40%	11-20%	1-10%	0%

Agricultural lands under organic and most forms of subsistence agriculture are less likely to be associated with problems of erosion, increased run-off, soil depletion, pesticides and wholesale habitat destruction than mechanised agriculture.

Question number: 13

Sub-index: REI

Categorisation: Anthropogenic, Agriculture

Factor type: Risk Factor

Intrinsic weighting: 1

Tonnes of pesticides produced or imported / 10,000 sq. km land area / year (average last 5 years)

Scoring levels:

1	2	3	4	5	6	7
0	1-100	101-500	501-1,000	1,001-5,000	5,001-10,000	>10,000

This question examines the loading of agricultural and urban land areas with pesticides which can then combine into further toxic compounds and/or find their way into streams, groundwater, coastal areas and therefore other ecosystems.

Question number: 14

Sub-index: REI

Categorisation: Anthropogenic, Agriculture

Factor type: Risk Factor

Intrinsic weighting: 1

Tonnes of N,P,K fertilisers produced or imported / 10,000 sq. km land area / year (average last 5 yrs)

Scoring levels:

1	2	3	4	5	6	7
0	1-100	101-500	501-1,000	1,001-5,000	5,001-10,000	>10,000

When these fertilisers find their way into other ecosystems (usually aquatic) they can lead to problems of algal blooms (including toxic algae such as those which lead to red tides and paralytic shellfish poisoning - PSP) and eutrophication.

Question number: 15

Sub-index: REI

Categorisation: Anthropogenic, Agriculture

Factor type: Risk Factor

Intrinsic weighting: 5

Rate of deforestation of primary forest (% of remaining forest lost per year) (average of last 5 years)

Scoring levels:

1	2	3	4	5	6	7
0	0.1-1%	1.1-2%	2.1-3%	3.1-4%	4.1-5%	>5%

Question number: 16

Sub-index: REI

Categorisation: Anthropogenic, Agriculture

Factor type: Risk Factor

Intrinsic weighting: 1

Percentage of agriculture land which is mechanised, monoculture and/or commercial

Scoring levels:

1	2	3	4	5	6	7
0	1-10%	11-20%	21-40%	40-60%	60-79%	80-100%

Chemical farming methods includes the use of insecticides, herbicides, fungal agents, vermicides etc, for aquaculture this includes antibiotics. Also included in this question is the use of chemical fertilisers including hydroponics.

Question number: 18

Sub-index: REI

Categorisation: Anthropogenic, Fisheries

Factor type: Risk Factor

Intrinsic weighting: 1

Number of commercial offshore fishing vessels / area of EEZ / year (average of last 5 years)

Scoring levels:

1	2	3	4	5	6	7
0-10	11-25	26-50	51-100	101-150	151-200	>200

This is an approximate measure of the amount of off-shore and pelagic fisheries pressure in the state.

Question number: 19

Sub-index: REI

Categorisation: Anthropogenic, Fisheries

Factor type: Risk Factor

Intrinsic weighting: 1

Destructive fishing methods used? (dynamite, cyanide, muro ami, rotenone)

Scoring levels:

1	2	3	4	5	6	7
No			Some			Common

Destructive fishing methods usually are a result of and further exacerbate problems of not only overfishing, but also habitat destruction. When the fish habitats are destroyed the renewability of the fishery resource decreases.

Question number: 23

Sub-index: REI

Categorisation: Anthropogenic, Government

Factor type: Mitigating Factor

Intrinsic weighting: 1

Environmental Legislation

Scoring levels:

1	2	3	4	5	6	7
Law			Draft			None

Question number: 24

Sub-index: REI

Categorisation: Anthropogenic, Government

Factor type: Mitigating Factor

Intrinsic weighting: 1

Percent of development projects accompanied by EIA (Environmental Impact Assessment)

Scoring levels:

1	2	3	4	5	6	7
95-100%	70-94%	50-69%	21-49%	6-20%	1-5%	0%

Question number: 25

Sub-index: REI

Categorisation: Anthropogenic, Government

Factor type: Mitigating Factor

Intrinsic weighting: 1

Percent of terrestrial zone set aside as reserves

Scoring levels:

1	2	3	4	5	6	7
>20%	11-20%	6-10%	1-5%			0%

This question refers only to national parks and sanctuaries of natural habitat areas within which no hunting or collecting is permitted.

Question number: 28

Sub-index: REI

Categorisation: Anthropogenic, Mining

Factor type: Risk Factor

Intrinsic weighting: 1

Kilotonnes of all mining material (ore + tailings) extracted / 10,000 sq. km land area / year (average last 5 years)

Scoring levels:

1	2	3	4	5	6	7
0-100	101-250	251-500	501-1,000	1,001-1,500	1501-2,000	>2,000

Question number: 29

Sub-index: REI

Categorisation: Anthropogenic, Pollution

Factor type: Risk Factor

Intrinsic weighting: 1

Total tonnage of imported toxic or hazardous wastes / 10,000 sq. km land area / year (average last 10 years)

Scoring levels:

1	2	3	4	5	6	7
0	1-50	51-200	201-300	301-500	501-1,000	>1,000

Question number: 30

Sub-index: REI

Categorisation: Anthropogenic, Pollution

Factor type: Risk Factor

Intrinsic weighting: 1

Millions of litres of hydrocarbons used / 10,000 sq. km land area / year (average over last 5 years)

Scoring levels:

1	2	3	4	5	6	7
0-100	101-200	201-300	301-400	401-500	501-600	>600

Question number: 31

Sub-index: REI

Categorisation: Anthropogenic, Pollution

Factor type: Risk Factor

Intrinsic weighting: 1

Number of nuclear facilities (power, medical/research facilities, waste, weapons) / 10,000 sq. km land area

Scoring levels:

1	2	3	4	5	6	7
0		<0.1	0.1-1	1.1-10	11-100	>100

Question number: 33

Sub-index: REI

Categorisation: Anthropogenic, Pollution

Factor type: Risk Factor

Intrinsic weighting: 1

Electricity consumption kilowatt hours / capita / year

Scoring levels:

1	2	3	4	5	6	7
0-1,000	1,001-2,000	2,001-3,000	3,001-5,000	5,001-7,000	7,001-10,000	>10,000

Question number: 34

Sub-index: REI

Categorisation: Anthropogenic, Pollution

Factor type: Risk Factor

Intrinsic weighting: 1

Number of cars / 1,000 persons

Scoring levels:

1	2	3	4	5	6	7
0-10	11-20	21-100	101-200	201-350	351-500	>500

Question number: 36

Sub-index: REI

Categorisation: Anthropogenic, Pollution

Factor type: Risk Factor

Intrinsic weighting: 1

Percent of population with at least secondary sewage treatment

Scoring levels:

1	2	3	4	5	6	7
100	80-99	60-79	40-59	20-39	1-19	0

Question number: 37

Sub-index: REI

Categorisation: Anthropogenic, Population

Factor type: Risk Factor

Intrinsic weighting: 5

Annual population growth rate (average over last 5 years)

Scoring levels:

1	2	3	4	5	6	7
Negative		0%	0.1-1%	1.1-2%	2.1-3%	>3%

Question number: 38

Sub-index: REI

Categorisation: Anthropogenic, Population

Factor type: Risk Factor

Intrinsic weighting: 5

Total human population density (per sq. km land area)

Scoring levels:

1	2	3	4	5	6	7
0	1-100	101-200	201-300	301-400	401-500	>500

Question number: 42

Sub-index: IRI

Categorisation: Country characteristics

Intrinsic weighting: 1

Number of endemic species per 10,000 sq. km land area

Scoring levels:

1	2	3	4	5	6	7
0	<0.26	0.26-1	1-25	26-50	51-100	>100

Countries with large numbers of endemic species will tend to be more vulnerable to risks because localised extinctions cannot be resupplied from elsewhere by natural or augmented recolonisation. The loss of endemic species can lead to far-reaching secondary impacts on the functioning of ecosystems. This indicator includes mammals, birds, reptiles, amphibians, fishes and plants.

Question number: 45

Sub-index: EDI

Categorisation: Ecosystems

Intrinsic weighting: 1

Has nuclear testing occurred?

Scoring levels:

1	2	3	4	5	6	7
No						Yes

Question number: 46

Sub-index: EDI

Categorisation: Ecosystems

Intrinsic weighting: 1

Percent age area of land desertified since 1950

Scoring levels:

1	2	3	4	5	6	7
0	1-2%	3-4%	5-6%	7-8%	9-10%	>10%

Question number: 48

Sub-index: EDI

Categorisation: Ecosystems

Intrinsic weighting: 5

Percentage of primary / old growth forests or vegetation remaining (e.g. prairies, savannah, desert, tundra)

Scoring levels:

1	2	3	4	5	6	7
90-100%	61-89%	31-60%	21-30%	11-20%	1-10%	0%

Question number: 49

Sub-index: EDI

Categorisation: Ecosystems

Intrinsic weighting: 1

Percent of fisheries stocks overfished

Scoring levels:

1	2	3	4	5	6	7
0	1-10%	11-20%	21-30%	31-40%	41-50%	>50%

Question number: 50

Sub-index: EDI

Categorisation: Ecosystems

Intrinsic weighting: 1

Percentage of land under agriculture including plantation / forestry (now)

Scoring levels:

1	2	3	4	5	6	7
0-10%	11-20%	21-30%	31-50%	51-60%	61-79%	80-100%

Question number: 52

Sub-index: EDI

Categorisation: Ecosystems

Intrinsic weighting: 5

Percentage of original mangrove / saltmarsh area remaining

Scoring levels:

1	2	3	4	5	6	7
90-100%	71-89%	61-70%	51-60%	11-50%	1-10%	0%

Question number: 53

Sub-index: EDI

Categorisation: Ecosystems

Intrinsic weighting: 1

Number of harmful algal blooms including ciguatera, red tides etc over the last 5 years / 10,000 sq. km coastal area

Scoring levels:

1	2	3	4	5	6	7
0			1-2	3-5	5-10	>10

Question number: 54

Sub-index: EDI

Categorisation: Ecosystems

Intrinsic weighting: 1

Percent total land area affected by mining / quarrying

Scoring levels:

1	2	3	4	5	6	7
0	<0.1%	0.1-1%	1-3%	4-6%	7-10%	>10%

Question number: 55

Sub-index: EDI

Categorisation: Biodiversity

Intrinsic weighting: 1

*Number of species which have become extinct this century / 10,000 sq. km land and (coastal area * 0.5)*

Scoring levels:

1	2	3	4	5	6	7
0	<0.1	0.1-0.5	0.6-1.0	1.1-5	6-10	>10

These figures should be available for mammals, birds, reptiles, amphibians, fishes and plants (e.g. IUCN Red List). Because the coastal area is defined as a 1km strip on either side of high tide mark, it was necessary to divide the coastal area by half to avoid overlap with the measurement of land area.

Question number: 56

Sub-index: EDI

Categorisation: Biodiversity

Intrinsic weighting: 1

*Number of endangered and threatened species / 10,000 sq. km of land and (coastal area * 0.5)*

Scoring levels:

1	2	3	4	5	6	7
0	<0.1	0.1-0.5	0.6-1.0	1.1-5	6-10	>10

Question number: 57

Sub-index: EDI

Categorisation: Biodiversity

Intrinsic weighting: 1

Number of introduced terrestrial species / 10,000 sq. km land area (over last 100 years)

Scoring levels:

1	2	3	4	5	6	7
0	<0.1	0.1-0.5	0.6-1.0	1.1-5	6-10	>10

Appendix C
Site and Impact Checklist

A Site and Impact Checklist from *Site Planning*, Appendix G (Lynch 1984).

Early in a project it is useful to set down a list of site data that will be required in order to guide the collection of original and existing information. Such a list should be short at the beginning and lengthen as understanding of the site evolves. Too many data should not be gathered at first stages, not only to save energy for later investigations but also to avoid being drowned in partly irrelevant material.

Having said that, we present a list of data that is far too long for any project. At most, many of these topics would be handled sketchily. Use it as a checklist to decide what data need *not* be collected, as well as those that must.

It is customary to make an environmental impact study when project planning is complete, in the form of an indictment or a whitewash. We advocate that the impact study commence with the first gathering of site data. The impact analysis then develops as the design develops, and thus guides and is guided by it. In its final form, then, like the analysis of cost (which is what is in a broader sense), it will contain no nasty surprises.

Like the site analysis, it should also be concise and pointed, covering the most critical subjects in depth, touching briefly on those whose impact is negligible. Its content largely overlaps the more general site analysis list since it is a schedule of information about those particular conditions which will have a primary effect on the neighbors of a project. In each subsection below, under the heading of "typical impact question," we list the issues most likely to be crucial in environmental impact studies. Site and impact analysis should proceed together, and both should focus on essentials. Both contain negative and positive elements; neither determines a decision by themselves. Design, and then judgement, must be applied.

A. General Site Context

- (1) Geographic location, adjacent land use patterns, access system, nearby destinations and facilities, stability or change in development pattern.
- (2) Political jurisdictions, social structure of the locality, population change in surrounding areas.
- (3) Ecological and hydrographic system of the region.
- (4) Nature of the area economy, other proposals or projects nearby and their effects on the site.

Typical impact Questions:

Will important locations or resources become inaccessible to the general public?

Will energy, water, food, or other scarce resources be depleted or degraded?

Will the health or safety of the surrounding population be endangered?

Will the project put an undue traffic load on its surroundings?

Will surrounding political, social, or economic systems be disrupted?

Will the project have a negative impact on existing businesses or institutions?

Will its construction or maintenance lay undesirable financial burdens on the surrounding community?

B. Physical Data, Site and Adjacent Land

(1) Geology and Soil:

- a. Underlying geology, rock character and depth, fault lines.
- b. Soil types and depth, value as an engineering material and as a plant medium, presence of hazardous chemicals or contaminants.
- c. Areas of fill or ledge, liability to slides or subsidence, capability for mining.

Typical Impact Questions:

Are landslides, subsidence, or earthquakes likely to occur?

Will the soil be contaminated?

Can the soil absorb likely wastes without damage?

Will the topsoil or its nutrient balance be lost?

(1) Water:

- a. Existing water bodies-variation and purity.
- b. Natural and man-made drainage channels-flow, capacity, purity.
- c. Surface drainage pattern-amount, directions, blockages, flood zones, undrained depressions, areas of continuing erosion.
- d. Water table-elevation and fluctuation, springs, flow directions, presence of deep aquifers.
- e. Water supply-location, quantity and quality.

Typical Impact Questions:

Will the purity, oxygen level, turbidity, or temperature of surface waters be affected?

Will siltation occur?

Can the drainage system accept the additional runoff?

Will lands be flooded, erosion be induced, or water bodies caused to fluctuate?

Will the water table rise or fall, affecting vegetation, basements, or foundations?

Will groundwater be contaminated, or the recharge or draw-down of aquifers be affected?

(1) Topography:

- a. Contours.
- b. Pattern of landforms-typology, slopes, circulation possibilities, access points, barriers, visibility.
- c. Unique features.

Typical Impact Question:

Will unique or valued landforms be damaged?

(1) Climate:

- a. Regional pattern of temperature, humidity, precipitation, sun angles, cloudiness, wind direction and speeds.
- b. Local microclimates: warm and cool slopes, wind deflection and local breeze, air drainage, shade, heat reflection and storage, plant indicators.
- c. Snowfall and snow drifting patterns.
- d. Ambient air quality, dust, smells, sound levels.

Typical Impact Questions:

Will the project cause general climatic changes, such as in regard to temperature, humidity, or wind speed?

Will local microclimates be affected adversely-by the deflection or funneling of wind, the shading or reflection of sunlight, the drying or humidifying of the air, the intensification of diurnal temperature ranges, or the drifting of snow?

Will air pollution increase of dust or obnoxious odors be generated?

Will the project increase or decrease disturbing noise levels?

Will the project cause any radiation or other toxic hazards?

(1) Ecology:

- a. Dominant plant and animal communities-their location and relative stability, self-regulation, and vulnerability.
- b. General pattern of plant cover, quality of wooded areas, wind firmness, regeneration potential.
- c. Specimen trees-their location, spread, species, elevation at base, whether unique or endangered, support system needed.

Typical Impact Questions:

Will important plant and animal communities be disrupted?

Will it be difficult for them to relocate or to regenerate themselves?

Will rare or endangered species be destroyed or pest species increase?

Will the project cause eutrophication of water bodies or algal blooms?

Will the plan remove significant agricultural uses or make it difficult for them to be reestablished in the future?

(1) Man-Made Structures

- a. Existing buildings: location, outline, floor elevations, type, conditions, current use.
- b. Networks: roads, paths, rails, transit lines, sewers, water lines, gas, electricity, telephone, steam-their location, elevations, capacity, condition.
- c. Fences, walls, decks, other human modifications to the landscape.

Typical Impact Questions:

Will present and planned roads and utilities serve the site without adverse impacts on adjacent areas?

Will the project require a substantial investment in surrounding roads and utilities?

Can these new facilities be adequately maintained and operated?

Will new structures conflict with or damage existing ones?

(1) Sensory qualities:

- a. Character and relationship of visual spaces and sequences.
- b. Viewpoints, vistas, focal points.
- c. Quality and variation of light, sound, smell.

Typical Impact Questions:

Is the new landscape in character with the existing one?

Are existing views and focal points conserved and enhanced?

Are the new buildings compatible in character with the existing structures to be retained?

C. Cultural Data, Site and Adjacent Land

(1) Resident and using population:

- a. Number, composition, pattern of change.
- b. Social structure, ties, and institutions.
- c. Economic status and role.
- d. Organization, leadership, political participation.

Typical Impact Questions:

Will any of the existing population be relocated?

Will any segment of this population be disadvantaged?

Will present disadvantaged groups be aided?

How will existing jobs and businesses be affected?

Will the plan modify current lifestyles or cultural practices in undesirable ways?

(1) Behavior settings: nature, location, participants, rhythm, stability, conflicts.

Typical Impact Questions:

Will the plan destroy important patterns of use without replacing them?

Will new uses conflict with old ones or endanger safety?

Is future change and expansion provided for?

(2) Site values, rights, restraints:

- a. Ownerships, easements and other rights.
- b. Zoning and other regulations that influence site use and character.
- c. Economic value and how it varies across the site.

- d. Accepted "territories."
- e. Political jurisdictions.

Typical Impact Questions:

Will the economic values of the site or its surroundings be depreciated or enhanced?

Will ownerships or customary "territories" be significantly disrupted?

(1) Past and future:

- a. History of the site and its visible traces.
- b. Public and private intentions for future use of site, conflicts.

Typical Impact Questions:

Are historic structures conserved?

Are archaeological sites and information conserved and developed?

Does the plan disrupt or facilitate current change?

Does it conflict with any existing plans for the future?

(1) Site character and images:

- a. Group and individual identification with aspects of the site.
- b. How the site is organized in people's minds.
- c. Meanings attached to the site, symbolic associations.
- d. Hopes, fears, wishes, preferences.

Typical Impact Questions:

Does the plan destroy or enhance group and individual identification with the site?

Does it disrupt or reinforce existing ways of mentally organizing the site?

Is it in accord with the hopes, fears, and preferences of the users?

D. Correlation of Data

- (1) Subdivisions of the site: areas of consistent structure, character, problems.
- (2) Identification of key points, axes, areas best left undeveloped, areas where intensive development is possible.
- (3) Ongoing changes, and those likely to occur without intervention-the dynamic aspect of the site.
- (4) Ties to context-current and possible linkages, areas where consistent uses are desirable, patterns of movement to be preserved.
- (5) Summary of significant problems and potentials, including a summary of the key positive and negative impacts of the proposal.

Appendix D

Public Input

The following information regarding community participation is excerpted from *Smart Growth for Tennessee Towns and Counties: A Process Guide* by Mary R. English, Jean H. Peretz, and Melissa Manderschied. The guide is available on the Internet at <<http://eerc.ra.utk.edu/smart.htm>>. Questions or comments concerning this guide should be directed to Dr. Mary R. English, Research Leader, or Ms. Jean H. Peretz, Research Scientist, at the Energy, Environment and Resources Center, 311 Conference Center Building, University of Tennessee, Knoxville 37996-4134. Phone 423-974-4251; fax 423-974-1838; or e-mail menglish@utk.edu or speretz@utk.edu.

IDENTIFYING VALUES AND SETTING GOALS

Vision Statements

Scenarios

Surveys

Visual Preference Surveys

Forums

Town Meetings

Committees and Task Forces

Focus Groups

Video-Based Techniques

Computer-Based Polling in Meetings

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Nominal Group Technique

IDENTIFYING VALUES AND SETTING GOALS

Values are a person's internal conceptions of what is desirable for themselves and others. Values are not static; while some values are deeply held, others can change as a person learns more about a situation. Values help to shape what people want for (and from) their community; thus, values are important in goal-setting. Community goal-setting should transcend individual values, however. Goals for the community should be a product of personal reflection and collective dialogue.

Developing a Community Vision ...

Questions that can help the process along:

Identifying values and setting goals can lead to different "products," such as vision statements, scenarios, and surveys.

Vision Statements

Vision statements have become popular, not only as a part of the strategic planning of individual companies and organizations, but as part of community planning. They have been promoted by groups such as the National Civic League, which regards vision statements as one of several essential components within collaborative planning processes. According to the National Civic League:

A community vision is an expression of possibility, an ideal state that the community hopes to attain... The vision provides the basis from which the community determines priorities and establishes targets for performance. It sets the stage for what is desired in the broadest sense, where the community wants to go as a whole. It serves as a foundation underlying goals, plans, and policies... Only after a clear vision is established is it feasible to effectively begin the difficult work of outlining and developing a clear plan of action.

Derek Okubo. *The Community Visioning and Planning Handbook*. Denver, CO: National Civic League, p. 31

The National Civic League recommends that vision statements be reached by consensus, include strong visual descriptions, and be directed toward a period stretching at least 10 years—preferably 15 to 25 years—into the future. They recommend a brainstorming exercise to warm up a group; then breaking the group into smaller working groups of 7 to 10 people to develop vision themes, which then get reported back to the larger group and integrated into a statement. They suggest a weekend visioning retreat as an effective format, but note that typically the vision statement will be developed over two non-consecutive evenings.

Key issues:

- Vision statements should be broad, but they should set a direction. Finding the right level of generality can be difficult.
- Getting the right mix of people to develop a vision statement is challenging but crucial. It will affect the credibility and usefulness of the statement for later planning.
- People's views and visions won't always agree. Looking for areas of agreement can be time-consuming, and important differences may be papered over.

- Vision statements, and visioning more generally, may seem cheap but have hidden costs in terms of staff and participant time. To justify time investments, vision statements should clearly set the stage for action.

Scenarios

Scenarios tell stories about the future—either about what people think will happen, or about what they hope will happen. The latter kind of scenario—the "preferred future" kind—can be used for articulating values and goals. Either way, they need to be constructed methodically. For recommendations on constructing forecasting scenarios, see "Gathering, Integrating, and Forecasting Information" in the Smart Growth Guide.

There are different tactics to generate the "preferred future" kind of scenario. One is to ask people to put themselves into some point in the future and then describe where they are and how they got there...in effect, a hypothetical reflection on the past. A similar tactic is to ask participants to project themselves into the scenario and describe their reactions. In both, concrete examples and representative events should be used, and links among different factors should be described.

As described in *Shaping A Region's Future* (William R. Dodge and Kim Montgomery, 1995) scenarios can also be used to test alternative visions. Participants can discuss a "best case" version of a vision, where everything goes the best way possible, and then a "worst case" version of the vision, where everything goes wrong. They can then discuss other versions, such as a trended version, where things go as they have to date. By using scenarios in this way, visions can be tried out and refined.

Key issues:

- Participants need to have a good working understanding of their community's economy, social life, and natural environment to generate either forecasting or "preferred future" scenarios. This may necessitate learning about the community before participating in a scenario-building session. (See "Gathering, Integrating, and Forecasting Information" in the Smart Growth Guide.)

- If scenarios developed by individuals or small groups are to be used for community goal-setting, the scenarios will have to be integrated by looking for broad themes or areas of agreement.

Surveys

Surveys can be conducted to elicit opinions on a variety of subjects. The survey can be directed toward a targeted population, a random sample, or a stratified random sample (i.e., population components are identified and then randomly sampled). Key decisions include the purpose of the survey; the sampling technique and the number of people to be surveyed; the method of administering the survey (typically, by mail, by phone, or face-to-face); the design of the survey instrument; and how results will be recorded, analyzed, and communicated. Surveys may be repeated to assess changes in views over time. In general, formal survey procedures, large sample sizes, and high response rates all help to make the survey results more representative. However, informal surveys—e.g., a survey in a local newspaper—can give some indication of local views.

Key issues:

- In general, surveys that produce valid, generalizable results are time-consuming and involve high costs (in either dollars or staff and volunteer time). In contrast, informal surveys can be done fairly quickly but produce results that aren't necessarily representative of the community as a whole.

- Unbiased, informative survey instruments are surprisingly difficult to design. Also, people are more likely to respond to short than to long surveys, so survey items must be chosen with care.

- Most surveys ask "closed-ended" questions—i.e., the respondent is posed a question and then chooses from a limited set of responses, such as "yes," "somewhat," "no." This facilitates summarizing and analyzing results across a large number of responses, but it may not provide much insight into people's views. The survey may need space for open-ended comments, or it may need to be accompanied with other, less-directed means of seeking people's views.

Visual Preference Surveys

A Visual Preference SurveyTM (VPS) uses images (typically, photographic slides) with evaluation forms. One purpose of a VPSTM is to learn what community members think about the community's present appearance; a second purpose is to build consensus about what its future character should be.

The concept of surveying visual preferences has been refined and popularized by A. C. Nelessen (*Visions for a New American Dream*, 1994). Images of scenes in the community or elsewhere are selected to represent a range of settings (e.g., farmland, residential neighborhoods, and businesses) and a range of attributes (e.g., wide or narrow streets, compact or low-density housing). The images represent features of the community as it is today and features that it could have in the future; the images are presented randomly, sometimes with paired or redundant images to check for bias. The images may be assembled by planning staff or their consultants. Alternatively or in addition, a group of diverse community members could assemble the images.

As each image is shown, community members are asked to numerically rate it on a positive to negative scale (e.g., from +10 to -10). Mean scores for each image are then calculated, and the images are ranked accordingly from most desirable to least desirable. A zero indicates a neutral impression of the image.

Key issues:

- VPSTM lets community members respond to images rather than to words. It makes abstract ideas tangible, and it may reach people who have limited reading, writing, or public speaking abilities.

- The results can be translated by planners and architects into building codes, subdivision controls, and other design criteria.

- VPSTM works best in large group settings—for example, public meetings and school groups—where a number of people can be shown the images. (An alternative might be to put the images and survey on a Web site, where people could respond at their convenience from home or public library computers.)

- While the concept is simple, selecting the images is difficult. Images must represent a range of existing and possible features in the community but must not be so numerous that people are reluctant to participate.

- The image may be distorted by perspective or subject matter—for example, by focus on an especially beautiful tree or an especially ugly billboard. This may lead to distorted responses.

- To avoid the bias of familiarity, scenes that are typical of the community but are taken elsewhere may be used. These may be more difficult to obtain, and they require more judgments about what images should be shown.

- Respondents may become more lenient or strict in their evaluations as they go through the images; this may distort the scores. (For this reason, a few slides at the beginning and end of the series may not be included in the analysis.)

- It is important to couple numerical testing with the evaluations from the photographic images.

Forums

Methods for bringing people together can be at least as important as the resulting products. These methods can involve large gatherings, such as forums and town meetings, or small groups, such as committees, task forces, and focus groups.

Forums provide situations where people with different backgrounds and experiences can get together to discuss different topics. As one example, in 1993 and 1994, the Cambridge Civic Forum in Cambridge, MA, organized forums around seven areas: ecology, the built environment, health and well-being, education and training, business and employment, social justice and governance, and arts and transcendent values. At the forums, individuals and groups met together with representatives of civic organizations, government departments, and businesses. The purpose of the forums was to share visions and concerns, engage in dialogue, and generate an action plan for Cambridge's future.

Key issues:

- Forums encourage crossing socio-cultural barriers by providing situations in which diverse groups and individuals can meet as equals. However, they may be dominated by a vocal few unless they are carefully facilitated.

- The large-group setting of a forum provides a sense of community but may not provide a setting in which all views can be expressed; furthermore, people who attend and speak out may not represent the spectrum of views in the community.

- Forums may lead to a sense of "all talk and no action" unless they are well-structured, with action items as outcomes.

Town Meetings

In the classic New England-style town meeting, local government decisions are reached by popular vote at the meeting and are binding on the local administration. As the term "town meeting" has come to be used, however, it often does not refer to a form of government. Instead, it refers to a meeting where people come together to exchange ideas on a particular topic—very much like a forum, but sometimes a bit more structured and focused. Anyone can attend, and the issues to be discussed typically are policy issues (not highly technical issues or detailed planning or program review). As with a forum, an experienced moderator is needed; in addition, for discussions to be useful later, they must be accurately summarized. Typically, consensus is not sought at non-governmental "town meetings"; instead, they provide an opportunity to air one's own views and hear other's views. If the size of the population or geographic area is large, several town meetings may be held in different locations on the same topic. Town meetings may also be repeated on different topics or at different stages in a visioning and planning process.

Key issues:

- Town meetings (in their popular, non-governmental sense) have many of the same key issues as forums. They improve acquaintance and communication among diverse community members, but a representative spectrum of people may not turn out; some people feel uncomfortable speaking out in

large-group settings while others may attempt to dominate; and the meetings may seem to be "all talk and no action" unless they have clear outcomes.

- Town meetings and their counterparts demand only limited time commitments from their participants, but they can place heavy demands on the staff and volunteers who arrange and publicize meetings, conduct them, and summarize their results.

- Because decisions usually are not made at town meetings, one question that will likely arise is, "How are you going to use all this input?" The answer to this question will depend upon the larger process, but it's important to have an answer.

Committees and Task Forces

Everybody knows what a committee is. There are, however, several different ways to set one up. A committee can be a collection of volunteers, or it can be appointed. If appointed, members can be selected for their expertise, or because they represent important organizations, population groups, or viewpoints. Most committees are small (a dozen or so people), but some are much larger. While some committees are "standing committees" of indefinite duration with revolving memberships, most committees established for a visioning and planning process meet for a limited period of time. During the process, the same committee might meet, or it might be augmented or otherwise changed at different stages of the process. Committees typically must work out their own procedures: whether they will have a chair, how they will keep records of their meetings, and how they will make decisions (e.g., by consensus or by majority vote).

Task forces are like committees, but they usually are directed toward one or a few issues—either policy or technical issues—and usually continue for a specified period, until they have completed their task. Committees may be supplemented with task forces or subcommittees to address specific issues. Subcommittees typically include a few members from the main committee but may have other members as well; task forces may or may not have a completely independent structure. When a committee is augmented with subcommittees or task forces, a way of integrating findings and recommendations will need to be developed and clearly understood, as will an allocation of responsibilities.

Key issues:

- Self-selected committees or task forces are more likely to have enthusiastic, committed participants, but they may not be well-balanced. However, selecting a committee's members requires that someone (or a steering committee) do the selecting.

- Committees established for the purpose of helping to advise on and guide a community's visioning and planning process are mostly likely to be effective and received as credible if they represent a number of different sectors within town. Inclusiveness must be balanced with workability, however; a committee is most effective if everyone has the opportunity to speak and exchange views (typically, no more than 12 to 15 members). An alternative is to break into subcommittees, but then the question of how to integrate advice must be addressed.

- A basic decision will be needed: Should local elected and administrative officials be involved, or should this be a "citizens committee"? One alternative is to have local officials serve as ex-officio members, but this may not sufficiently engage their attention.

- The committee's purpose and scope of authority need to be well-understood at the outset, but still may evolve during the process.

- Committees of volunteers often require considerable staff support and expertise; they have hidden costs in both the volunteer and the staff time required.

- Rather than setting up a new committee, an existing committee (or board, or panel) may be able to fill the bill. But if an existing committee is used, its main agenda should not be allowed to dominate or overshadow the agenda of the visioning and planning process, and the committee may need to be supplemented with other members to round out its composition.

During the focus group session, individuals participate in a "group interview"; through the group discussion and interactions, values and preferences are clarified and expressed. The purpose is not to get a consensus position from the group, but rather to get a sense of the nature and range of views. Typically, focus groups are not used for grappling with technical issues.

Key issues:

- Focus groups don't lead to well-integrated recommendations. They can, however, help to reveal which issues are on people's minds; they thus can help to structure surveys, community meetings, or committee deliberations.

- To be useful, focus groups need to be conducted early in a process; they should not be an add-on.

- To be useful and not give a biased impression, focus groups for a number of different population groups are likely to be needed.

- Focus groups are time-consuming to conduct, and they require skill in both leading the "group interview" and recording and interpreting its results.

Many different techniques can be used to facilitate identifying values and setting goals. A few are noted below.

Video-Based Techniques

Particularly with the advent of community channels, television can be used to discuss issues and elicit opinions. For example, during the program, viewers may be asked to fill out and mail in a questionnaire that was previously distributed with notice of the televised program. (The questionnaire might have been sent by mail, publicized in the local paper, or distributed in public gathering places.) In effect, the program provides a means to present information (see "Gathering, Integrating, and Forecasting Information" in the Smart Growth Guide) that may help to inform people's expressed values and goals for the community; it is accompanied with an informal survey.

Another way to use video technologies is through "video conferencing." People at multiple satellite locations view a program which is transmitted from the central location.

They then phone in questions or opinions which are answered or relayed at the central location. Alternatively, with sophisticated video conferencing, the set-up is fully interactive and people can exchange information and questions directly.

Key issues:

- Using a community channel to convey information and elicit opinions may reach people who watch television often but are unable or disinclined to attend community meetings.
- With video-based techniques, information presentations must be formatted to transmit well on television.
- Video-based techniques may be expensive and difficult to set up, especially if satellite locations and interactive conferencing techniques are used.

Computer-Based Polling in Meetings

Participants in a medium- or large-group meeting are given keypads connected to a central computer. They can then "vote" on issues raised, and the votes are instantly tallied. Immediate feedback is provided on a display screen connected to the computer. A facilitator is needed to pose questions that can be answered using the keypads, and an assistant usually is needed for the computer. The votes typically are advisory only; they provide a sense of the opinions of the people in the room to both the participants there and those who are gathering opinions.

Key issues:

- A number of issues can be addressed quickly with anonymous, rapid feedback; however, the formal, computer-based procedure may give people the impression that they are actually voting rather than simply registering an opinion.
- Computer-based polling requires either having the equipment and expertise to run the meeting or hiring a consultant to do so.
- The number of participants is limited to the number of keypads.
- Some participants may feel intimidated by the technology and pressured by the situation (particularly the need to respond quickly by pressing a button); some may also have difficulty comprehending the computer-generated graphs displaying responses.
- A skilled facilitator is needed to both frame the questions and know how to encourage rather than shut off discussion using the computer polling technique.

"Voting Dots"

The "voting dots" technique uses small, colorful adhesive dots available at school and office supply stores. Several variations are possible. A typical one is described below.

Upon entering the meeting, all participants are given the same number of dots and told that they will be used later in the meeting. The meeting facilitator poses a question to the participants, who are encouraged to respond but keep their answers brief and to-the-point. Other participants or the facilitator may seek clarification of a response but should not challenge or debate it. The facilitator or an assistant writes each response separately in large print on a large sheet of paper, which is then posted at the front of the room. The facilitator poses a second question and again seeks responses, which are written on another large sheet of paper. The process is repeated for each question. (Usually, the questions are few and general in nature.)

Very similar responses may then be combined with the agreement of the participants.

During a break, the participants use their dots to vote for the responses they think are the most important. If they choose, they may "spend" all their dots on one response, or they may spread them around. The responses are rated and ranked according to the number of dots received. Discussion of the results may follow.

For very large groups, it may be necessary to break into smaller groups and run the process concurrently in several different rooms. The process occurs in the same manner, and the ratings are tallied across groups, using each group's response and voting results. Some validity is lost, however, because like items from the different groups are combined by the facilitators without the participants' input.

Key issues:

- Participants need to understand how the meeting and its results fit into the larger process.
- Participants need reasonably good reading skills for the voting procedure.
- Because the voting procedure is not anonymous, participants may feel pressure to vote for some responses over others.
- Some people may feel uncomfortable speaking in front of a large group. (To deal with this problem, participants may be invited to write down responses as well. These responses are then listed for all the participants to see.)
- Some important issues may not fare well in the voting process: With a limited number of dots, people must make forced choices and a few dominant issues may receive most of the dots. (To lessen this problem, people may be given several dots in different colors and instructed to use the different colors for different thematic categories, such as "economic," "environmental," and "social.")

Nominal Group Technique

This is one of several techniques that can be used to elicit and clarify opinions and develop group recommendations. The nominal group technique can be used for a small group or for a larger group that is broken out into small groups.

Each small group is given the same question for participants to address, and each has a facilitator who may also participate. Participants begin by individually writing down responses to the question at hand. They then go around the group, each person stating one item from his or her list, and repeat going around until all items have been covered. The facilitator writes each item verbatim on a flip chart; the group holds off on discussion. Items are then discussed, clarified, and numbered but not combined. Each participant writes down the numbers of their top ten items, using index cards—one card for each item—and then prioritizes those items, ranking them from 10 (top) to 1. The facilitator collects the cards and records the number of "votes" each item received. The group discusses the results and then each participant ranks the 10 highest-scoring items, using the same procedure as before. If more than one group is involved, each facilitator gives his or her group's results to the meeting coordinator.

Key issues:

- The nominal group technique draws out opinions that might otherwise go unvoiced, by giving participants equal time.

- Through this technique, people with different backgrounds can communicate their views and together clarify issues; however, this and other techniques that rely on writing and reading skills may marginalize people who lack these skills.

- Forced ranking may lead to dropping out important issues that don't make the final cut. (One possible solution might be to rank within but not across categories. Another solution might be for participants to rate all items by whether they are low, medium, or high priority using scores of 1, 2, and 3, respectively. The scores are then summed for each item.)

- It may be important to distinguish near-, medium-, and long-term items.

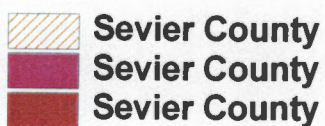
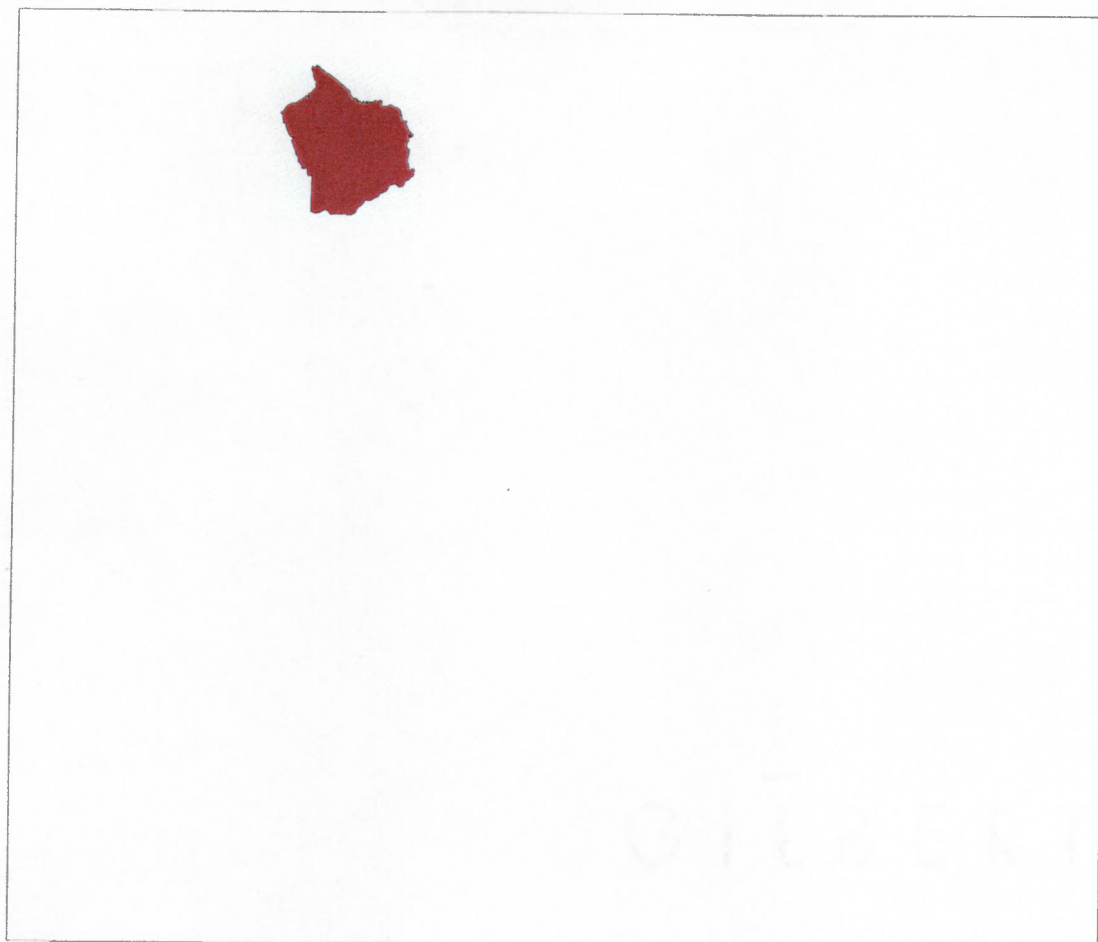
- "Rolling up" the results from several small groups may present a problem. One possible solution might be to have the small groups re-assembled as a large group to vote on the combined results within categories.

Appendix E

Maps

Contents–Appendix E

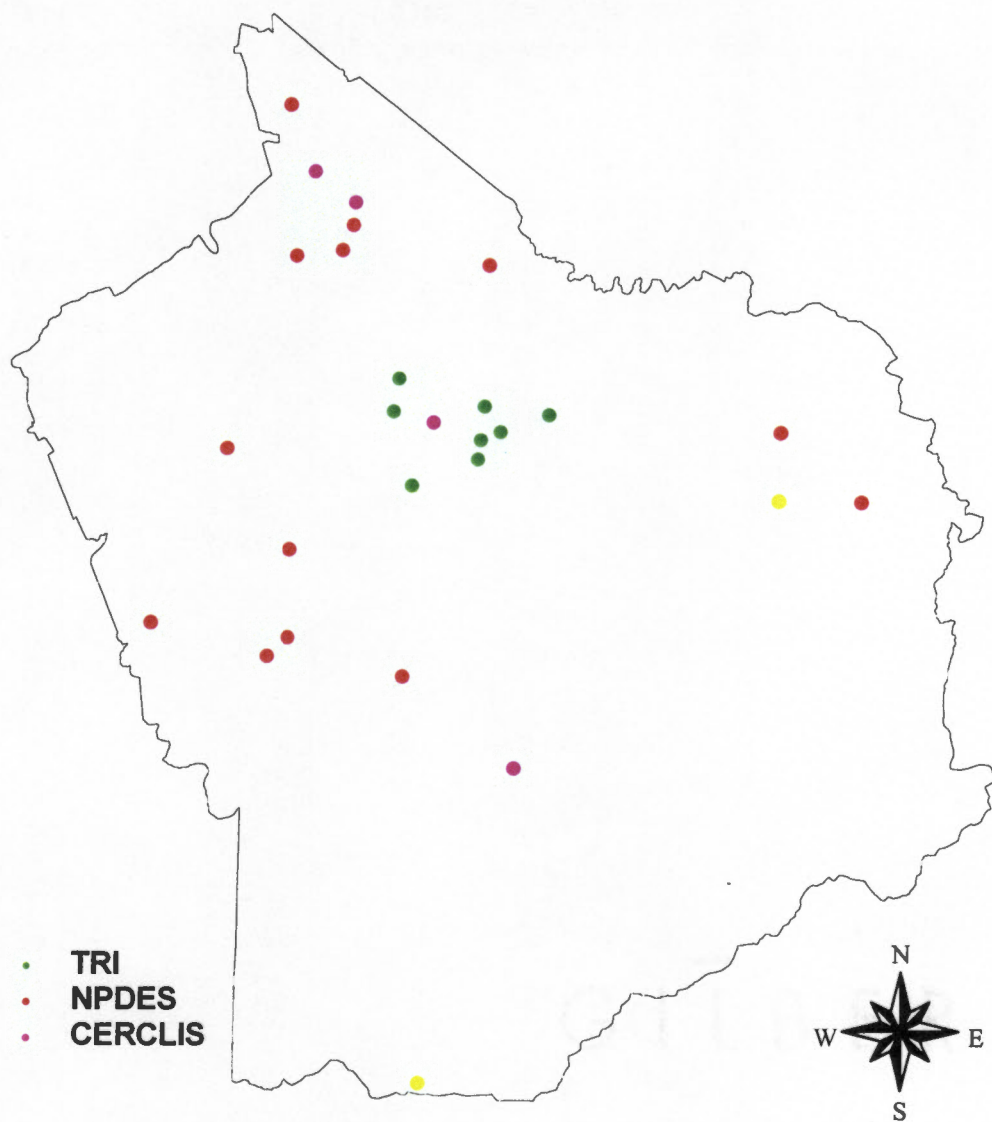
Map 1: Spatial Referencing Incongruencies	pg.138
Map 2: Point Data Inaccuracies	pg.139
Map 3: Landcover	pg.140
Map 4: Slope	pg.141
Map 5: Surface Waters	pg.142
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Map 8: Natural Resources Composite Map	pg.145
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Map 10: Landcover Reclassification	pg.147
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Map 12: Prime Farmland Soils Grid	pg.149
Map 13: Cumulative Analysis	pg.150
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Map 15: Riparian Zones and Human Impacts	pg.152
Map 16: A Closer View of Sevierville-Gatlinburg Corridor.....	pg.153



Note: There are actually three county shapes inside the box. Two are so small that they are not visible. None of them have matching boundaries.

Map 1: Spatial Referencing Incongruencies

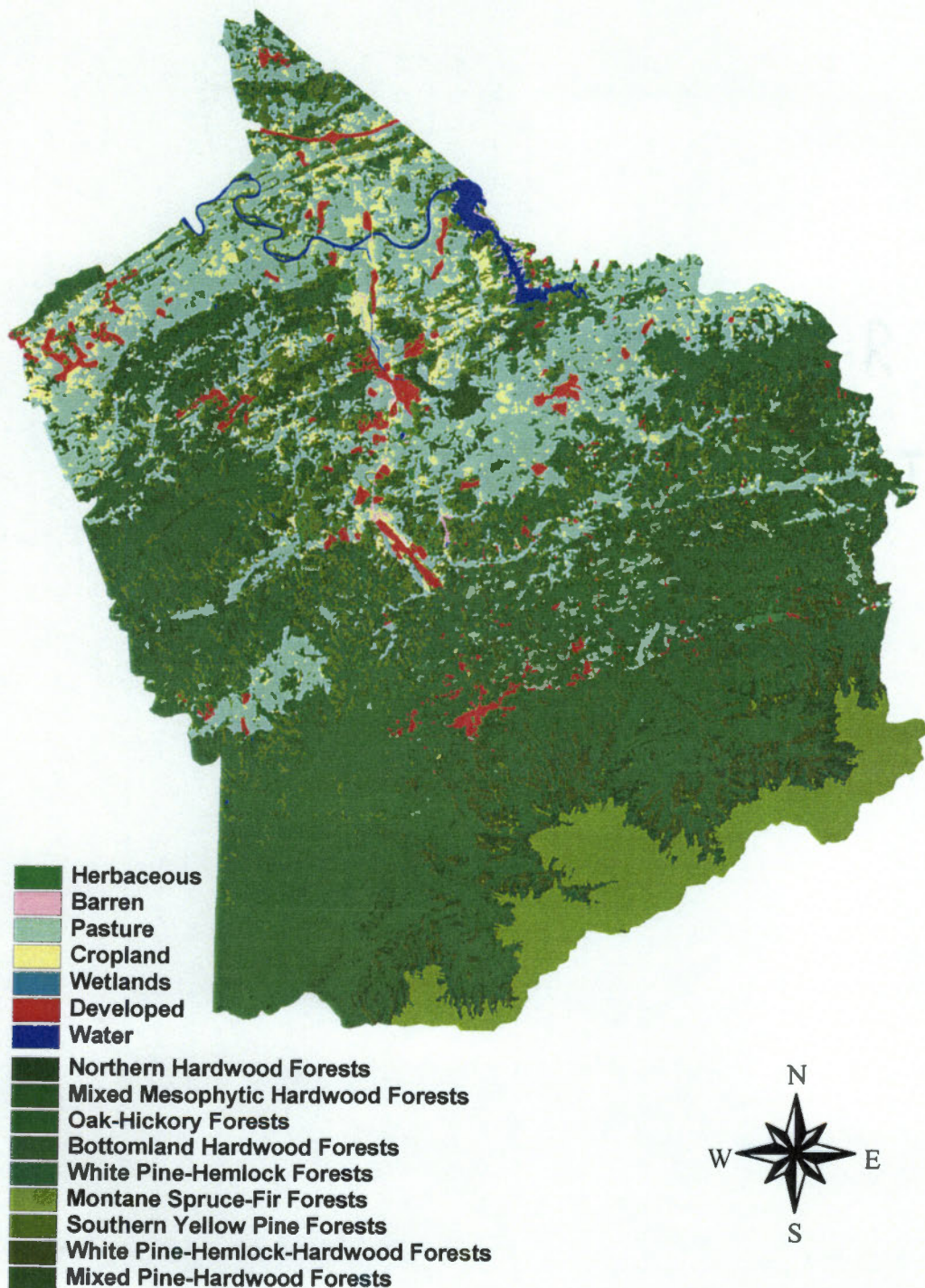
Source: The Southern Appalachian Assessment GIS Data Base CD ROM Set. 1996. The Southern Appalachian Man and the Biosphere Program. Norris, TN.



Note: The yellow dot on the east side of the county is referenced as being located in adjacent Cocke County, TN. The yellow dot on the south border of the map is referenced as being in adjacent Swain County, NC.

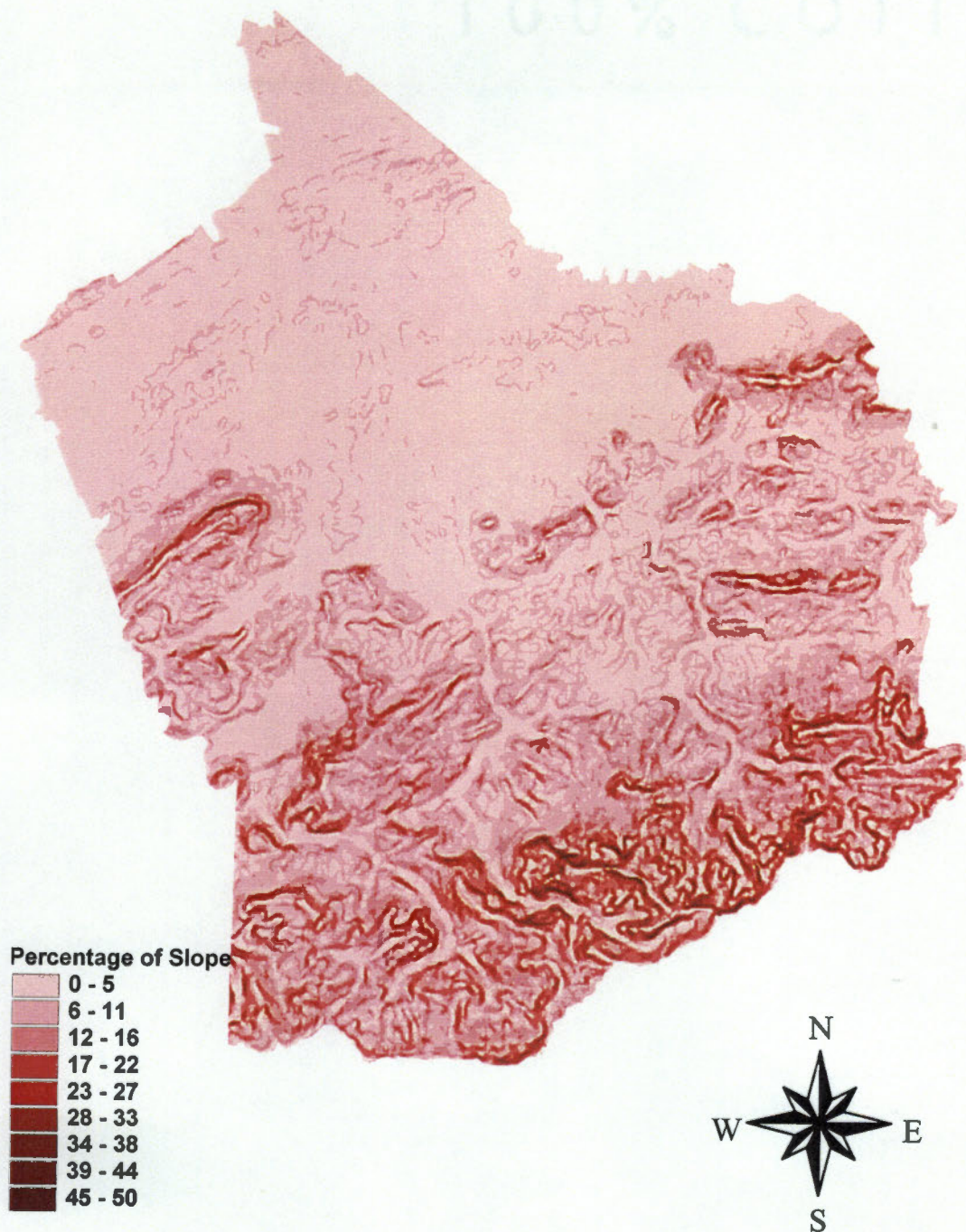
Map 2: Point Data Inaccuracies

Source: The Southern Appalachian Assessment GIS Data Base CD ROM Set. 1996. The Southern Appalachian Man and the Biosphere Program. Norris, TN.



Map 3: Landcover

Source: The Southern Appalachian Assessment GIS Data Base CD ROM Set. 1996. The Southern Appalachian Man and the Biosphere Program. Norris, TN.



Map 4: Slope

Source: The Southern Appalachian Assessment GIS Data Base CD ROM Set. 1996. The Southern Appalachian Man and the Biosphere Program. Norris, TN.

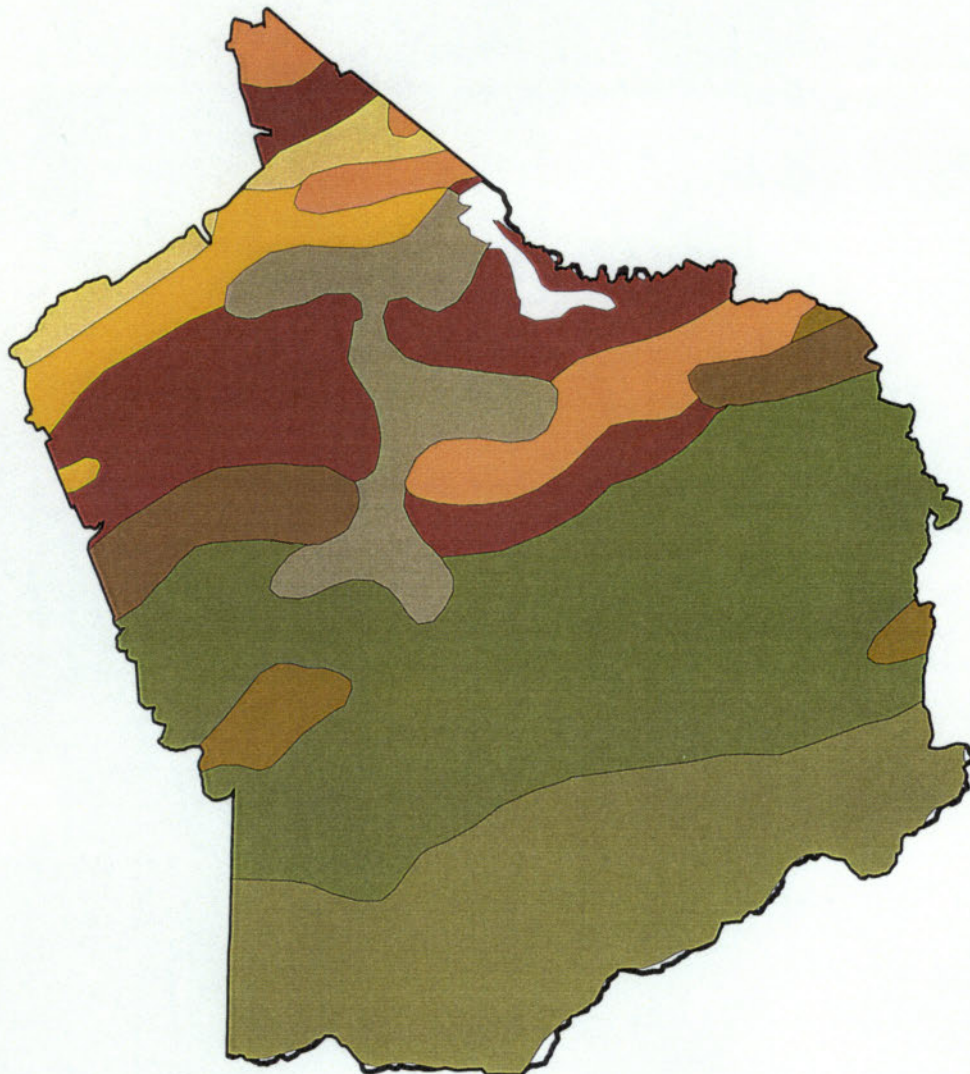


 **Streams**



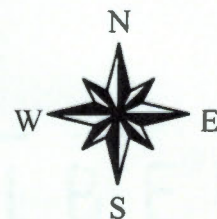
Map 5: Surface Waters

Source: The Southern Appalachian Assessment GIS Data Base CD ROM Set. 1996. The Southern Appalachian Man and the Biosphere Program. Norris, TN.



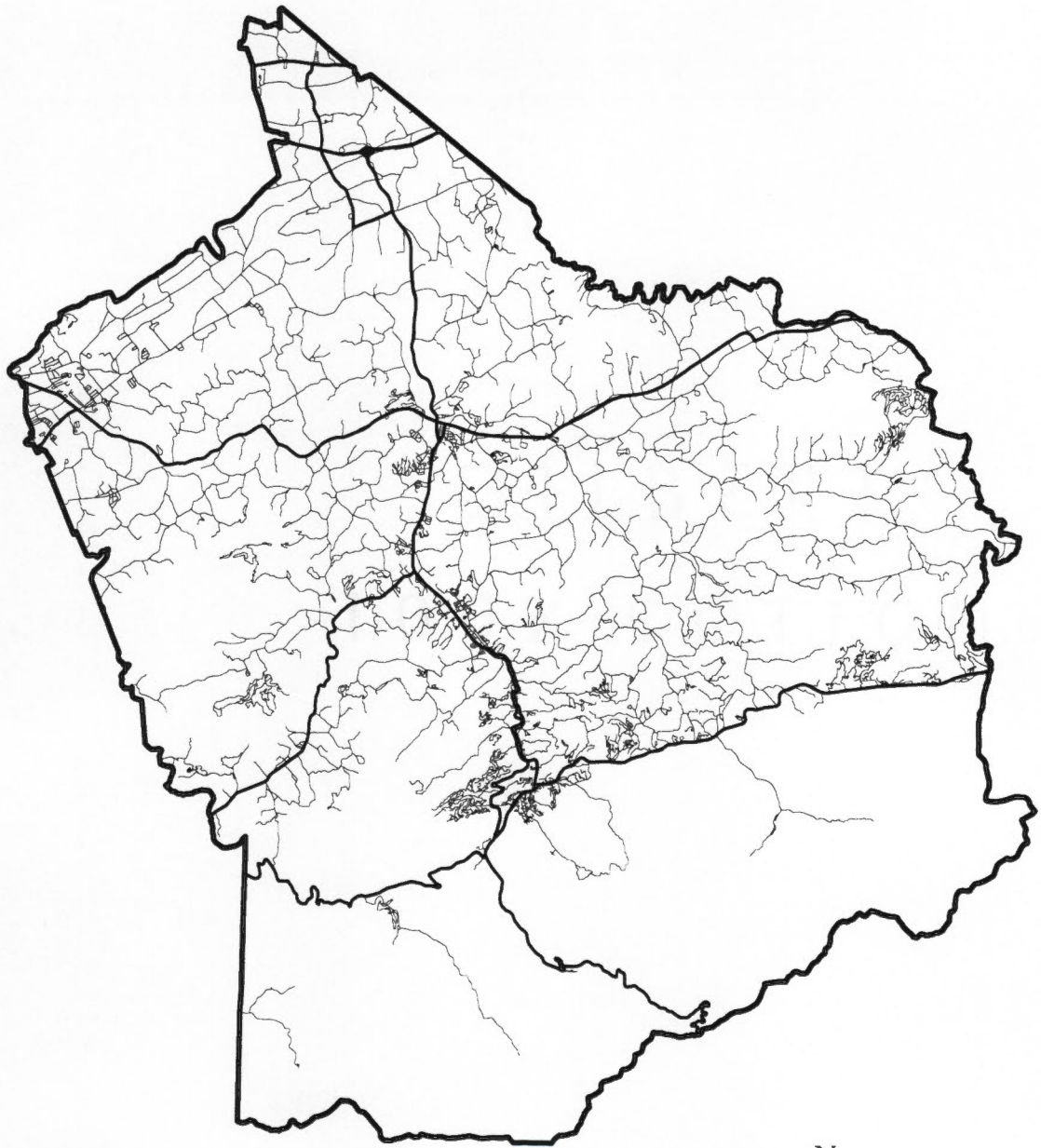
Soil Associations

- Dandrige - Needmore - Whitesburg
- Decatur - Dewey - Waynesboro
- Ditney - Jeffrey - Brookshire
- Dunmore - Dewey
- Holston - Monogahela
- Jefferson - Allen - Statler
- Litz - Sequora - Talbott
- Sylco - Ranger - Citico
- Wallen - Jefferson - Ramsey



Map 6: Soils

Source: The Southern Appalachian Assessment GIS Data Base CD ROM Set. 1996. The Southern Appalachian Man and the Biosphere Program. Norris, TN.

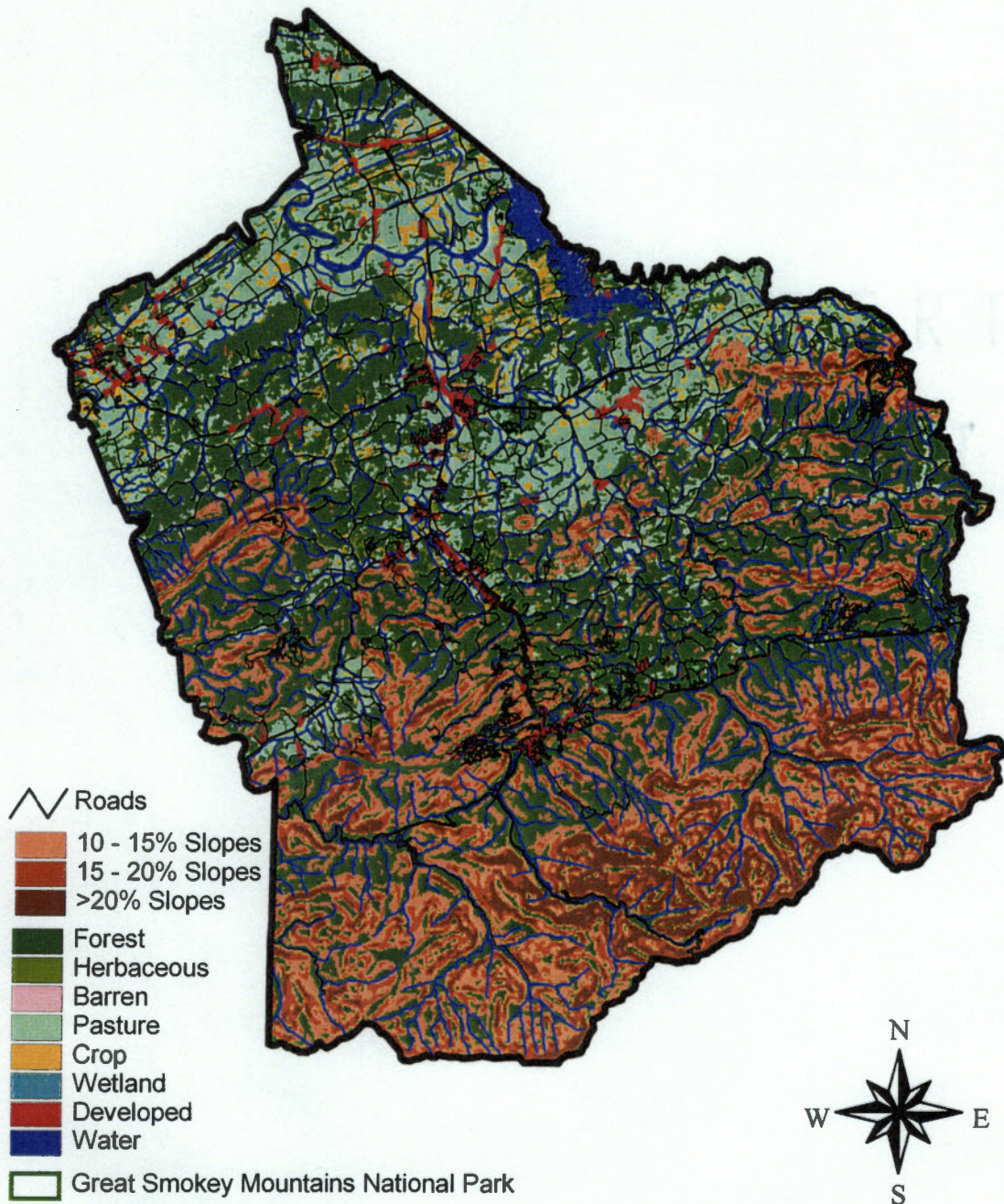


 Roads



Map 7: Roads

Source: The Southern Appalachian Assessment GIS Data Base CD ROM Set. 1996. The Southern Appalachian Man and the Biosphere Program. Norris, TN.

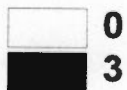


Map 8: Natural Resources Composite Map

Source: The Southern Appalachian Assessment GIS Data Base CD ROM Set. 1996. The Southern Appalachian Man and the Biosphere Program. Norris, TN.

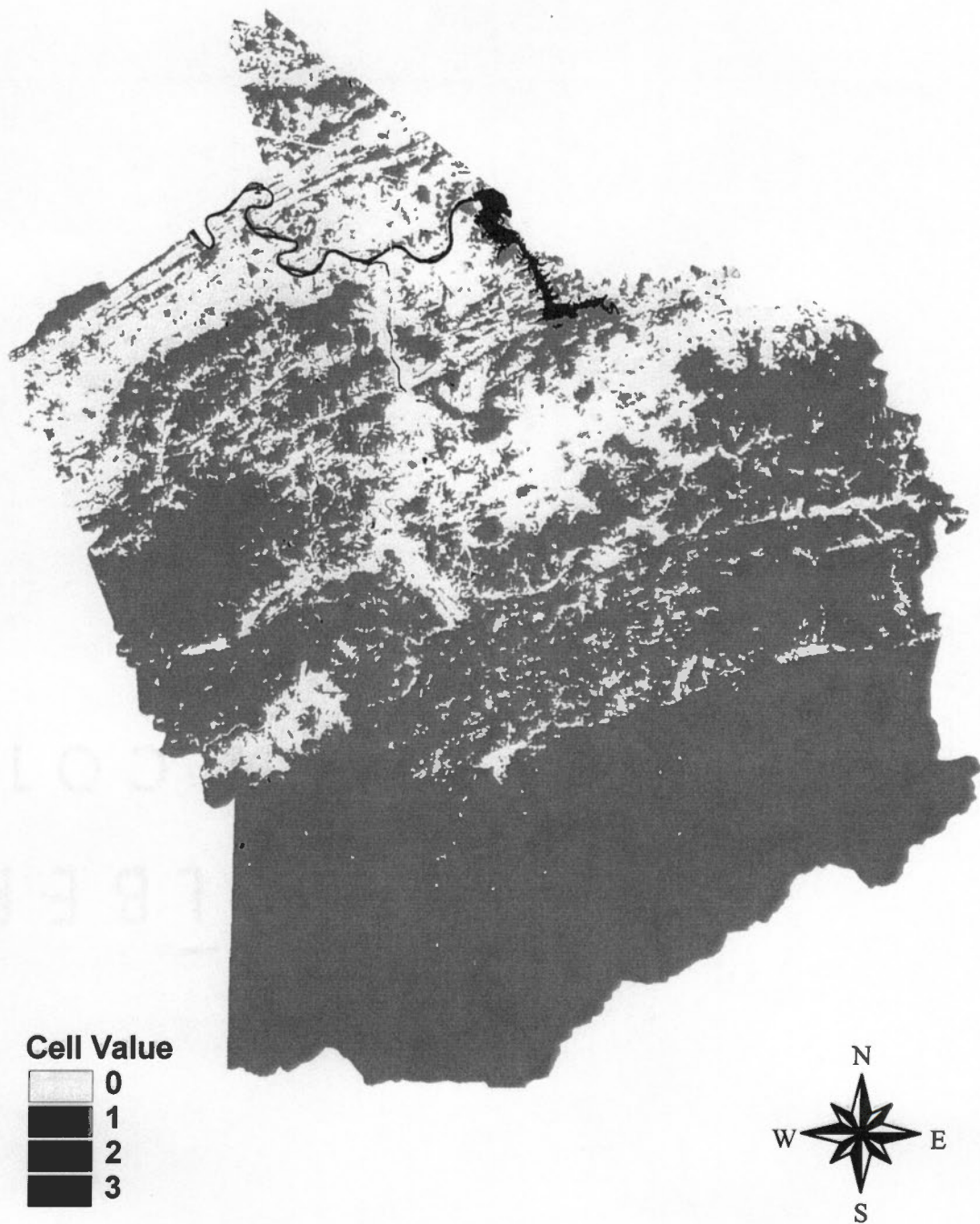


Cell Value



Map 9: Stream Grid

Source: The Southern Appalachian Assessment GIS Data Base CD ROM Set. 1996. The Southern Appalachian Man and the Biosphere Program. Norris, TN.



Map 10: Landcover Reclassification

Source: The Southern Appalachian Assessment GIS Data Base CD ROM Set. 1996. The Southern Appalachian Man and the Biosphere Program. Norris, TN.



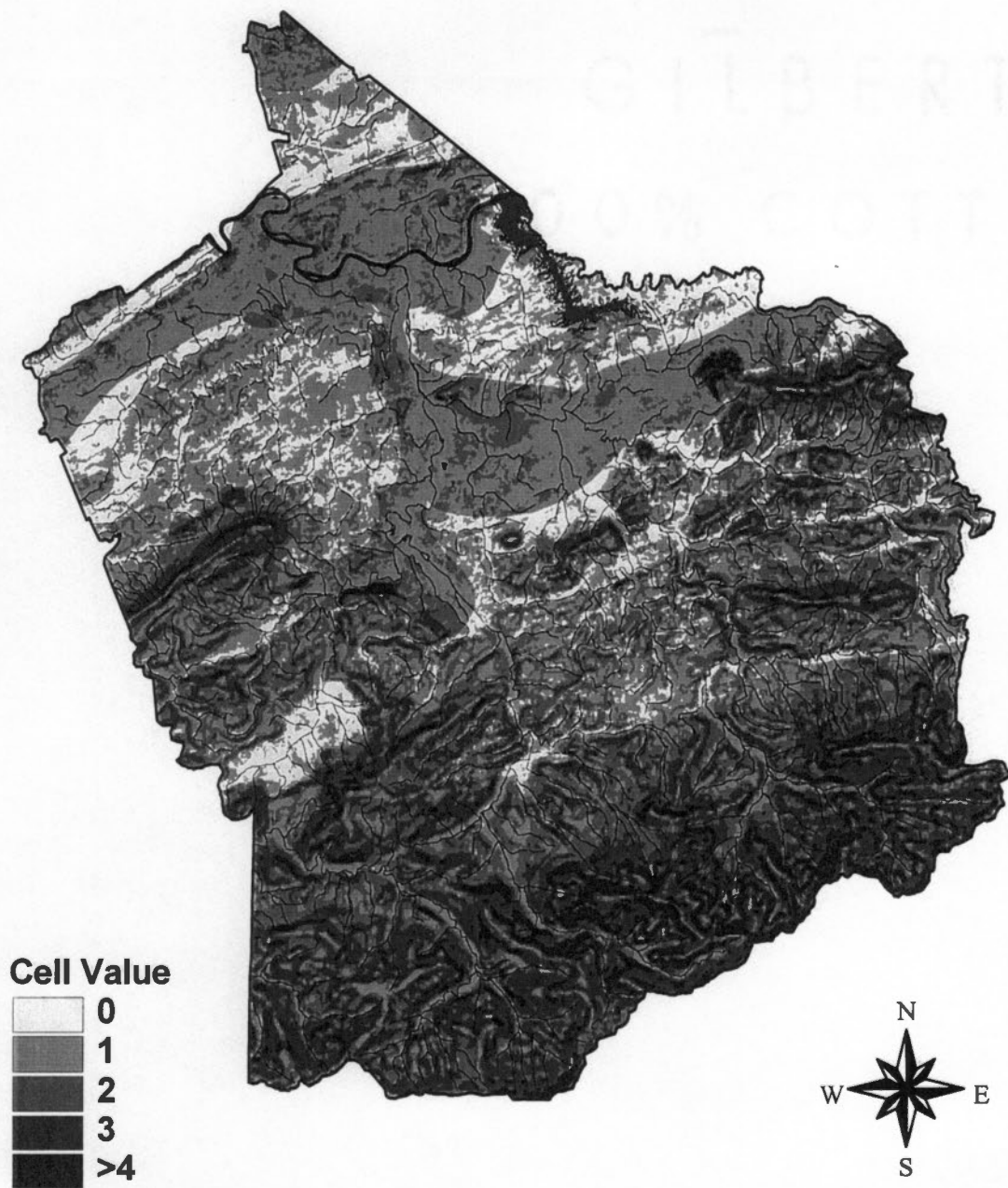
Map 11: Slope Reclassification

Source: The Southern Appalachian Assessment GIS Data Base CD ROM Set. 1996. The Southern Appalachian Man and the Biosphere Program. Norris, TN.



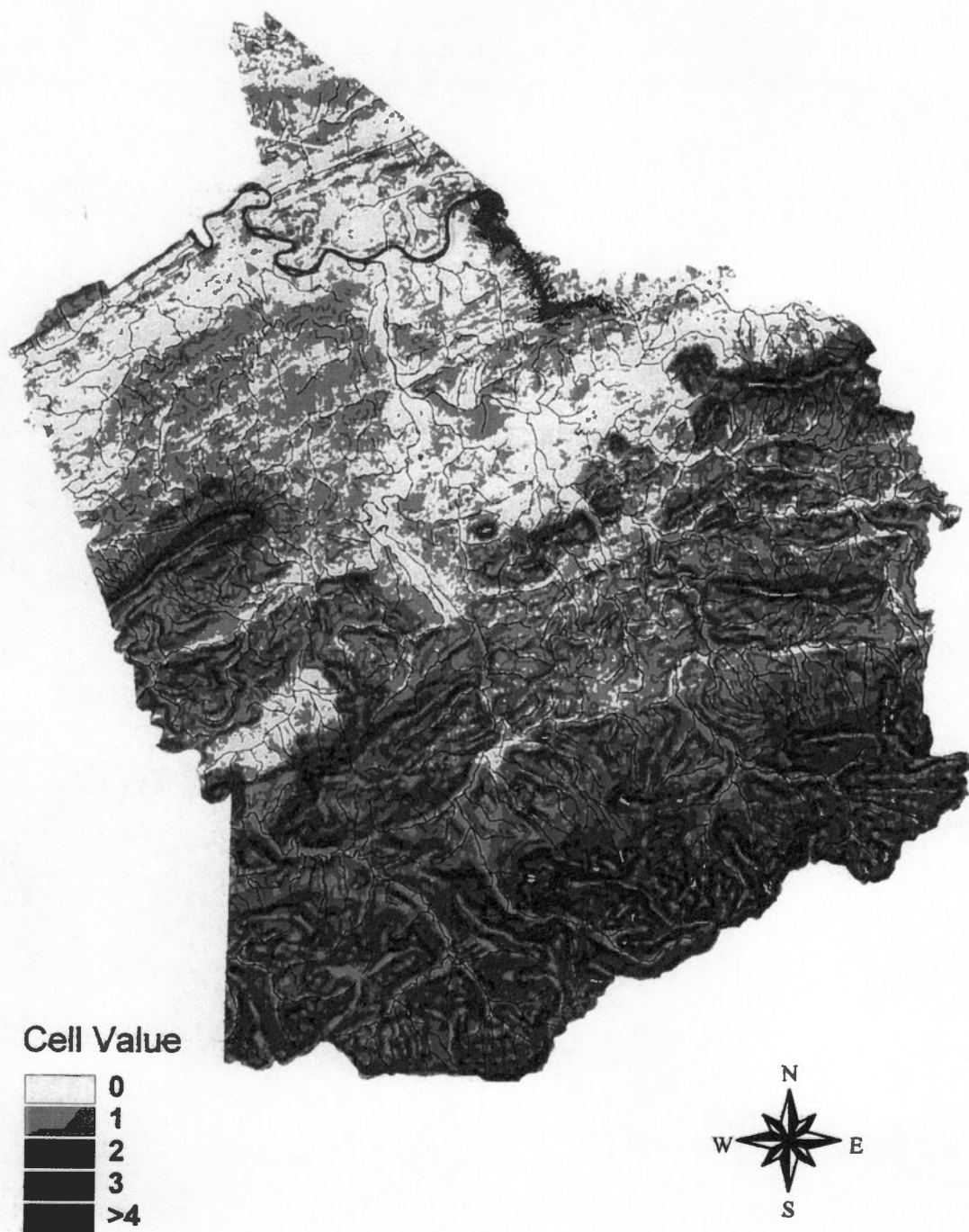
Map 12: Prime Farmland Soils Grid

Source: The Southern Appalachian Assessment GIS Data Base CD ROM Set. 1996. The Southern Appalachian Man and the Biosphere Program. Norris, TN.



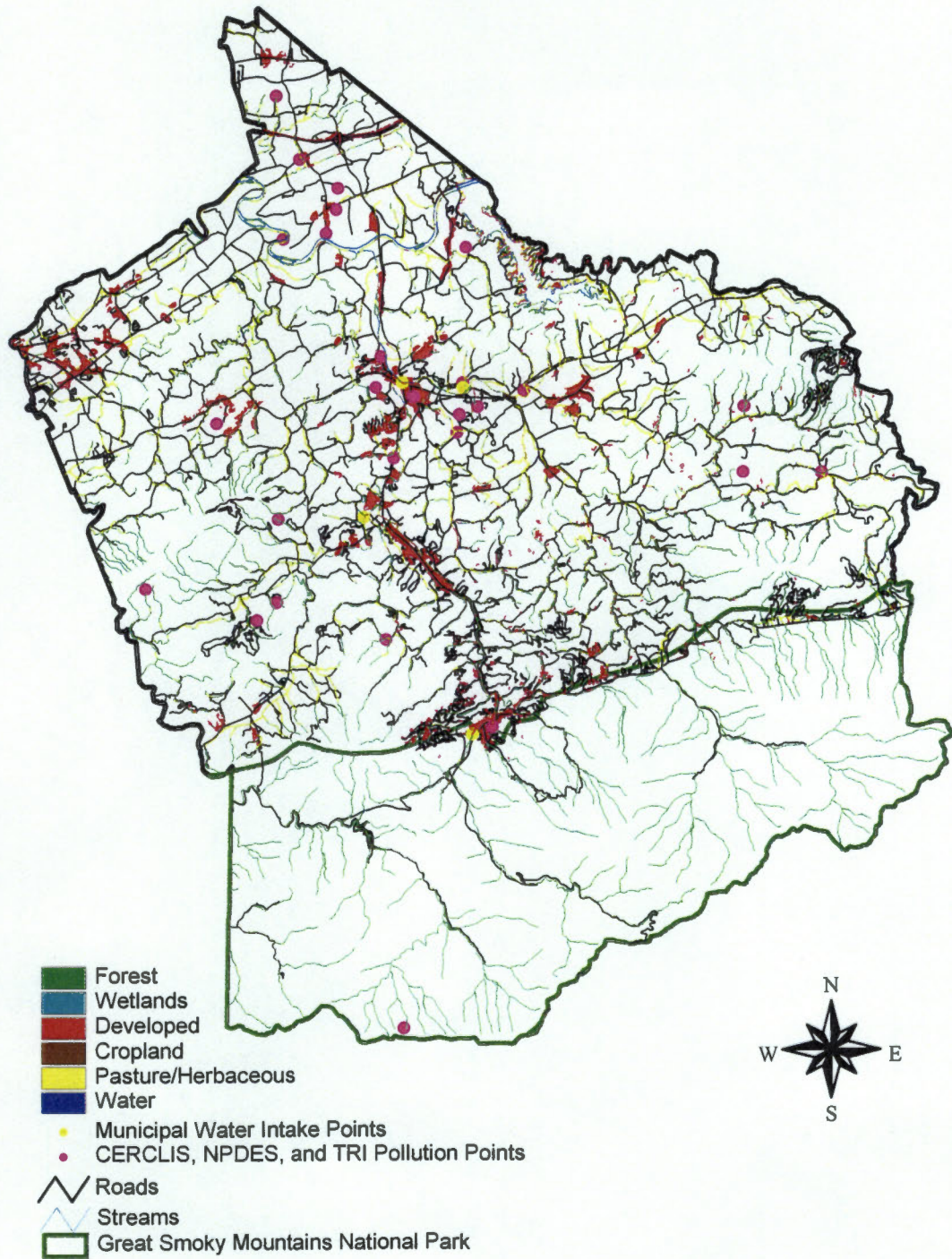
Map 13: Cumulative Analysis of Sensitive Natural Resources

Source: The Southern Appalachian Assessment GIS Data Base CD ROM Set. 1996. The Southern Appalachian Man and the Biosphere Program. Norris, TN.



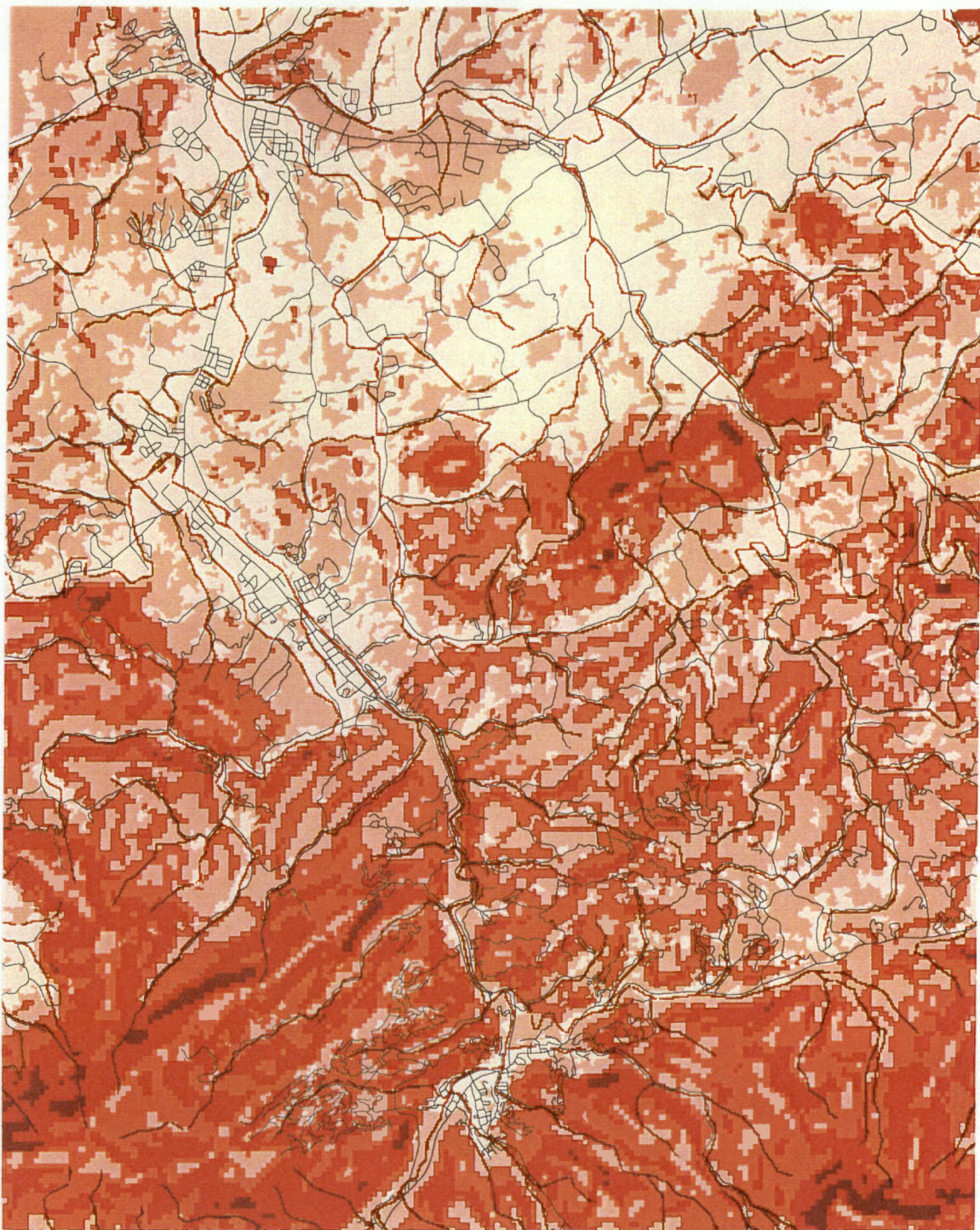
Map 14: Cumulative Analysis Without Soils

Source: The Southern Appalachian Assessment GIS Data Base CD ROM Set. 1996. The Southern Appalachian Man and the Biosphere Program. Norris, TN.



Map 15: Riparian Zones and Human Impacts

Source: The Southern Appalachian Assessment GIS Data Base CD ROM Set. 1996. The Southern Appalachian Man and the Biosphere Program. Norris, TN.



Map 16: A Closer View of Sevierville-Gatlinburg Corridor

Source: The Southern Appalachian Assessment GIS Data Base CD ROM Set. 1996. The Southern Appalachian Man and the Biosphere Program. Norris, TN.

Appendix F
Southern Appalachian Assessment GIS Data Base: Contents

The Southern Appalachian Assessment GIS Data Base CD ROM set consists of five CDs. The structure and contents are described in the following pages. A forward slash (/) indicates a directory. Indentation indicates subdirectories or directory contents (coverages or files). Each page (separated by *****) will show only one nested level of the structure.

saa1/ CD disc 1

readme/ Contents Information and Data Base Parameters

saa_100k/ ARC/INFO 1:100,000 scale coverages

saa_250k/ ARC/INFO 1:250,000 scale coverages

saa_2mil/ ARC/INFO 1:2,000,000 scale coverages

saa_pts/ ARC/INFO Point coverages

saa_tab/ INFO tables and ARC/INFO state and county 1:100k coverages for relates

saa2/ CD disc 2

readme/ Contents Information and Data Base Parameters

saa_24k/ ARC/INFO 1:24,000 coverages

saa3/ CD disc 3

readme/ Contents Information and Data Base Parameters

saa_rast/ ARC/INFO GRID coverages (raster data)

saa4/ CD disc 4

readme/ Contents Information and Data Base Parameters

saa_lc/ARC/INFO polygon coverages of the SAA produced Land Cover data (1:100,000)

saa5/ CD disc 5

readme/ Contents Information and Data Base Parameters

saa_gra/ Postscript graphics

saa_misc/ Species Matrix and other Spreadsheets

saa_modl/ ARC/INFO Polygon Coverages of Modeled data

saa_rast/ Additional ARC/INFO GRID coverages (raster)

saa1/ CD disc 1

readme/ Contents Information and Data Base Parameters

saa_100k/ ARC/INFO 1:100,000 scale coverages

saa_250k/ ARC/INFO 1:250,000 scale coverages

saa_2mil/ ARC/INFO 1:2,000,000 scale coverages

saa_pts/ ARC/INFO Point coverages

saa_tab/ INFO tables with ARC/INFO state and county
 coverages for relates 1:100k

(saa1/)

saa_2mil/ ARC/INFO 1:2,000,000 scale coverages

readme/ Directory Information

metadata/ Metadata

info/ INFO data base

climate/ Workspace of Climate Division data

acid_sen Acid Deposition Sensitivity

appal_tr Appalachian Trail

bailey Bailey's Ecoregions

boundary SAA Boundary

br_pkwy Blue Ridge Parkway

cher_res Cherokee Indian Reservation

class_1 Class 1 areas (Clean Air Act)

clip_box Rectangular Window for viewing the SAA region

co_135 SAA Counties (135 version)

counties SAA Counties (151)

dogwooda Dogwood Anthracnose Occurence (by County)

fed_lnds Federal Lands

military Military Lands

nat_fors National Forests Proclamation Boundaries

nat_pks National Parks

nat_recs National Recreation Areas

nat_scen National Scenic Areas

oak_mort Oak Mortality Areas

omer_huc Omermik's Ecoregions intersected with watershd (HUCs)

omernik Omernik's Ecoregions

roads Major Highways

st_lines State Lines

states States

streams Major Rivers

tm_scene	Landsat TM Satellite Scene Areas
topo_30s	Topographic Relief - ARC/INFO GRID (raster) (derived from DMA 30 Arc Second DEM)
trout_m	Trout Range
waterbod	Major Water Bodies
watershd	Major Watersheds (Hydrologic Units)
wateruse	Water Use (by County)
wilderns	Wilderness Areas
ws_river	Wild and Scenic Rivers

(saal/saa_2mil/)

climate/ Climate Division data

readme/	Directory Information
metadata/	Metadata
info/	INFO data base

cldv Climate Divisions

pcp83 Monthly Total Precipitation - 1983

pcp84	"	"	1984
pcp85	"	"	1985
pcp86	"	"	1986
pcp87	"	"	1987
pcp88	"	"	1988
pcp89	"	"	1989
pcp90	"	"	1990
pcp91	"	"	1991
pcp92	"	"	1992
pcp93	"	"	1993

phi83 Monthly Palmer Hydrologic Drought Index 1983

phi84	"	"	1984
phi85	"	"	1985
phi86	"	"	1986
phi87	"	"	1987
phi88	"	"	1988
phi89	"	"	1989
phi90	"	"	1990
phi91	"	"	1991

ttmp83 Monthly Average Temperature 1983

ttmp84	"	"	1984
ttmp85	"	"	1985
ttmp86	"	"	1986
ttmp87	"	"	1987
ttmp88	"	"	1988
ttmp89	"	"	1989
ttmp90	"	"	1990
ttmp91	"	"	1991
ttmp92	"	"	1992
ttmp93	"	"	1993

(saa1/)

saa_250k/ ARC/INFO 1:250,000 scale coverages

readme/ Directory Information
metadata/ Metadata
info/ INFO database
landcov/ Workspace of USGS GIRAS Land Cover data

al_soils Alabama Soils
fus_lob Fusiform Rust - Loblolly
ga_soils Georgia Soils
nc_soils North Carolina Soils
quads Quadrangles
sc_soils South Carolina
tn_soils Tennessee Soils
topo_3s Topographic Relief - ARC/INFO GRID (raster)
(derived from DMA 3 Arc Second DEM)
va_soils Virginia Soils

(saa1/saa_250k/)

landcov/ USGS GIRAS Land Cover data

readme/ Directory Information
metadata/ Metadata
info/ INFO data base

atlan Atlanta quadrangle
balti Baltimore quadrangle
birni Birmingham quadrangle
bluef Bluefield quadrangle
charl Charlotte quadrangle
charls Charleston quadrangle
charlv Charlottesvile quadrangle
chatt Chattanooga quadrangle
corbin Corbin quadrangle
cumber Cumberland quadrangle
gadsen Gadsden quadrangle
greens Greensboro quadrangle
greenv Greenville quadrangle
jcity Johnson City quadrangle
jenkin Jenkins quadrangle
knoxv Knoxville quadrangle
roanok Roanoke quadrangle
rome Rome quadrangle
washin Washington quadrangle
wsalem Winston-Salem quadrangle

(saa1/)

saa_100k/ ARC/INFO 1:100,000 scale coverages

readme/ Directory Information
metadata/ Metadata
info/ INFO data base
 EROSION.DAT Soil Erosion (relate to watershd (HUC))
 STR_DEN.DAT Stream Density (relate to watershd (HUC))
 AQ_TE_HUC.DAT Aquatic Threatened and Endangered Species
 Summarized by watershd (HUC)
census/ Workspace of US Census Block Groups and STF3A data

add_str SAA digitized streams (additions to RF3)
boundary SAA Boundary
br_pkwy Blue Ridge Parkway
class1rd Class 1 Roads with Traffic Counts
class2rd Class 2 Roads with Traffic Counts
class3rd Class 3 Roads
class4rd Class 4 Roads
co_135 Counties (135 version)
co_136 Counties (136 version)
counties Counties (151)
eco_lta Ecological Land Type Associations
eco_sect Ecological Sections
eco_subs Ecological Subsections
fish_adv Fish Advisory
pub_own Public Land Ownership
quads Quadrangles
railroad Railroads
st_lines State Lines
states States (SAA area only)
streams Rivers and Streams (River Reach File 3)
troutstr Wild Trout Streams
troutst2 Trout Streams Outside of the Wild Trout Range
trails Trails
utility Pipelines, Transmission Lines, and Misc. Transportation
waterbod Waterbodies
watershd Watersheds (Hydrologic Units)

(saa1/saa_100k/)

census/ US Census Block Groups and STF3A data

readme/ Directory Information
metadata/ Metadata
info/ INFO data base

al_90bg Alabama 1990 Block Groups and STF3A
ga_90bg Georgia 1990 Block Groups and STF3A
nc_90bg North Carolina 1990 Block Groups and STF3A
sc_90bg South Carolina 1990 Block Groups and STF3A
tn_90bg Tennessee 1990 Block Groups and STF3A

va_90bg Virginia 1990 Block Groups and STF3A
 wv_90bg West Virginia 1990 Block Groups and STF3A

(saa1/)

saa_pts/ ARC/INFO Point coverages

readme/ Directory Information
 metadata/ Metadata
 info/ INFO data base
 fhm/ Workspace of Forest Health Monitoring Sites and Data
 ozone/ Workspace of Ozone Monitoring Sites and Data (1983 - 1993)
 pm_mon/ Workspace of Particulate Matter Monitoring Sites
 tri/ Workspace of Toxic Release Inventory Sites and Data

 ibi_fish Index of Biotic Integrity (sample sites)
 campgrds Campground Locations
 cerclis Comprehensive Environmental Response, Compensation, and Liability Information
 System (CERCLIS), includes National Priority List (NPL or Superfund) Sites
 cities Cities and Towns
 co_site Carbon Monoxide Sources
 fia_mon Forest Inventory and Analysis Monitoring Site
 fire_nfs Fire Occurrence Sites on National Forests Land
 hexpts Environmental Monitoring and Assessment Program (EMAP) monitoring sites
 macroinv Macroinvertebrates
 maj_city Major Cities
 mines Mine Locations
 npdes National Pollutant Discharge Elimination System (NPDES)
 no2_site Nitrogen Oxide Sources
 nris_pts National Registry Sites (Historic)
 oak_decl Oak Decline Sites
 pb_site Lead Sources
 pm_site Particulate Matter Sources
 rec_exce Recreation Sites Where Capacity is Exceeded
 so2_site Sulfur Dioxide Sources
 voc_site Volatile Organic Compounds Sources
 wat_qual Water Quality Monitoring Sites
 wat_supl Water Supply Sites

(saa1/saa_pts/)

fhm/ Forest Health Monitoring Sites and Data

readme/ Directory Information
 metadata/ Metadata
 info/ INFO data base
 BIODIV
 SOIL_FLR
 SBE
 SOIL_MIN

SOIL_CAR
 CC_OAK
 CC_WCOAK
 CC_NBOAK
 DAMAGE_H
 DAMAGE_S
 DEFOL_H
 OAK_REGN
 DAMAGE_A
 PLOTVIEW
 SUBP93
 SUBP94
 SUMMARY

fhm_pts Forest Health Monitoring Sites

(saa1/saa_pts/)

ozone/ Ozone Monitoring Sites and Data (1983 - 1993)

readme/ Directory Information
 metadata/ Metadata
 info/ INFO data base

o3ptm_4 Ozone Monitoring Sites and Index Data for April for 1983 - 1993
 o3ptm_5 Ozone Monitoring Sites and Index Data for May for 1983 - 1993
 o3ptm_6 Ozone Monitoring Sites and Index Data for June for 1983 - 1993
 o3ptm_7 Ozone Monitoring Sites and Index Data for July for 1983 - 1993
 o3ptm_8 Ozone Monitoring Sites and Index Data for August for 1983-1993
 o3ptm_9 Ozone Monitoring Sites and Index Data September for 1983 -1993
 o3ptm_10 Ozone Monitoring Sites and Index Data for October 1983 - 1993
 o3pts Ozone Monitoring Sites and Index Data for all seasonal (April - October)
 averages for 1983 - 1993

(saa1/saa_pts/)

pm_mon/ Particulate Matter Monitoring Sites

readme/ Directory Information
 metadata/ Metadata
 info/ INFO data base

anntsp Annual Total Suspended Particulates
 annpm10 Annual Particulate Matter (PM10)
 qtts Quarterly Total Suspended Particulates
 qtpm10 Quarterly Particulate Matter (PM10)

(saa1/saa_pts/)

tri/ Toxic Release Inventory Sites and Data

readme/ Directory Information
 metadata/ Metadata
 info/ INFO data base

al_tri92 Alabama Toxic Release Inventory Sites and Data for 1987 - 1992
 ga_tri92 Georgia Toxic Release Inventory Sites and Data for 1987 - 1992
 ky_tri92 Kentucky Toxic Release Inventory Sites and Data for 1987 - 1992
 nc_tri92 North Carolina Toxic Release Inventory Sites and Data 1987-1992
 sc_tri92 South Carolina Toxic Release Inventory Sites and Data 1987 - 1992
 tn_tri92 Tennessee Toxic Release Inventory Sites and Data for 1987 - 1992
 va_tri92 Virginia Toxic Release Inventory Sites and Data for 1987 - 1992
 wv_tri92 West Virginia Toxic Release Inventory Sites and Data 1987 - 1992
 tri_93 Toxic Release Inventory Sites and Data for 1993

(saal/)

saa_tab/ INFO tables with ARC/INFO state and
 county 1:100k coverages for relates

readme/ Directory Information
 metadata/ Metadata
 info/ INFO data base

SPB.DAT Southern Pine Beetle Occurrence
 BUTERNUT.DAT Butternut Occurrence
 CHESTNUT.DAT Chesnut Occurrence
 EHEMLOCK.DAT Eastern Hemlock Occurrence
 CHEMLOCK.DAT Carolina Hemlock Occurrence
 CENS70.DAT Census Data - 1970
 CENS80.DAT Census Data - 1980
 CENS90.DAT Census Data - 1990
 AGCENSP1.DAT Agricultural Census
 AGCENSP2.DAT Agricultural Census
 AGCENSP3.DAT Agricultural Census
 CENS PROJ.DAT Census Projections
 INTEREST.DAT Interest Groups
 LANDUSE.DAT Land Use by State
 MILES.DAT Road Miles
 ERSTYPE.DAT County Characterizations
 MIGRATE.DAT Migration Data
 COCODE.DAT SAA Subregions
 IMPLAN.DAT USFS IMPLAN Data Base Extractions
 MINECODE.DAT Special Mining Counties
 POPPROJ.DAT Population Projections
 RECONPCT.DAT Demographic Data
 RFARMSAA.DAT Farm Data
 RHOUSPCT.DAT Housing Data
 RPOPPCT.DAT Demographic Data
 RSSASQM.DAT Population Density
 TMBCODE.DAT Special Timber Areas

GYPMOTH.DAT	Gypsy Moth Occurrence
GYPMOTH.SUM	Gypsy Moth Occurrence
HRSA_C.DAT	Heritage Resource Database
FIPS_ALT.DAT	Alternative FIPS Codes
TRI_90.DAT	Toxic Release Inventory - 1990
GREENWAY.DAT	Greenway Programs
FIA_STAT.DAT	Forest Ownership
GAMESTAT.DAT	Game Species Occurrence
EOR_CNTY.DAT	Element of Occurrence Record Summaries
PULPWOOD.DAT	Pulpwood Production
SAWLOG.DAT	Sawlog Production
NFTIMB.DAT	National Forest Timberland
COMPBORD.DAT	Composite Board Material Production
TIMBER.DAT	Timber Production
DISTRICT.DAT	Ranger District Groupings
DOGWOOD.DAT	Dogwood Anthracnose Occurrence
REC_EMP.DAT	Recreation Employment
WATERUSE.DAT	Water Use
MASTER.DAT	County Environmental Attributes Compiled by EPA
STR_DEN.DAT	Stream Density
AQ_TE_CO.DAT	Aquatic Threatened and Endangered Species Summaries by County
CO_BPAT.DAT	County Business Patterns Data
ATP_1.DAT	County Indices and Construction Data
ATP_2.DAT	for graphics in:
ATP_3.DAT	saa5/saa_gra/hd_gra/hd_gra2
ATP_4.DAT	"
ATN_5.DAT	"
ATN_6.DAT	"
ATN_7.DAT	"
ATN_8.DAT	"
ARP_1.DAT	"
ARP_2.DAT	"
ARP_3.DAT	"
ARP_4.DAT	"
ARN_5.DAT	"
ARN_6.DAT	"
ARN_7.DAT	"
ARN_8.DAT	"
TRP_1.DAT	"
TRP_2.DAT	"
TRP_3.DAT	"
TRP_4.DAT	"
TRN_5.DAT	"
TRN_6.DAT	"
TRN_7.DAT	"
TRN_8.DAT	"

co_135	Counties (135 version)
co_136	Counties (136 version)
counties	Counties (151)
states	States

saa2/ CD disc 2

readme/ Contents Information and Data Base Parameters

saa_24k/ ARC/INFO 1:24,000 coverages

(saa2/)

saa_24k/ ARC/INFO 1:24,000 coverages

readme/ Directory Information
metadata/ Metadata
info/ INFO data base
gsmnp/ Workspace of Great Smoky Mountains National Park Data
gypmoth/ Workspace of Gypsy Moth Data
nf_topo/ Workspace of National Forests Topographic
Relief (gray shaded GRIDS of 30 meter DEM)
ownership/ Workspace of National Forest Ownership by District
stands/ Workspace of National Forest Stands by District

all_stnd National Forest Stands
dis_lnd Distinctive Landscapes (National Forests)
nat_fors National Forest Ownership
ogft Potential Old Growth (National Forests)
quads Quadrangles
roadless Roadless Areas (National Forests)
sprucfir Spruce-Fir Forest Type
wilderns Wilderness Areas

(saa2/saa_24k/)

gsmnp/ Great Smoky Mountains National Park Data

readme/ Directory Information
metadata/ Metadata
info/ INFO data base

boundary GSM National Park Boundary
gsm_topo Topographic Relief (gray shaded GRID)
roads Roads
streams Streams

(saa2/saa_24k/)

gypmoth/ Gypsy Moth Data

readme/ Directory Information

metadata/ Metadata
info/ INFO data base

allyrdef Gypsy Moth Defoliation - All Years
va85def Virginia Gypsy Moth Defoliation - 1985
va86def " " 1986
va87def " " 1987
va88def " " 1988
va89def " " 1989
va90def " " 1990
va91def " " 1991
va92def " " 1992
va93def " " 1993
va94def " " 1994
wv86def West Virginia Gypsy Moth Defoliation - 1986
wv87def " " 1987
wv88def " " 1988
wv89def " " 1989
wv90def " " 1990
wv91def " " 1991
wv92def " " 1993
wv93def " " 1993
wv94def " " 1994

(saa2/saa/24k/)

nf_topo/ National Forests Topographic Relief (gray shaded GRIDS of 30 meter DEM)
ARC/INFO GRIDS (raster)

readme/ Directory Information
metadata/ Metadata
info/ INFO data base

d30m_ref Polygon coverage of Topo Zones
top1_30m Topographic Relief - Zone 1 (derived from USGS 30 meter DEM)
top2_30m Topographic Relief - Zone 2 (derived from USGS 30 meter DEM)
top3_30m Topographic Relief - Zone 3 (derived from USGS 30 meter DEM)
top4_30m Topographic Relief - Zone 4 (derived from USGS 30 meter DEM)
top5_30m Topographic Relief - Zone 5 (derived from USGS 30 meter DEM)
top6_30m Topographic Relief - Zone 6 (derived from USGS 30 meter DEM)
top7_30m Topographic Relief - Zone 7 (derived from USGS 30 meter DEM)
top8_30m Topographic Relief - Zone 8 (derived from USGS 30 meter DEM)

(saa2/saa_24k/)

ownership/ National Forest Ownership by District

readme/ Directory Information
metadata/ Metadata
info/ INFO data base

armuchee	Armuchee NF District Ownership
blksburg	Blacksburg NF District Ownership
brasstwn	Brasstown NF District Ownership
chattoog	Chattooga NF District Ownership
cheoah	Cheoah NF District Ownership
chestate	Chestatee NF District Ownership
clinch	Clinch NF District Ownership
cohutta	Cohutta NF District Ownership
deerfld	Deerfield NF District Ownership
dryriver	Dry River NF District Ownership
fr_broad	French Broad NF District Ownership
glenwood	Glenwood NF District Ownership
grndfthr	Grandfather NF District Ownership
highland	Highlands NF District Ownership
hiwassee	Hiwassee NF District Ownership
james_rv	James River NF District Ownership
lee	Lee NF District Ownership
monongah	Monongahela NF
mt_roger	Mount Rogers NF District Ownership
newcastl	New Castle NF District Ownership
nolichuk	Nolichucky NF District Ownership
ocoe	Ocoee NF District Ownership
pedlar	Pedlar NF District Ownership
pickens	Andrew Pickens NF District Ownership
pisgah	Pisgah NF District Ownership
shoal_ck	Shoal Creek NF District Ownership
taladega	Talladega NF District Ownership
tallulah	Tallulah NF District Ownership
tellico	Tellico NF District Ownership
toccoa	Toccoa NF District Ownership
toecane	Toecane NF District Ownership
tusquite	Tusquitee NF District Ownership
unaka	Unaka NF District Ownership
warm_spg	Warm Springs NF District Ownership
watauga	Watauga NF District Ownership
wayah	Wayah NF District Ownership
wythe	Wythe NF District Ownership

(saa2/saa_24k/)

stands/ National Forest Stands by District

readme/	Directory Information
metadata/	Metadata
info/	INFO data base

armuchee	Armuchee NF District Stands
blksburg	Blacksburg NF District Stands
brasstwn	Brasstown NF District Stands
chattoog	Chattooga NF District Stands
cheoah	Cheoah NF District Stands

chestate	Chestatee NF District Stands
clinch	Clinch NF District Stands
cohutta	Cohutta NF District Stands
deerfld	Deerfield NF District Stands
dryriver	Dry River NF District Stands
fr_broad	French Broad NF District Stands
glenwood	Glenwood NF District Stands
grndfthr	Grandfather NF District Stands
highland	Highlands NF District Stands
hiwassee	Hiwassee NF District Stands
james_rv	James River NF District Stands
lee	Lee NF District Stands
mt_roger	Mount Rogers NF District Stands
newcastl	New Castle NF District Stands
nolichuk	Nolichucky NF District Stands
occoee	Ocoee NF District Stands
pedlar	Pedlar NF District Stands
pickens	Andrew Pickens NF District Stands
pisgah	Pisgah NF District Stands
shoal_ck	Shoal Creek NF District Stands
taladega	Talladega NF District Stands
tallulah	Tallulah NF District Stands
tellico	Tellico NF District Stands
toccoa	Toccoa NF District Stands
toecane	Toecane NF District Stands
tusquite	Tusquitee NF District Stands
unaka	Unaka NF District Stands
warm_spg	Warm Springs NF District Stands
watauga	Watauga NF District Stands
wayah	Wayah NF District Stands
wythe	Wythe NF District Stands

saa3/ CD disc 3

readme/ Contents Information and Data Base Parameters

saa_rast/ ARC/INFO GRID coverages (raster data)

(saa3/)

saa_rast/ ARC/INFO GRID coverages (raster data)

readme/ Directory Information

metadata/ Metadata

info/ INFO data base

allroads All Road (Zones) characterizations combined

aspect3s Aspect Derived from DMA 3 Arc Second DEM

d30m_ref Polygon Reference for 30 meter DEM Zones

de3s_hue	Topographic Elevation Hue (DMA 3 Arc Second DEM)
de3s_sat	Topographic Elevation Saturation (DMA 3 Arc Second DEM)
de3s_val	Topographic Elevation Value (DMA 3 Arc Second DEM)
dem1_30m	USGS 30 Meter DEM - Zone 1
dem2_30m	USGS 30 Meter DEM - Zone 2
dem3_30m	USGS 30 Meter DEM - Zone 3
dem4_30m	USGS 30 Meter DEM - Zone 4
dem5_30m	USGS 30 Meter DEM - Zone 5
dem6_30m	USGS 30 Meter DEM - Zone 6
dem7_30m	USGS 30 Meter DEM - Zone 7
dem8_30m	USGS 30 Meter DEM - Zone 8
dem_30s	DMA 30 Arc Second DEM
dem_3s	DMA 3 Arc Second DEM
gsm_dem	USGS 30 meter DEM for the Great Smoky Mountains National Park
gsmnp_lc	GSMNP Land Cover (90m)
gsm_topo	Topographic Relief - GSMNP (USGS 30 meter DEM)
landcov	SAA Land Cover - Final Version (Raster version of Final Polygons)
lc_s_res	SAA Land Cover - Intermediate Version (90 meter Resampling of lc_scan version)
lc_scan	SAA Land Cover - Intermediate Version (Scan Product derived from lc_orig version)
lc_theme	Land Cover Themes
lcd3_hue	Topographic Land Cover Hue (DMA 3 Arc Second DEM)
lcd3_sat	Topographic Land Cover Saturation (DMA 3 Arc Second DEM)
lcd3_val	Topographic Land Cover Value (DMA 3 Arc Second DEM)
natroad	Naturally Appearing Road (Zone) Characterization
pub_90	Public Ownership
rural	Rural Road (Zone) Characterization
settings	Settings for Nature-Based Recreation Activities
slope_3s	Slope Derived from DMA 3 Arc Second DEM
suburb	Suburban Road (Zone) Characterization
top1_30m	Topographic Relief - Zone 1 (derived from USGS 30 meter DEM)
top2_30m	Topographic Relief - Zone 2 (derived from USGS 30 meter DEM)
top3_30m	Topographic Relief - Zone 3 (derived from USGS 30 meter DEM)
top4_30m	Topographic Relief - Zone 4 (derived from USGS 30 meter DEM)
top5_30m	Topographic Relief - Zone 5 (derived from USGS 30 meter DEM)
top6_30m	Topographic Relief - Zone 6 (derived from USGS 30 meter DEM)
top7_30m	Topographic Relief - Zone 7 (derived from USGS 30 meter DEM)
top8_30m	Topographic Relief - Zone 8 (derived from USGS 30 meter DEM)
topo_30s	Topographic Relief (derived from DMA 30 Arc Second DEM)
topo_3s	Topographic Relief (derived from DMA 3 Arc Second DEM)
transit	Transitional Road (Zone) Characterization
uindex	Human Use Index
urban	Urban Road (Zone) Characterization
saa_lc.cm	Land Cover Color map
saa_lc.key	Land Cover Shade Key
saa_lc.shd	Land Cover Shadeset
saa_lcag.cm	Land Cover Color Map (Aggregated Classes)
saa_lcag.key	Land Cover Shade Key (Aggregated Classes)
settings.cm	Settings Color Map

saa4/ CD disc 4

readme/ Contents Information and Data Base Parameters

saa_lc/ ARC/INFO polygon coverages of the SAA
produced Land Cover data (1:100,000)

(saa4/)

saa_lc/ ARC/INFO polygon coverages of the SAA
produced Land Cover data (1:100,000)

readme/ Directory Information

metadata/ Metadata

info/ INFO data base

al_lcp Final Land Cover Polygons for Alabama

ga_lcp Final Land Cover Polygons for Georgia

nc_lcp Final Land Cover Polygons for North Carolina

sc_lcp Final Land Cover Polygons for South Carolina

tn_lcp Final Land Cover Polygons for Tennessee

va_lcp Final Land Cover Polygons for Virginia

wv_lcp Final Land Cover Polygons for West Virginia

saa_lc.key Land Cover Shade Key

saa_lc.shd Land Cover Shadeset

saa_lcag.key Land Cover Shade Key (Aggregated Classes)

saa5/ CD disc 5

readme/ Contents Information and Data Base Parameters

saa_gra/ Postscript Graphics

saa_misc/ Species Matrix and other Spreadsheets

saa_modl/ ARC/INFO Polygon Coverages of Modeled Data

saa_rast/ Additional ARC/INFO GRID Coverages (raster)

(saa5/)

saa_gra/ Postscript Graphics

readme/ Directory Information

ar_gra/ Aquatic Resources Graphics

at_gra/ Atmospheric Graphics

fh_gra/ Forest Health Graphics

fhm_gra/ Forest Health Monitoring Graphics
 fp_gra/ Forest Products Graphics
 gis_gra/ Miscellaneous Graphics
 hd_gra/ Human Dimensions Graphics
 pa_gra/ Plant and Animal Graphics
 re_gra/ Recreation Graphics
 rw_gra/ Roadless/Wilderness Graphics

(saa5/)

saa_misc/ Species Matrix and other Spreadsheets

readme/ Directory Information
 ar_misc/ Aquatic Team Spreadsheets
 pa_misc/ Plant and Animal Team Spreadsheet

(saa5/saa_misc/)

ar_misc/ Aquatic Team Spreadsheets

contents.txt Directory Information
 aqspdst.txt aqspdst Spreadsheet Information
 aqspdst.xls Spreadsheet
 strmown.xls Spreadsheet

(saa5/saa_misc/)

pa_misc/ Plant and Animal Team Spreadsheet

contents.txt Directory Information
 saamatr.txt Spreadsheet Description
 saamatr.doc Spreadsheet Description (MS Word 6.0)
 saamatr.xls Spreadsheet of Species - Habitat Matrix

(saa5/)

saa_modl/ ARC/INFO Polygon Coverages of Modeled Data

readme/ Directory Information
 metadata/ Metadata
 info/ INFO data base
 ozone/ Workspace of Modeled (Kriged) Ozone

bbrd_hab Potential Black Bear Habitat

(saa5/saa_modl/)

ozone/ Modeled (Kriged) Ozone

readme/ Directory Information
 metadata/ Metadata
 info/ INFO data base

sum6_83 Kriged Ozone - SUM06 - 1983
 sum6_84 Kriged Ozone - SUM06 - 1984
 sum6_85 Kriged Ozone - SUM06 - 1985
 sum6_86 Kriged Ozone - SUM06 - 1986
 sum6_87 Kriged Ozone - SUM06 - 1987
 sum6_88 Kriged Ozone - SUM06 - 1988
 sum6_89 Kriged Ozone - SUM06 - 1989
 sum6_90 Kriged Ozone - SUM06 - 1990
 sum6_91 Kriged Ozone - SUM06 - 1991
 sum6_92 Kriged Ozone - SUM06 - 1992
 sum6_93 Kriged Ozone - SUM06 - 1993
 w126_83 Kriged Ozone - W126 - 1983
 w126_83c Kriged Ozone - W126 - 1983 (clipped to SAA)
 w126_84 Kriged Ozone - W126 - 1984
 w126_84c Kriged Ozone - W126 - 1984 (clipped to SAA)
 w126_85 Kriged Ozone - W126 - 1985
 w126_85c Kriged Ozone - W126 - 1985 (clipped to SAA)
 w126_86 Kriged Ozone - W126 - 1986
 w126_86c Kriged Ozone - W126 - 1986 (clipped to SAA)
 w126_87 Kriged Ozone - W126 - 1987
 w126_87c Kriged Ozone - W126 - 1987 (clipped to SAA)
 w126_88 Kriged Ozone - W126 - 1988
 w126_88c Kriged Ozone - W126 - 1988 (clipped to SAA)
 w126_89 Kriged Ozone - W126 - 1989
 w126_89c Kriged Ozone - W126 - 1989 (clipped to SAA)
 w126_90 Kriged Ozone - W126 - 1990
 w126_90c Kriged Ozone - W126 - 1990 (clipped to SAA)
 w126_91 Kriged Ozone - W126 - 1991
 w126_92 Kriged Ozone - W126 - 1992
 w126_93 Kriged Ozone - W126 - 1993

(saa5/)

saa_rast/ Additional ARC/INFO GRID Coverages (raster)

readme/ Directory Information
 metadata/ Metadata
 info/ INFO data base

bbearhab Potential Black Bear Habitat
 dec_hab Deciduous Forest Habitat
 helevhab Potential Habitat for General High Elevation Forest Species
 lc_orig SAA Land Cover - Intermediate Version
 (final pixel level classification prior to scanning (filtering))

no3_mean	Mean of Annual Nitrate Deposition (Wet) for 1983 - 1990
rd_dens	Road Density
sg13_hab	Potential Habitat for Area Sensitive Deciduous Forest Species
so4_mean	Mean of Annual Sulfate Deposition (Wet) for 1983 - 1990
spfirhab	Potential Habitat for Spruce-Fir Species
rip_zone	Riparian Zone
rip_z_lc	Land Cover within the Riparian Zone

Appendix G

Metadata

Contents–Appendix G: Metadata

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Riparian Zone.....	pg.187
Soils.....	pg.188
Streams.....	pg.189
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Landcover Metadata

saa3\saa_raster\metada\landcov.txt

Data Set Title / Coverage Name: SAA Land Cover - Final Version
(Raster version of Polygons)

SAA Version 3.0

Version Date: 3/21/96

Identification Information

Data Layer Name: landcov

Description: SAA Land Cover (2 acre minimum mapping unit)
(Final Raster Version - derived from Polygon Version)

Keywords: land cover, land use, Landsat TM satellite data

Citation:

Native Data Set

Environment: UNIX; ARC/INFO 7.0.3

pathname:

Scale: 1:100,000

File Format: ARC/INFO 7.0.3 GRID

Use

Restrictions: none

Access

Restrictions:

Spatial Reference Information

Datum: North American Datum 1983 (NAD83)

Precision: single

Projection: Albers Equal Area

Units: meters

Spheroid: WGS-84

1st Std Parallel: 34 00 00

2nd Std Parallel: 38 00 00

Central Meridian: -82 00 00

Origin: 33 00 00

False Northing: 0.0

False Easting: 0.0

Extent:

West Bounding Coord.: -421536.500

East Bounding Coord.: 354593.500

North Bounding Coord.: 732100.594

South Bounding Coord.: 16270.594

Distance Resolution: 30 meters

Vertical Resolution: n/a

Data Quality Information

Thematic Accuracy: unknown Confidence: unknown
Accuracy Method: unknown
Horizontal Accuracy: unknown Confidence: unknown
Accuracy Method: unknown
Vertical Accuracy: n/a
Logical
Consistency:
Completeness:

Source Information

Source Material: Landsat TM satellite scenes

Organization: Multi Resolution Landscape Characteristics Consortium,
US Forest Service, Tennessee Valley Authority

Date:

Distance Resolution: unknown

Contribution: spectral data, multitemporal coverage

Source Material: Stands, Spruce-Fir extent delineations

Organization: US Forest Service

Date:

Distance Resolution: unknown

Contribution: spruce-fir class, training material, aerial photography

Source Material: USGS LUDA (GIRAS) data, DMA 3 Arc second DEM

Organization: US Geological Survey

Date:

Distance Resolution: unknown

Contribution:

Source Material: River Reach 3 File (RF3)

Organization: US Environmental Protection Agency (USGS - Digital Line Graph (DLG))

Date:

Distance Resolution: unknown

Contribution: streams

Source Material: National Wetland Inventory

Organization: National Biological Service

Date:

Distance Resolution: unknown

Contribution: wetlands class

Processing History Information

Process Description:

The following text has been extracted from the "Southern Appalachian Assessment Land Cover Mapping Project Final Report" produced by Pacific Meridian Resources, Inc. (PMR). PMR was contracted to perform the land cover classification.

I did minor editing to the extracted material.

Karl A. Hermann

3/21/96

All image classifications were performed using ERDAS (Atlanta, Georgia) software.

The initial design of this project was to acquire all the imagery at once and then process all of the data

simultaneously through each of the image processing tasks. Delays in receiving data resulted in the imagery being processed as three sets of scenes. The following describes the methods used to classify a single scene from start to finish.

Classification Scheme

The first step in any mapping project is the specification of a classification system which categorizes the features of the earth to be mapped. Specifications of the system are driven by (1) the anticipated uses of the map information, and (2) the features of the earth that can be discerned with the data (e.g., aerial photography, satellite imagery) being used to create the map.

A classification system has two critical components: (1) a set of labels (Herbaceous, Spruce-Fir, Northern Hardwood, etc.); and (2) a set of rules—or a system—for assigning labels (e.g., a "Northern Hardwood forest will consist of 70% or more of the total forested area in sugar maple, beech or yellow birch."). Without a clear set of rules, the assignment of labels to types can be arbitrary and lack consistency. The land use/land cover classification scheme for this project was designed to best meet the needs of all agencies involved in the SAA study. Primary concerns in determining the scheme were balancing project time and budget constraints while still meeting the needs of all agencies involved.

Table 2 presents the final classification labels for the data layers developed from the satellite image classification. Appendix A contains the definitions for determining the appropriate land cover classification label.

Table 2. Final Classification Scheme

Class Number SAA Class Descriptions

- 1 Northern Hardwood Forests
- 2 Mixed Mesophytic Hardwood Forests
- 3 Oak Forests
- 4 Bottomland Hardwood Forests
- 5 White Pine / Hemlock Forests
- 6 Montane Spruce-Fir Forests
- 7 Southern Yellow Pine Forests
- 8 White Pine / Hemlock / Hardwood Forests
- 9 Mixed Pine / Hardwood Forests
- 10 Herbaceous
- 11 Barren
- 12 Agriculture - Pasture
- 13 Agriculture - Cropland
- 14 Wetlands
- 15 Developed
- 16 Water
- 17 Indeterminate - Clouds, Shadows

Data Preprocessing

A total of fourteen Landsat TM scenes (Table 3) were needed to cover the SAA study area. This imagery was obtained from three sources: Multiresolution Land Characteristics (MRLC) through the EROS Data Center, EOSAT , and the Tennessee Valley Authority (TVA).

With multitemporal data available for most scenes, the amount of data involved in this mapping project was enormous. Both hardware and time constraints for the project made data reduction a necessity. The first step in dealing with the imagery was therefore to subset the bands to be used in the classification.

Table 3.
Landsat TM Imagery use to Classify the Southern Appalachians

Scene	Date
1633	3/1/92, 5/20/92
1634	5/20/92, 9/28/93
1733	10/2/92, 7/17/93
1734	9/14/91, 10/2/92
1735	5/11/92, 11/3/92
1834	9/29/94, 11/29/93
1835	10/25/92, 6/6/93
1836	6/6/93, 4/19/93
1935	4/23/92, 7/31/93
1936	7/12/92, 11/17/92
1937	7/31/93, 10/3/93
2035	6/28/90
2036	6/12/90
2037	11/11/93, 8/26/94

Several statistical techniques exist to select the best combination of spectral bands of the imagery. (Jensen, 1986; Swain, 1978), (Jensen, 1986), (Johnson and Wischern, 1982). In cover type classification and biophysical variable analysis, there is no one optimum choice of spectral bands. Band selection for this project was based on the sensor involved, the area of interest, hardware limitations, and time constraints. For each scene area, an eight-band, multi-temporal image was created that consisted of bands 3, 4, 7 and a ratio of band 3 to band 4 from both image dates. There were two exceptions to this eight band selection. Only one scene date was received from the TVA for scenes 20/35 and 20/36 and therefore only four bands were used, and band 7 was not delivered with these scenes so band 5 was used to replace band 7.

Since the majority of the TM scenes and most of the ancillary data were delivered in UTM zone 17 with a NAD83 projection processing was completed in this coordinate system. Any imagery not in UTM zone 17, NAD83 projection was converted using PROJECT in ARC/Info.

The nearest neighbor algorithm was used. In addition, the single date scenes received from the TVA had to be resampled to 30 meter pixels then projected into UTM zone 17.

All scenes were checked for anomalies such as striping, clouds, leaf status and proper projection/rectification. Several scenes were reordered because both dates were 'leaf off'. Hydrology and roads coverages were used to check rectification of the scenes. One date for each of the three scenes 17/35, 18/35 and 20/37 was mis-registered. Their registration was corrected by shifting the upper left coordinates by an amount specified by the EROS Data Center, from whom the data was received. Each scene was cut to the SAA study area with an additional one mile buffer and scene to scene overlap was minimized.

Preliminary Field Visit

The purpose of visiting the study area for field data collection is twofold: 1) to assess and document ground vegetation variation and 2) to transfer knowledge between Forest Service and Pacific Meridian personnel. Variation in vegetation is directly correlated with the spectral variation in satellite imagery. This variation is correlated with spectral variation in the satellite imagery during the image classification

process. For this to be successful, a merging of the knowledge of forest vegetation with the knowledge of spectral reflectance is imperative. The best means of bringing these two factors together is through teamwork in the field.

Prior to any processing, an initial field visit was made to acquire a general knowledge of the vegetation in the Southern Appalachians.

This was a week long trip in visiting forests from northern Georgia to northern Virginia. Forest Service personnel accompanied Pacific Meridian in the field giving an overview tour of their forest and explaining the causes of vegetation variation in their districts.

This was an excellent start to the project and notes from this trip were used in all steps that follow.

Image Classification

Upon completion of pre-processing and the preliminary field visit, each image was stratified into urban agriculture and other areas using the Land Use Data Analysis (LUDA) layer provided by the National Biological Service. Stratification of imagery allows the image processor to narrow the range of expected classification results based on ancillary knowledge. Areas in the LUDA data labelled as agriculture or urban were used to mask corresponding areas from the imagery.

An ISODATA unsupervised classification of approximately 25 clusters was then run on these areas and the classes were identified using aerial photos and the image processors knowledge of satellite imagery. The image processors first labelled the clusters as either forested, non-forested or mixed classes. Forested areas were set aside to be processed later. Non-forested areas were further separated into urban, pasture, crop or mixed. Areas that were labelled as agriculture in the LUDA data and that Pacific Meridian identified as crop or pasture were considered to be correctly classified. Likewise urban areas identified by Pacific Meridian which matched the LUDA data were also considered to be correct. These areas were set aside and not considered for future processing.

The mixed classes were then run through another ISODATA unsupervised classification for further class separation and identification. Again, classes were identified as urban, pasture, crop, forested, or mixed and compared to the LUDA data as discussed above. Any classes still identified as mixed then defaulted to the LUDA classification with agricultural areas being labelled pasture or crop based on photo interpretation by the image processors.

Forested areas were placed back with the original imagery for the remainder of the classification.

An ISODATA unsupervised classification was then run on the remaining imagery. Depending on the variation in the imagery, fifty to seventy-five spectral classes were identified in the classification. Several classes were identified as being spectrally very similar but representing very general landcover types within the study area. For example, water, pasture, and herbaceous were each represented by multiple spectral classes. In cases where a spectral class could reliably be found to represent a single land cover type, i.e. water, barren, etc., the spectral classes were simply relabeled to that land cover type. Classes that could be identified as a general class type, such as deciduous, but not as a specific cover type, such as northern hardwood, were labeled as deciduous, coniferous, etc.

More confused spectral classes were given a unique color so they could be easily distinguished. This newly recolored spectral variation map was used to identify areas to be field visited. As many of the different spectral classes as possible were targeted for field visits to collect field data pertaining to vegetation cover type for the entire range of spectral reflectance present in the study area. The goal was to correlate the spectral variation in the imagery with the variation in the land cover.

Field Data Collection

Field work occurred during the months of May and July, 1995. Draft maps of the initial classification were taken to the field and compared to the vegetation on the ground. Notes were taken to indicate where the classification was accurately identifying the land cover and where it was inaccurate. General notes were also recorded that documented all spectral and vegetative variation encountered. These field notes were used to assist image processors in checking the results of unsupervised classifications and identifying training sites for completing image classification of the study area.

More than 100 person days were spent visiting the study area and meeting with Forest Service personnel from each of the forests in the study area. Pacific Meridian image processors completed the field data collection with the assistance of Forest Service personnel. The image processors responsible for completing image classification were responsible for the field data collection, ensuring consistency throughout the entire mapping project.

Re-Processing

After returning from the field, Pacific Meridian used the knowledge gained in the field to refine the unsupervised classifications. Areas noted in the field as correctly classified were set aside. Areas noted as being incorrect were masked from the imagery and re-classified. In addition, a few supervised training sites were added where the unsupervised classification could not distinguish between classes.

As a classification was completed, digital elevation data, hydrology layers, field notes, aerial photography, and ARC/INFO stand inventory layers were used to identify possible problem areas in the maps. For example, digital elevation models were compared with the classification to identify areas where northern hardwoods were appearing below 4000 foot elevations. While this combination is not impossible for the area, it is an unusual occurrence and warranted checking. Aerial photos and field notes were used to check these areas. Where the classification was determined to be correct, the area was set aside so as not to be changed. Areas classifying incorrectly were selected for re-processing and run through another iteration. This continued until no further gains in class identification could be achieved from the imagery. Any remaining modifications would be achieved with the use of ancillary data and manual editing.

From the start of the mapping project, several classes were known to be difficult to achieve strictly from the satellite imagery. These included wetlands and bottomland hardwoods. Bottomland hardwoods were classified using the imagery along with hydrology and elevation data. A one hundred meter buffer of streams at lower elevations was used to confine these hardwoods to the bottomlands. An unsupervised classification was run and bottomland hardwood classes identified using field notes and aerial photography.

Wetlands were based exclusively on the Fish and Wildlife Service National Wetland Inventory (NWI). Wetlands were defined as the palustrine wetland sub-classes of forested, emergent, scrub-shrub, and moss/lichen that were greater than two acres in size. The only exceptions were that "Water" and "Bottomland Hardwood" classes would always take precedence where the NWI and SAA classes overlapped.

In addition, the Forest Service's 1992 montane spruce-fir was used as the spruce-fir classification.

Draft Map Review and Editing

Draft maps were plotted at 1:100,000 scale and delivered to the National Forests within the study area for review and comment. Unfortunately, Forest Service input during the draft map review was inconsistent.

Several of the draft map reviews were excellent, identifying both correct and incorrect classes as well as having comments on the general ecology of the area being reviewed. However, several draft map reviews were incomplete and were never returned (see Appendix B). Of the total 74 draft 1:100,000 maps prepared for review, only 22 were returned with comments.

As Pacific Meridian received the reviewed draft maps, image processors made final enhancements and corrections to the classification. Since few corrections had been identified by Forest Service personnel during the draft map review, image processors reviewed aerial photography where available while making edits. As no aerial photo coverage was provided for much of the private lands, only limited editing could be accomplished in these areas.

Edgematching

The remaining step in the development of the land use/land cover raster classification was the joining of all fourteen scene classifications into one file. When several scenes are classified independently and then joined together, inconsistencies in data can result along scene boundaries. These inconsistencies are the result of several factors:

- 1.) Differences in adjoining scene dates can capture the seasonal variation in vegetation as well as natural or man made disturbances and cloud cover variation.
- 2.) Incomplete ancillary data, such as gaps in the wetlands data where data collection is not yet complete;
- 3.) Variation in or lack of draft map comments. For example, the comments received for scenes 16-17/33 indicated that "White Pine/Hemlock" areas occurred throughout the area. Comments from adjoining scenes 16- 17/34 indicated that "White Pine/Hemlock" occurred very infrequently in the area.
- 4.) Inconsistency in image classification due to processing of adjoining scenes by different personnel.

Edgematching minimizes inconsistencies between adjoining scenes. The classified scenes were stitched together and then visually checked against the imagery and aerial photography. Inconsistencies caused by variation in scene dates and incomplete ancillary data were not changed because the data, based on the scene classified, is correct. Inconsistencies due to differences in draft map reviews were changed only if a definitive distinction between the correct class and the incorrect class could be identified on the aerial photography. Remaining inconsistencies were checked against the imagery, aerial photography and other ancillary data and the appropriate edits were made.

After edgematching, the final step was to transfer the data to an Arc GRID format and convert it to the SAA Albers projection.

Polygon Creation

The final land cover classification raster layer was used to develop the polygon GIS coverage. The polygonization process has three distinct stages: raster scan; conversion to ARC for elimination; and polygon labeling.

1. Raster Scan - The raster scanning process smoothes or generalizes pixel data to produce homogeneous units. The resulting pixels represent areas of homogeneous land cover pixels. The scanning process was accomplished using a series of scanning routines in ERDAS.
2. Conversion to ARC and Elimination - The products of the ERDAS scanning routine are converted to

an ARC polygon coverage and all polygons less than 2 acres were removed. First, all polygons less than .3 acres were removed using a simple DISSOLVE command. The remaining polygons less than 2 acres in size were removed using a series of intelligent eliminates. Intelligent eliminates compare the less than 2acre polygon to the polygons surrounding it and prioritize the surrounding polygon with which it should be merged. For example, if a one acre white pine/hemlock polygon was surrounded by an oak polygon and a white pine/ hemlock/hardwood polygon the one acre polygon would be merged with the latter. Due to software constraints, the study area had to be processed in five parts.

3. Polygon Labeling - After vectorization of the classified pixel data, polygon attributes or labels were added to the polygon data. Polygon pixel summaries were calculated for each polygon and a label was assigned based on the composition of the classes within the polygon. For example, if a polygon was 65% oak, 25% white pine - hemlock, and 10% barren the polygon received the label of Oak Forest. The rules used to label the polygons can be found in Appendix C.

Crosswalk between Map Class and Accuracy Assessment Class

SAA Class Descriptions	Accuracy Assessment Class
Northern Hardwood Forests	Hardwood
Mixed Mesophytic Hardwood	Hardwood Forests
Oak Forests	Hardwood
Bottomland Hardwood Forests	Hardwood
White Pine / Hemlock Forests	Conifer
Montane Spruce-Fir Forests	Conifer
Southern Yellow Pine Forests	Conifer
White Pine / Hemlock /	Conifer/Hardwood Forests
Mixed Pine / Hardwood	Conifer/Hardwood Forests
Herbaceous	Herbaceous
Barren	Barren
Agriculture - Pasture	Agriculture
Agriculture - Cropland	Agriculture
Wetlands	Wetlands
Developed	Developed
Water	Water
Indeterminate - Clouds, Shadows	Indeterminate

The USFS and Pacific Meridian will incorporate fuzzy set theory to assess the accuracy of this data. Color infrared, Forest Health Monitoring (FHM) stereo triplicate photography at a scale of approximately 1:12,000 was chosen as the primary sampling unit (PSU) for accuracy assessment. The center of each forest health photo set was digitized and buffered to create a circular PSU of approximately 1,236 acres. A total of 236 PSUs were buffered. The polygon coverage was then intersected by these PSUs to produce a final coverage representing the population of polygons available for accuracy assessment sampling. The list of polygons available for sampling were summarized in a database which was then sent to the Rocky Mountain Forest and Range Experiment Station for polygon sample selection. The goal was to select 50 polygons of at least 40 acres for each land use/land cover class for accuracy assessment analysis.

An accuracy assessment still being conducted. Results are expected by July or August 1996.

This classification is a comprehensive database for the area and provides a powerful tool for resource

planners to utilize in increasing the effectiveness of resource management. This database is currently being assessed for accuracy. The database will be made available by the Forest Service on multiple CD ROM in early 1996. For information on the CD-ROM, contact Karl Hermann at the National Biological Service, University of Tennessee, 17 Ridgeway Road, Norris, TN 37828.

Appendices

Appendix A Southern Appalachian Assessment Land Cover Classification Key

```

If clouds, shadows .....Indeterminate
If NWI = Palustrine or Lacustrine wetland and area is not open water or bottomland hardwood species ...
.....Wetlands
If vegetation > 25% ..... Vegetated
  If > 25% tree crown cover .....Forested
    If > 70% of the total tree crown cover is deciduous .....Deciduous
      Northern Hardwood Forests
      Mixed Mesophytic Hardwood Forests
      Oak Forests
      Bottomland Hardwood Forests
    Else if > 70% of the total tree crown cover is
evergreen ..... Evergreen
      White Pine - Hemlock Forests
      Montane Spruce - Fir Forests
      Southern Yellow Pine Forests
    Else .....Mixed
      White Pine - Hemlock - Hardwood Forests
      Mixed Pine - Hardwood Forests
    Else if tree crown cover < 25%
  If cropland or pasture .....Agriculture
    Improved Pastures
    Croplands
  Else .....Herbaceous
Else if vegetation < 25% .....Non-Vegetated
  If > 50% synthetic surface (LUDA) .....Developed
  If lake, river, pond ..... Water
  Else if > 75% is non-vegetated .....Barren
  
```

Appendix C Polygon Labeling Rules

```

If c17 >= 75% then label = c17
If (c12+c13) >= 66% then label = whichever is greater between c12 and c13
If any other class (c1 through c11 or c14 through c16) >= 66% then label = that class
If class with majority of pixels has >= 30% more of the polygon area than the next highest
class then label = majority class.
For this rule, c12 and c13 should be added together for consideration as a majority class and then if these
to classes are >= 30% then the label will be whichever is greater between c12 or c13.
  
```

```

If _(c1 through c10,c12,c13,c14) >= 25% then
  If _(c1 through c9) > 25% then
    If _(c1 through c4)/_(c1 through c9) >= 70% then
      If c1 >= c2,c3 and c4 then label = c1
      If c4 >= c1,c2 and c3 then label = c4
      If c3 >= c1,c2 and c4 then label = c3
      else label = c2
    If _(c5, c6, c7)/_(c1 through c9) >= 70% then
      If c6 >= c5 and c7 then label = c6
      If c5 >= c6 and c7 then label = c5
      else label = c7
    If _(c8,c9)/_(c1 through c9) >= 70% then
      If c8 >= c9 then label = c8
      else label = c9
    If _(c5,c6,c8) >= _(c7,c9) then label = c8
    (**Please don't simplify this and the next line with "else c7".
    I want to catch labels that fall through)
  If _(c5,c6,c8) < _(c7,c9) then label = c7
  Else if _(c1 through c9) <= 25% then
    If _(c12,c13) >= c10 and c12 >= c13 then label = c12
    else if _(c12,c13) >= c10 and c12 < c13 then label = c13
    else c10
  Else if _(c1 through c10,c12,c13,c14) < 25% then
    If c15 >= 50% then label = c15
    else if c16 >= 50% then label = c16
    else if c11 >= 50% then label = c11
    else if c11 >= c15 and c11 >= c16 then label = c11
    else if c15 >= c16 then label = c15
    else if (c16 - c15) <= 15% then label = c15
    else if (c16 - c15) > 15% then label = c16
  Else label = default value of 20

```

Where

c1 = Class 1 = Northern Hardwood Forests	10 = Herbaceous
c2 = Class 2 = Mixed Mesophytic Hardwood Forests	11 = Barren
c3 3 = Oak Forests	12 = Pastures
c4... 4 = Bottomland Hardwood Forests	13 = Crop
5 = White Pine - Hemlock	14 = Wetlands
6 = Spruce-Fir	15 = Developed
7 = Southern Yellow Pine	16 = Water
8 = White Pine- Hemlock - Hdwd	17 = Indeterminate
9 = Mixed Pine - Hardwood	

Entity/Attribute Information

Entity: LANDCOV.VAT

Definition: land cover class

Attributes: VALUE

COUNT

Entity:
Definition:
Attributes:

Entity:
Definition:
Attributes:

Status Information

Data Set Status: Available
Release Date: 3/21/96

Metadata Reference Information

Date: 3/20/96
Review Date:
Contact: Karl A. Hermann
National Biological Service Cooperative
University of Tennessee
17 Ridgeway Road
Norris, TN 37828

samab@utk.edu
(423)-632-1452

Distribution Information

Distribution Contact: Karl A. Hermann
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(423)-632-1452

Distribution Liability:
File Compression Technique: UNIX compress,
Arc/Info export format
Transfer Size:

Contact Information

Contact Person: Karl A. Hermann

Contact Mail Address: National Biological Service Cooperative
University of Tennessee
17 Ridgeway Road
Norris, TN 37828
Contact Phone: (423)-632-1452
Contact Fax: (423)-632-1612
Contact email: samab@www.lib.utk
Home Page for Updates: <http://www.lib.utk.edu/samab>

Slopes Metadata

Not Available.

Riparian Zone Metada

saa5\saa_raster\metada\rip_z_lc.txt

GRID Name: RIP_Z_LC

Description: Riparian zone land cover grid.

Processing History: The Landsat land cover grid was aggregated to 7 classes as defined below. The stream coverage (RF3 1:100,000) was buffered by 30 meters. A mask grid was made out of this buffer and it was used to 'clip' the land cover grid resulting in RIP_Z_LC.

Item Description: RIP_Z_LC.VAT

Record	VALUE	DESCRIPT
2	1	Forest
3	2	Wetlands
4	3	Developed/Barren
5	4	Cropland
6	5	Pasture/Herbaceous
7	6	Water
8	7	Indeterminate

Other: The original land cover grid has 17 classes. These were aggregated to 7 classes in Arc/Info using the following reclass tables:

1 9 : 1
10 10 : 5
11 11 : 3
12 12 : 5
13 13 : 4
14 14 : 2
15 15 : 3
16 16 : 6
17 17 : 7

Contact: Dennis H. Yankee
Tennessee Valley Authority
Norris, TN 37828

(423)-632-1541
(423)-632-1612 FAX
email: dyankee@mhs-tva.attmail.com

Soils Metadata

General Soils Data for the SAA by State (excluding WV)

SAA Version 3.0

Data Set Names: **_soils (where ** indicates the State postal code)

NOTE: These are old State Soils data and should be used for general information only. The Natural Resources Conservation Service (formerly SCS) has newer general soils data called STATSGO.

Any serious user of soils data in the SAA should acquire the STATSGO data.

SAMAB plans to cooperate with its new partner, the Natural Resources Conservation Service to provide the STATSGO data through the SAMAB Home Page:

<http://www.lib.utk.edu/samab>

Contact: Brian Spears

US Forest Service

200 Weaver Blvd.

Asheville, NC 28802

(704)-257-4843

Streams Metadata

Stream data for the SAA region
SAA version 3.0
Version Date: 21 March 1996

Identification Information

Data Layer Name: Streams

Description: 1:100,000 EPA River Reach 3 stream coverage for the SAA region

Keywords: stream, river, RF3

Citation: Richard A. Dulaney
Lockheed Engineering and Sciences Company
1050 E. Flamingo Rd., Suite 126
Las Vegas, Nevada 89119

and

Mason J. Hewitt III
U. S. Environmental Protection Agency
Environmental Monitoring Systems Laboratory
Las Vegas, Nevada 89193-3478

Native Data Set

Environment: Unix; Arc/Info 7.1
pathname: /<path>/hucs.e00.Z
Scale: 1:2,000,000

File Format:

The data layer is in one Arc/Info line coverage and is available in compressed Arc/Info export format.

Use

Restrictions: Data set must be cited when used.

Access

Restrictions: none

Spatial Reference Information

Datum: North American Datum 1983 (NAD83)

Precision: single

Projection: Albers Equal Area

Units: meters

Spheroid: WGS-84

1st Std Parallel: 34 00 00
2nd Std Parallel: 38 00 00
Central Meridian: -82 00 00
Origin: 33 00 00
False Northing: 0.0
False Easting: 0.0

Extent:

West Bounding Coord.:
East Bounding Coord.:
North Bounding Coord.:
South Bounding Coord.:
Distance Resolution:

Vertical Resolution: n/a

Data Quality Information

Thematic Accuracy: unknown Confidence: unknown
Accuracy Method: unknown

Horizontal Accuracy: unknown Confidence: unknown
Accuracy Method: unknown

Vertical Accuracy: n/a

Logical
Consistency:

Completeness:

Source Information

Source Material:

Organization:
Date:
Distance Resolution: unknown

Contribution:
Source Material:
Organization:
Date:
Distance Resolution: unknown
Contribution:

Source Material:

Organization:
Date:
Distance Resolution: unknown
Contribution:

Processing History Information

Process Description:

The RF3 file is based upon the USGS 1:100,000 scale hydrography DLGs. The data were acquired by EPA-OW on 240 tapes which contained 54,000 files. The first processing performed was to convert from UTM to latitude/longitude. This conversion was accomplished preserving the nearest 1/10,000 of a degree, which is well within the stated resolution of these data. The data were then collapsed into line records (trace files) without nodes, and the line records were concatenated. There were then 4 million line elements and 93 million latitude/longitude coordinates. Each line, or trace, retained a key record that can be directed back to the original DLG data tape if necessary.

Traces were then assigned to USGS Cataloging Units (CU). Traces that crossed CU boundaries were assigned to both CUs. A CU is a geographic area representing all or part of a surface drainage basin, a combination of basins, or a distinct hydrologic feature. There are approximately 2150 CUs in the Nation. The USGS CU boundaries were developed at a scale of 1:2,000,000 (see Figure 1). They represent the "smallest element in the hierarchy of hydrologic units" (U.S. Geological Survey, 1982). Cus are not accurately correlated to topography and do not always correspond directly to true watersheds as they are more administrative in function.

Horizon Systems Corporation, the prime contractor to EPA-OW, developed a software tool called PC Reach File (PCRF). PCRF is the program that performs the RF3 file construction. Production development of RF3 proceeds in discrete units corresponding to the CU. Because of the ability to run many of the steps in batch, a given analyst running PCRF may be working on as many as 25 CUs at a time.

Building The RF3 Network.

In order to update the RF2 file to RF3, the RF2 data, the DLG data and the CU boundaries are all downloaded to a PC running PCRF. There, an analyst identifies a starting point for the automated construction of the network topology. The starting point designated was the furthest reach downstream and the network was built up in the reverse direction of flow. Between reaches there may be gaps, usually along map sheet boundaries. Therefore, a search tolerance of 3/10,000 of a degree or approximately 100 feet was specified in order to "bridge" these gaps. Edgematching takes place by the addition of segments in these gaps. Once this has been completed, the analyst will "replay" and supervise the network that was created. There may be some network discrepancies that are not able to be resolved by PCRF and that may cause a break in the processing. These are resolved by the analyst.

Once the network is built, segment and milepoint numbers must be assigned along the network. The analyst begins this session by viewing both the RF2 and the processed DLG data together, color coded for differentiation. The analyst then will "tag" the RF2 segment endpoints to the corresponding DLG points. PCRF will then work upstream from the downstream end of the segment and allocate milepoints. The RF2 milepoints are retained in RF3, despite the actual length of the new segments. In other words, the milepoint figures will not reflect the true length of the RF3 reaches. For example, if an RF2 segment had ten reaches (differentiated by milepoints), the more detailed RF3 segment will also have ten milepoints, but

the trace of these reaches will be entirely different. New milepoints are not being created because this would disrupt databases that index to the earlier Reach Files. The actual length of reaches as derived from the DLG trace is recorded in a field called SEGL. New segments and reaches are not an uncommon outcome of this conversion to the more highly resolved hydrography network. In this step, PCRf will assign new SEG/MI numbers to traces that appear in the 1:100,000 DLG that did not exist in the previous 1:500,000 Trace File.

Class 1 Roads Metadata

Data Set Title / Coverage Name: SAA Class 1 Roads

SAA Version: 3.0

Version Date: 3/21/96

Identification Information

Data Layer Name: class1rd

Description: Class 1 roads (major highways)

Keywords: roads, highways

Citation:

Native Data Set: USGS DLG's

Environment: UNIX; ARC/INFO 7.0.3

pathname:

Scale: 1:100,000

File Format: ARC/INFO 7.0.3 Line coverage

Use

Restrictions:

Access

Restrictions:

Spatial Reference Information

Datum: North American Datum 1983 (NAD83)

Precision: single

Projection: Albers Equal Area

Units: meters

Spheroid: WGS-84

1st Std Parallel: 34 00 00

2nd Std Parallel: 38 00 00
Central Meridian: -82 00 00
Origin: 33 00 00
False Northing: 0.0
False Easting: 0.0

Extent:

West Bounding Coord.:
East Bounding Coord.:
North Bounding Coord.:
South Bounding Coord.:
Distance Resolution:

Vertical Resolution: n/a

Data Quality Information

Thematic Accuracy: unknown Confidence: unknown
Accuracy Method: unknown

Horizontal Accuracy: 1:100K Confidence: unknown
Accuracy Method: unknown

Vertical Accuracy: n/a

Logical
Consistency:

Completeness:

Source Information

Source Material: 1:100,000-Scale DLG Hydrography & Transportation CD's

Organization: US Geological Survey
Date: 1993
Distance Resolution: unknown

Contribution:
Source Material:
Organization:
Date:
Distance Resolution: unknown
Contribution:

Source Material:

Organization:
Date:
Distance Resolution: unknown
Contribution:

Processing History Information

Process Description: DOS DLG files converted to unix and DLGARC'd into Arc-7 line coverages. Reselected Major/Minor code pairs 170/201 through 170/204. Road number codes converted to concatenated road numbers, and other significant code pairs stored in "special" attribute.

Item 'TCOUNT' contains the average daily traffic count for the road segment. Traffic counts estimates were provided by the various State Department of Transportation offices on printed maps. The digital attributes were assigned to road segments by University of Tennessee graduate students and US Forest Service staff.

Special cases of TCOUNT values include:

TCOUNT	description
--------	-------------

- | | |
|-------|---|
| - 777 | Class 1 roads within National Parks -
(Blue Ridge Parkway, Route 441 in the
Great Smoky Mountains National Park, and
Skyline Drive in the Shenandoah National Park.) |
| - 888 | Road segments inside of cities with
unknown traffic counts |
| - 999 | missing data on traffic counts |

Entity/Attribute Information

Entity: CLASS1RD.ATT
Definition: Major highways within SAA counties
Attributes: RD-NUM
SPECIAL
TCOUNT

Entity:
Definition:
Attributes:

Entity:
Definition:
Attributes:

Status Information

Data Set Status: Available

Release Date:

Metadata Reference Information

Date:

Review Date:

Contact:

Distribution Information

Distribution Contact: Karl A. Hermann

Distribution Liability:

File Compression Technique: UNIX compress, Arc/Info export format

Transfer Size: Arc/Info coverage = 2.7mb

Contact Information

Contact Person: Don Norris

Contact Mail

Address: USFS, 4931 Broad River Rd., Columbia, SC 29210

Contact Phone: (803) 561-4031

Contact Fax: (803) 561-4004

Contact email: /s=d.norris/ou1=r08f12a@mhs-fswa.attmail.com

Appendix H

List of Abbreviations

List of Abbreviations

BASINS: Better Assessment Science Integrating Point and Nonpoint Sources (EPA's Internet mapping program for water quality)
CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS: Comprehensive Environmental Response, Compensation, and Liability Information System
DNR: Department of Natural Resources
EMAP: (U.S. EPA) Environmental Monitoring and Assessment Program
EPA: U.S. Environmental Protection Agency
EROS: USGS's Earth Resources Observation Systems
ESA: Endangered Species Act
ESRI: Environmental Systems Research Institute, Inc.
EVI: Environmental Vulnerability Index
FEMA: Federal Emergency Management Agency
FGDC: Federal Geographic Data Committee
GAP: GIS analysis of habitat fragmentation (USGS)
GIS: Geographic Information System
ESRI: Environmental Systems Research Institute, Inc.
LUCAS: The Land-Use Change Analysis System
METLAND: The Metropolitan Landscape Planning Model
MRLC: Multi-Resolution Land Characteristics
NALC: The North American Landscape Characterization Project (U.S. EPA/USGS)
NASA: National Aeronautics and Space Administration
NASIS: The National Soil Information System
NAWQA: North American Water Quality Assessment (USGS)
NEPA: National Environmental Policy Act
NPDES: National Point Discharge Elimination System
NPS: National Park Service
NRI: National Resource Inventory (USDA's Natural Resources Conservation Service)
NRCS: Natural Resources Conservation Service
NWI: National Wetlands Inventory
OIRM: Office of Information Resources Management (EPA)
RICRA: Resource Conservation and Recovery Act
RCRIS: Resource Conservation and Recovery Information System
RMTF: Hamilton County's Resource Management Task Force
SAA: Southern Appalachian Assessment
SAMAB: Southern Appalachian Man and the Biosphere project
SOPAC: South Pacific Applied Geoscience Commission
SSURGO: Soil Survey Geographic (NRCS's most detailed level of soil mapping)
STATSGO: The State Soil Geographic Database
TVA: Tennessee Valley Authority
TCL: Tennessee Conservation League
TDEC: Tennessee Department of Environment and Conservation
TIGER: Topologically Integrated Geographic Encoding and Referencing (U.S. Census Bureau's GIS mapping data)
TRI: Toxic Release Inventory (EPA)
TWRA: Tennessee Wildlife Resources Agency
U.S. FWS: United States Fish and Wildlife Services
USGS: U.S. Geological Survey

Vita

Jeff Pfitzer was born in Cookeville, Tennessee, on September 12, 1964. He attended private schools in Chattanooga, Tennessee, where he graduated from Notre Dame High School in 1982. In 1994 he received a Bachelor of Arts from the University of Tennessee at Chattanooga in Philosophy and Religion with Departmental Honors. In 1994 and 1995 he took Masters courses in Religious Studies at Arizona State University under a Teaching Assistantship. In the interim, he was largely self-employed in various sectors of the construction industry and operated a small woodworking shop. In the fall of 1997 he entered into the University of Tennessee Graduate School of Planning to pursue studies in Environmental Planning. Work at UT included minor concentrations in Land Use Planning and in Environmental Planning, and additional course work in Environmental Policy. While at UT, he has been involved with collaborative projects involving U.S. Geological Survey, Environmental Protection Agency, and the Southern Appalachian Man and the Biosphere program. In the summer of 1999, he worked with an international, cross-disciplinary, planning team in Santa Comba Dao, Portugal developing a regional revitalization plan. He also worked closely with Planning Agency of Maryville, Tennessee, holding public meetings for their "Vision 20/20" planning process.