THE PROCEEDINGS OF THE WORKSHOP ON REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEMS FOR USE IN MANAGING THE ALBEMARLE-PAMLICO ESTUARY

November 9-10, 1987

Albemarle-Pamlico Estuarine Study
and
The University of North Carolina
Water Resources Research Institute

The Proceedings of the Workshop on Remote Sensing and Geographic Information Systems for Use in Managing The Albemarle-Pamlico Estuary

November 9-10, 1987
Raleigh, NC

Sponsored by:

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Opening Remarks

James M. Stewart
(Associate Director
UNC Water Resources Research Institute)
Workshop Organizer

This is the third in a series of special workshops conducted for the Albemarle-Pamlico Estuarine Study. The other workshops were on water quality and hydrodynamic modeling and on fish diseases. All of these workshops were held to clarify issues and needs in these subject areas and to establish priorities for studies and programs.

We want to acknowledge the inputs to this workshop by Karen Siderelis and Tom Tribble in the Land Resources Information System office of the Division of Land Resources. Their help and cooperation in developing the program and identifying expertise were valuable.

The list of applications of remote sensing and geographic information systems is impressive and continues to grow. This growth coupled with the expected tenfold increase in the next 10 years of computer power and greater access and convenience of computers make it an exciting time for professionals in information systems.

We are especially pleased to have an impressive group of experts in this field to participate in this workshop to suggest specific initiatives and strategies which might be undertaken as a part of the Albemarle-Pamlico Estuarine Study. We seek your recommendations for studies and programs that have potential use and application by the resource managers. In addition to specific studies and programs, you may have recommendations for institutional and policy changes which will enhance the use and application of remote sensing and GIS information.

Managers of the Albemarle-Pamlico Estuarine system must make tough decisions and take courses of action with limited data and information. We know that applications from remote sensing and GIS can benefit those managers. You can suggest ways to improve the exchange and use of data and computer software, ways to achieve greater integration of information, and ways to put it into operational programs.

Let me review with you the specific objectives of the workshop:

1. To develop an understanding of the state-of-the-art in remote sensing and geographic information systems (GIS) and of the advantages, limitations, and processes of integrating remotely sensed data with other spatial data in a GIS.

2. To assess the State's current capabilities in remote sensing and GIS that could be enhanced and utilized for developing and maintaining a land-use inventory

for the Albemarle-Pamlico region and for incorporating the data in the APES data system.

3. To explore approaches for using land-use information to address water quality, fisheries, recreation, and other resource management issues in the Albemarle-Pamlico Estuarine Study.

4. To benefit from the experience of other agencies that have attempted similar programs.

5. To recommend a practical strategy for implementing an operational program to develop and maintain a land-use inventory for the Albemarle-Pamlico Estuarine Study.

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Albemarle-Pamlico Estuarine Study

Douglas Rader
Study Coordinator

This presentation is an overview of the Albemarle-Pamlico Estuarine System and some of the key processes that are the major focuses for management of the system. It will also include an overview of the operation of the Albemarle-Pamlico Estuarine Study because we are interested in integrating remote sensing and geographic information systems into what we have already done.

The Albemarle-Pamlico System is a very major estuary on the East Coast--the second largest in water surface area after Chesapeake Bay to our north. Throughout the drainage basin there have been very striking changes in land surface disturbance patterns. The management of land-use change and its effects will form the focus for the Albemarle-Pamlico Study.

Study Area Not Limited to Coastal Fringe

The study area itself encompasses roughly 31,000 square miles, comprising 33 counties in North Carolina and the Chowan and Back Bay drainages in Virginia. The Albemarle Sound to the north and the Pamlico Sound to the south are coastal lagoons with a number of tributaries, the most important of which are the Neuse River, the Pamlico River, the Roanoke River, and the Chowan River. Currituck Sound in the extreme north connects with the Back Bay in Virginia. Also included in the system are Core Sound and Bogue Sound further south.

One of the major tributaries, the Neuse River is a predominantly urbanized stream in the southern part of the study area. At times of low-flow at New Bern, between 85 and 90 percent of the total flow in the stream is waste. Another key tributary, the Pamlico River has recently been the locus for a great number of environmental changes.

As you can see, in this study we are not looking only at the coastal fringe because an enormous number of human impacts come from upstream. A look at the relative contributions of up-basin and down-basin effects makes clear the need to insure intergovernmental cooperation throughout the study area.

Area Is Rich in Resources, Economically Crucial to State

This area is enormously rich in natural resources related to the estuaries. The fishes and the human lifestyles that fishing supports are very important to the state of North Carolina. Throughout the system are nursery areas for various kinds of economically important species, either anadromous fish upstream or brackish-marine species in some of the so-called primary nursery areas that fringe Hyde and Pamlico counties. (See Figure 1)

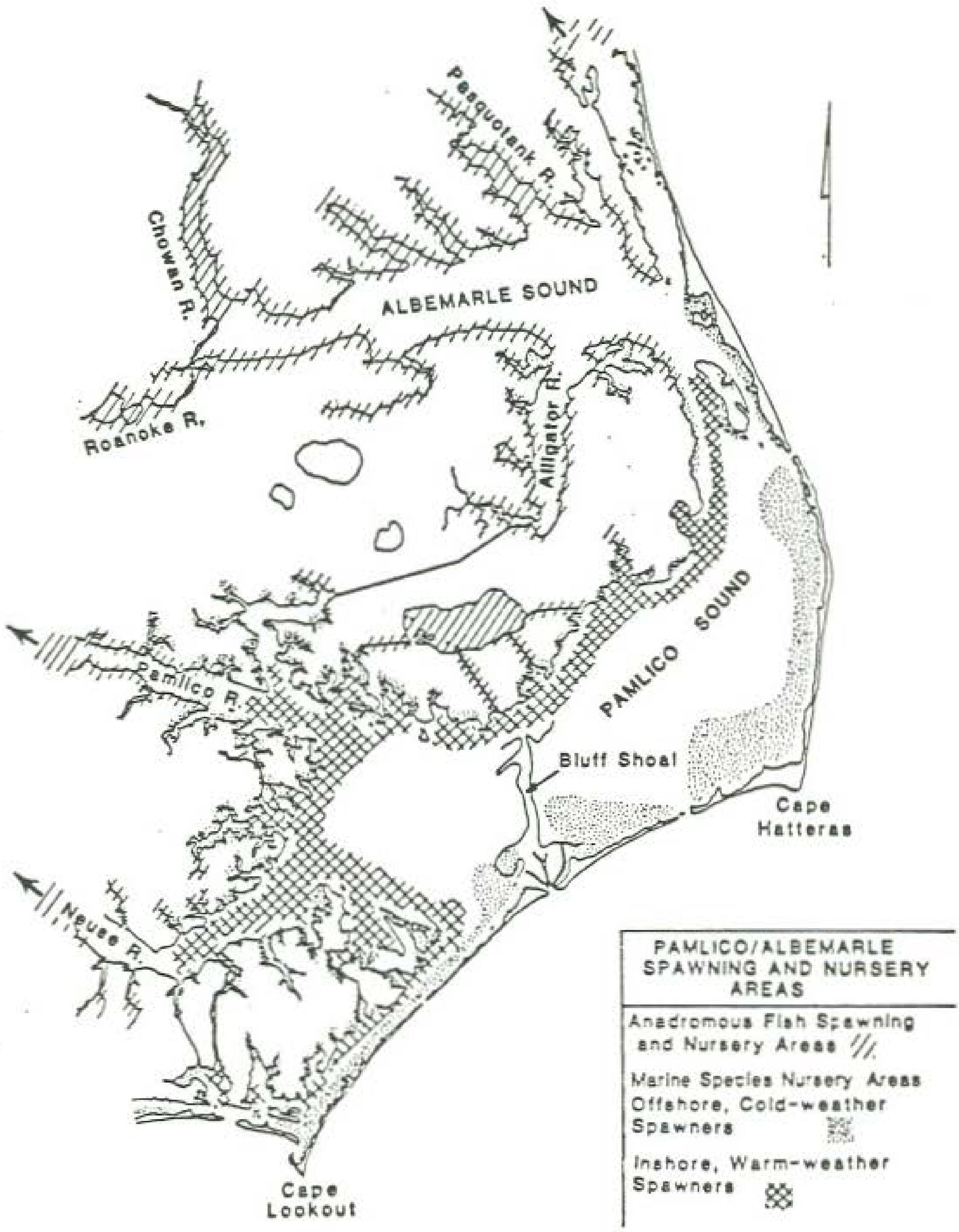


Figure 1 - **Pamlico/Albemarle spawning and nursery areas:** General depiction of major nekton nursery and anadromous fish spawning areas in the Pamlico-Albemarle complex for economically important species (N.C. Div. Mar. Fish., unpubl. data). The nursery areas for warm-weather spawned fish are mainly for weakfish and silver perch. Anadromous nursery and spawning areas are combined, but spawning areas are mostly upriver while nurseries are mostly downriver. (from Technical Memorandum NMFS-SEFC-175, National Marine Fiseheries Service, NOAA, U.S. Dept. Commerce)

No one knows precisely how much of the fisheries productivity on the East Coast is supported by the Albemarle-Pamlico Estuarine System. The implication is that it is fairly high, especially for species like menhaden that are harvested all along the East Coast. All the little creeks and bays that serve as primary nursery areas are surrounded by wetlands that, prior to the mid-1970s, had not been disturbed. A great deal of conversion of wetlands took place in this system between about 1975 and 1982-1984.

This area is also enormously rich in shellfish resources, whether they are fringing saltmarsh oysters or scallops in Core and Bogue Sounds.

Historically, the areas between the numerous tributaries were swamp forests, wetlands and pocosins. They have been changing through time, but overall these areas are very, very low in elevation--not basin wide, but in the Albemarle-Pamlico peninsula in particular. (In Hyde County a dredged spoil mound is probably the highest point in the entire country.)

Land-Use Change is Overtaking Wetlands Fringing Nursery Areas

However, change is overtaking these wetlands. Today there is a mosaic of land uses throughout the area, including, along with the residual swamp forests, agriculture and silviculture. Agriculture is now the predominant use, by land area, in the entire drainage basin for the Pamlico Sound.

In the 1970s and 1980s, agribusiness came into the area in a big way, and there are now enormous areas dedicated to megafarming with all its ramifications and implications. Because this area is so low it is necessary to drain almost all the land before you can do anything with it. The very dense drainage systems that have been put into place have the potential to significantly impact the nursery areas I described previously. Not all the relationships are well understood, but it is well understood that the drainage systems carry the bulk of the fresh water, sediments, nutrients, and toxicants coming off agricultural and silvicultural land to the receiving streams and on to the estuaries. In some areas the pumped drainage is very high in volume.

Drainage practices are subject to management, and if we can develop ecologically sound drainage techniques, we can go a long way toward reconciling important humans uses of the coastal resources.

In addition, animal operations have exploded along the coast. Broiler and hog production are both way up from the mid-1970s.

Next to agriculture, however, silviculture represents the major land use on the coast. A great deal of swamp forest clearing took place in the 70s and 80s, and the paper and other silviculture-related industries are probably the major point source dischargers in the system. There are major paper-making facilities on the Roanoke River, on the Neuse River, and on the Chowan River in Virginia. There is also a world-class phosphate operation on the Pamlico River, with a mine and processing facility. It is the largest single point source discharger in terms of volume of waste in the Pamlico System and one of the largest open-pit phosphate mines in the world. It discharges approximately 45 percent of the total phosphorus in the entire Albemarle-Pamlico system. It also has other important management implications. Other waste products from phosphate mining are voluminous. One of the wastes is the phosphate clay or slime.

Population of Study Area Predicted to Double by the Year 2000

Now, in addition to the large land conversions for agricultural and silvicultural purposes, the resort potential of the coastal area is being exploited, and large numbers of marinas are opening. If you look at the total population in the East, there have been linear increases from the 70s--constant population growth. Some demographers predict that between now and the year 2000, the population of the total study area will double. The lesson from that is simple and provides the primary impetus for the study: change is coming, and now is the time to manage the change.

Even with the economic foibles of the last few years there has been pretty much a constant increase in total harvested agricultural land in many counties in the study area. There has been a linear increase in the total number of major permits permitted for development in the coastal counties of North Carolina since 1983. It's obvious the area will continue to see more people, more development, more sewage.

Environmental Tolerances of System Are Being Taxed, Fish Harvest Decreases

At the same time the change is coming, there is evidence that environmental tolerances in the system are being exceeded. There are evidences of environmental stress. A major one is eutrophication, visually evident by the nuisance growth of blue-green algae in several tributaries. The Chowan and the Neuse rivers have experienced blooms for several years, and last summer, in the Pamlico River, where the water is more saline than blue-green algae can stand, there was growth of more salt-tolerant algae that exceeded the state standards for algal pigment by ten times.

The consequences of oxygen absorption which that level of algal growth causes can be obvious. Between January and July of 1987 there were 37 total fish kills reported in the entire state of North Carolina. Of that 37, 14 were in the Pamlico system. In addition to fish kills, there are several important diseases of fish and crustaceans that sometimes reach epizootic proportions. The most prevalent is ulcerative mycosis, a sore-forming disease which sometimes reaches 85 to 90 percent incidence in menhaden schools in late spring and late fall and affects other commercially important species such as flounder. There is also a guild of nine other bacteria, fungi, and viruses that infects all kinds of fishes in the Albemarle system with diseases called "red sore." This past summer we had an unusual outbreak of a crab disease called "burnt crab disease" or "brown crab disease" that is caused by a bacterium which eats away the carapace. This disease was centered in the Pamlico River.

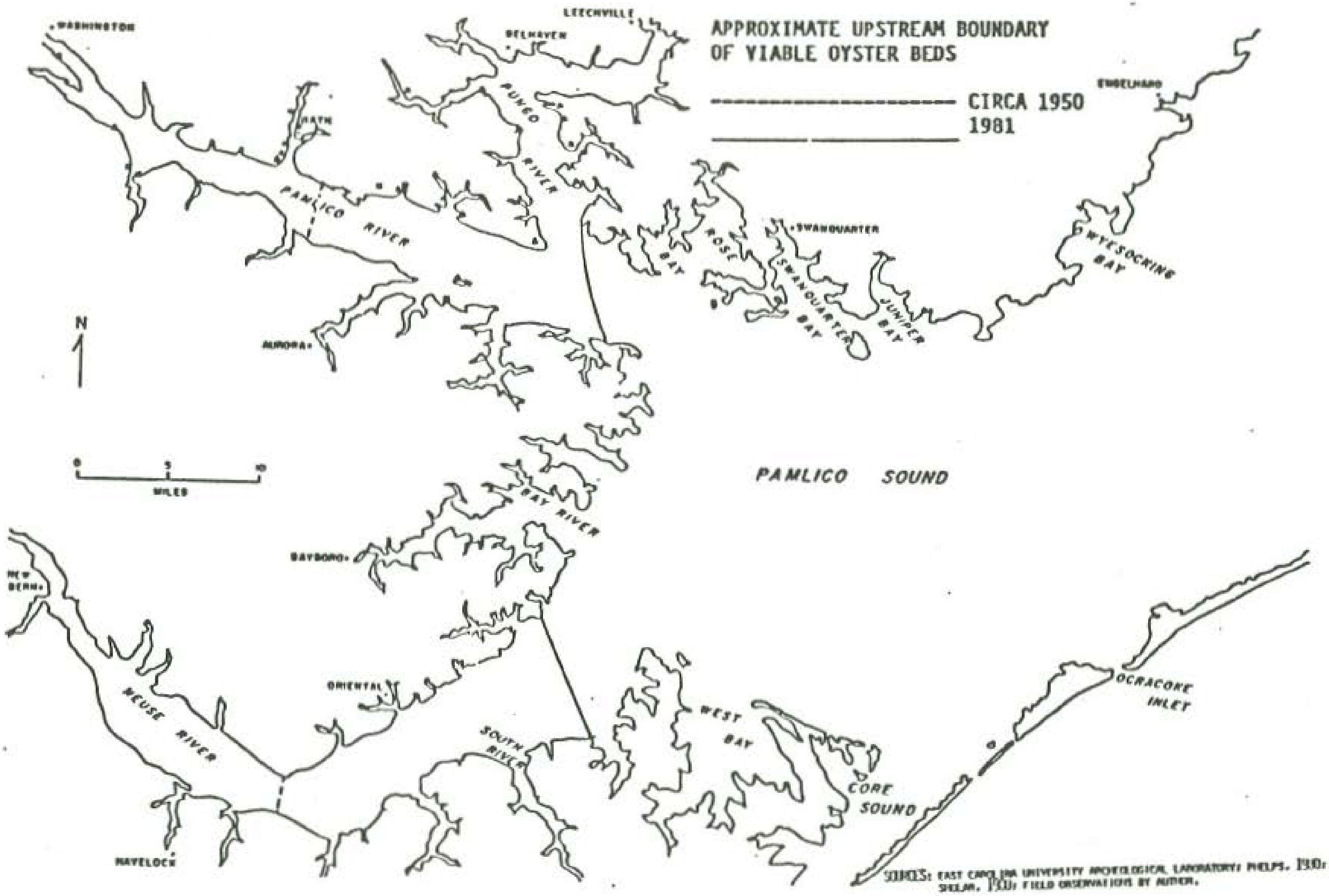


Figure 2 - Historic oyster ranges: Oyster displacement is an example of the biotic responses that often accompany salinity changes. (from "Salinity in Pamlico Sound, North Carolina: A Space-Time Approach," a master's degree thesis by Jonathan David Phillips under the direction of Richard A. Stephenson, East Carolina Department of Geography and Planning, April, 1982)

Another consequence of development in this system, especially of nonpoint sources of pollutants, is the increase in closure of shellfishing waters because of contamination by fecal coliform. From 1971 to the present there has been a stepwise increase in closure due to contamination from residential sources. That doesn't necessarily mean that it is worse now than it used to be because there are institutional and administrative factors folded into these figures, but that conclusion is suggested.

Further, viable oyster beds are shifting. Since World War II, there has been a 10 to 15 mile downstream shift. (See Figure 2) This is a complex indicator of change. Harvesting of oysters, sedimentation, and a variety of other factors enter into this change.

The total effect of all these factors on fisheries has been a stepwise decrease of harvest of all edible finfish in the area adjacent to the Albemarle Sound since 1980.

Another change that parallels those discussed above is the disappearance of submerged plants such as wild celery throughout the system.

Nonpoint Source Pollution Resulting from Land-Use Changes Drives Environmental Changes in Estuaries

The impact of all these conditions is obvious: there is a great deal of anthropic stress on the system. We want to design a management plan between now and November 1992 to address these changes and to try to preserve the long-term productivity of the system.

Most of these changes, presumably, are driven by nonpoint pollution arising from land-use conversion and its effects. The challenge is to manage land use: to evaluate the effects of land use and all its consequences for in-stream activities.

One final special topic that is of great concern in this region of very low wetlands is the large deposits of deep organic soil (known as peats) that are subject to mining. Several peat-mining projects are now pending that are subject to environmental management.

The Albemarle-Pamlico Estuarine Study, we hope, will heighten public awareness of the value of the resources in the system and thereby bring about a consensus on management practices that will allow diverse public activities and private activities in the tributary areas of the system to coexist. In order to bring about this consensus, we must look at all the ways people use and affect the system. This will include examining the effects of fishing on the resource itself and the effects of economic change on the fishing industry. In order to produce an effective management plan, this study must be based upon collaboration among academics, federal and state agencies, and the private sector--including agricultural and industrial interests.

There is a great deal of work being done by federal and state agencies in North Carolina now that can contribute to this study. There is an ambient (water quality) monitoring network. Between now and March 1988 we must decide how best to expand and complement this network, possibly with a combination of continuous sensors and citizen monitoring, to produce a long-term dependable and supportable data base to support remote sensing and modeling in the system.

The Albemarle-Pamlico Study has three main components:

(1) Information acquisition: We are currently funding 17 research projects to get the information we need in order to make rational management decisions .

(2) Information management: We are in the process of adopting the concept of integrated data management for study use. Karen Siderelis will address this.

(3) Public awareness building: This may be the most important part of the whole thing. We have five projects underway and will spend roughly $150,000 a year to promote public awareness in the system.

Clearly, we need all the help we can get in completing the study and constructing the management plan. We will be grateful for your advice.

Albemarle-Pamlico Data Management Program

Karen Siderelis
N.C. Land Resources Information Service

(The N.C. Land Resources Information Service [LRIS] is the agency designated to provide comprehensive mapping and data management services for the Albemarle-Pamlico Estuarine Study. LRIS is a unit of the N.C. Department of Natural Resources and Community Development.)

The purposes of my presentation are to (1) review the data management program for the Albemarle-Pamlico Estuarine Study, and (2) to summarize the availability and limitations of existing data for the region.

We have developed an overall but general data management plan for the study that was endorsed by the study's policy committee in June of this year. Remote sensing falls under the umbrella of data management so today I will emphasize the parts of our plan that relate to remote sensing.

The overall goal of the data management plan is to provide management support for accomplishing the objectives of the overall study. We intend to furnish managers and scientists with information to aid in addressing a number of the issues that were outlined in the study overview previously presented.

Our objectives are as follows:

(1) Catalog and access literature and data about the region

(2) Establish mechanisms for accessing, integrating, and analyzing pertinent automated data

(3) Provide the resources for automating existing data not currently automated and new data resulting from other study activities

(4) Develop automated reporting and tracking systems that summarize the conditions in the estuarine area

Data Management System Is Designed for Flexibility, Acessibility, and Long-Term Utility

The criteria around which we developed the data management system included the following:

(1) A geographic information system (GIS) must be an integral part of the Albemarle-Pamlico Estuarine management program. We felt that the capability for compiling, storing, and analyzing data for this purpose is an absolute requirement.

(2) The data management system must be designed to minimize duplication. We want to avoid as much as possible duplicating hardware, software, and data. We felt that bringing together all the data we could find about the area into one large data base is probably impractical. We will take the approach of leaving the data where it is and developing links with remote data bases, where practical.

(3) Access to the system and to the data ought to be available both remotely and locally. We have 33 counties and numerous managers distributed throughout the study area, and we decided we ought to provide them remote access to the data system.

(4) The system must be flexible to accommodate data needs as they arise and to accommodate the addition of new data throughout the study period. Related to this is the ability to allow managers ad hoc query.

(5) The system must be cost effective. This is particulary true in the area of remote sensing.

(6) The system utility must extend beyond the five-year life of the study. We want to establish programs that the state can support over the long run. In regard to remote sensing, we have to develop practical, reasonable techniques. We cannot establish a research program. We must have an operational program based on the kind of technology that can provide useful results. We need your help in identifying the technologies that are mature enough to provide the operational techniques we must have.

LRIS has about ten years' experience in the operation of a geographical information system. Unfortunately, remote sensing has not been a major part of our GIS.

Data Base for Albemarle-Pamlico Estuarine Study Has Three Components

The data base for the study will have three components:

(1) An indexed catalog of literature and data about the area

(2) Tabular data. This will be nongeographic data, and it may not necessarily be stored in one data base.

(3) Geographic data. This would include existing data in LRIS about such things as soils, political

boundaries, watershed boundaries, fisheries data related to primary and secondary nursery areas and shellfish areas, drainage basins, monitoring sites, and ground cover.

It is not known at this point precisely what data will be required to construct the management plan for the study. As data needs are uncovered, they will be integrated into the plan.

Some Data Exist Which Will Support Study Objectives

Current availability of data is better in some areas than in others. As regards land use, the available data are unsatisfactory. We do have USGS data from the early 1970s for the entire state, including the study area, but we feel the data are old and that there are integrity problems that would require an unreasonable amount of computer processing to resolve.

We also have data from an environmental geologic atlas produced by East Carolina University in the early 1980s involving interpretation of high-altitude photography. The data cover five counties in the study area--Dare, Hyde, Tyrrell, Washington, and Carteret. The major problem we see with this data is that it does not cover the entire study area.

A third set of land-use information we have is for a 12-quad area in the western part of the study area. These data were developed for the state's bid for the Superconducting Super Collider Project. Again it does not provide good coverage, and again it is based on interpretation of high-altitude photography. Largely because of digitizing costs, it would be very costly to expand this data to the entire study area. From investigating this set of data we discovered that it costs about $100,000 to map and digitize a 12-quad area using this technique.

The water quality data currently available come from the Division of Environmental Management's ambient monitoring program. DEM has 115 stations in the study area. In addition USGS has 35 stream-flow monitoring locations throughout the study area and plans an additional 24 or 25 in the region in the coming year. There are plans to supplement this network with a citizens monitoring program of perhaps 3500 stations.

Discussion

Question: Are the water quality monitoring stations in tidal waters?

Rader: They are spread out. One of the problems with the current program is that the sampling frequency is very low, especially in the open water of the sound.

I tried to pull together all the water quality data collected by those ambient stations since January of this year and got very little data from the computer. Some of the stations have no records at all. I don't know whether the samples haven't been analyzed in the lab or whether the data haven't been entered or what. However, some of the stations near regional offices have very good data. So the coverage is very uneven.

We have a clear mandate, and most probably funds, to expand that network.

Khorram: What types of data are collected?

Rader: A fairly standard series of water quality data. Between now and March we have to formulate a comprehensive baseline monitoring plan. We hope to construct that monitoring program so we can integrate the expanded wet chemistry water quality data into remote-sensed water quality data.

So, I would emphasize that we're looking not only at the possibility for remotely sensed land-use and land-cover data but also at hydrographic data.

Khorram: Do the existing stations collect hydrodynamic data?

Rader: Not really.

Khorram: How far back to the water quality data go?

Rader: Some of it goes back to the late 1970s. Some privately collected information exists, including some that was collected for the Texasgulf permit.

Khorram: Are there any large vessels that routinely collect data in the estuarine system? We're talking about a really dynamic environment, and the ability to move around the system and monitor conditions instantaneously might be helpful.

Rader: Absolutely. In fact, for most of the parameters concerned--dissolved oxygen, nutrient concentration, chlorophyll a--noninstantaneous records are almost meaningless. If you sample 20 minutes later or a few yards away from a static site, you may get completely different numbers. There are very strong diurnal patterns in all three of the parameters I mentioned.

We are faced with coping with this problem. Perhaps we can do that by getting data instantaneously from satellites or continuously from monitors and integrating the wet chemistry data into that. Obviously, the problem with using large vessels is cost. I understand the Chesapeake Bay Study has spent millions of dollars on their monitoring effort.

Khorram: For a study of the San Francisco Bay done by USGS early 1970s, the decision was made to get a couple of large vessels--about a 120 feet or so--and equip them with all kinds of instrumentation for continuous monitoring as well as sampling and onboard wet chemistry analysis. Every two weeks they sent back the data.

Comment: There would be problems in our estuarine system with vessels of this size. The waters are so shallow, any vessel larger than 24 feet is going to run into lots of problems.

Rader: Also, the monitoring effort we initiate must be something the state has the money to sustain over the long term. We can expect about $100,000 to $200,000 a year for the monitoring program at most, and that is not a lot.

What we are trying to do is create a solution by combining layers of effort. That is one reason why I am so attracted to citizen lay monitoring.

Comment: Digitizing data is very labor intensive and expensive and there may be loss of data in the process. There are alternatives, such as predigitized maps.

Rader: We are working with EPA to obtain base maps at the 100,000 scale.

Collins: We are acquiring the USGS data set on 1/100,000 hydrography, the LUDA data, digital elevation model data base, roads--the basic data sets for our whole region. These data sets will be available to the states in digitized form. TVA is digitizing the general soils maps for all of North Carolina, and those can be acquired. So we have some form of the basic data sets that Karen mentioned--including monitoring sites, streams. We have seen the state of Utah use the combination of digital elevation model data, land-use data, and stream data to determine nonpoint runoff in a very effective way.

Perchalski: In your cost data from the SSC proposal, do you have any information on what the information extraction costs versus the digitizing costs were? It has been our experience that digitizing costs about three to four times as much as data extraction.

Siderelis: To the best of my recollection the costs were about the same. I don't think we experienced that kind of ratio at all.

Perchalski: What was your mapping unit?

Siderelis: Three to five acres.

Perchalski: We're down to a quarter of an acre (TVA Soils mapping), and I think you may find you need greater detail for nonpoint source information. When you talk about things like animal waste sites, you sometimes have to look at which side of the barn the site is on. You need to keep your objectives in mind. To solve nonpoint problems, you need the capability to look at individual fields. If it's just a GIS exercise, it doesn't matter what you put into the system. But if you're out to solve problems, you have to have the right data on the front end.

A lot of the historical data we have came from dealing with point source problems, and that doesn't tell you much about dealing with nonpoint sources. However, if you start trying to digitize all the information you need, it quickly gets to be very expensive. We've been looking at some alternatives. You can do some on-the-ground, meaningful, publicly visible things without spending a lot of time or money. (See Perchalski presentation)

State of the Art and Issues in Remote Sensing and Geographic Information Systems

Stuart Doescher
EROS Data Center

I will first identify some of the Geographic Information Systems (GIS) concepts and characteristics and discuss a GIS data flow, using the data flow in the EROS Data Center as a framework. I will not try to present any solutions but will present ideas for discussion.

Following a discussion of GIS, I will go into remote sensing in some detail, discussing some of the numerous data sources and processing requirements.

Basically the GIS is multiple, registered layers of geographic data (See Figure 3) either in vector (polygon, line, or point) format or raster (matrix or grid cell) format. In some cases the data may be in tabular format. The building of the data base usually has the biggest impact on the analysis capability and sometimes accounts for up to 80 percent of the total GIS effort.

Another GIS concept is that of a nucleus of hardware and software which is responsible for building the data base, integrating data, providing analysis tools, outputting data, and providing an effective user interface. (See Figure 4) To use today's GIS, a person needs to know two things basically: He needs to know what he wants to do and how to do that job with the tools the system makes available to him.

Nature and Capabilities of Geographic Information System Are Determined by Hardware, Software, and Data Organization

GIS characteristics are determined by the hardware and systems software at the heart of the system, the organization and characteristics of the data base, and the output capabilities. The usefulness of the system can be gauged by considering the following:

(1) Input functionality for building of the data base, including how the maps are digitized and how data from other digital sources are brought into the system

(2) Query and analysis capabilities

(3) Output--map and report generation capabilities

Data bases may be organized in several ways: raster, arc, vector, polygon, point, line. There is a lot of information available in all these forms for use in geographic information systems. There must be a compatibility between the data sources and the desired output.

A raster data base is an array of grid cells in which each data value

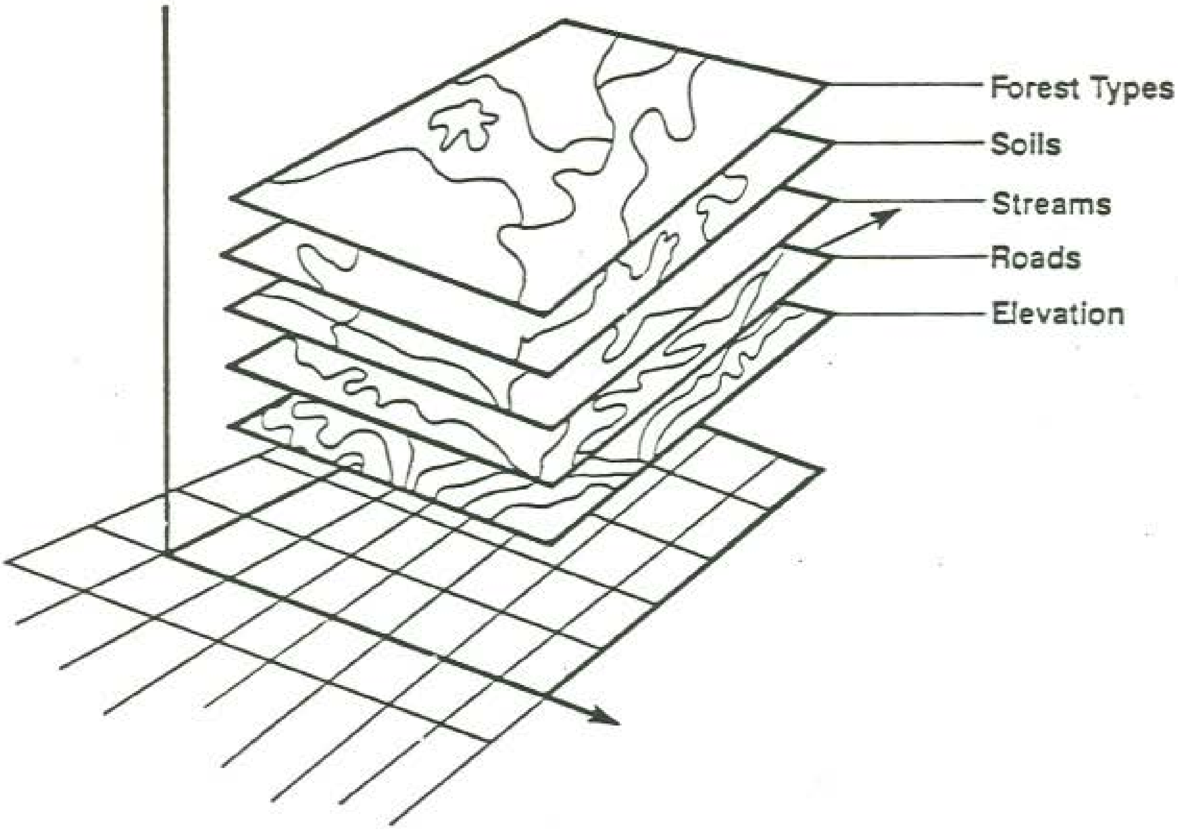


Figure 3 - A Geographic Information System conceptualized as a set of geographically registered data layers

that is within that grid cell has a particular attribute corresponding to it. (See Figure 5) That attribute could be reflectance value, brightness value, elevation, slope, land-cover classification or any number of other things.

A vector data base is built of points and lines and is based on complex polygons. (See Figure 6) In this format, the attributes are usually handled in a separate tabular or relational environment.

Integrated Raster and Vector Approach Captures Strengths of Both Formats

There is a major advantage in working with raster. Usually, the algorithms used are much simpler to work with. That means that modeling within this data structure is easier to implement. The primary disadvantages of the raster format are that it requires more storage and the output is problematic in that it has the jagged-edge effect.

The principal vector format advantage is that it requires less storage However, the algorithms that it uses are much more complex. Within vector analysis topology must be maintained and attributes must be handled separately so continuous data, such as elevation data, are not readily accommodated.

At the EROS Data Center, we use a blend of both raster and vector to take advantage of the strengths of both formats.

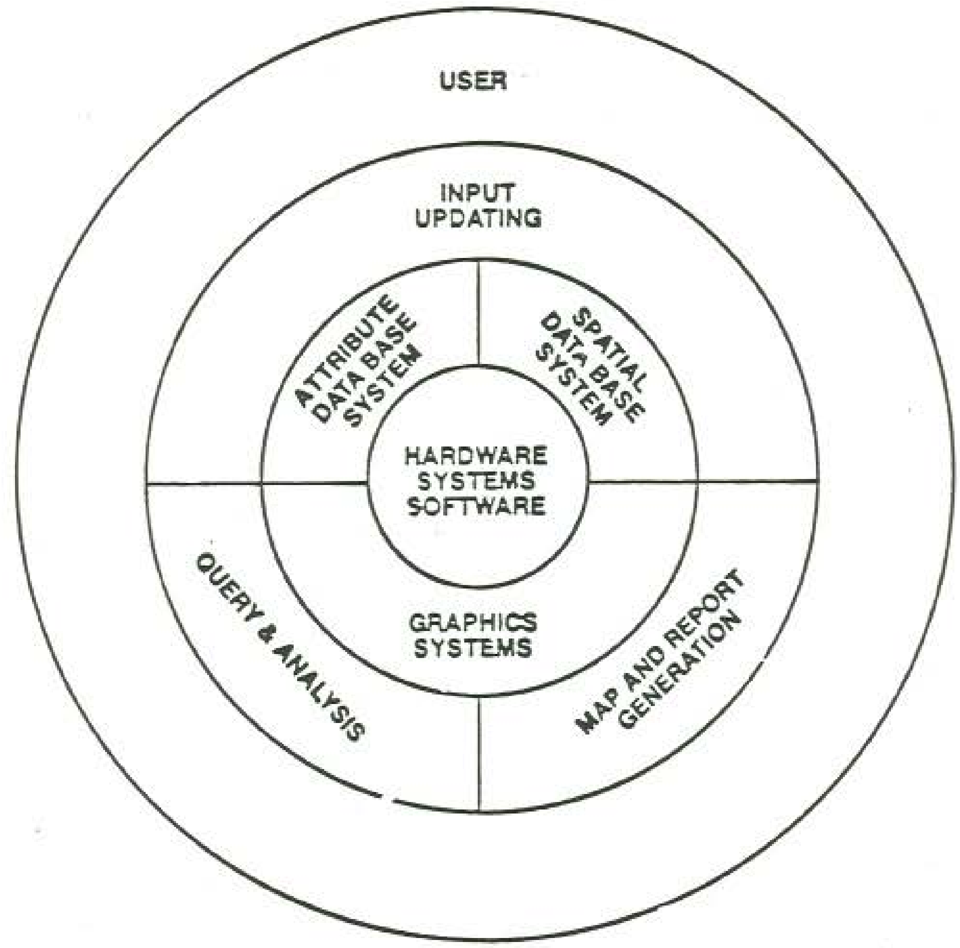
At EROS we do a large number of cooperative projects with other federal agencies, trying to solve their particular problems and trying to put them into an appropriate operational environment. This means we have to work with data from a large number of different sources. The data come to us in raster, vector, and tabular format, and we must support systems using all these formats. We provide raster analysis, vector analysis, and pathways to connect and integrate these and the tabular or statistical data, as well as comprehensive output capabilities.

The Kind of Remotely Sensed Data Needed Depends Upon the Goals of the Project

Some sources for remotely sensed data are the Advanced Very High Resolution Radiometer (AVHRR) operating from the NOAA satellite, (Multispectral Scanner (MSS) and Thematic Mapper (TM) operating from the Landsat satellite, High Resolution Visible (HRV) operating from the French SPOT satellite, and National High Altitude Photography (NHAP) and other aerial photography. There is also a variety of other sources.

The different characteristics of each satellite instrument are shown in Table 1. Resolution is an important characteristic to know, and the resolution you aim for will depend upon the nature of the study you are undertaking. Frequency of coverage is also an important consideration. Sometimes the length of the repeat cycle will be more important than other factors. For example, you may need greater frequency of coverage to overcome the conditions of cloud cover.

Figure 4 - Conceptual GIS model



The AVHRR has about 1 kilometer resolution in terms of its footprint on the earth. It has a huge viewing angle, so it provides wide overall coverage. It does have the advantage of 12-hour repeatability, so if you need to do real-time monitoring in which you're not concerned about resolution but perhaps need to do a regional analysis, the AVHRR imagery may be appropriate.

MSS has about 80-meter (one-acre) resolution with about 185 kilometer swath width and a repeat cycle of 16 days. TM has about 30-meter footprint, with a 185 kilometer path and a repeat cycle of 16 days. SPOT has both a multispectral and a panchromatic mode. The multispectral has a 20-meter footprint and the panchromatic has a 10-meter footprint. But the field of view or path is only about 60 kilometers and the repeat cycle is 26 days.

Your requirements for remote sensing must come through some kind of analysis that includes consideration of resolution, coverage, frequency, and the specific information to be extracted from the data.

Spectral Characteristics Should Also Be Considered in Choosing Source for Remotely Sensed Data

Figure 7 is a summary of the significance of the spectral bands recovered from each of the satellite systems discussed. Characteristics expressed by AVHRR, for example, have significance in terms of turbidity of water, greenness of vegetation, and thermal values. MSS covers primarily the greenness and some of the turbid water indicators. The TM provides a much broader spectrum of coverage.

There are, as I indicated, a variety of other systems up there, and in the future we will see a lot more, such as radar capability. It is anticipated there will be a commercial Landsat VI sometime about 1990 and other countries are expected to continue to put up new remote sensing systems.

Your analysis of remote sensing requirement should include consideration of what spectral characteristics your study needs to identify.

For a flood monitoring study we have helped with in Kingsbury County, South Dakota, we used AVHRR to help monitor on a gross scale and to identify problem areas. We then use higher-resolution systems to focus in on these problem areas. AVHRR has very good mosaicking ability.

For U.S. AID, we have been doing monitoring as part of a famine early warning program in some of the African countries. In countries such as Gambia and Senegal we have used AVHRR data values to monitor changes in greenness and provide U.S. AID with indications of vegetation decline.

Using MSS data, we mosaicked seven scenes of the Denver, Colorado, area so that we could construct a 1:100K map of the area. Using TM data, we have monitored the cooling pond at Chernoble, USSR.

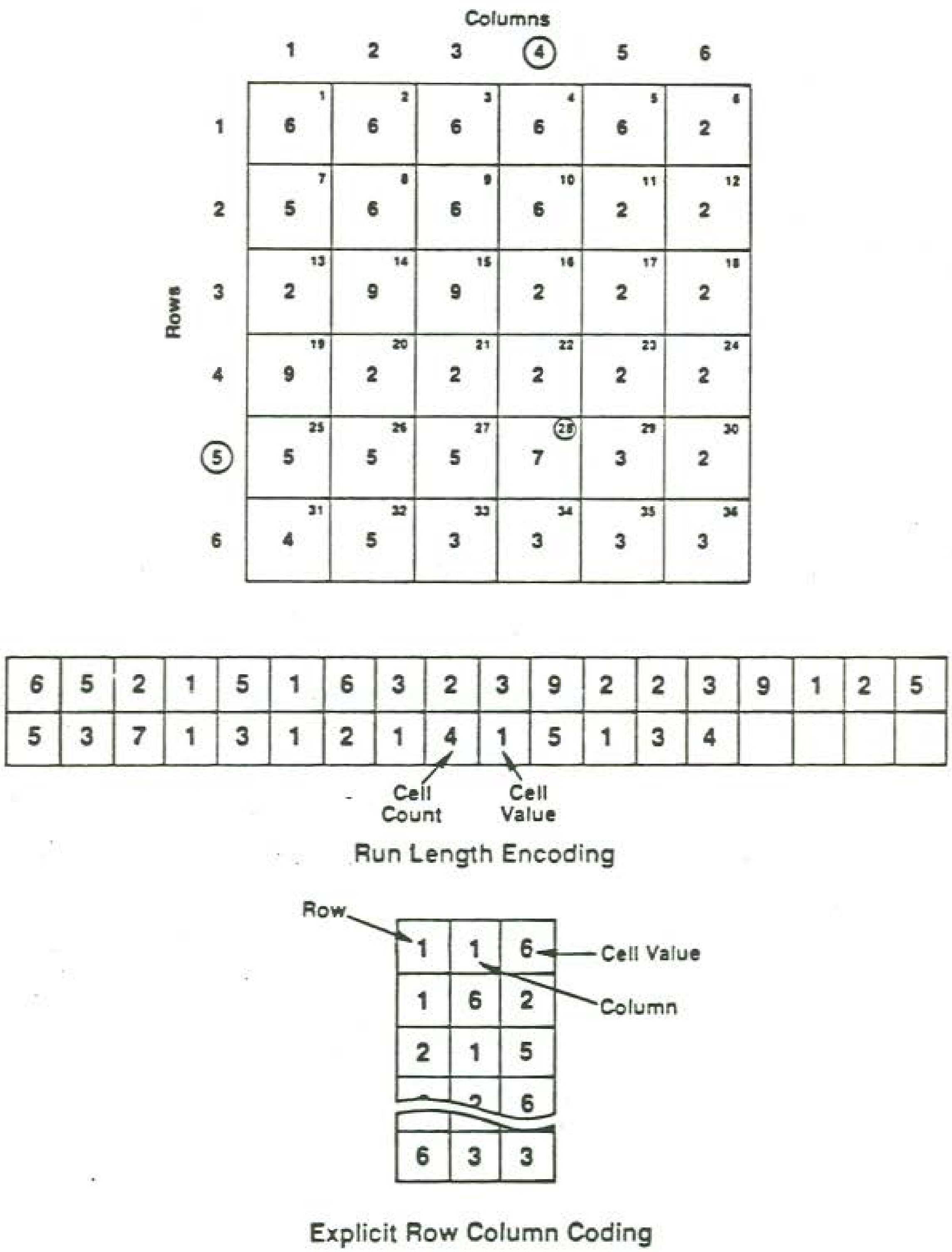
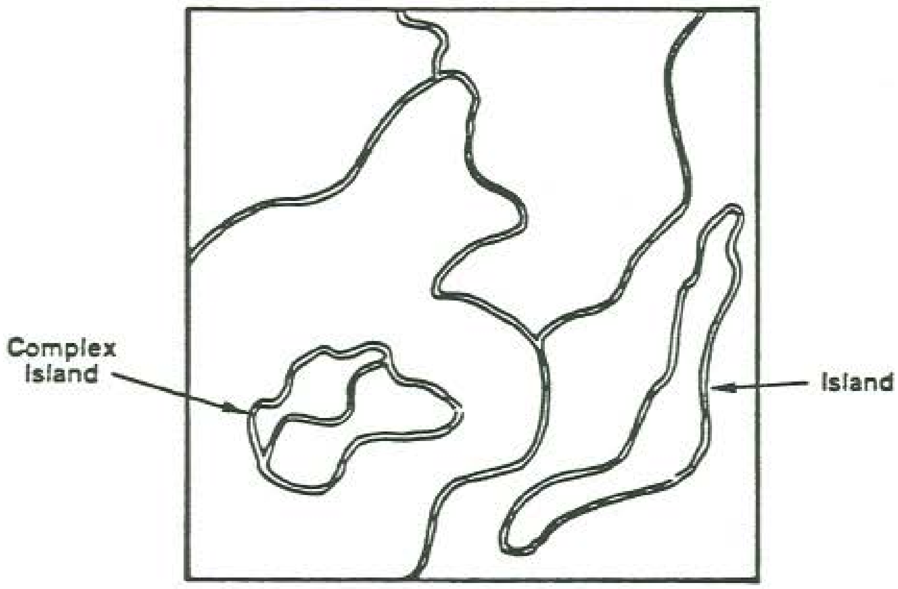
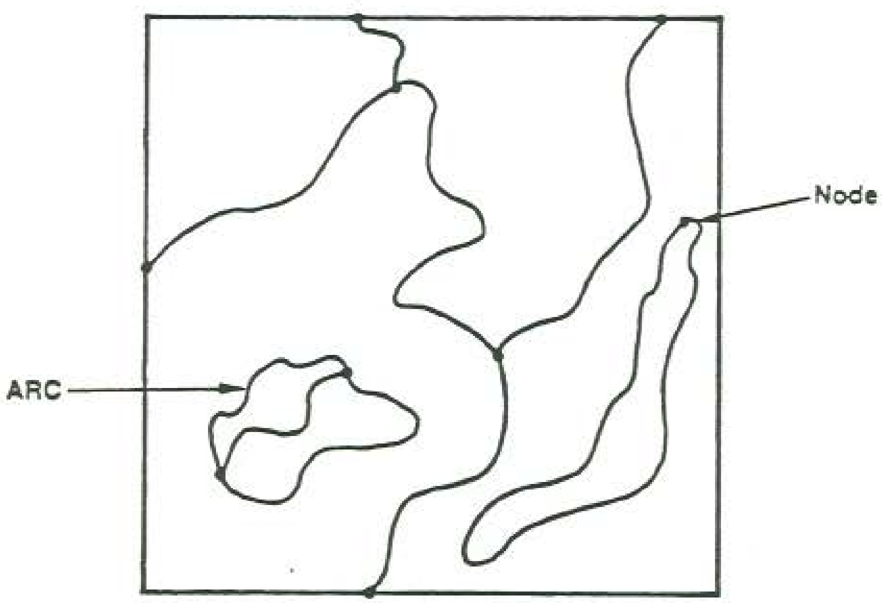


Figure 5 - Three raster data organizations



(Coincident Lines Drawn Slightly Separated)

Polygonal Data Structure



ARC-Node Data Structure

Figure 6 - Two vector data structures

Remotely Sensed Data Must Be Preprocessed Before Information Can Be Extracted

It is neccessary to get remotely sensed data into a format so it can be analyzed. "Preprocessing" is the term applied to getting the data ready for analysis. Preprocessing may include the following steps:

* Radiometric corrections including (1) sensor calibrations; (2) destriping or noise reduction; and (3) contrast or edge enhancement

* Geometric corrections including (1) systematic correction (taking out the skew of the earth's rotation and taking out the effects of the satellite's roll, pitch, and yaw); (2) control point selection (referencing to existing map or image in data base); (3) relief correction

* Accommodating mosaicking--the ability to bring multiple scenes together is very important and injects certain requirements: (1) tie point control (correcting the edge or border between two overlapping pairs) and (2) feathering

* Resampling including (1) nearest neighbor; (2) bilinear interpolation; (3) cubic convolution; (4) restoration

In the area of image enhancement for manual interpretation there are several processes that can be used:

* Radiometric, including (1) haze removal and (2) contrast enhancement

* Physical Value Calculation, including radiance measurement or albedo

* Mathematical conversions, including (1) band ratios, (2) normalized difference, (3) difference images, (4) hue-intensity-saturation (HIS)

* Statistical transformations, including (1) principle components, (2) canonical analysis, (3) tasseled cap

As an example, to accomplish hue-intensity-saturation enhancement, a form of dimensionality reduction, you can take the three bands of the TM, transform them into color states (hue, intensity, and saturation), replace the intensity with new data values from a different source (say the SPOT panchromatic value), come back from the HIS phase into RGB and produce a TM/SPOT panchromatic merge. The original spectral information combined with the spatial intensity produces a good result for analysis.

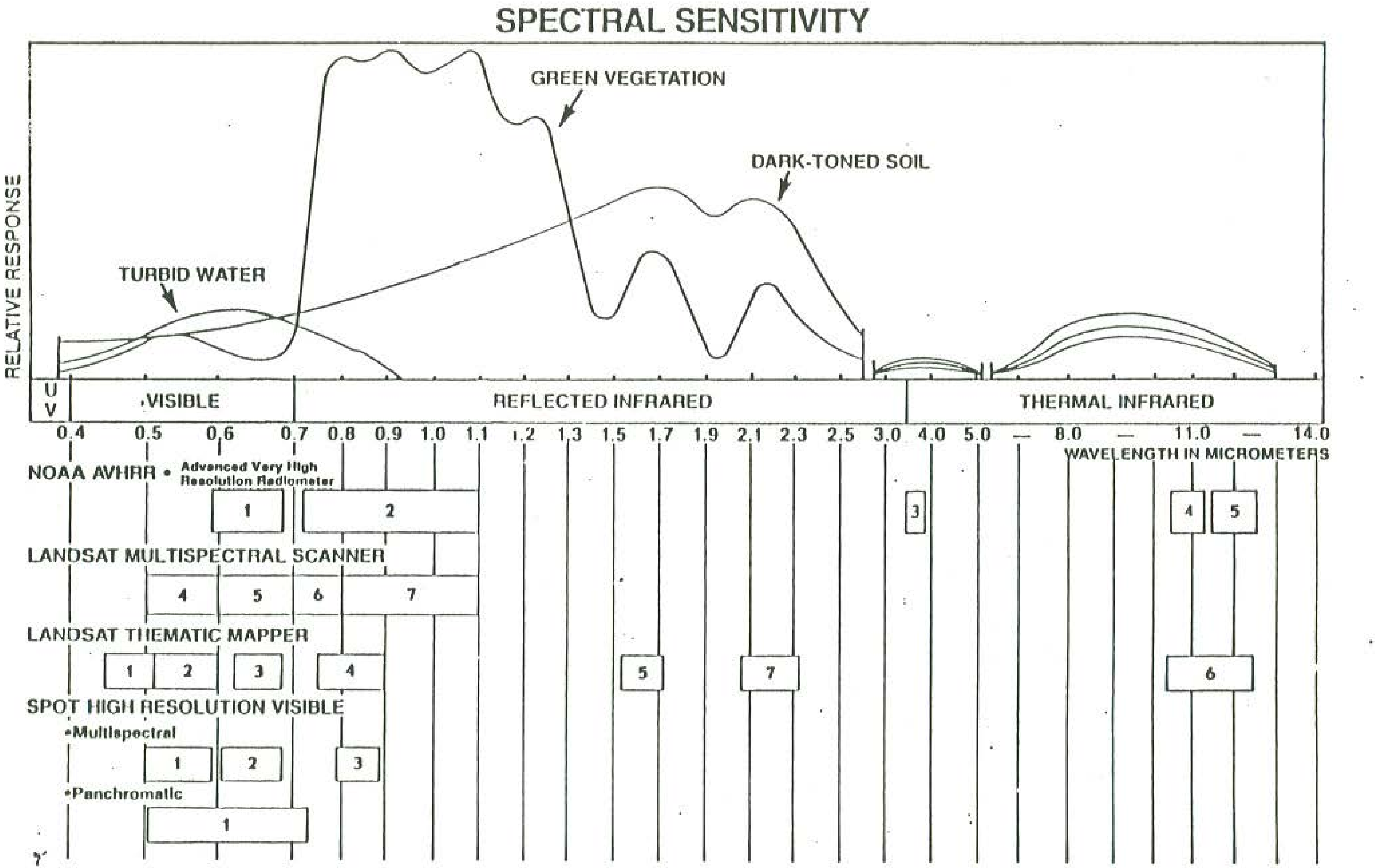


Figure 7 - Spectral sensitivity of remote sensing satellites

In the area of multispectral classification, we attempt to group pixels into meaningful classes based on their spectral, and in some cases spatial, organization.

In regard to raster data, the issue of modeling is also relevant. Statistical and logical combinations within that raster framework let us develop models that try to predict what the effect will be from the different layers.

Example Project Shows Capabilities

A project we are working on with the Water Resources Division in Washington is aimed at determining irrigated areas and crop types. This is a pilot project from which we hope to determine the effectiveness of using remotely sensed data from TM and MSS in solving problems related to agricultural irrigation. Water Resources wants to be able to estimate the yearly water application rate and pumpage. We are using data from MSS in an effort to effectively discriminate between the land-cover classifications. We also have TM data for the same area and well-logged data about wells and data from groundwater maps. We were able to come up with three spectral classes encompassing land cover, soil type, and amount of rainfall that they wanted to work with. Those classes within the area of irrigated land turned out to be small grains, alfalfa, and a group called corn and potatoes.

The accuracy of MSS in crop identification was about 72 percent and for TM was about 71 percent. Accuracy for water-use category (irrigated or nonirrigated) identification was about 84 percent for TM, but water-use category was not obtainable for MSS. We were able to adequately maintain field boundaries with the TM data.

Discussion

Question: What percentage of your effort goes into each phase of constructing a geographic information system utilizing remotely sensed data?

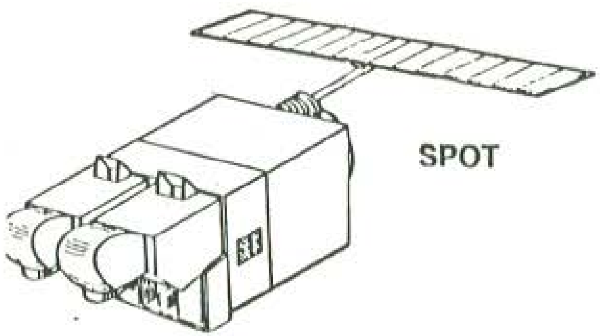
Doescher: It varies from project to project, but in a general sense, about 80 percent of the effort is involved in gathering data and putting it into an effective data base. Building and maintaining the data base is the major part of the effort.

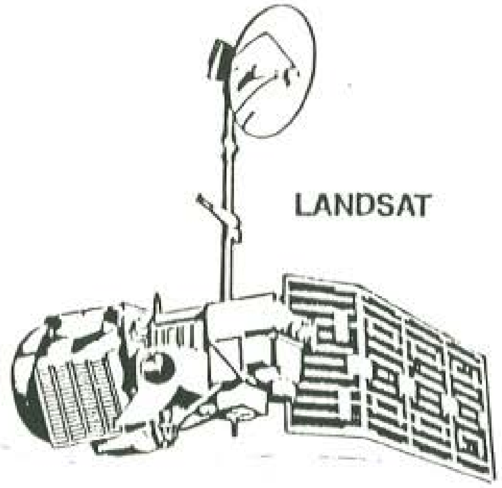
Question: Does EROS Data Center or any other federal agency have arrangements with the Japanese or Canadians to purchase satellite data?

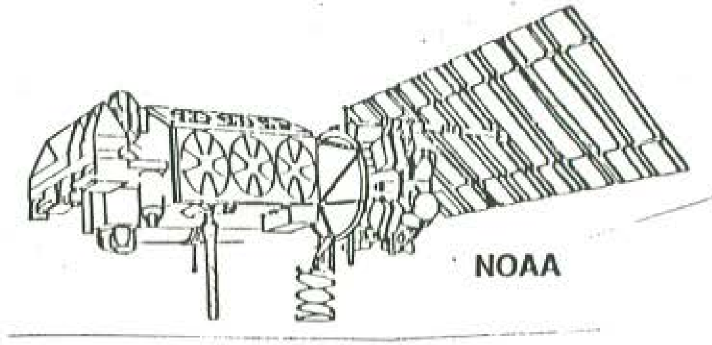
Doescher: Yes, we do. We have an agreement whereby federal agencies can purchase through us the Landsat MSS & TM through Earthsat and SPOT.

Question: Are you making a transition from IDIMS to TAE/LAS and how far along are you?

Doescher: Yes, we are about 80 percent there. IDIMS has in the past been the main workhorse for our raster data analysis. We think we have full functionality in terms of LAS in the VMS environment now, but we're primarily overloaded in our systems so we go back to IDIMS.







SATELLITE CHARACTERISTICS

SATELLITE	INSTRUMENT	MODE	ALTITUDE	IFOV	SWATH WIDTH	REPEAT CYCLE	BANDS
NOAA	AVHRR	multispectral	833 km	1100 m	2400 km	12 hours	5
Landsat	MSS	multispectral	705 km	80 m	185 km	16 days	4
Landsat	TM	multispectral	705 km	30 m	185 km	16 days	7
SPOT	HRV	multispectral	832 km	20 m	60 km	26 days	3
		panchromatic	832 km	10 m	60 km	26 days	1

Table 1 - Satellite characteristics

State of the Art
and Summary of Issues

Stephen J. Walsh
UNC-Chapel Hill Department of Geography

The management of the Albemarle-Pamlico Estuarine System is an imposing undertaking. The physical size and the biological-hydrological-societal complexity of the system combine to provide a significant challenge to our ability to identify and understand such complex interrelationships and manage the system for maximum benefits to the people of North Carolina and the nation. The combination of remote sensing and geographic information systems (GIS) can contribute to the decision-making capability of the managers of this system.

Converting Remotely Sensed Data into Useful Information Involves Several Steps

Remote sensing systems borne in aircraft and on satellite platforms capture data reflected from earth in analog and digital formats in various parts of the electromagnetic spectrum. Computers can then convert this data to useful information about terrestrial, hydrologic, biological, and social/cultural conditions and changes. The four types of resolution--spatial, temporal, spectral and radiometric--serve as a guide for selecting the most appropriate remote sensing system for a specific biophysical resource inventory and analysis.

Converting raw spectral response data into useful information involves several steps, including preprocessing, enhancement and/or classification. Sophisticated approaches are in place for each of these operations.

Prior to data extraction through either enhancement or classification of remotely sensed data, certain preprocessing procedures should be followed. Removal of banding or striping in the data, checking for atmospheric caused biasing of the data, and georeferencing of the satellite scenes have become rather standard procedures in data preprocessing. Other preprocessing considerations involve the normalization of solar elevation effects present in multitemporal data sets. Finally, preprocessing should include the conversion of digital numbers for individual pixels to radiance values. This conversion is completed in order to transform the sensitive spectral channels to the same scale for direct comparisons among the channels.

Data extraction techniques include an array of procedures and alternatives. Principal components analysis, histogram equalization, channel ratio, and mean value of channels are but a few enhancement techniques available to the analyst. All data extraction methods are designed to heighten the subtleties within the data to more effectively assess biophysical conditions such as aquatic and ecological transition zones, spatially minor but significantly important locations of phenomena, temporal variations, and concentrations of selected variables.

Classification techniques include the supervised, unsupervised, and control clustering approaches with a variety of special treatments. Classification techniques, in general, are used to categorize landscape phenomena on the basis of similar spectral responses and to do so on a multitemporal basis and over a spatially extensive area.

The results of enhancement techniques can be entered into the classification to increase the spectral dimensions available for landcover classification.

Data Can Yield Information about Landcover, Submerged Features, and Water Quality Parameters

Similar to enhancement techniques, biophysical indices can be derived and applied to the satellite spectral responses to highlight specific landscape conditions, such as vegetation greenness and leaf area. Indices can then be combined with the raw satellite spectral responses for added sensitivity in the classification process. Enhancements and the application of vegetation indices can be applied as stand-alone techniques for appraising biomass fluctuations within watersheds and between watersheds on a spatial and temporal basis; assessing the location and character of submerged phenomena and shorelines; and for defining the distribution and quality of aquatic vegetation.

Remotely sensed data can be applied to the assessment of landcover type and condition within watersheds and subwatersheds within the Albemarle-Pamlico Estuarine System. Within the estuaries themselves, remote sensing can be used to evaluate the distribution of water quality parameters such as chlorophyll a, total suspended sediments, turbidity, and to a lesser degree of exactness, salinity. The process involves the collection of actual water samples coincident with the time of satellite overpass. The collection of samples could be made at existing water sampling stations distributed throughout the estuarine system or at project-specific stations within the estuaries. In the latter situation, ascertaining one's location within the water body can be difficult. Generally, triangulation of the sampling site can be accomplished through telemetry devices and shore installations. Bottom reflection in shallow waters is a critical concern when relating such water quality measures to spectral responses of the satellite data.

After water samples are collected and analyzed, laboratory data can then be related to satellite data. The remotely sensed data must be preprocessed, and generally a 3 X 3 pixel window is used to coincide the location coordinates of the water sampling stations and the extracted spectral responses.

Mathematical Models Using Remotely Sensed Data Can Predict Relationship Among Landcover, Weather and Hydrologic Conditions, and Water Quality

Simple and multiple regression analyses can be applied to evaluate the most useful spectral channels of the remote sensing device for explaining the highest level in the variability of the water quality parameter under investigation. The statistical models should be tested and calibrated before they are applied to the remainder of the study area to characterize the spatial significance of each water quality element. Multitemporal analyses can be completed to define some baseline measure of water quality parameter concentrations and distributions. Models can be developed containing remote sensing inputs that relate landcover conditions, meteorologic values, and hydrologic flows to water quality conditions.

Statistical regression models of water quality parameters have been developed based exclusively on remote sensing measures. Often, however, a variety of biophysical variables can be included in mathematical or empirical models. For example, the Universal Soil Loss Equation has been applied to the evaluation of sediment loss within watersheds and subwatersheds. Remote sensing has been applied to the equation in the form of landcover coefficients. Soil, terrain, meteorology, and land conservation practices are merged with the landcover data to evaluate sediment loss and to suggest landcover and land conservation modification strategies to reduce sediment loss to the hydrologic system. Models and the spatial significance of variables can be developed and assessed through the use of Geographic Information Systems.

Geographic Information System Allows Integration of Data from Disparate Sources into Comprehensive Data Set

With the use of a GIS, managers can correlate landcover and topographic data, for example, with a variety of environmental parameters relating to such indicators as surface runoff, drainage basin acreage, and terrain configuration. This approach permits water quality data from various sources to be integrated into a comprehensive system capable of combining and cross referencing such diverse elements as conventional maps, satellite and aircraft analog or digital data, and tabular data obtained remotely or in-situ. The advantages of archiving data in a GIS include ease of retrieval, variety of output products to fit almost any need, ability to discover and display information gained by testing the interactions between natural resource phenomena, and the capability to organize and appraise variable coefficients for predictive models.

In designing a GIS, a host of technical and administrative issues must be confronted, including questions of appropriate data structure and organization, required spatial and temporal resolutions and data coverage, data quality standards and methods of error assessment, data processing facilities and strategies, and analytical techniques and graphic requirements. Administrative considerations include questions of personnel, space, funds, and the user community.

Both the manual and the automated approaches to GIS can be applied. The manual approach involves the physical overlaying of cartographically prepared map sheets that indicate a certain spatial element of the phenomena or problem addressed. The manual overlay approach to data synthesis, however, is plagued by the excessive time required for initial map generation and map updates, data storage inefficiencies through the analog approach, and the complexity of integrating spatial and nonspatial information through the development of a number of thematic analog overlays. For these reasons, the integration of numerous variables from a variety of formats representing a complex spatial pattern and demanding highly analytical data manipulations warrants an automated computer-based overlay and analysis approach.

Programs, Capabilities, and Expertise of the North Carolina State University Computer Graphics Center

Siamak Khorram
NCSU

The Computer Graphics Center was established in 1983 as a university-wide center and conducts and facilitates research in the areas of remote sensing, image processing, Geobased Information Systems, and database management systems. I, as the director report directly to the Provost even though academically I am in two department (Forestry and Electrical and Computer Engineering). We have a variety of research projects at CGC ranging from North Carolina sites to other places in the United States and the world.

Our staff consists of about 20 people, almost equally divided into computer specialists--systems analysts, systems programmers, electronic technicians, and so forth--and discipline specialists, whom we call remote sensors. We have people involved in forestry applications, wetland applications, land use/land cover applications, and water resources applications, which primarily deals with water quality. We also have a database management system team, which deals with a large number of principal investigators around the country to develop large databases on acid rain research.

The main computer in our system dedicated to remote sensing is the VAX 11/780 which has about 16 megabytes of memory. It is linked to a number of national networks as well as the Triangle Universities Computation Center by broadband. We also have dialogue capabilities with some local and remote users. Through the ETHER NET we are connected with other campus facilities. We have whatever is needed in terms of peripherals--tape drives, disk drives, printers, plotters and so forth. A number of smaller computers in our center are up and operating for various research applications.

Image Processing, GIS Are Integrated by In-house System

Our system is divided into two kinds of activities:

* image processing. For image processing we use a work station, the IKONAS Display Processor. It has 1024 X 1024 resolution capability and is software switchable so that it displays real color and can be used to produce color graphic overlays for GIS systems. You can display political and geographic boundaries, soil data, or any other kind of digitized data. It connects through the vector to raster conversion and is displayed on top of the previous data. These displays can be reproduced in the form of slides or in some cases 5" X 7" transparencies or negatives by the matrix color graphics camera system.

* geographic information system. The GIS is partially married to the image processing activity by software developed in-house.

Our GIS work station is a Tektronix 4105A with Strings package. We are also in the midst of acquring ARC/INFO.

Our systems software includes the VMS 4.4 operating system; a FORTRAN compiler, a "C" compiler and DECNET.

Major applications software that we support includes the following:

* Oracle Relational Database Management System. We are responsible for designing, developing, and managing a data base management system to integrate GIS kinds of information, meterological data, control exposure experiment data, and field data for the $34 million National Acid Precipitation Assessment Program (NAPAP), which involves more than 100 principal investigators collecting data from a variety of sites in the eastern United States. We are responsible for very fine validating and for what EPA calls QA/QC--quality assurance/quality control. Information for this project must stay constantly available on line. For this project we have modified the Oracle Relational Database Management System and linked it to the GIS.

* Transportable Applications Executive (TAE) coupled with the Image Analysis System (IAS). IAS is the new name for LAS, which Stuart Doescher mentioned in his presentation. We were one of the few centers to interface with the Century Computing firm which developed TAE and IAS for NASA's Goddard Space Flight Center. Since we did work with them, they let us have a copy of IAS and TAE version 1. We have replaced all our image processing software with these. Other organizations running these systems are EROS Data Center, Jet Propulsion Laboratory, University of Miami, and NASA installations.

* HACKSAT Image Processing System. This is a system we developed in house to use for projects of local interest in which there is a need to develop a specific image classification algorithm to isolate a particular type of land cover and break it down into subcategories. For example this system could be used to distinguish between pavement and concrete to pick out a mall area, for instance, or to distinguish between pine and hardwood forests. We developed this software because part of our mission is to develop operational capabilities.

* Strings R is a geobased information system.

As mentioned previously, we are acquiring ARC/INFO.

We also have some utility software for producing graphs or dealing with libraries such as the International Math. Statistics Library (IMSL), and we continually revise and develop new software to meet format conversion, data integration, and other needs.

We have the capability to link with LRIS in terms of data exchange so preprocessed and classified remotely sensed data can be imported from our system directly into the system at LRIS to be integrated into a GIS system.

Current Project Incorporates Remotely Sensed Data into Water Quality Model for N.C. Nutrient-Sensitive Waters

Since the establishment of the NCSU Computer Graphics Center about five years ago, we have done 22 remote sensing research projects. The primary area of our work has been water quality studies, beginning with water quality modeling and going to water quality mapping and to water quality monitoring. We have done projects on both the West Coast--San Francisco Bay and Delta--and East Coast--the Neuse River Estuary and Albemarle and Pamlico Sounds.

The Neuse River Estuary project was the first project we sought in North Carolina and was funded by the Water Resources Research Institute. We looked at the Landsat Multispectral Scan data and coupled that with simultaneous data on a number of water quality parameters, in an effort to determine how to go about developing water quality models from remote sensing data. We built on that to do a project funded by the Division of Environmental Management of NRCD which we are in the process of writing a final report on. This project is Water Quality Modeling of Nutrient Sensitive Waters of North Carolina from Landsat-TM Digital Data. For this particular project, the term nutrient-sensitive waters includes the Albemarle Sound, the Pamlico Sound, the Neuse River Estuary, the Pamlico River, part of the Chowan River, Falls of the Neuse Lake, and Lake Jordan. Water quality parameters we are mapping are salinity, chlorophyll concentration, total suspended solids, and turbidity. In some cases, we are collecting temperature data but really the gradients are not there.

Also, we are now in the process of developing water quality models for the San Francisco Bay and Delta from Landsat-TM and Airborne Ocean Color Imager for a number of federal and California agencies and developing water quality modeling for Venice Lagoon from Landsat-TM data for the Italian National Research Council and water quality modeling of Augusta Bay (an industrialized bay in Sicily). In addition, we are one of 22 PEPS projects funded by the French to compare the SPOT data with Landsat-TM data. We are looking at how useful these data sources are for commercial forestry inventory along the North Carolina coast.

By the way, I am glad to say to you, that Landsat Thematic Mapper provides much better and much more reliable information for some of the purposes you have, including land use/land cover and more importantly water quality monitoring, in spite of the fact that SPOT has 10-meter panchromatic resolution and 20-meter multispectral resolution.

We are also mapping the land use/land cover of Sicily from Landsat-TM and MSS data and developing a remote sensing center in the University of Cantania, Italy, and transferring remote-sensing technology. That project has a water quality component which identifies how water quality is related to the land use around it.

Another project in which we are involved is a multidate study of spruce-fir decline in the Black Mountains of North Carolina using Landsat-TM digital data. It is funded by the National Vegetation Survey, part of NAPAP. It includes the years 1983-87 over the southeastern Appalachians, and the first phase is the Black Mountains. We are to map the damage done to fir forests by acid rain problems.

Our database management system projects funded by the Spruce Fir Research Cooperative and the Southern Commercial Forest Resources Cooperative contain information on the field data from the entire eastern United States study sites and data from very large experimental NAPAP projects.

Remote Sensing Experience and Capabilities of North Carolina State University's Department of Marine, Earth, and Atmospheric Sciences

Farid Askari
NCSU

Remote sensing data can be a valuable tool for monitoring the conditions which relate to fish recruitment, water quality, and sediment transport. The types of satellite remote sensing data available to us include the advanced very high resolution radiometer (AVHRR) data which is received at NCSU on a daily basis, seven and one-half years' of data from the Coastal Zone Color Scanner (CZCS) archived at the Satellite Data Services Division of NOAA, and the Landsat thematic mapper (TM) received every 16 days.

Examination of Water Quality Factors Should Include Hydrodynamics of System

Discussion in this workshop has centered on the impact of land use and drainage on water quality in the Albemarle-Pamlico Estuarine System. In order to properly address the water quality characteristics in the system, one must also consider the effects of the wind-driven circulation and the tidal exchange of water mass between the sound and the coastal ocean via the barrier island inlets. The wind-induced currents and sea level are directly responsible for salinity/temperature fluctuations inside the sound and the primary nursery areas. These actions also create pathways for fish migration, influence movement of sediments, and modify the hydrological regime of the rivers.

We saw from the first space photographs of the North Carolina coast taken by the Apollo 9 Astronauts evidence of plume-like patterns pouring out of the inlets into the coastal ocean. Originally, these plume patterns were explained only as tidal-ebb flow currents, traveling as jets. However, we have discovered that in addition to flooding and ebbing tides, nonlocal forcing or oceanic-to-estuary sea level pressure gradients induced by the wind can drive currents in and out of the sound.

AVHRR Imagery Can Furnish Accurate Information on Temperature Differences That Reveal Hydrodynamics

Satellite AVHRR imagery has provided us with a unique opportunity to monitor the sea surface temperature distribution both inside and outside the sound. Satellite imagery clearly shows that, depending on the time of the year, there can be noticeable differences in horizontal temperature inside the sound. For example in the January 21, 1986, image we can see the relatively cooler Virginia coastal waters (10-11 degrees C) entering the sound via the Oregon Inlet, and relatively warmer Carolina coastal and Gulf Stream waters (19-20 C) entering from the Ocracoke and Hatteras inlets. Temperatures inside the sound ranged between 6 and 9 degrees C. Distinct pockets of cold water (6-7 degrees C) are found to the east of Bluff Shoals, with the temperature rising to about 9 degrees C to the west. In the October 1986 AVHRR image, we can see an interesting example of a warm water plume pouring into the sound through the Ocracoke and Hatteras inlets. Finally, during the month of June, when the air-sea temperature differences were at minimum, we can see from the AVHRR image a uniform temperature pattern across the sound.

With the advent of the newly developed atmospheric correction procedures, we are now in a position to calibrate the sea surface temperatures down to a 0.2 degrees C accuracy and to monitor temperature fronts, cold-warm pockets, and plumes, which provides essential information to the managers of estuarine resources.

We should also take advantage of the wealth of information that was left behind from the CZCS of the Nimbus 7 satellite. During its seven-and-one-half-year life span, the satellite collected data in the 443, 520, 550, 670, and 1150 nanometer ranges, and to date numerous algorithms have been developed to derive from this data water quality parameters such as chlorophyll-a concentration, total suspended solids, and the attenuation coefficient.

Spatial Patterns Can Help Identify Trends and Causation

An important issue here is that the great accuracy of the values of the estimated parameter, i.e., the absolute concentration of chlorophyll-a, is not actually necessary. Rather, the historical data sets should be examined for seasonal and/or monthly trends or episodic events, and the various causal relationships and critical periods for future studies should be identified. Further, the spatial patterns (i.e. patches of sediment) derived from the satellite imagery should be combined and compared with the results of the existing three-dimensional, time-dependent hydrodynamic model for the sound and the evolution and movement of the patterns should be tracked. This combination can be very powerful in identifying the sources of sediments--whether they come from rivers or tidal action or result from resuspension.

Remotely Sensed Data Must Be Complemented by In-situ Water Quality Sampling Data

Before developing a remote sensing-aided water quality monitoring program, a comprehensive in-situ water quality sampling effort must be undertaken. Ideally, this sampling program should be conducted concurrently with aircraft or satellite data-acquisition overpasses. With the experience gained through the water quality programs conducted in the past in the Chesapeake Bay, Delaware Bay and Neuse River, we have learned that the knowledge of the physical-optical properties of the water column are absolutely essential to understanding the remote sensing data, and furthermore are necessary for developing bio-optical algorithms which are stable in time and space. It has been demonstrated that the remote sensing procedures which rely strictly on correlation techniques break down when extrapolated over time and space. However, the algorithms which are constructed based on the physical optics of the water column work remarkably well time and time again. The optical measurements are relatively inexpensive to obtain. A submersible spectro-radiometer is used to measure the spectral distribution of light as a function of depth. This information coupled with the other water quality parameters such as concentration or grain size distribution set the foundation for developing site-specific algorithms.

Discussion

Khorram: I would just like you to clarify the point about problems with transportability of models. Perhaps you can predict cholophyll concentrations on a date within a system, but how transportable is the model from one area to another and from one day or week to the next?

Askari: If you have an image you have calibrated using site samples, you have integrated the atmospheric effect into your signal, so the algorithm you derive may not be applicable to the next day or a week from now because you do not account for atmospheric variables. When you take the entire atmospheric signal out of everything and base your calibration on optical characteristics of the water column, you do start with an algorithm that's transportable in time and space.

Programs, Capabilities, and Expertise of the Department of Geography of the University of North Carolina at Chapel Hill

Stephen Walsh
UNC-CH

The Department of Geography at the University of North Carolina at Chapel Hill offers course work and research opportunities in conjunction with advanced degrees in geography that focus upon the use of Geographic Information Systems, remote sensing, computer cartography, and manual cartography for enhanced training in physical geography, social/cultural geography, resource management, and spatial analysis techniques.

The Department operates Spatial Analysis Laboratories that include a Cartography and Computer Graphics Laboratory (Table 2) and a Remote Sensing/Geographic Information System Laboratory (Table 3). Both labs are concerned with the capture, storage, manipulation, analysis, and display of spatial data sets in support of geographic research and instruction.

An assortment of computer software mapping packages including PCMAP, ATLAS, SURFER, GOLDEN, and MAP are available to the labs. A host of other packages, maintained on the university mainframe computer, are utilized by the computers within the labs. Those packages include SURFACE II. SYMVU, SYMAP, SASGRAPH, POLYVRT, and CALFORM. Statistical packages also are available as well as compilers and interpreters.

The Remote Sensing/Geographic Information System lab operates two principal GIS software packages. ERDAS is a satellite image processing software package as well as a raster-based GIS. Other software modules permit computer tape input and output, use of graphic digitizers for data capture, and output of data to graphic screens, line printers, and color ink-jet printers. The ARC/INFO software package developed by ESRI (Environmental Systems Research Institute) and the two modules NETWORK and TIN serve as the primary vector-based GIS software.

Both labs are linked through an ethernet/broadband approach for rapid transfer of data sets of significant sizes between each lab and their computers and to other remote computers within the university community, state government, and elsewhere.

Applications of remote sensing and Geographic Information System technology have included the assessment of forest practices throughout a one million acre forest; statistical modeling of evapotranspiration and drought; assessment of nonpoint source water pollution; wildlife habitat mapping; coal strip mine reclamation; and periglacial modeling and water quality evaluation to mention just a few of our prior activities. Research has also focused on the assessment of data quality and verification within GIS analyses and the use of the Advanced Very High Resolution Radiometer (AVHRR), Landsat Thematic Mapper (SPOT), and SPOT High Resolution Visible (HRV) data for studies related to soil moisture, plant biomass, forest characteristics and drought indicators.

Grant funds have been obtained from a host of state and federal organizations, including the National Science Foundation and the national Aeronautics and Space Administration.

TABLE 2
UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL
Cartography and Computer Graphics - Principal Facilities

Tektronix 4907 Disk Systems (3)
Tektronix 4054 Graphics Terminal
Tektronix 4051 Graphics Terminal
Tektronix 4663 Interactive Digital Plotter
Tektronix 4956 Graphics Tablet
Tektronix 4631 Hard Copy Unit
IBM-XT Microcomputers and Image Writers
MacIntosh Microcomputers and Image Writers and laser printers
MacIntosh 2 Microcomputer

TABLE 3
UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL
Remote Sensing/GIS - Principal Facilities

DEC MICROVAX II computer system
DEC Tape Drive, 9 track, 1600 bpi
DEC LA50 Line Printer
DEC VT220 Operator Terminal
Tektronix 4696 Color Ink-Jet Printer
Calcomp 9100 Graphic Digitizer
Gould FD5000 Image Processing System
IBM-XT Microcomputers and Image Writers
MacIntosh Microcomputers and Image Writers and laser printers
ERDAS Image Processing and GIS software
ESRI ARC/INFO GIS software
ESRI TIN and NETWORK GIS software modules

Programs, Capabilities, and Expertise of the N.C. Land Resources Information Service (LRIS)

Tom Tribble
LRIS

The N.C. Land Resources Information Service is an agency of the Division of Land Resources located in the Department of Natural Resources and Community Development and headquartered in the Archdale Building. Established in 1977, LRIS operates the Geographic Information System for the State of North Carolina, which was one of the first states to have a fully operational, centrally located GIS.

Our basic role is to develop and maintain a statewide digital geographical data base on land resources information and to provide GIS services to other government agencies. We are primarily a project-oriented agency and have done a great deal of work for the federal government, state government, and local and county government agencies. We occasionally do work for the private sector, but that is not our primary role. LRIS is a receipts-funded agency operating on a cost-recovery basis.

LRIS has been designated the primary computer system and data management center for the Albemarle-Pamlico Estuarine Study (APES). The university researchers and the federal and state agencies involved in the study will use the LRIS computers and staff resources to accomplish data management for the study.

North Carolina Will Benefit from Using LRIS for APES Data Management

We feel that the state of North Carolina and the APES will receive several benefits from the service of LRIS to the APES.

First, there is an infrastructure already available at LRIS in the form of staff, facilities, and procedures for operating the system. The primary advantage of this infrastructure is that APES will avoid the cost of establishing a new system for the study, as some other National Estuarine Study programs have had to do. The second benefit is that the system will support an effective interface with existing computer systems, and, perhaps through the APES, we will upgrade our communications capabilities to provide interface with end users and existing systems that support major data bases relevant to the study.

Secondly, LRIS has a fairly large existing data base on the coastal area, and we are continually adding to that data base from sources separate from the APES study.

Another advantage of using LRIS for the APES is that the system developed will have long-term utility. At the conclusion of the APES, the State of North Carolina will have the responsibility of implementing the management strategy developed through the study, and the data base being developed now must be available to managers of estuarine resources.

LRIS System is Vector-Based

The main computer in LRIS is a Data General MV8000-II super minicomputer. We have two other smaller systems associated with the main computer that primarily support geographic data capture. (See Table 4 for system description) The system will be expanded by the addition of memory, disk storage, and data ports as required by the APES.

Communications hardware is either already in place or scheduled for installation. We currently support communications among the various components of the system at LRIS and with the state IBM 390/400 through the state data communications network.

LRIS started its GIS system with COMARC software, a package that most of the forestry companies--early practitioners of GIS--used, and a package that, at the time, gave us the capabilities we needed. We realized several years ago that we wanted to take a different direction, and within the last year we've installed ARC/INFO.

I'd like to emphasize the fact that ARC/INFO is a vector-based system, and that all the data we have and the work that we do has been in a vector-based format as opposed to raster format. The point needs to be made that remotely sensed data for the APES will need to be converted to the vector format so that we can use it in conjunction with the other data that is already available. We also have ARC/INFO/TIN and Interactive Surface Modeling (ISM) software.

Our staff of 15 fulltime people is organized into three units: a GIS data base management and research unit, a programming and system management unit, and a production staff. The staff has about 50 years of experience in GIS as well as background in geography, remote sensing, computer science, archeology, parks and recreation, forestry, soil science, natural resource management. Although our expertise is in GIS and not in modeling or in natural resource management, we find that we must have this variety of backgrounds to help the users understand what the system can do.

Existing Data Base Includes Layers Useful for APES

In our data base we have a variety of data including county and municipal boundaries, primary road networks, geology for the entire state, census boundaries--which will be useful for this study in terms of demographics, federal properties, and a few others.

One of the projects we are currently involved in is a cooperative project with the U.S. Geological Survey to digitize 7-1/2 minute quad base-map data for the state for incorporation into the National Digital Cartographic Data Base. We have been working on the project for about six years, and we are the only state that has such an arrangement with USGS. Fortunately, most of the work we have done on this project has been in the coastal area of the state. We have completed more than 100 quads, almost all located within the APES area. We hope to accelerate this project so that we will have full 7-1/2 minute coverage of the area within a couple of years. In the meantime, EPA Region IV is acquiring the USGS 1-to-100,000 scale base map data--hydro and transportation--which will be available to NRCD.

Another ongoing project that has produced a great deal of data for the study area is the Nutrient-Sensitive Watershed Program work. The three areas currently designated nutrient-sensitive watersheds are the Chowan River, Falls of the Neuse Lake, and Jordan Lake watersheds. Most of these watershed areas fall within the area of the APES. We have been digitizing detailed soil survey information within those watersheds.

We have also worked very closely with the Division of Marine Fisheries to capture data on the state's fishery nursery areas. The primary nursery areas have been mapped and the information is in our system. Secondary nursery areas have been mapped and the data will go into the system shortly. We also have data layers on shellfishing areas, biological monitoring stations, some seagrass beds, and some limited land-use data within the APES area.

LRIS is affiliated with the State Data Center, and that affiliation gives use access to U.S. Census Bureau data. This will be very important for demographic studies to assess the impact of growth.

Discussion

Question: Would you review what kind of land-use data you have for the study area.

Tribble: There was a traditional manual remote-sensing land-use inventory done in 1982 from NHAP photography for five counties in the APES area, four of which are in the actual Albemarle-Pamlico peninsula--Dare, Washington, Tyrrell and Hyde as well as Carteret. The inventory was mapped on 1-to-24,000 scale quads, and we digitized directly from that. It is very detailed, down to USGS level three and four classifications. There's a lot of data there.

We also have the twelve quad photo interpretation for an area including Person, Granville, northern Durham counties, which is the westernmost part of the study area, done for the Superconducting Super Collider proposal. It was done in 1984, I believe. It was done from NHAP photography on a 1-to-58,000 scale, which is pretty detailed.

SYSTEM DESCRIPTION

North Carolina Land Resources Information Service (September, 1987)

The Land Resources Information Service (LRIS) currently supports four computer systems. The systems are described below.

1. **Data General MV800-II super mini-computer with**
   - 6 megabytes of memory
   - floating point processor
   - 16 asynchronous data ports

   Peripherals:
   - 1600/800 b.p.i. tape drive
   - line printer
   - Calcomp plotters (1077, 1044)
   - Tektronix color graphics terminals (4105, 4109, 4207)
   - Calcomp digitizing tables (6000, 9100)
   - Data General alphanumeric terminals (6053)
   - Tektronix color inkjet plotter (4696)

   System software:
   - AOS/VS operating system
   - Fortran 5 compiler
   - Fortran 77 compiler
   - Xodiac/X.25 networking and communications
   - SNA/SDLC/RJE/3270 communication (connects to State's IBM mainframe)

   GIS Software:
   - ESRI's
   - ARC/INFO
   - ARC/INFO/TIN
   - COMARC'S (formerly)
   - CIMS digitizing
   - PLN (polygon, location, network)
   - GRID
   - TOPO

2. **Data General Eclipse S/230 minicomputer with**
   - 3/4 megabyte of memory
   - 96 magabytes of disk storage
   - 8 asynchronous ports

   Peripherals
   - 800 b.p.i. tape drive
   - Tektronix graphics terminals (4010, 4012)
   - Calcomp digitizing tables (6000)
   - Nicolet Zeta plotter (3600S)

   System Software
   - AOS operating system
   - Fortran 5 compiler
   - AOSSORT
   - Xodiac/X.25 networking and communications

   GIS Software
   - COMARC's (formerly)
   - CIMS digitizing
   - PLN (polygon, location, network)
   - GRID
   - TOPO

3. **Digital LSI 11/23 microprocessor with**
   - 64 kilobytes memory
   - 2 500-kilobyte, eight-inch floppy disk drives
   - 20 megabytes hard disk storage

   Peripherals
   - Visual 550 graphics terminal
   - Altek Datatab digitizing table

   System Software
   - RT-11 operating system

   GIS Software
   - GeoBased System's
   - STRINGS digitizing and editing

4. **Digital MicroVax II with**
   - 9 megabytes of memory
   - 318 megabytes disk storage
   - 8 asynchronous data ports

   Peripherals
   - Tektronix color graphics terminal (4111)
   - Matrix 6000 color graphic recorder
   - Digital alphanumeric terminal (VT 220)

   System Software:
   - Micro VMS
   - Vax Fortran compiler

   Software
   - Dynamic Graphics' Interactive Surface Modeling (ISM)

Table 4 - System description: North Carolina Land Resources Information Service

The Economics of Information

Leon E. Danielson
North Carolina State University
Department of Economics and Business

My comments will be focused on two topics: (1) using geographic information systems to incorporate economic incentives to clear and drain poorly drained coastal soils, and (2) applying economic principles to development of data, information, and information systems.

Economic Incentives to Convert Poorly Drained Soils Can Be Mapped for Integration into GIS

A topic of major interest in recent years has been the conversion of wetlands and poorly drained soils to farm and forest land because of the potential negative impacts such activities may have on the coastal fishery. In particular, special attention has been given to economic incentives to clear and drain coastal wetlands because of the importance of landowners' economic goals in using their land, and because of the importance of federal income tax and agricultural price and income support policies in helping establish the level of these incentives. Thus, it is not adequate to merely estimate the productive potential of undrained wetlands to predict conversion pressures on wetlands since economic factors also play a major role in decision making.

To further understand this process, economic models have been developed to estimate the economic incentives to clear and drain coastal pocosin wetlands as a function of a variety of relevant production characteristics and federal tax policies (capital gains rates, deduction of expenses of clearing and draining, tax credits, marginal tax rates, reforestation credits, etc.) and agricultural price and income supports.

Once these incentives are estimated at the detailed soils series level it is possible to generate overlays using geographic information systems to show where wetlands of varying conversion incentive levels are located, and whether they are in immediate proximity of primary nursery areas and other areas of environmental concern. If they are in close proximity, they are more apt to impact the fishery area. Conversely, if they are not in close proximity to nursery areas or other areas of environmental concern their conversion is less apt to impact the fishery. Such mappings can also present a clear picture of the magnitude of acreage possessing selected conversion incentive levels. This information, both the magnitude and location of wetland acreage that is profitable to clear and drain under a variety of price and income conditions, should be useful in deliberations of citizens and policy makers involved in the wetland conversion issue.

To Get the Greatest Data Value, Know When You Have Collected Enough, and Allocate Sufficient Resources for Analysis

Before discussing the application of economics to generation of information for use by policy makers, it is essential that certain definitions and key principles be understood.

Economics: Wunderlich and Moyer ("Economics of Land Information." NGS/UW Conference on Land Information Systems, Madison, WI, December 1986.) define economics as "a body of principles to explain the processes of choice." Behrens (John O. Behrens. "Cost Considerations in Designing Land Information Systems." in The Economics of Land Information: A Symposium of The Institute of Land Information. The Institute of Land Information. Washington, DC.) explains that "economics...involves making choices, not only among goods differing in value, substance, and profusion, but also among courses of action..." Textbooks often explain that economics is a "way of thinking."

Because development of data systems, collection of data, and development of information are costly and because they typically occur under situations of a limited budget, economic principles are useful in making choices about what data to collect, the level of accuracy of the data, the extent to which data are analyzed to create information for policy makers, and related alternatives.

Needs vs. demands: Demands for automobiles, clothes, beach houses, or data and information are often mistakenly thought of as needs. However, needs imply that the item is acquired regardless of its price, or that it can be purchased at zero cost. Demands recognize that items are not free, that they can be purchased only by foregoing something else, and that there are trade-offs when spending decisions are made. Demand is the set of quantities that will be purchased at alternative price levels. Relative to demands, thinking in terms of needs results in excess consumption, whether it be automobiles, clothes, or data and information.

Data vs. information: Choices in creating land information systems are made at several different levels, including at least three: system level (e.g. whether multipurpose or single purpose), media level (types of output e.g. maps, tables, photos, hard copy vs. screen output), and message level (text, sentences). Levels one and two primarily involve creation of data. In level three data is processed into messages for decision makers to use through analyses and interpretation. (See Figure 8) Planners often focus upon the system and the media, whereas users focus on the message. It is important to realize that all three levels are essential if information rather than data is to be produced, and if the results of the efforts are to be useful to policy makers in making decisions. Most importantly, if information systems are to have greatest value, information must be produced rather than simply data.

Cost and value of data and information: More is known about the costs of data collection and information generation than about its value. Costs are a function of a variety of factors including the level of accuracy desired, local conditions, the availability of pre-existing information, technology, equipment available, and expertise. Other costs, such as for training, data base maintenance, updating and overhead should not be overlooked. Because costs are easier to measure than value there is a tendency to overly dwell on cost-related goals such as producing a predetermined set of data at least cost, maximizing accuracy with a given budget, or minimizing the number of sample points to get some level of accuracy.

But this is focusing on the trees rather than the forest. How important is great accuracy or cost-minimization if the wrong data is collected or if it means other sets of data with possible high value cannot be collected? Or, how valuable is accurate, efficiently obtained data if the analyses to convert data to information for policy making are not made?

Development of an optimal data system must include estimation of the value of data as well as its cost. This allows for collecting information of greatest value with the funds available, for making cost-value trade-offs among alternative data sets and among alternative levels of accuracy and helps insure that the wrong data is not collected.

Understanding Public Good Characteristics of Information Can Help Avoid Providing Too Little Information for Decision Makers

Diminishing returns: In production of most products, successive increases in the level of one input while holding all other inputs constant results in smaller increases in output. The returns to, or value of, increasing amounts of information vary in the same way. That is, as more and more information is produced to answer some specific question the value of the additional information increases at a less than proportionate rate. At some point, the value of the additional information may be zero or less.

Increasing costs: On the cost side, the cost of additional information increases at an increasing rate. If the concern is with increased accuracy of data, the cost of successive one percent increases in accuracy becomes more and more expensive. As 100 percent accuracy is approached the cost of additional accuracy will likely become prohibitive, although excessively high cost may be incurred much before that. Amounts of information would behave in the same way, with the cost of increasing amounts of information becoming more and more expensive and, at some point, becoming prohibitive.

The optimal amount of information: The optimal amount of information is reached when the value of the marginal unit of information is equal to its cost. Under situations of increasing costs and diminishing returns, the value of additional information would exceed its cost if less than optimum information was provided; and providing too much information would result in providing data whose cost exceeds its value at the margin. Thus, focusing on both cost and value of information, rather than solely its cost, allows for the realization that increased accuracy, or increased amounts of information are valuable, but only out to a certain point. Similarly, if the choice is between spending additional money on the collection of more data versus spending the money to have the data analyzed more fully thereby providing better information to policy makers, the choice should be made based upon a comparison of net benefits of the two options, not merely on which costs less.

Technological improvements: As noted above, the costs of generating data and information are dependent upon the level of technology, equipment available, and related technological parameters. Development of geographic information systems that run on microcomputers is a good example of new technology that will greatly improve data generation capabilities. Technological improvements typically reduce the costs of obtaining data of a given accuracy or reduce the costs of getting additional data items. Thus, over time the optimal amount of information produced may increase since the cost curve has shifted downward while the value curve is assumed to remain unchanged.

Public good characteristics of information: The information of interest in the context of the Albemarle-Pamlico Estuarine Study has public good characteristics because once available, use by one person or agency does not reduce the value or amount of information that is available for others to use. In this situation, economic theory tells us that the level of information produced will often be below optimum. This occurs because the information has value to all potential users. That is, when the costs of additional information are compared with its value to determine when increased costs just equal increased value, it is the sum of values over all users that must be used, not just one user. This principle is important because it can help avoid under-provision of data and information for use in decision making.

When cost of data exceeds value: When economic principles are being followed in designing a data information system there may be cases where the cost of the data exceeds its value. Realization of this may help avoid expenditure of money on information that is worth less than its cost, thus leading to increased efficiency. However, there is an important point that involves the nature of a public good, the cost of the data, and fee setting that also deserves emphasis. When data is available to be shared equally among many users the cost of the data should likewise be shared by the users. This means the data will be available at relatively low cost to many users, thus leading to greater conversion of data to information for decision makers than if it were more expensive. The essence is that care should be taken that public data is not made available at costs which are excessive and which therefore would otherwise result in under-utilization of the data.

There Are Several Ways to Estimate Data Value

The economics of information is a relatively new field of inquiry and the theory is more advanced than is the application. However, understanding the principles of economics as applied to information systems will contribute to improved decision making, at least incrementally.

As noted, cost information is more readily available than is value information. Thus, it is important that efforts be continued to improve estimates of information value. Two currently available methods of obtaining value information are surveys of users in contingent valuation studies, and estimation of costs foregone because of the availability of new information. A third method that is more applicable to private data markets is estimation of the value of information in private transactions.

Because the principles of economics are not yet well applied to information systems, the following general assessment of data and information generation projects may apply in North Carolina and elsewhere:

(1) Substantially more money is spent on data collection than on analyses by which data is converted to

information; therefore, a shift of emphasis may improve information value;

(2) The principles of diminishing returns and increasing marginal costs of data collection are only generally acknowledged so that costs of increased data often exceed the value of the data and information generated;

(3) Data that has public good characteristics are probably under provided;

(4) Efforts to estimate and incorporate the value of information would improve the allocation of scarce public dollars available for data collection; and

(5) In some cases data access is overpriced thus precluding analyses that would produce additional information for decision makers.

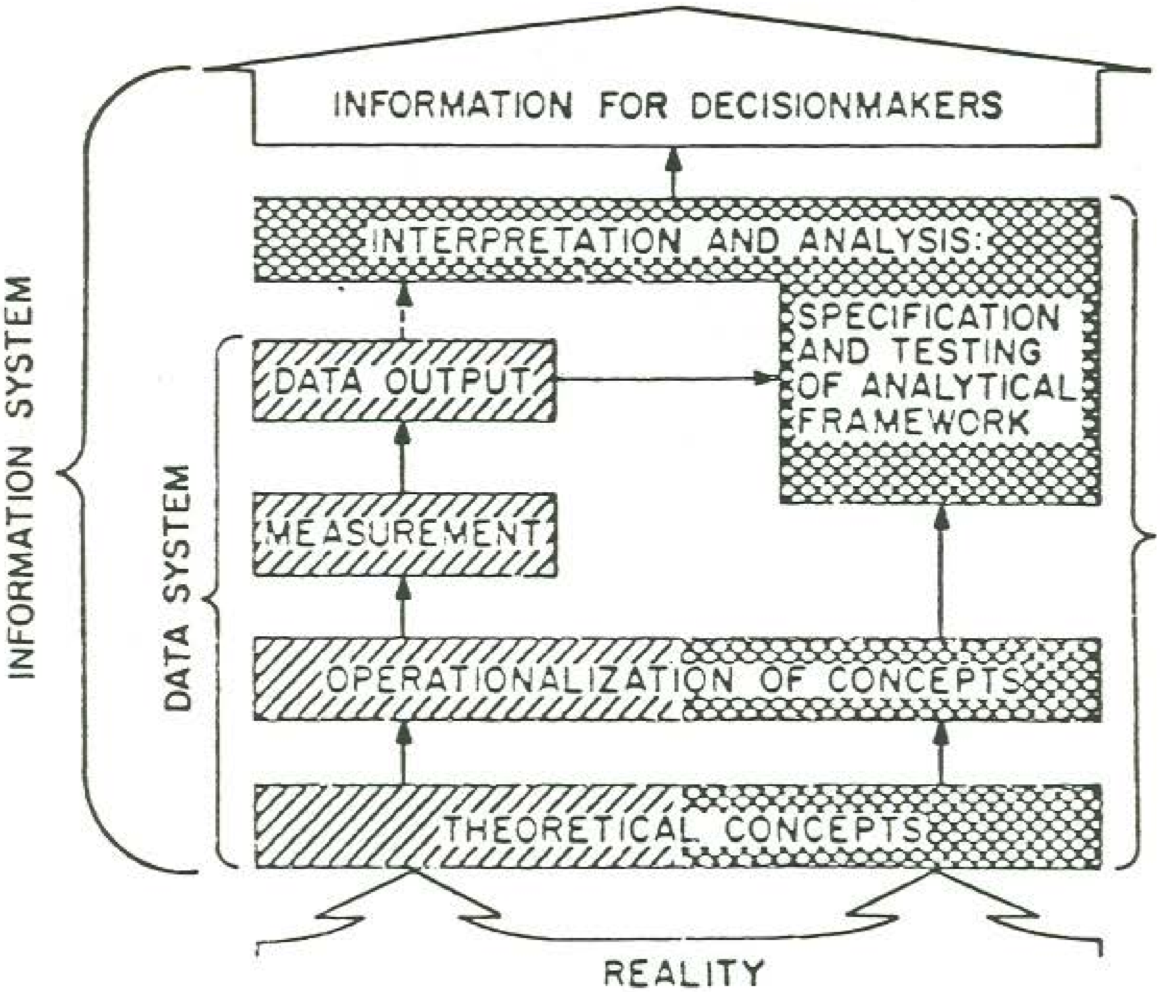


Figure 8 - **An information system** (from "The Demand for Water Resources Information: A Conceptual Framework and Empirical Investigation," a PhD dissertation by Carl T. Osborn at the Department of Agricultural Economics, Blakcsburg, VA, 1986)

N.C. Department of Natural Resources and Community Development, U.S. Geological Survey Cooperative Mapping Program

Steve Conrad
N.C. NRCD Division of Land Resources

One of the primary missions of the U.S. Geological Survey has been national responsibility for topographic maps. Under the National Topographic Mapping Program, the U.S. Geological Survey prepares, publishes, and distributes maps of the National Topographic Map Series covering the United States and outlying areas.

In developing the program, needs for mapping are evaluated according to relative importance and urgency. New projects are added annually to the extent available funds and capacity will permit. Although new areas in the program are generally selected from those requests having the highest composite priority, and effort is made to insure that new work financed by appropriated federal funds is equitably distributed throughout the country.

Federal map-using agencies arrange their mapping requests in order of priority or urgency and annually present this information to the Geological Survey.

State agencies present their needs for topographic maps to the Geological Survey either directly or through State Mapping Advisory Committees, who evaluate the relative priority of topographic map needs within their states and advise the Survey periodically.

Counties, municipalities, and non-governmental groups also request mapping, and their needs are considered in developing the national program.

For some mapping projects, state or local agencies share the cost of mapping equally with the federal government. These cooperative projects expedite mapping in areas of particular interest to the cooperating agency and help expedite the National Topographic program

The North Carolina Cooperative Program Has Produced 7-1/2 Minute Quadrangle Maps Covering the Entire State

North Carolina has from time to time cooperated financially with the Geological Survey almost from the time USGS started topographic mapping. The North Carolina Geological and Economic Survey cooperated in a topographic mapping program in 1897 and from 1902 through 1910. From 1946 through 1952 cooperation was with the Division of Mineral Resources in the Department of Conservation and Development. Cooperations was resumed in 1962 with the Division of Mineral Resources and has continued to the present time through the Geological Survey Section, Division of Land Resources, Department of Natural Resources and Community Development.

Prior to 1962, the cooperative program was sporadic, and relatively small sums of state funds were allocated for topographic mapping. consequently, most of the state was not covered by topographic maps. Exceptions were the western part of the state, mapped by the Tennessee Valley Authority, and the Eastern Seaboard, mapped by the USGS primarily for defense purposes during World War II.

Beginning in 1969, the state undertook a substantially increased cooperative program to accelerate topographic mapping to provide complete coverage of modern topographic maps at the 7-1/2 minute scale. The General Assembly appropriated $100,000 for each year of the 1969-71 biennium. In 1973, the appropriation was increased to $310,000 per year and remained at that level until about four years ago when it was reduced to about $220,000 per year.

As an interim measure to provide useful 7-1/2 minute quadrangle maps for the entire state, a cooperative orthophotoquad mapping program was initiated in 1973. A five-year update of the orthophotoquad program will be completed in fiscal year 1988.

As a result of the cooperative program with the U.S. Geological Survey, North Carolina now has complete coverage of the state with 7-1/2 minute quadrangle topographic maps. The final maps are scheduled to be printed this year.

Recent discussions with the USGS have resulted in a tentative five-year plan to continue the cooperative mapping program. Major elements of the five-year plan include completion of the orthophotoquad update, photo revision, limited revision, complete revision of some of the older maps, and initiation of 100K scale mapping in both printed and digital format.

National Cartographic Information Center

Alan R. Stevens
Eastern Mapping Center, USGS

Prior to becoming part of the Eastern Mapping Center, I was chief of the National Cartographic Information Center (NCIC) in Reston, Virginia. In 1972, an executive directive instituted a task force of civilian and military managers from all major federal mapping agencies to assess the health of mapping activities throughout the federal community. One of the task force recommendations was to create a national clearinghouse for cartographic information. Another was to develop digital mapping capabilities within the federal sector.

NCIC was instituted in 1974 and assigned administratively to the national Mapping Division (NMD) within the U.S. Geological Survey. Its mission is to be a clearinghouse for information on all cartographic products for the general public as well as other federal and state agencies and the private sector. Its focus is national, i.e., NCIC collects information on cartographic products from all the federal, state, regional, and local agencies and private firms it can.

While the focus may be limited to national coverage, the focus on cartographic products is all encompassing. This includes maps, charts, aerial photography, satellite imagery, digital data, geodetic control, atlases, textbooks, software, etc. While NCIC is headquartered in the USGS Reston facility, people may call in or write to one of many USGS offices across the country to receive assistance.

In addition, the NCIC has developed 58 state affiliated offices across the nation. North Carolina's Land Resources Information System (LRIS) is an example of a well-run full facility state affiliate office.

Table 5
NCIC Offices

National Cartographic
Information Center
U.S. Geological Survey
507 National Center
Reston, Virginia 22092
Telephone: 1-800-USA-MAPS

National Cartographic
Information Center
U.S. Geological Survey
1400 Independence Road
Rolla, Missouri 65401
Telephone: 314-341-0851

National Cartographic
Information Center
U.S. Geological Survey
Denver Federal Center
Denver, Colorado 80225
Telephone: 303-236-5829

National Cartographic
Information Center
U.S. Geological Survey
345 Middlefield Road
Menlo Park, California 94025
Telephone: 415-329-4309

National Cartographic
Information Center
U.S. Geological Survey
National Space Technology
Laboratories
Building 3101
NSTL Station, Mississippi 39529
Telephone: 601-688-3544

National Cartographic
Information Center
U.S. Geological Survey
4230 University Drive
Anchorage, Alaska 99508-4664
Telephone: 907-271-4159

National Cartographic
Information Center
Tennessee VAlley Authority
200 Haney Building
311 Broad Street
Chattanooga, Tennessee 37401
Telephone: 615-751-MAPS

Goal Is to Gather and Digitize Elevation and Horizontal Cartographic Data for Country

One of the National Mapping Division's missions is to complete the national coverage of its primary product--the 7-1/2" quadrangle series. Within recent history, the Survey has become much more diversified to include, among many other products, the collection, processing, and archiving of cartographic data in digital form--both elevation and horizontal data. The type of data collected and/or distributed can be seen below.

Digital Data Distributed by
the National Mapping Division

* Digital Elevation Data derived from:
  - 1:24,000-scale maps
  - 1:250,000-scale maps (DMA)
* Digital Line Graph data derived from:
  - 1:24,000-scale maps
  - 1:1,000,000-scale maps (Census)
  - 1:2,000,000-scale maps (Atlas)
  - Land use/land cover maps
* Geographic Names Information System (GNIS)
* Other Special Products

Elevation data is typically referred to as digital elevation models (DEM) and consists of elevations spaced uniformly across the quad. Horizontal data is commonly referred to as digital line graphs (DLG) and the data collected consists of hydrography, transportation, boundaries, U.S. Public Land Survey System (USPLSS), surface cover, etc.

The success of collection of DEMs and DLGs varies from data type to data type. For instance, complete coverage exists for DMA elevation data at 1:250,000 scale, 1:2 million-scale DLG data, and for all of transportation and hydrographic DLG data of the 1:100K-scale map series. In contrast, the land use/land cover data (LU/LC) is about 50% complete and the 7-1/2" quadrangle elevation data is only about 25% complete. Actually, there is a fair coverage within the east coast states and the Albemarle-Pamlico Estuary study area is liberally covered.

<u>Summary</u>

One of the long-term goals of the NMD is to convert from a mission whose primary focus is on new mapping to one of revision. Further, the goal is to conduct this revision more frequently and by using digital techniques. As a result, there exist two prerequisites: (1) to develop a comprehensive digital revision scheme, (2) to collect and archive digital cartographic data for the most current mapping coverage of mapping of the U.S. Geological Survey.

Discussion

Siderelis: Are there plans to collect the elevation data for the 1:100,000 maps.

Stevens: Yes, we do have plans to collect that data, but they are not nearly as elaborate as the plans to collect the horizontal data. One of the problems is that we have to get the elevation data by collecting contours, putting them in DLG format and then converting to DEM. We are starting to get this effort operational, but we are not very far along at this point.

Siderelis: Are you planning to do anything about political boundaries?

Stevens: Yes, this is similar to the question above on hypsography. It is the Division's goal to collect and archive all data for the 100K series including political boundaries. As above, we will not collect this data with the fervor that we collected transportation and hydrography because the priority is not as demanding as the Census project.

Data Bases & Services Available from EPA, Region IV

George J. Collins
EPA Office of Integrated Environmental Analysis

First, the objectives of the Albemarle-Pamlico Estuarine Study need to be restated; then the role of remote sensing and GIS in achieving the study objectives can be more appropriately evaluated.

The law which authorizes the National Estuarine Study Program obliges the Albemarle-Pamlico Estuarine Study to develop the capability to do the following:

1. identify and prioritize the problems in the estuary
2. relate these problems to causes and recommend what actions are needed to solve the environmental quality problems
3. track environmental trends
4. evaluate effectiveness of past control activities

These should be objectives of all estuarine studies, and the success of studies can, and will, be judged in terms of developing the ability to analyze data to achieve these objectives.

EPA has developed an "in-house" GIS which has the ability to analyze data for your study objectives. The system provides automated techniques to display all water monitoring stations and to identify and prioritize all water quality violations on a computerized map. Permits can be overlayed to help determine if the cause of problems are point or nonpoint. Computer maps for violations of different time frames can be generated to track progress. Violations are ranked by size to prioritize problems. The system can handle biological data as well.

Rather than "reinvent the wheel," the existing GIS capability can be used. This will avoid spending additional money to develop something which has already been developed to accomplish the objectives of this study. The system works on EPA's computer, and the software is developed. Only terminals are needed.

The work that has been done using this system is being used by EPA and by the states. The data and the system are available to the Albemarle-Pamlico Study. Data collected for the study and existing state and EPA data on permits, biological and chemical monitoring, grants, and so forth can be integrated and analyzed together using existing software to achieve the above four objectives.

As was pointed out in an earlier presentation at this workshop, most studies collect significant amounts of data but few analyze it and present it to managers in a useful form. It is in the area of data analysis that the Chesapeake Bay Study has fallen short, and this shortcoming has caused other problems. Their experience should serve to guide this study toward better data analysis.

Success of the Albemarle-Pamlico Estuarine Study will be judged on the basis of developing the capability to meet the above four objectives and on developing a data management system that helps track these objectives.

The Cooperative Soil Survey Program

Horace Smith
USDA Soil Conservation Service

Soil surveys are made to provide a description of the soils of a certain area, their location, and a discussion of the suitability, limitations, and management of the soils for specified uses.

Many factors about the soils are addressed in the North Carolina Cooperative Soil Survey. For example, soil scientists observe the physical landscape features such as the steepness, length, and shape of slopes; the size of streams and the general pattern of drainage; the kinds of crops and native plants growing on the soils. They dig many holes to study the soil profile, which is a sequence of natural layers, or horizons, in a soil. The soil profile extends from the surface down into the unconsolidated material from which the soil formed.

The soils in a survey area occur in an orderly pattern that is related to the geology, the landforms, relief, climate, and the natural vegetation of the area. Each kind of soil is associated with a particular kind of landscape or a segment of the landscape. Understanding of this soil-landscape relationship and on-site observations of soil profiles, enables the soil scientist to predict the kinds of soils and to draw their boundaries on aerial photographs.

Soil Survey in North Carolina is a Cooperative Program

The Cooperative Soil Survey Program in North Carolina is a joint effort among the USDA Soil Conservation Service, the N.C. Department of Natural Resources and Community Development, North Carolina State University, the N. C. Land Resources Information Service, N.C. A&T State University, the U.S. Forest Service, EPA, and several other federal, state, and local agencies.

A soil survey basically provides information on the top five feet of soil of the earth's surface. In a published survey, data is provided in tabular format that shows different physical and chemical properties of the soil including permeability, available water capacity, soil reaction, shrink-swell potential, corrosion potential for uncoated steel and concrete, erosion factors--K and T (T is soil loss tolerance of the Universal Soil Loss Equation), and organic matter. Also provided is a table that interprets soil conditions for use of septic tanks, sewage lagoons, and other sanitary facilities. Tables that rate the soil for cover material, hydrologic conditions, flooding, high water table, and other factors are also provided in the soil survey.

Soils Information Available for Most of Study Area

Soil survey information is available for most counties in the Albemarle-Pamlico Estuarine study area. Some of the published surveys are old ones. The maps in the old surveys are good, but the interpretations are somewhat

LEGEND

25	MODERN PUBLISHED SOIL SURVEY
30	MODERN SOIL SURVEY WITH FIELD MAPPING COMPLETED-AWAITING PUBLICATION
22	MODERN SOIL SURVEY IN PROGRESS
11	OLD PUBLISHED SOIL SURVEY
2	EXISTING SOIL SURVEY BEING UPDATED
10	NO MODERN SOIL SURVEY IN PROGRESS, SOIL MAPPING BY REQUEST

Figure 9

STATUS OF SOIL SURVEYS
NORTH CAROLINA

OCTOBER 1987

0 25 50 75 100 MI

0 50 100 150 KM

SOURCE: Data compiled by SCS Field Personnel

REVISED OCTOBER 1987 1000126

outdated, and we want to go back and update those surveys. Seventeen counties have published soil survey reports. Eleven counties have field mapping completed and are awaiting publication. Five counties have soil surveys in progress. One county does not have a soil survey in progress. (See Figure 9)

The Land Resource Information Service and others are working with individual counties to digitize their resource information, which includes soil survey information. This approach is strongly endorsed by the N.C. Cooperative Soil Survey. The LRIS status map shows the counties in the study area that have digitized soil map information. (Figure 10)

Soil survey base maps will be made available for GIS use when they are approved for publication. Newer base maps are now ortho photography, which is a suitable base for digitizing. Soils information on the older, non-ortho base, needs to be transferred to ortho base if digitizing is planned.

Since soils are a major component of the landscape, knowledge of their location and responses to the various land uses is invaluable to management processes. Information can be used to plan the use and management of soils for crops, pasture, and woodland; as sites for buildings and sanitary facilities, highways and other transportation systems, parks and other recreation facilities; and for wildlife habitat. It can be used to identify the limitations of each soil for specific land uses and to help prevent construction failures caused by unfavorable soil properties.

Planners and others using soil survey information can evaluate the effects of specific land use on productivity and on the environment in all or part of the survey area. The survey can help planners to maintain or create a land-use pattern that is in harmony with nature.

Discussion

Tribble: The General Soils Map Data Base, which I believe is in digital format, has been completed by the Soil Conservation Service and will be available fairly soon. That data may be at an appropriate scale to use for certain applications for the Albemarle-Pamlico Estuarine Study.

Smith: Yes, we're working on that now and have a January deadline to get the material back to TVA for digitizing. That data will be tied to an interpretation base, which will have the interpretations that we provide for detail maps. We don't have the capability in the state office of digitizing, but we will be experimenting with digitizing at the field level in the near future. We're thinking about using the project survey in Granville County as a guinea pig, and we hope to provide them with the tools for digitizing at the field level. We do have the capability of digitizing at the regional office in Ft. Worth.

Question: Are Natural Resources Inventory data available for the study area? If they are I would think they would be very helpful for the study.

Smith: The 1982 data are public. We're in the process now of finalizing the 1987 data, but it's not in digital format.

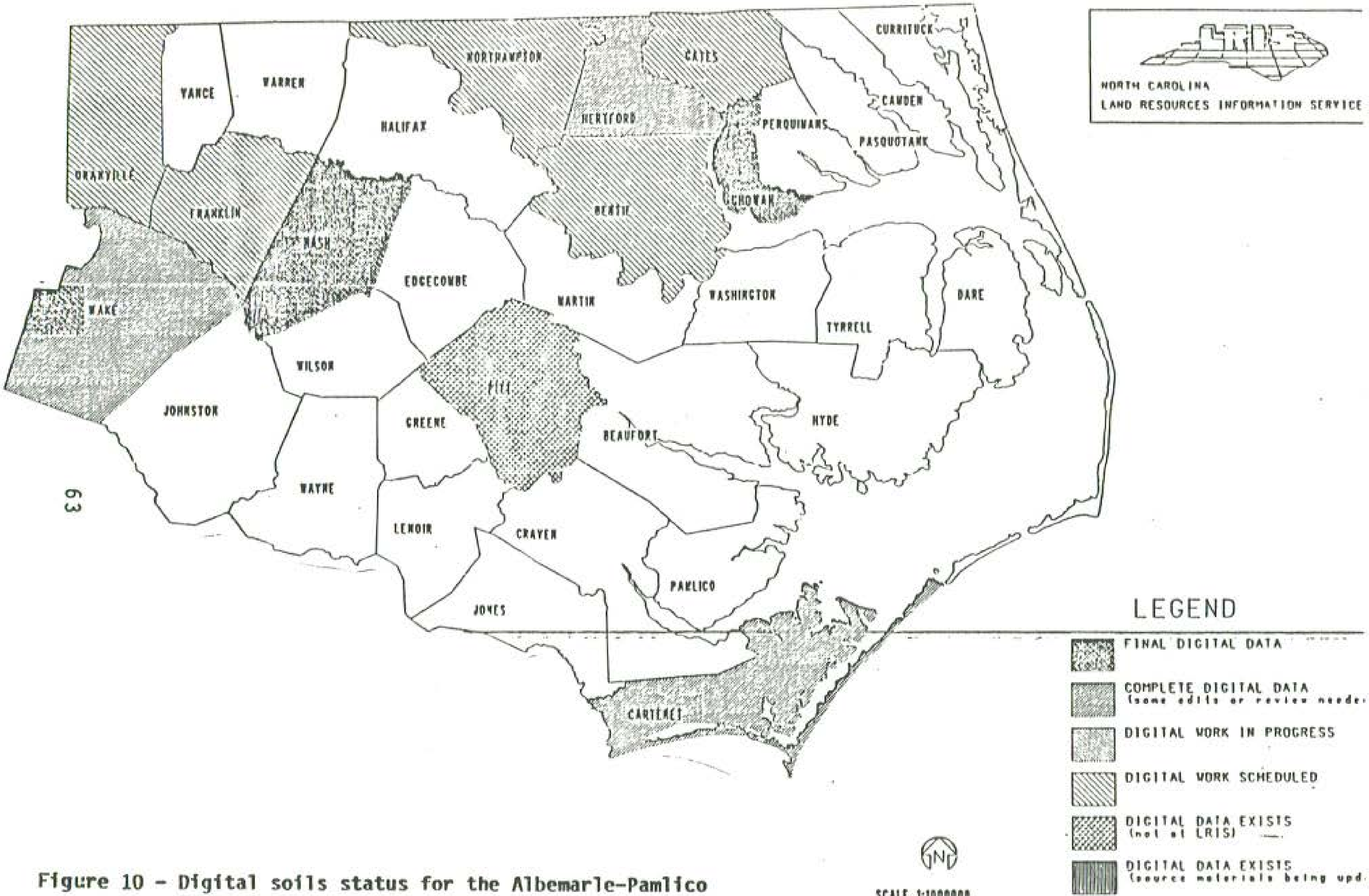


Figure 10 - Digital soils status for the Albemarle-Pamlico Estuarine Study area 11/87

The National Wetlands Inventory in North Carolina

John M. Hefner
U.S. Fish and Wildlife Service

The U.S. Fish and Wildlife Service is conducting an inventory of wetland and deepwater habitats of the United States, the purpose of which is to provide land managers and others with information on the type, location, and extent of wetlands and other water resources. Because eastern North Carolina represents the last coastal zone area in the country to be inventoried and mapped, the National Wetlands Inventory (NWI) has identified mapping of the area as its highest priority in 1988.

Current Inventory Is Fourth But First to Produce Maps

The current inventory is the fourth wetland inventory to be conducted by the federal government. Inventories accomplished by the Department of Agriculture in 1906 and 1922 were designed to identify wetlands which could be modified or drained for agricultural development. A previous inventory by the U.S. fish and Wildlife Service was conducted in the middle 1950s to identify important wildlife habitat, especially for waterfowl. These earlier inventories differed from the current project in that maps were not produced.

The NWI was begun over thirteen years ago with the development of a hierarchical wetlands classification system and the selection of a remote sensing technology to be used for the project. Operational mapping began in 1978.

Photo Interpretation Is Being Used for Current Inventory, But Satellite Data Could Track Subsequent Changes

Because of the magnitude of the task of inventorying wetlands across the entire United States, the project clearly required the utilization of remote sensing technologies. In preparation for operational mapping, both the manual interpretation of high altitude aerial photography and computer (automated) analysis of Landsat imagery was tested. Comparisons of these techniques were carried out in the prairie pothole region of the Dakotas and over a large portion of Alaska. The manual interpretation of aerial photography was found to be superior to the use of Landsat imagery since it allowed greater detail, below one acre for 1:60,000 scale photographs compared to perhaps 10 to 15 acre minimum sizes on the satellite images. Likewise, the ability to differentiate various types of wetland was much greater using aerial photographs.

Although the inventory is now being conducted through the interpretation of aerial photographs, usually color infrared at a scale of 1:58,000, there appears to be great potential for automated activities using satellite data. Its greatest utility may ultimately be for monitoring changes in areal extent or classification of wetlands after traditional NWI mapping has been completed. The NWI is now participating with Ducks Unlimited in a major study to test new Landsat technologies for inventorying and monitoring wetlands in the central prairies of the United States and Canada. Recent results indicate that limitations still exist particularly for identifying small wetlands less than five acres in size.

Interpreters Work with Biologists to Classify Wetlands

The wetlands inventory in North Carolina, as in most of the United States, is being conducted with the help of contract personnel which augment the small U.S. Fish and Wildlife Service staff associated with the NWI. Once suitable aerial photography is obtained, usually through the National High Altitude Photography program of the U.S. Geological Survey, there are seven major steps in the mapping process. They are:

* field investigations
* photo interpretation
* review of existing wetland information
* quality control
* draft map production
* interagency review
* final map production

Field investigations are conducted to obtain specific information on the variety of wetlands within the map area. In this manner photo interpreters become familiar with the various signatures of the different wetland types as they appear on the photographs. Interpretation is done while viewing the photographs stereoscopically through four power optics. Delineations are made on a clear plastic film attached directly to the photographs. The interpreters not only draw boundaries between wetlands and nonwetlands but also assign a classification to each wetland. During photo interpretation, biologists examine existing wetland information found on topographic maps, in soil surveys, in special reports, and in other sources. Once interpretation is complete, the work is reviewed and checked for accuracy, completeness, and consistency with NWI specifications by U.S. Fish and Wildlife Service personnel in the regional office as well as project personnel located at the central project facility in St. Petersburg, Florida.

After acceptable review of the photo interpretation, wetland delineations are transferred and adjusted to fit standard U.S. Geological Survey 1:24,000 scale topographic map bases. The composite draft maps, showing topographic and cultural features as well as wetland boundaries and classifications, are then available for distribution and review. Draft maps are distributed to agencies or individuals who have expressed an interest in reviewing and commenting on their accuracy. This interagency review process has resulted in significant improvements to earlier map products prepared in North Carolina. After approximately a year review period, comments are collated and the final editorial corrections are made to the maps.

The NWI has developed three modes of distribution for map products. Public agencies are supplied wetland maps at no charge from the NWI. Secondly, arrangements have been made with 22 states to make maps available at a nominal duplication charge from state distribution centers. Thirdly, NWI maps can be purchased from the U.S. Geological Survey by calling 1-800-USA-MAPS. During the period from July 1 to September 30, 1987, 160 different organizations ordered 3,252 maps through this outlet.

Draft Maps for All APES Area Wetlands To Be Available by Fall of 1988

The NWI has completed maps for 51 percent of the lower 48 states. Inventory efforts in North Carolina have been concentrated primarily in the lower coastal plain and in the Raleigh area. At present, 32 final maps are available, 82 draft maps are being reviewed, and 75 additional maps are in cartographic preparation. Most of the mapping has been cooperatively sponsored by the Army Corps of Engineers, the Navy and Marine Corps, and the North Carolina Department of Natural Resources and Community Development (NRCD). Assistance in the draft map review process has been provided by a variety of state and federal agencies. A cooperative agreement between the NRCD and the U.S. Fish and Wildlife Service has been initiated to lend assistance and quality control review throughout the map making process.

Completion of wetland maps within the coastal zone of North Carolina is of highest priority for the NWI in 1988. Because of uncertainties related to cooperative funding, the U.S. Fish and Wildlife Service will unilaterally fund mapping of the area. Work is planned for 199 new maps, beginning with the northeastern counties surrounded by Currituck Sound, Albemarle Sound, and the Chowan River. Draft maps should be available by fall 1988. With the completion of this new mapping, nearly 40 percent of the state will have been surveyed.

Usefulness of Maps Can Be Increased by Digitizing

Wetland maps have proved extremely useful for resource management. In fact, over one hundred uses have been documented. However, they do not meet the needs of many planners and managers requiring acreage data, particularly on a county-by-county basis. Having maps of just one scale, 1:24,000, often makes comparisons with other land cover and land use maps difficult. Converting the maps to digital data for computer analysis would overcome both these limitations and would enhance the overall utility of the maps as well. From a digital format, custom maps could easily be prepared, other map data could be compared with wetland information, and acreage statistics could be generated to meet specific study and management requirements. Although the digitization process is expensive, the array of users that could benefit from the digital data seems to make it extremely worthwhile.

Finally to increase the availability of NWI products, a state wetland map distribution point at which maps could be obtained quickly and at a reasonable cost should be established. Fees for map products could be designed to fully compensate the distribution center. Logical placement of the center appears to be within the Land Resources Information Service of NRCD.

N.C. Land Records Management Program

Steve Conrad
N.C. Division of Land Resources

The North Carolina Land Records Management Program was created in 1977 by the General Assembly. Originally located in the Department of Administration, it is now part of the Geodetic Survey Section of Division of Land Resources in the Department of Natural Resources and Community Development. It currently has a staff of four professionals. Current legislation contains a sunset provision requiring the program to end in 1991.

The goal of the program is to provide technical and financial assistance to counties to modernize and standardize local land records. Assistance is provided in four major areas:

* base mapping
* cadastral (property boundary line) mapping
* a standardized system of parcel identifiers
* automation of land records

Matching grants in the amount of $2,764,469 have been provided to 70 counties. Funds (currently $325,000 per year) are allocated on a prorated formula of funds available and the total cost of the counties' documented eligibility for funding in the fiscal year that funds are requested. With limited funds available in 1986-87, the prorated amounts were modified by the imposition of a "ceiling" of $8,000 per county. An awards committee composed of one representative from DOA, Cultural Resources, Revenue, and two from NRCD meet and make recommendations on grant awards to the secretary of NRCD.

Counties Can Receive Technical Assistance

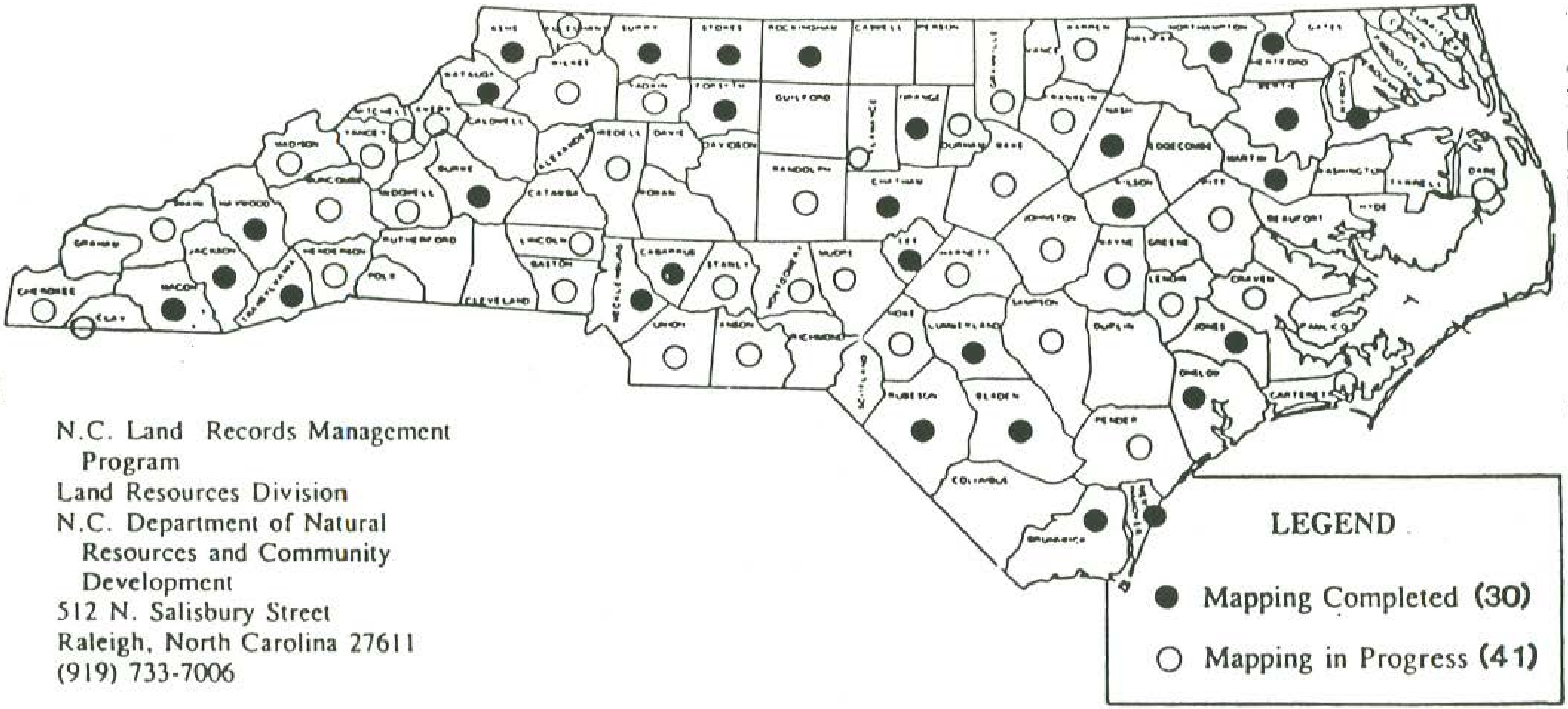
Since the program began in 1977, technical assistance has been provided to 85 counties. This assistance has included the following areas:

* mapping--RFPs, contracts, specifications, map editing, map maintenance training (workshops and schools)
* management audits of register of deeds offices
* automation--parcel identifier indexing, computer software (register of deeds, tax billing and collection, planning, building permits, revaluation) interactive graphics mapping systems, microfilm reader printers, computer output microfilm (COM)

A number of states and counties outside North Carolina have received assistance from the program. Most requests have been for our mapping

MAPPING STATUS

(ORTHOPHOTO AND CADASTRAL)



N.C. Land Records Management Program
Land Resources Division
N.C. Department of Natural Resources and Community Development
512 N. Salisbury Street
Raleigh, North Carolina 27611
(919) 733-7006

Figure 11 - Mapping status (orthophoto and cadastral)

SEPTEMBER 1987

specifications and documentation on the Orange County system of land records management.

Orthophoto and Cadastral Maps Complete for 30 Counties

The types of maps being developed are orthophoto base maps prepared using state plane coordinate, the official survey base of North Carolina, and cadastral maps of all parcels in the counties. Interest has been generated in soils mapping as an additional layer of data. These soils data can be utilized in the octennial land revaluation. Other types of maps that are being prepared include maps of utilities (water, sewer, gas, power), flood plains, and topography. Digital mapping is also underway.

Currently mapping has been completed in 30 counties and is underway in 36 counties. The program has no mapping activities underway in 34 counties. (See Figure 11)

State Data Center

Celia Fuller
Information Consultant, SDC

The State Data Center is a federal/state cooperative program initiated in the late 1970s by the Bureau of the Census. It is located in the Office of State Budget and Management and is a clearinghouse for demographic and economic data for the State of North Carolina.

The State Data Center is really a loose association of three groups, each with an independent function and a commitment as part of the center. The lead agency is the Office of State Budget and Management, and the three coordinating agencies are the Land Resources Information Service (LRIS), the State Library, and the Institute for Research in Social Science (IRSS).

Each coordinating agency serves a special function. The State Library houses the census reproducible maps and the census publications and microfiche products. IRSS maintains a tape library of census products to serve primarily the academic community. LRIS, as the newest coordinating agency, is working toward integrating census data into Geographic Information Systems.

Regional Affiliates Can Provide Census Data on Regional and County Levels

At a third level in the State Data Center organization are affiliate organizations. There are 18 Lead Regional Organizations and ten libraries which serve different regions within the state. Each affiliate has and can disseminate all the census data about its region.

The State Data Center has two major functions: (1) to be the clearinghouse for census information and (2) to be statistical coordinator for the state.

We receive the census tapes and other products from the 1980 decennial census, from the economic census and the agricultural census (which are conducted every five years), and from a large variety of annual surveys. We also distribute data for the Bureau of Economic Analysis and have annual data available at the county level.

The 1980 Census provides data not only about the number of people in an area but also detailed data about where they work, what their jobs are, their education, their income, their commuting patterns, their migration patterns, and a great deal of information about their housing--whether they rent or own, what kind of sanitation facilities they have, how many vehicles their housing unit has, and many other things. The information is available on a number of fairly small areas--county, city, and township level, and, in rural areas, enumeration district level. In the urban areas data is collected by census tracts, which are further subdivided into block group data and individual block data.

The State Data Center produces technical reports about particular topics, such as North Carolina commuting patterns, in which we take information from the census and try to make it more usable.

Publications Present Data Analyses, Announce Series Availability

In our function as statistical coordinator for the state, we publish frequently requested data in one place. We survey as frequently as possible to produce documents in which we put together data series from a variety of different sources. Normally, county-level data is the most frequently requested geographic unit so that is what we publish most often. However, there are tables available at the place level. Examples of these publications are the Statistical Abstract--last published in 1984, the Profile of North Carolina Counties--published as a full edition every five years with an annual update, the State Data Center Newsletter--published about three times a year and provided free of charge to anyone who is interested. In our newsletter, we highlight data about North Carolina and announce publications and statistical series that are available.

The State Data Center also serves as distributor of two other kinds of information produced in the state budget office: (1) current population estimates and projections, and (2) economic forecast for the state.

County Profile, Population Data Available On Line through State Computer Center

We are also working on a register, which is a listing of all statistical series produced in state government that we have cataloged. We have this information in a data base and can, ourselves, use the information now, but we hope to have it published in a few months. The data base includes subject, description, the smallest geography for which it is available, when the series started, how frequently it is produced, any publications, and the agency and contact person with a telephone number. We think the register will be helpful in identifying who in state government has specific information needed by people doing studies such as the Albemarle-Pamlico Estuarine Study.

An on-line data system we call LINC (Log Into North Carolina) became operational this year on the state computer center mainframe. Anyone with access to the state computer center can obtain a number and documentation from us to access this data system, which contains all the information in the Profile of North Carolina Counties and a number of other things, including the latest population estimate and projections. Most of the series on LINC are at the county level, but we do have some municipal data available as well. The benefit of having this data on line is that it is more up to date than published data.

At the State Data Center, we work as much as possible by taking phone calls and trying to respond by phone using publications, microfiche, and other data sources. If we cannot provide the information needed that way, we will provide photocopies at a small charge above a certain number. When computer processing is required because something is on tape but not in published form, we charge for computer and programming time above a certain amount. Someone working in a county and needing county data should call the local affiliate before calling the state office.

Discussion

Question: You archive no information on land, water, or air related data?

Fuller: No

Stewart: What about data on second home development and tourism?

Fuller: There is some information in the census data on second homes, but not much. The other data that might be useful in that regard are the data on building permits, which the Census Bureau publishes monthly and annually.

Rader: How do you handle unpublished reports from sources such as NRCD and unpublished theses at universities? Will they be listed in the register?

Fuller: The register contains information we got back from state agencies in a survey done two years ago. We did not survey the university system. If the report is a publication, we may have it, and it should be in the State Library. In that case it will be cataloged. But if it is a data base or an unpublished report, we will have only a listing -- and then only if the agency identified it. Since this register represents a first effort, there will undoubtedly be gaps. Our hope is that over the years, we will be able to fill in the gaps.

U.S. Geological Survey Eastern Mapping Center: Experience in Constructing a Digital Cartographic Data Base

Alan R. Stevens
Eastern Mapping Center, National Mapping Division
U.S. Geological Survey

The purpose of this presentation is to discuss the cooperative project between the U.S. Geological Survey (USGS) and the Bureau of the Census. The Census project is an example of one method of populating data bases to support Geographic Information Systems (GIS). It will also help to explain some USGS techniques for collection, processing, and archiving digital cartographic data.

As described in my first presentation, two of the recommendations that came out of the Federal Mapping Task Force were (1) to develop a National Cartographic Information Center (NCIC) and (2) to institute a new program to collect, archive, and use digital information to prepare USGS maps.

The NMD's digital program has been under development and operating for about 10 years. Recently the Division has conducted a searching analysis relative to experience with data collection, processing, and archiving. Out of that self-analysis came several observations and recommendations. One such observation was that the National Mapping Program was nearing completion of one-time coverage of the 7-1/2" quadrangle series with about 92% coverage of the conterminous United States. The resultant recommendation was to refocus our efforts toward the use of digital production techniques to revise all of our products. In order to do this, it is necessary to convert all existing graphic products to digital form. Accordingly, a second recommendation was to collect selected categories of cartographic data in digital form and develop and populate a nationally oriented data base with the resultant data--the National Digital Cartographic Data Base (NDCDB).

Therefore, one of the Division's major tasks is to digitize all data that has already been compiled in map form. All four NMD production centers are cooperating in this effort as is the Land Resources Information System of the State of North Carolina. All such data collected in accordance with our standards is entered into the NDCDB.

Several different techniques are used to capture and process the digital cartographic data, but I would rather discuss that in the context of a cooperative project between the USGS and the Bureau of the Census.

Census Project Was to Build Data Base to Produce Enumerator Maps

The Bureau of the Census was not satisfied with the manner with which the enumerator maps were gathered and/or prepared for the 1980 census. The census enumerator maps are a primary tool for conducting a census. In the past, virtually any map at any scale was secured and cut and/or pasted together for coverage of any one of thousands of districts that make up the United States. They were then used by field enumerators in door-to-door data collection.

As an outgrowth of this prior experience, Census officials proposed the creation of a nationwide digital data base from which one could extract eloquent parts at a size and/or scale appropriate to area(s) in question. The USGS agreed to assist in this massive undertaking. Specifically, the agreement focused on the completion of transportation and hydrography, graphic overlays for all 1:100,000=scale maps, and the collection, processing, and archiving of digital data associated with both overlays at that scale by spring/summer of 1987.

The 1:100,000-scale series was selected for several reasons. First, the task was accomplishable. There are 1,823 1:100,000-scale quadrangles that cover the conterminous United States. In contrast, there are about 55,000 7-1/2" quadrangles that cover the same area. This large number plus the increased level of detail associated with this scale, would have created an impossible task for the given timeframe. Secondly, the 1:100,00-scale series was originally designed to simplify digitizing--roads are not cased, lines were not symbolized, etc.

As stated earlier part of the goal was to digitize the transportation and hydrography overlays. This actually was further subdivided into three subsets consisting of hydrography, roads and trails, and miscellaneous transportation. The miscellaneous transportation consists of railroads, pipelines, transmission lines, airports, ports, and related facilities. Different procedures were followed for each as described below.

Miscellaneous Transportation

Because the miscellaneous transportation overlay is not very dense, each quadrangle was digitized using manual line following procedures. This procedure results in vectorized data. Once collected, the data was plotted for visual inspection. Having passed this and a subsequent software check, it was sent to the data base for archiving.

Roads and Trains, and Hydrography

Due to the density of data, both the roads and trails, and hydrography layers were digitized using raster scanning techniques. After some manual annotation, each overlay was placed on a cylindrical drum which spins past an eye that records the data in a binary form.

Conceptually, this is much like viewing each quadrangle as a piece of graph paper with thousands of tiny squares called cells. Further, the process of scanning is similar to painting the map by filling in each cell in accordance with the type of data that falls within each cell. The resultant scanned data creates lines that are made of a series of cells. The lines appear to have rough edges due to the fact that they are made of a series of squares.

After the collection process, the data is edited to correct geometric inconsistencies. As with the manual digitizing, this data is plotted for a visual inspection and subsequently, it is vectorized, i.e., the lines are thinned to one cell width. This is followed by some additional processing and the data is ready for tagging.

Tagging is the act of assigning attribute codes to all points, lines, and areas. Essentially, there are two major philosophies for digital data capture and use. Each individual category of data could be collected in individual layers, e.g., each class of road could be captured separately as could each trail, all gas lines, all transmission lines, etc. Conversely, one can capture all types of transportation and provide an elaborate scheme for identifying and separating each. The USGS has chosen the latter for long-term implications.

Correspondingly, the next step in the census process was to assign attribute codes to each quadrangle overlay using interactive edit stations. As before, the data is then subjected to further checks and forwarded to the data base for archiving.

After all three layers have met final USGS edits, they are sent to the Census Bureau for a final test, i.e., to insure that all layers are vertical and horizontally integratable. The Bureau of Census will add additional data to develop a seamless nationwide data base. Although it is too early to draw conclusions, every indication is that this data base will vastly improve the enumeration process.

Summary

In July of 1987, all 1,823 quadrangles of data successfully passed final muster. As a result of this cooperative effort, the USGS has populated the NDCDB with national coverage of the 1:100,000-scale data for transportation and hydrography. All such data is available for sale to the public in 30' X 30' blocks. Further information on this data and all USGS digital data may be obtained by contacting the National Cartographic Information Center, U.S. Geological Survey, 507 National Center, Reston, Virginia 22092, telephone (703) 860-6045.

The emergence of the GIS technology offers vast new horizons certainly in the world of resource management from a local/regional context to global perspective. Mapping scientists have learned that the GIS is only the tip of the iceberg. It is essential that an elaborate base be developed first. A massive collection and processing effort must proceed, and the NMD is committed to collecting and distributing the highest quality data possible.

These more elaborate resource intense procedures make the processing of data in Geographic Information Systems much more efficient. The USGS is convinced that the future of the mapping industry resides in the ability to provide assistance to other Federal and State as well as the private resource managers by being able to combine their data with selected base cartographic data to improve decision making.

University of Delaware College of Marine Studies: Experience in Identifying Critical Watersheds Using Remotely Sensed Data

Charles Bostater
University of Delaware

Before getting into our work in the Delaware Bay, I would like to make a recommendation from past experience. Having worked in the Chesapeake Bay program, I am aware that trying to control point and nonpoint sources and trying to justify that control by establishing a link between the pollution sources and the decline of a living resource is very difficult. It is especially difficult to go to zoning people and the state legislature for authority and money for the controls with weak causal linkages. One thing that prevents us from establishing strong links between pollution and estuarine decline is lack of the right kind and quantity of monitoring data. I see a real potential for the use of remote sensing for providing input to conceptual or numerical models--the hydrodynamic models, watershed models, water quality models, and the living resources models.

It takes a great deal of very clear thinking to define the kinds of input that will support the capabilities for all these kinds of modeling--potential loads, the effect of these loads on water quality in terms of dissolved oxygen, and the link to living resources, which is really critical.

One objective of estuarine studies is to prioritize watersheds by their contribution of nutrients to the system so that relevant land-use activities can be controlled. But we have to consider the economic impacts of whatever control measures we recommend and be able to justify these measures quantitatively.

High Resolution Is Needed to Support Tributary Waste Load Allocation Models

Waste load allocation in tributaries is based upon basic transport and water quality models. These models take into account time rate of change of concentrations as a function of diffusion, perhaps settling; advection; and tidal conditions in the tidal areas; winds; source sink terms or point/nonpoint source loads. In the end, this is what we want to be able to describe with some degree of specificity so we can say with some authority that a specific amount of point/nonpoint source load that will produce a specific level of dissolved oxygen and a specific level of chlorophyll, which we believe to be related to impacts on living resources. It comes down to being quantitative.

The initial boundary conditions for these kinds of models can be provided by mapping information. But there is a difference between mapping concentrations and modeling concentrations. Mapping algorithms are not models. In mapping, you take an existing set of data from five or ten monitoring (ground truth) stations and generalize to the rest of the area. To develop models you need higher resolution data supported by monitoring data that will allow a tight coupling of the physical, hydrological and optical characteristics of the system.

Classifications Levels for Remotely Sensed Data

Level I	Level II	Level III
urban and built-up land	residential	
	commercial	
	industrial	
	transportation	
	other	
agricultural land	cropland	crop types
		crop condition
	pasture	
	orchard	
	other	
forest land	deciduous	tree types
		condition
	evergreen	tree types
		condition
	mixed	
barren land	sand	
	rock	
	other	
wetland	salt water marsh	Spartina alterniflora
		Spartina patens
		Distichlis spicata
		Phragmites communis
		Iva frutescens
		Baccharis halimifolia
		Minor Species
	fresh water marsh	
	non-vegetated wetland	mud
		water
		tidal elevation
water	type (stream, lake, etc.)	
	water masses	turdibity
		chlorophyll
		acid dumps
		sludge dumps
		circulation
		temperature
	sea state	wind waves
		internal waves
	hydrography	shallow water
		deep water

Table 6 - Data classification levels

In our efforts to protect living resources, if we must go to court or to the state legislature, regardless of the direction we take, we have to have scientific credibility, which can be translated to the support of scientists. So, I recommend strongly that you give a lot of thought up front to defining the different kinds of remotely sensed data available and to developing the monitoring system that will support various kinds of models that, in the end, can provide the kinds of quantitative loading estimates that scientists can support.

Knowledge of Physics of Estuarine System Is Crucial to Extracting Accurate Information from Remote Images

In the Delaware, we have been working with data from Thematic Mapper that let us look at the interaction between the shelf and Delaware Bay in terms of temperatures and fronts. This information is valuable only if it means something to the managers of the resource who must make decisions about point and nonpoint sources. We must be able to extract the biological meaning from the images, to identify and estimate the export and import of nutrients associated with fronts. We can identify frontal regimes, suspended sediments along the shoreline, and so forth, but unless the spectral and spatial resolution are great enough, we cannot identify where the sources are coming from. It is crucial to think about the physics of the individual system, or the algorithms you develop may point to the wrong conclusions because they fail to take into account simple facts of bathymetry. Think carefully before you relate statistical (mapping models) and remotely sensed data to the physics and the biology of your system.

It is possible to use different dates of satellite information to increase classification accuracy. In this regard, think about storing not only your final product but also original information so that you can always go back and maintain a connection with your radiance or digital data. Various algorithms will be developed and you will need to go back to your original data as algorithms and application requirements change.

Remotely Sensed Data Can Provide Input for Various Models and Mapping Efforts

In the area of remote sensing, you can use watershed analysis as input into a hydrodynamic model for an estuarine area where you may be interested in the resuspension of sediment and how tidal circulation effects the distribution of pollutants. The input that remote sensing can provide for the hydrodynamic model can also be used for water quality modeling. Remote sensing can also provide mapping information on the monitoring program--mapping of chlorophyll and suspended sediment--and mapping of their association with living resources.

To date, remote sensing has not been applied to mapping living resources, and I think that is where the real importance in the future will lie because of the connection, the link, that needs to be made to protect the living resources. In order to use remote sensing for this purpose, we need high resolution--spectral, radiometric, as well as spatial--remotely sensed data. We need to be able to look into the spawning and nursery grounds and be able to estimate what the concentrations of suspended materials are there. One way in which AVHRR data can provide us data about living resources is by revealing fronts along which fisheries migrate up and down the coast and into estuaries.

At the beginning it must be asked what level of input will be needed. There may be multiple uses of the information, and it is possible to go great detail. (See Table 6) It may be desirable, for instance to break urban into several other categories--residential, commercial, transportation and so forth. Or, with wetlands, you may want to break marshes down into spartina, phragmites, all the different groups. You need to keep your ultimate goals--for instance, making the link between water quality and economic community development--in mind as you plan for acquiring remotely sensed data.

Remote Sensing Signals Are Signatures of Fundamental Physical Properties

We can use AVHRR data to look at turbidity, but will this level of data provide you information to pinpoint the critical watershed for point or nonpoint sources? I am working on a project in which we are using this kind of imagery to compare eutrophication susceptibility of several estuaries on the Atlantic Coast of North America. We are using different imagery--AVHRR, TM, SPOT, CZCS--to give us the range (small to large) of spatial resolution that will take us back to the "critical watershed concept."

If we are interested only in land use, we may need only TM resolution and may need only one image in a year. But when we look at estuaries, we need the high spectral resolution, high radiometric resolution, and perhaps high spatial resolution. So, we face a change in the kind of imagery we may need when we move from land-based concerns to water-based concerns.

In the Delaware, we are involved in another project in which we are using historical TM, MSS, and AVHRR data and using existing algorithms to map out suspended sediments, chlorophyll, and using published and newly developed algorithms to look at how these parameters--chlorophyll and suspended sediments--varied in time. We are also in the process of collecting new ship data and using historical ship data for the development of new and improved algorithms which are based upon--not statistics, not regression--but the radiative transfer problem. We are looking at the spectral signatures of water attenuation with the goal of developing and verifying new algorithms to be used with historical data, but based upon fundamental mathematical physical principles, not just statistical regression-based models.

We are interested in the signal coming out of the water--the upwelled energy, the backscattered light. The light coming into the water is scattered downward and absorbed and is scattered back out of the water. It is the character of the ratio between backscattering, absorbtion, and scattering--the ratio between what goes in and what comes out, that we are interested in. This is the irradiance reflectance. There are ways of solving differential equations to show how those signals are signatures of fundamental chemical and physical properties. You can do statistical (photon) Monte Carlo simulation to determine if your estimates are reasonable. There are relationships like this in which we can determine the attenuation of light in the water and the backscattered coefficient as a function of different concentrations--concentration 1 or concentration 2. We can invert and solve the problem for concentration 1 or concentration 2, corrected for the presence of chlorophyll or sediment, as an example.

Monitoring Should Support Coupling of Optical Properties and Remotely Sensed Data

In using remotely sensed data for studying estuaries, we need to think about how we can put together a monitoring program that allows us to get specific algorithms tied into specific satellites for determining optical properties. In the Delaware program we use a light meter that is simple to operate. We look at the upwelling and downwelling light above the water and below the water as a function of depth of the water column and develop high spectral resolution attenuation coefficients. Typically what we find is that the attenuation coefficients vary as you go from coastal into estuarine conditions. In the estuarine environment, light attenuation is much greater and is different, being a function of wave length and water type, i.e. dependent upon water quality characteristics.

We are developing attenuation coefficients which we will use over a period of time to refine our water quality algorithms based on physics to be used in mapping and for water quality modeling. I would urge you to develop improved models for describing Albemarle and Pamlico Sounds hydrological optical properties. You may not be able to do that initially, but as you design your modeling program, think very carefully about the value of collecting this information. You may not use it in this program, but ten years from now, these simple measurements will be extremely valuable. I wish I had recommended this as part of our monitoring strategy for the Chesapeake Bay.

Discussion

Question: With the classification approach in the estuary, what level of classification do you think you were able to go with, for example, the MSS?

Bostater: There are existing algorithms that will allow us to make turbidity and chlorophyll estimates. Light attenuation, I believe, we can do very well, given sufficient ground truth information. If you are willing to back off the satellite to the point of developing light attenuation--because that is what a lot of this is based upon--you can also go to the point of relying on known water pollution functions relating light attenuation to chlorophyll concentration and productivity. You can decouple yourself from remote sensing very quickly if you want to. But you require it to estimate the light attenuation coefficient.

Question: So you were able to get through level 2 and you are pushing at some of the extremes in terms of level 3?

Bostater: Yes.

Askari: With the light meter, what band width were you sampling in?

Bostater: What we are using now is a ten nanometer band width.

Askari: How do you spatially sample optics?

Bostater: In the Delaware we are using about 10 to 15 stations. We have just begun this so we have information from only two cruises. We are also going across the estuary looking at conditions from the shallows to the deep.

I believe that it is possible to do these detailed spectral attenuation measurements in a program like this to provide, especially in the long term and in the short term, the capability to use TM or MSS to look at water quality in the nearshore environments where local watershed impacts may be seen. In Maryland, I was involved in doing recruitment studies, trying to determine the impact of water quality on the recruitment of living resources. If we had this kind of information about the habitat and spawning areas, it would have been very helpful.

Another approach to this is time series measurements. You place an instrument out in the field and let it continuously collect data. The problems with that are that you have to have people going out into the field cleaning the probes and so forth. That approach will give you the temporal resolution but it will not give you the spatial resolution which, I think, planning people need. There are a lot of time series studies we can do to figure out diurnal fluctuations. There are also charged coupled video devices that will probably prove to be extremely useful for fixed platform or low altitude surveys.

Bisterfeld: Are you saying that we can confuse resuspension of sediments with an immediate nonpoint source runoff problem?

Bostater: With current techniques, you can estimate the concentration of suspended sediments. But when you interpret the figures, you must say how much of the sediment in the water column has been resuspended by tidal currents, how much by fronts due to the bathymetry of the system, and how much by wind. And, when you map water quality parameters, you have to ask how the distributions are related to resuspension, winds, stratification, and fronts, and how much is due to point or nonpoint sources. When you interpret imagery, you must be aware of the dynamics of the system.

Question: What degree of complexity is added by the fact that the Albemarle and Pamlico are both very shallow bodies of water?

Bostater: That <u>has</u> to be taken into account.

A GIS Approach to Understanding Biogeochemical Processes

Carolyn A. Clark
Lockheed Engineering and Management Services

This study represents the remote sensing portion of a project conducted over several years in the Florida Everglades National Park to advance our understanding of the increasing concentration of methane (CH_4) in the atmosphere. The project has been funded by NASA headquarters as part of its Biospheric Research Program and has been conducted by a consortium of scientists from the National Park Service, Langley Research Center, and NASA Earth Resources Laboratory in Mississippi.

The objectives of the remote sensing portion of the project were to

1) examine capabilities of current remote sensing instruments to delineate wetland vegetation types found to be significantly correlated with methane flux;

2) develop and test a Geographic Information System, within the context of a pilot experiment, for estimating methane emissions from wetland ecosystems.

Examining Capabilities of Three Remote Sensing Systems Was One of Project's Major Tasks

The pilot experiment was conducted in the Everglades National Park and comprised two major tasks:

1) conducting comparative analyses of thematic mapper (TM), multispectral scanner (MSS), and advanced very high resolution radiometer (AVHRR) mapping results to determine the utility of each for biogeochemical studies;

2) developing a spatial data base combining geobased information (surface cover, inundation, topography) with ground-based methane flux measurements.

Aerial color infrared photography taken with a Wild RC-9 (or similar aerial mapping camera) was made of the Everglades National Park. This imagery was used for setting up a sampling strategy, for locating ground plots, and for assessing accuracy of digital TM, MSS, and AVHRR imagery.

Remotely Sensed Data Yielded Local Vegetaive Cover Map; In Situ Measurements of Methane Flux Showed Positive Correlation with Major Vegetative Cover Types

A TM-derived surface cover stratification was made of Shark River Slough. This map was developed specifically for the pilot methane emissions experiment

SCENARIO FOR PILOT EXPERIMENT

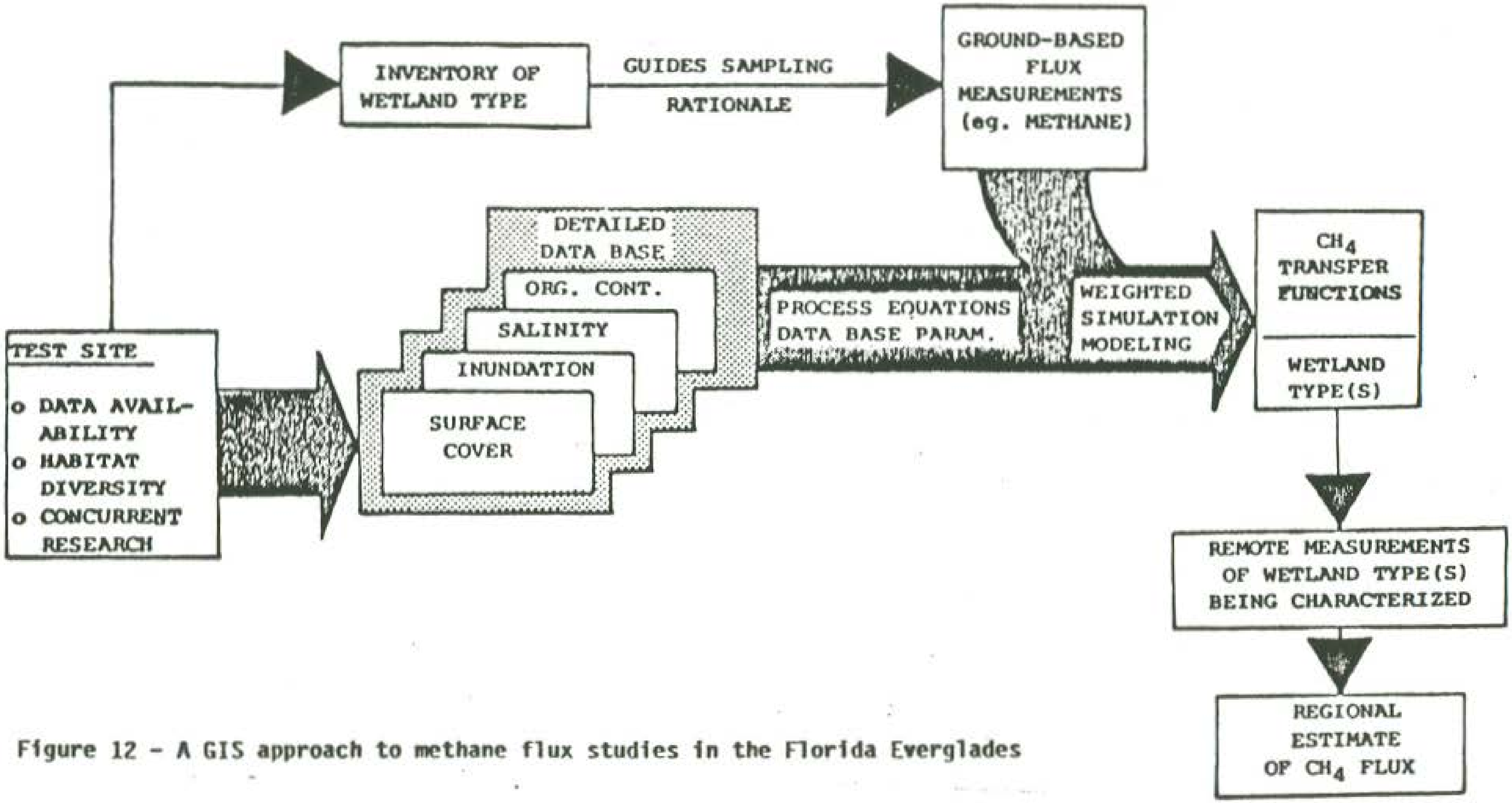


Figure 12 - A GIS approach to methane flux studies in the Florida Everglades

and was provided to the field team to guide CH_4 sampling missions. A spatial model of methane emissions was made for Shark River Slough based on in situ methane flux measurements. This noninteractive model was partitioned into 25m cells, whose outputs, according to measured methane flux rates, were summed to produce an overall methane emission estimate for Shark River Slough. The model is show in schematic in Figure 12.

Other Factors Affecting Methane Emissions Were Overlayed To Estimate Rates

TM and MSS surface cover maps with areal extent estimates of each cover class were made. In situ methane flux rates were found to have a positive correlation with major vegetative cover types (swamp forest, sawgrass, sawgrass/spikerush, sawgrass/cypress, cypress swamp, and mangrove). By mapping areal extent of significant cover types, overlaying topography or inundation boundaries, flux rates per cover type, and significant ambient temperatures, estimates of methane emission rates could be extrapolated.

Estimates Were Expanded to Regional Scale

To expand to a regional scale, AVHRR surface cover maps were made with areal extent estimates of significant vegetative types. These were to be used to expand the methane flux rates from the Everglades across the Gulf Coast.

From the ground data (in situ methane flux rates, inundation boundaries from topography and Park Service precipitation records, ambient temperatures) and the areal extent estimates of vegetative cover types, a digital data base was established to develop transfer functions relating gas flux rates to the appropriate environmental parameters in the data base.

The Tennessee Valley Authority's Experiences with Spatially Complex Water Resource Problems

Frank Perchalski
TVA

The Tennessee Valley Authority, in cooperation with the Soil Conservation Service and several Tennessee Valley region states, has recently applied an aerial photography-based data-collection approach to the solution of several water resource problems. The primary conclusion from our experience, so far, is that there are significant misconceptions about the usefulness of existing data in solving problems on the forefront of water resource management. These concerns probably apply just as strongly to most environmental monitoring activities.

Much of the data which can be handled easily in a GIS has been collected to evaluate problems with relatively simple spatial components and is usually inadequate for solving problems with more complex two- and three-dimensional distributions and interactions. Existing data may be helpful in identifying regional consequences of pollution, but different and more spatially complex data are needed to evaluate local effects and to mitigate source problems, particularly problems related to nonpoint sources and groundwater.

We have found that information extracted from stereoscopic analysis and interpretation of conventional aerial photography can supplement traditional map information with valuable spatial detail and spatial relationship data.

Existing Data Bases Found Inadequate for Goals of Duck River Water Quality Project

The inadequacy of existing data bases for dealing with nonpoint and groundwater problems became apparent when our staff began inventorying data on locations and distribution of nonpoint sources of water pollution for several subwatersheds of the Duck River Watershed in central Tennessee. It was our intention to use existing data bases to develop water quality sampling plans, to prioritize subwatersheds and sources within the subwatersheds for establishment of best management practices to help mitigate water quality problems, and to design a monitoring program to document the effectiveness of the mitigation efforts.

Several alternative approaches are typically available for evaluating nonpoint source problem areas: (1) generalizations based on knowledge of soil types and their characteristics and distributions, (2) statistical sampling of conditions, (3) extensive field data collection, and (4) remote sensing data collection and information extraction.

Since remedial actions and follow-up monitoring were anticipated, the first two data collection strategies did not appear to be appropriate. Statistical summaries and generalizations about nonpoint source distributions and conditions would possibly have provided an overview of the watershed but would not have permitted the design of a sampling and monitoring plan or the planning of remedial actions.

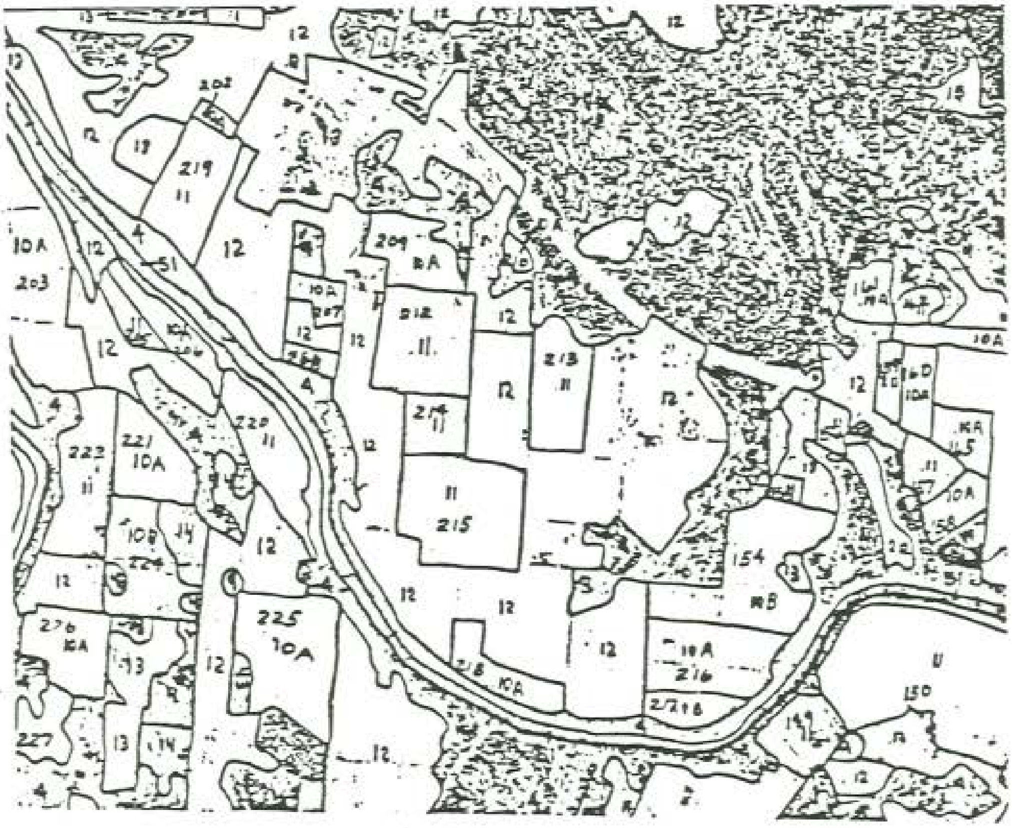


Figure 13 - Illustration of TVA land-use inventory atlas format: Each polygon contains a number representing a land-use or land-cover category. Fields with erosion potential also contain a second number, representing the number of the field on a particular aerial photographic base map and corresponding 7 -1/2" quadrangle.

The staff then compared annotated county maps to high altitude aerial photographs and found a large number of discrepancies between the two, indicating that an extensive field data effort would have to be undertaken in order to make the country maps useful. Time and budget constraints precluded a major field data collection project.

Photoanalysis of 1:24,000-scale Infrared Aerial Photos Served to Locate Nonpoint Sources

All of these considerations led to the decision to supplement existing information with a detailed aerial photographic data collection effort. A smaller aerial photographic inventory conducted on the Bear Creek Floatway watershed in northwestern Alabama served to test some procedures and products which we eventually used for the Duck River project.

The primary data source for the Duck River nonpoint source inventory was newly acquired 1:24,000-scale infrared color aerial photographic transparencies. These were analyzed stereoscopically, using mirror stereoscopes with 3X and 6X binocular attachments. Features were annotated on clear plastic overlays attached to the transparencies.

Through analysis of the aerial photographs, several kinds of nonpoint sources of possible water pollution were located and identified. Included were the effects of surface mining, septic system failures, animal waste sites, and soil erosion. The first three categories were fairly routine data extraction exercises. The soil erosion inventory however, presented some original difficulties.

Universal Soil Loss Equation was Combined with Aerial Photography to Quantify Soil Erosion

Initially, it was assumed that stereoscopic analysis of the relatively large scale aerial photographs would allow for almost immediate recognition of areas with actual or potential soil erosion problems. It soon became obvious that not all potentially erosion prone areas were being identified. The analysts were not "seeing" all of the erosion features. And, although some areas were obvious, it was difficult to quantify the amount of soil loss being experienced in an area. For many areas experiencing significant soil loss, the aerial photographic method provided no reliable clues upon which to make quantitative judgements.

A method was needed, therefore, to derive quantitative soil erosion information, using a combination of aerial photographs and other available information. A method was developed, in consultation with Soil Conservation Service district conservationists, whereby the Universal Soil Loss Equation (USLE) could be applied to each agricultural field. This was done by deriving and combining pertinent factors from existing county soils maps, aerial photographs, and judgement of the county conservationists.

An intermediate product, which was the primary spatial reference, consisted of county nonpoint source atlases. The located and identified sources were transferred from the annotated infrared color aerial photographs to clear plastic overlays attached to black-and-white enlargements of National High Altitude Photography (NHAP) Program aerial photographs. The NHAP enlargements were at a scale of 1:24,000, which allowed overlays to also be used with the corresponding 7-1/2 minute topographic quadrangles. Figure 13 illustrates the level of detail contained on the inventory atlas sheets. Each polygon contains a number representing a land use or land cover category. Fields with erosion potential also contain a second number, representing the number of the field on a particular aerial photographic base map and corresponding 7-1/2 minute quadrangle.

Three factors used in the USLE were derived directly through analysis of the aerial photographs. In the basic USLE equation, where

$$R \times K \times (LS) \times C \times P = \text{tons/acre/year of soil erosion}$$

the length and slope factor (LS), cover and cropping system factor (c), and farming practice factor (P) were determined for each field using the aerial photographs. The rainfall factor (R) for each county and the soil erodibility factor (K) for each soil type were provided by the district conservationists.

USLE factors for each agricultural field in each 7-1/2 minute quadrangle were entered into computer files and the USLE was calculated for each field, with corresponding codes which cross-referenced each field to its location on a 7-1/2 minute quadrangle and within each county. A notation (G) for each field was also included to record the presence or absence of observable gullies.

The analysis staff was provided the following materials for inventorying each 7-1/2 minute quadrangle:

* stereoscopic infrared color aerial photographs, at a scale of 1:24,000, and clear plastic overlays

* black-and-white, 7-1/2 minute quadrangle-centered, NHAP aerial photographic enlargements, at a scale of 1:24,000, and clear plastic overlays

* 7-1/2 minute topographic quadrangles

* blank coding sheets

* copies of the land use and land cover classification scheme, list of erodibility factors for each soil type, and length and slope factor (slope-effect) chart

* soils map

* miscellaneous analysis and drafting materials and equipment

The procedure used for the production of the atlas sheets and the tabular listing for each field and its corresponding soil loss consisted of the following operations:

* land uses and land cover types were delineated on the aerial photographs, including individual field boundaries

* land use and land cover annotations and field boundaries were transferred to the aerial photographic base map overlays

* fields, which had cover and cropping factors indicating soil erosion potential, were consecutively numbered on each base map overlay

* field number, rainfall index, and cover and cropping system factor were entered on coding sheets

* fields were again examined stereoscopically on the aerial photographs to determine slope length, degree of slope, farming practice, and presence of gullies

* length of slope, degree of slope, farming practice factor, and gully condition were entered on coding sheets

* each field was compared with the soils map, and the appropriate label and soil erodibility factor were entered on coding sheets

* the area of each field was measured using an electronic planimeter, and the value was entered on coding sheets

* coding sheets were entered into the computer files, USLE calculations were made, and summary sheets were printed

* atlas sheets and tabular computer summaries were assembled by county

The result of the soil loss analysis was tabular data listing USLE factors and resulting soil loss estimates for each agricultural field in the watershed. Using the tabular information, soil loss could be estimated for any area, from an individual field to county or subwatershed size areas. Since each field has a unique, but corresponding, number on both the tabular computer summaries and on the 7-1/2 minute quadrangle atlas sheets, other detailed analyses of spatial relationships for rather large areas are also possible.

Cost of Nonpoint Source Inventory Was Low, But Digitizing Must Be Done for Use in GIS

The Duck River project inventoried nonpoint sources for approximately 1,036,000 acres in four months at a total cost of $58,700 (about six cents per acre), which included the acquisition of new 1:24,000-scale infrared color aerial photographs. The cost per acre for the soil erosion inventory alone was less because the total inventory included animal waste sites and the connection of each animal waste site to the Duck River with a detailed surface water drainage line.

At the conclusion of the inventory, copies of the atlases and tabular summaries were presented to each of the four counties in the study area. Recent indications are that the information is being used to a greater extent than originally anticipated. Initial field checks of the data were within the erosion ranges shown by the inventory; therefore, the inventory information is being used for planning without significant additional field verification.

Information produced by the project is reducing the amount of time necessary for field data collection for water resource analysis. However, more time is required to evaluate the information content of the atlases. The next major change will result when the inventory information is digitized and stored in a Geographic Information System. This will enable the water resource investigator to significantly reduce the office time necessary to analyze the inventory information and to develop mitigation and sampling plans.

A test in one watershed using the full approach--from aerial data collection through analysis of resulting information using an automated mapping system--shows that once drainage and animal waste site data are in digital form, the water resource analyst can plan an optimum water sampling plan to support monitoring and remedial action in just a few hours.

Duck River Project Indicates GIS Capabilities and Needs

The Duck River experience and other nonpoint source inventories make the following apparent:

1. Existing data is not adequate to characterize nonpoint source water quality problems.

2. Collecting the right data simplifies the analysis.

3. Detailed information can be collected accurately and cost effectively through the analysis of aerial photography.

4. Geographic information system technology provides a tool to reduce data analysis time and support much more complex analyses, but the technology is still not widespread and the loading of data is still expensive.

These and other experiences also indicate that local governments collect most geographic information, and that little of this information is available to or used by anyone other than the collecting agency. Local governments should be responsible for the primary collection and maintenance of geographic information because data, even if they are to be shared, must be collected to meet the demands of the most detailed user. However, local data are often not well organized and may be dispersed in many different agency files. An alternative to having multiple agencies each collecting and maintaining the same information may be integration of locally collected data into a multipurpose automated land information system.

Today, there are two types of Geographic Information Systems: land records systems, generally related to ownership and parcel records; and resource management systems, generally at smaller scales and only tied to geographic coordinates. There is a need to integrate these two approaches.

There is also a need for more economical collection of geographic information in digital form. The two approaches to digital data collection are 1) the use of multispectial scanners or CCD cameras to collect digital images and 2) manual interpretation of a photographic image and digitizing of the results. In the short term, more detailed and accurate data can be obtained through manual interpretations, but there is a need to develop more efficient ways of loading the results of the interpretations into computer files.

Another major need is to develop a more multipurpose approach to data collection and GIS development. Although there are many technical problems, multifunctional problems are the most serious at this time. Ways must be found to meet special purpose needs through general purpose data collection programs, to share data between different levels of government, and to generalize large scale data to meet small scale requirements. This could help bring about the true integration of planning and resource management and local land information systems.

Estuarine Remote Sensing Using the NOAA AVHRR

Richard P. Stumpf
National Oceanic and Atmospheric Administration
Assessment and Information Service Center

Without synoptic water data, estuarine researchers and managers cannot easily place sampling stations in context, namely establish whether a station represents a large area of an estuary or an isolated patch. However, in all but the smallest estuaries, shipboard sampling cannot provide the frequency of synoptic data needed for studying or modeling the distribution of material and water masses. Imagery acquired from satellites can provide required synoptic data about indicators such as temperature and suspended material.

Gordon and Morel have shown that satellites can be used to estimate oceanic chlorophyll using the Coastal Zone Color Scanner (CZCS). ("Remote Assessment of Ocean Color for Interpretation of Satellite Visible Imagery," Lecture Notes on Coastal and Estuarine Studies. Springer-Verlag:New York, 1983.)

Strong and McClain demonstrated in 1984 that sea surface temperatures can be estimated using the Advanced Very High Resolution Radiometer (AVHRR). ("Improved ocean surface temperatures from space--comparisons with drifting buoys." Bull, American Meteorological Society: 65:138-142.)

The ability to estimate estuarine suspended solids using Landsat was documented in 1979 by Munday and Alfoldi, and, more recently, Stumpf showed that estuarine suspended solids could be estimated using AVHRR data.

Landsat imagery has been used predominately in estuaries because of its very high spatial resolution. Unfortunately, the sampling frequency is, at best, only two scenes per month at $600-$3,300 per scene (depending on resolution), greatly limiting the use of the data in studying estuarine variability. The AVHRR, by providing daily coverage that costs $20-$100 per scene, has greater potential in the study of estuaries.

Over the past two years, the Assessment and Information Services Center has been working on techniques to obtain useful data on estuaries from sensors such as the AVHRR. The information obtained from the AVHRR, in particular, is being combined with data from other satellites and sources, to help in the study of various estuarine problems (Johnson et al., 1986). The status of the techniques used to obtain information from the AVHRR data will be summarized in this paper.

AVHRR Offers Six-Hour Temporal Resolution, Data from Visible, Near-Infrared, and Thermal Bands

The AVHRR onboard the NOAA meteorological satellites, collects one daytime and one nighttime scene of any region every day. With two satellites operating, 6-hour temporal resolution is possible for temperature, and twice daily imagery is possible for water color and turbidity. The sensor pixel width is about 1.1 km. Therefore, the AVHRR can be used to investigate estuaries wider than 4-5 km and having areas greater than about 30 km^2.

The AVHRR provides data from 3 thermal (emitted) and 2 reflected radiance channels. The thermal data derived from the three thermal-IR channels are used to obtain sea surface temperatures corrected for atmospheric distortion. The temperatures are measurable within about plus or minus 1 degree C, but gradients of 0.25 degrees C can be detected. Sea surface temperature measurements from the AVHRR have been well documented over the 7 years the data have been collected (cf. Strong and McClain, 1984). Determination of water reflectance and color from channels 1 and 2 is a more recent development.

The visible and near-infrared bands can be used to determine both water reflectance, which can be used as a measure of turbidity (i.e. light attenuation) or suspended solids, and water color, which varies with the presence of pigments. The inclusion of atmospheric and sun angle corrections in the algorithms permit comparison of reflectances obtained from different scenes and from different sensors.

Stumpf (1987) has shown that a single form of nonlinear relationship can be used to equate reflectance with sediment concentration for typical estuarine conditions. The use of this relationship greatly reduced the quantity of calibration and verification data--in particular one calibration can apply to most of an estuary for several scenes or even several months of data. The use of this relationship further allows for adjustment of calibration coefficients for changes in the composition of the suspended materials. Estimates of suspended solids through this method can be accurate to within plus or minus 30% for average conditions.

Water color can be used to identify strong estuarine algal blooms during the summer. In addition, work in Chesapeake Bay has shown that water color, as measured by the AVHRR, has the potential to provide estimates of the chlorophyll concentration in turbid surface waters. Additional calibrations are being made to evaluate the range of conditions for which reliable estimates of chlorophyll can be made. However, the detection of blooms alone is valuable information. The sensor can provide greater information than in-situ data on the areal extent of a bloom and, when information on chlorophyll is obtainable, the sensor data can provide the approximate quantity of algae within the bloom.

AVHRR Data Can Provide Accurate Extrapolation of In-situ Data

Using imagery of estimated temperature, sediment, and algae distributions, the AVHRR can be used to identify and study spatial and temporal variations and events in estuaries of moderate size, such as Albemarle and Pamlico Sounds. While satellites such as the AVHRR cannot provide the variety or accuracy of measurements obtainable from ship, they can complement shipboard measurements by providing detailed spatial and temporal information, as well as accurate extrapolation of in-situ data. The imagery can also be used to detect surficial circulation patterns induced by changes in river discharge and wind stress, allowing the potential use of this data in initializing and verifying models of the system. In addition, by showing spatial distributions and variability, the satellite imagery can be used to improve the efficiency of an in-situ monitoring program.

DISCUSSION AND DEVELOPMENT OF STRATEGIES FOR UTILIZING REMOTELY-SENSED DATA AND A GEOGRAPHIC INFORMATION SYSTEM FOR THE ALBEMARLE-PAMLICO ESTUARINE STUDY

Statement of Problems to Be Addressed by APES and Workshop Objectives

Doug Rader

We have two very clear goals from the Clean Water Act and our designation package signed with EPA. This is what we have to do.

By October of 1990, we have to characterize status and trends in water quality and living resources and identify probable causes of environmentally significant changes.

That has two major components. The first is characterization of environmentally significant processes and estimation of their effects. These processes fall into two categories:

I. Watershed and cumulative impacts

a. land use conversion
b. nonpoint source pollution

II. Instream water quality

a. eutrophication
b. anoxia/hypoxia
c. sediment effects
d. toxicant effects

Once we've characterized the situation as it is, we must identify critical areas that are subject to management decisions. Once we know what the critical areas are, we can concentrate our efforts in these areas. Some of those critical areas we know now--the use intensive or resource critical areas--and we can begin to develop management plans for these areas. We have a policy mandate to begin doing that.

But our knowledge of the entire system is not nearly to that point yet. We know that the main stem of the Pamlico River has a guild of 10 or 15 significant environmental changes that have occurred in the last 15 years. We know that similar conditions exist in the Neuse River and Chowan River and other tributaries. We can draw the arrows to the problems. But we have no idea about how to allocate, either geographically or topically--that is by process, effort or money to solve the problems.

What we hope remote sensing applications can do is identify those concentrations of land use in close proximity to problem waters so we can target scarce money on the vulnerable areas.

One major thing we hope comes out of the study is a regulatory management program that will let us address cumulative impacts of land-use change. Right now we have no hope of evaluating, much less regulating.

It has always been my concept that we must go about this by first identifying critical areas instead of applying control measures uniformly across the entire basin. Keep in mind that by critical areas I mean both those areas where concentrated land-uses create problems or those areas that are critical to some resource that is threatened, such as primary nursery areas for shrimp. In some cases the two will coincide.

Once these areas have been identified the next step is to have some logical, consistent way for estimating with some accuracy what the effects of given management strategies will be.

So the first major part of the study involves (1) characterizing processes and effects, (2) identifying critical areas, and (3) evaluating the likely effects of alternate management strategies.

Once this part has been done--but no later than November of 1992--we must be ready to implement a control/management program, either in key watersheds or basinwide, for the long-term. That involves long-term information management with modest support--that is reduced federal support. And realistically, we could be talking about not more than $400,000 to $500,000 for the entire data program at that point, including monitoring, remote sensing, and administration.

The last thing we must do is test the effectiveness of our management strategies--that is evaluate how our control measure have helped. I think given the variability in the system it may be impossible to do this evaluation, but we're required to try.

Since it is the nonpoint source relations that predominantly drive the so-called environmental problems of the estuarine system we must have some tools to address nonpoint source problems. We are looking to your expertise to tell us what kind of help we can realistically expect from remote sensing and Geographic Information System technology.

We need for this workshop to:

1) produce a set of concrete recommendations about the possible integrations of a remotely sensed data base into a Geographic Information System that will let use address the management of nonpoint source relationships;

2) define how our need to construct models for regulatory and management purposes imposes certain data collection requirements and how our data collection requirements should

influence the design of our comprehensive monitoring program;

3) describe a system which fulfills the specific goals of this study and is, at the same time, adequately worthwhile and sufficiently economical to gain state support over the long-term.

Comments Relevant to Study Goals and Objectives of Remote Sensing/GIS for APES Study

Perchalski: TVA managers have tried to address similar problems in one of the world's largest river systems, and we're having a complete rethink of some of our concepts. There are no water quality problems. There are only land-and-water quality problems. You cannot address water quality as if it were independent of what's happening on land, and we know how to tackle problems on land.

If we have pesticides in the sound, are we going to spend the next decade trying to decide where the pesticides go, how they move, what their effect in the sounds is, when tomorrow, we can start controlling the sources of the pesticides on the ground?

Rader: We are required to characterize the situation as it exists--to identify which parts are becoming worse, which are becoming better, where the critical areas are that are subject to management. That way we can target our money where it will do the most good.

Perchalski: Yes, but I'm afraid the direction I see is that you'll spend your money trying to document that you have a problem when you could spend a lesser amount to eliminate the problem.

Rader: We don't have the option of not documenting. It won't work in this state from a policy standpoint. And, we've signed a document saying we'll do it. In some cases we've already had success in documenting problems and allocating money to bear on the problems.

The Agricultural Cost Share Program was created to address nonpoint source problems, and great amounts of money have been put into that program. However, the way it really works is that the people who yell the loudest or are the least resistant to change or who have the least personal interest in the problem are the subwatersheds within counties where the money goes. It's a first-come, first-served kind of arrangement. Instead, it should be targeted where the real problems are. What I hope a remote sensing application can do is document the problem areas so money can be effectively targeted.

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Perchalski: In the long-term the key to any nonpoint source control is education of the public. They have to do it, not you. You can't force all those farmers to control runoff. Loadings from watersheds can be calculated using Universal Soil Loss equation (gives you a pounds-per-acre-per-year value) and to do these calculations (with dollar constraints and time constraints) you need to use the less high-tech methods. We're talking about doing Universal Soil Loss Equations per field at a cost of 25 cents an acre.

Tribble: I have serious questions about the TVA cost figures. There's an infrastructure in terms of staff and capital investment available to TVA that is transparent. For our program to get up to that level will take a lot of time and money.

Paciocco: When it comes to the management part, I think a lot of what is being said is out of the ball park. If you want money and legislation to do your work, where are you going to get it? You are not going to impact the General Assembly with data no matter how much data you bring. Local governing bodies will impact the General Assembly's decisions. I'm not discounting the value of data, but I think you're coming at the management part by the back door. I think when you start recommending management strategies, that's when your local people will be your biggest supporters.

Bisterfeld: To me, that's exactly why you have to characterize the status and the trends.

Perchalski: We have a way right now to find out the effects of remedial work in a subwatershed so that the local people say "Yes, this worked. It cleaned up the stream in my backyard." That's when the legislature gets on your side.

Participant: In order to know what you need to do on the land, you have to know what the problem in the water is. Is it nitrogen, phosphorus, sediment, toxics? So, on the water quality side, you need that status and trends. On the land side, the gentleman from TVA sounds like he has a reasonable approach. So, remote sensing may be useful in helping you pick up land-use changes, then you can use the low-tech approach to go into those areas to see what has happened--that is has the farmer changed his crop or what.

Paciocco: Local agencies can tell you whether the land use is changing though. You can get your SCS people, your ASCS people, your Extension people, and information maintained by the counties and you can tell exactly where the land is changing, because you don't have that much urban development. From these sources, you can practically draw a land-use chart every year.

Stewart: Just what kind of water quality data is remote sensing going to give us that can be helpful?

Khorram: I would hope that whatever kind of remote sensing data is collected will be coupled with basic conventional biological studies done on the sites by biologists and water-quality specialists. These people can tell us that, for instance, we have a phosphate problem. Then the remote sensing data land-use/land-cover map can allow us to connect the phosphate problem with a type of land-use or land-cover so we can draw conclusions about the mechanism for the problem.

Doescher: Remote sensing data does not stand on its own. It has to be supported by data from many different sources.

Summary of Remote Sensing/GIS Concepts and Perspectives

Stuart Doescher

During the course of this workshop, we have gotten a good definition of the basic requirements for planning the remote sensing/GIS elements of the Albemarle-Pamlico Estuarine Study.

First, we must identify our particular need. Our need is to solve environmental problems in the estuaries.

Second, we must determine what data and what kind of modeling is needed to make this solution possible. We can determine what our fundamental data layers should be by determining the data needed for the modeling that must be done.

Two of the fundamental data layers that are obviously needed are (1) land-use/land-cover and (2) water quality monitoring. We have discussed a variety of other data in this workshop, but if we are going to identify accomplishable objectives, it is necessary to narrow the domain to fundamental data layers.

An important factor that we need to realize is that there is a spectrum of interests in regard to the data to be collected. There are those who are interested in basic research and development, and we must realize that while we don't have in place all the science needed to solve these problems, there is a continuing need for fundamental research and for data to support that research.

There is also an applied research interest. On the applied side, people want to take some of the fundamental data and start working on pilot projects or on concepts to see if the fundamental research makes sense when applied to specific fields.

There is also an interest in routine applications. People want to take the basic research and the applied research and routinely produce and/or refine usable products such as maps.

Another interest is in policy-making information--information to answer the "what if" questions. Data to support this kind of querying must be in our databases also.

The APES information system must accommodate all these interests.

Through this workshop, we have also seen a spectrum of techniques. There are older techniques that have been and continue to be used very effectively. These techniques--such as aerial photography--have an appropriate place. There are new techniques--such as GIS systems--in place. There is also the promise of future techniques. We know things will continue to evolve and be refined. The information system that is developed in support of APES must be flexible enough to take advantage of appropriate old and new techniques as well as future techniques as they are available.

Speakers at this workshop have also made it obvious that there is a spectrum of available data in terms of spatial, spectral, and temporal resolution.

We, as experts in remote sensing and Geographic Information Systems, must focus on identifying for the directors of the APES study, which of the techniques and which resolutions will yield the land-use/land-cover and water quality data they need to satisfy the spectrum of interests. We must also give the directors of the study some idea of the costs involved in collecting and processing the data needed.

INFORMATION GOALS

CHARACTERISTICS OF DATA NEEDED TO REACH INFORMATION GOALS	LAND-USE: CONVERSION	LAND-USE: PERMITTED POINT SOURCES	LAND-USE: WATERSHEDS	PATTERNS IN WATER QUALITY: Spatial, spatial/temporal distribution of (1) temperature, (2) salinity, (3) turbidity, (4) chlorophyll A, (5) total suspended solids.
CLASSIFICATION LEVEL	II+	ALREADY MAPPED, BEING INTEGRATED	IN PROCESS (100K HYDRO, 7 1/2" DLG'S)	
SPATIAL RESOLUTION	5-10 acres			
SPECTRAL RESPONSE				
TIMELINESS:				
• Frequency (Historical/realtime)	5 yrs at 1-yr interval			Biweekly March - October Monthly during winter
• Seasonal	leaf-on/ leaf-off			
ACCEPTABLE ACCURACY	75%			75% - 90% depending on parameter
SOURCE	TM			AVHRR for trends; TM for monitoring and following up specific events
COST				
• Raw data				
• Processing				
• Capital				
• Labor				

Figure 14 - Chart of some data needs and possible data sources for use in a Geographic Information System for APES

Development of Chart of Data Needs, Characteristics, and Sources

Stuart Doescher, Discussion Leader

(In this rather brief session an effort was made to reach consensus on the data needs of the Albemarle-Pamlico Estuarine Study and to bring closure to the two-day workshop. Due to the rapid pace of the discussion, not every comment could be recorded. Because of the somewhat selective nature of the transcription and a strong effort by the discussion leader to keep the discussion focused and avoid side issues, some comments may seem to be out of context. However, what follows generally represents the direction of the discussion.)

As a method of providing the advice needed, I ask all workshop attendees to participate in the development of a chart (See Figure 14) which identifies data needed for modeling and for a Geographic Information System for use in the Albemarle-Pamlico Estuarine Study, specifies the relevant data characteristics, and identifies which remote sensing sources can provide the needed data. We also wish to say something about the relative costs of each source.

This chart has two major data-need headings, as suggested by Doug Rader in his statement of problems: (1) land-use and (2) water quality. These headings are at the top of the chart. On the left side of the chart are the data characteristics that may be relevant and important. Now, we want to

(1) decide what data layers we need under each major heading,

(2) fill in the chart with specific recommendations as much as possible.

Discussion During Chart Development

Askari: On land-use, you can start with baseline data, which you get from low-altitude. Then you can say how that land-use is changing. High-altitude or satellite data can identify change. Then you can say what those changes are.

Doescher: So one of the primary things we want to know about land use is change or conversion.

Participant: Well, we need the baseline first. What is that baseline? It sounds like a lot of it is agriculture. It's not sufficient to draw lines around agriculture. We're probably going to want to draw lines around tighter groupings. Do we want to categorize the major categories of land-use?

Doescher: If we talk about categories of land-use, there are levels I, II, and III.

Participant: In terms of agriculture, we need something more refined than level I because the fields are going into the water.

Doescher: Based Dr. Bostater's chart of data classification levels (See Table 6, page 82), I would say we need level II plus.

Askari: The land-use data should be divided into static and dynamic factors.

Doescher: But if we get two cuts in time--a before and after--won't that take care of both?

Khorram: But if you want to talk about two different dates in respect to conversion, then you are limited by the availability of the remote sensing data.

Doescher: O.K., but let's worry about that when we start specifying the Source. Maybe we will have to go to other data sources depending upon the historical difference we get. Do we need point-source data as part of the land-use data?

Askari: That comes from your GIS.

Doescher: But I have to get it into my GIS. I don't have one yet. I don't have anything yet. So we need to get point source data because that is not part of the conversion problem. It is an entirely different contribution factor.

Clark: If what Doug Rader said is true about major watersheds and prioritizing those in terms of the impact they have on the total system, it looks as if one aspect of the land-use data you need is a definition and prioritization of watersheds.

Doescher: That naturally falls out. So we need watersheds as another layer of information under land use.

Participant: What is a point source? Are large animal feed lots considered point sources?

Rader: There's a gray area, but basically we're talking about permitted point sources such as pulp mills.

Doescher: What else do we need under land-use?

Siderelis: What about hydrology, geology and such?

Doescher: Those are important elements within your data base that are needed in terms of modeling. But here we're trying to crystalize land-use data. Now, what about water quality. What parameters do we need.

Khorram: You need to break it down into parameters of interest. What do you want? Turbidity, sedimentation, chlorophyll, biological activity, saltwater intrusion into freshwater areas?

Doescher: What I want to do is monitor, right?

Khorram: I think these parameters can be divided into physical, chemical, and biological factors, keeping in mind that these factors interact with one another at all times.

Askari: You need to specify the concentration of the parameter. Water quality monitoring is fundamental research. You can't get some of this information without it.

Doescher: But our goal is to get very quickly to a routine application. We have to establish a monitoring program very quickly.

Askari: The only way you're going to address those water quality parameters is to discover some patterns. You can't get down to the specifics--the concentrations--on a routine basis.

Doescher: So, we'll talk in terms of patterns in water quality. Now let's try to fill in this chart. Let's start with land-use conversion. This means that we have one use at level II classification at time, t. We want to see what that new level II classification is at time, t+. What resolution do we need to give us this information? Give me a range.

Khorram: 5 to 10 acres.

Doescher: What spectral response?

Khorram: That should be a function of technique development--what kind of information you want.

Doescher: We'll pass that characteristic for now. What about frequency?

Participant: One year.

Doescher: In what time frame?

Participant: In most places, land is being converted quite rapidly. Five years should be more than sufficient.

Siderelis: But do we have five years of historical data.

Doescher: We'll put down every year for five years, but we'll understand that cost factors may cause that to be refined.

Doescher: Does seasonal coverage--leaf-off/leaf-on--make a difference in this particular scenario?

Participants: Yes

Doescher: Now, with these decisions made, does a particular data source come to mind? My impression is we're looking at MSS or TM with a lot of supporting data--classification, field checking, and so forth.

Participant: You're going to need TM. MSS won't do it with the resolution you've specified.

Doescher: TM costs more.

Khorram: If you're going to be spending the time and money, you might as well do it right.

Doescher: TM costs more. Not just the original acquisition but all the follow up work. But that is where I'd aim. O.K. what about accuracy. If I look at a spot on that resolved map and I ask what is the percentage of chance that I'm going to be accurately identifying a land-use or cover, what percentage am I willing to accept?

Khorram: Somewhere between 75 and 85 percent, overall. That's pretty good. In terms of land-use conversion, that's going to yield a much higher degree of accuracy, 90 percent or better.

Doescher: Let's talk about point sources.

Stewart: Point sources are already reasonably well mapped.

Khorram: Point sources need to be integrated so that the GIS can have an overlay of point sources.

Rader: DEM is already doing that.

Doescher: What about watershed and drainage basins?

Tribble: Basically that is planned also.

Doescher: What's the methodology planned? Is it aerial?

Tribbel: Topo.

Siderelis: DLGs.

Doescher: Will that integrate into what we have here?

Khorram: To be compatible with your level II land-use conversion data, you need probably five stream orders, all the way from major to tributaries.

Siderelis: We hope to use hydro from 100Ks initially and fairly quickly replace those with 7 1/2 " DLGs. What we did for the SSC land-use/land-cover inventory was use the DLG information as a template. Then when we identified water bodies that were not on 7 1/2" quads, we included those in the land-use/land-cover with about a three acre minimum waterbody size.

We have not totally agreed that this is the way we'll do it for APES, but it did work out for SSC.

Tribble: The advantage is that the 100K data is there.

Participant: If you're talking three to four acres, 100K doesn't give you that. The 7 1/2" ought to get you there though.

Siderelis: The real goal is 7 1/2 ".

Paciocco: I think the real concern that we living on the coast have is that we get the lectures on water quality, and no one is looking at what is being done upriver before the water gets to us. We've researched Texasgulf to death. If we spend all this time researching downstream, and there's still more we need to do. But there's a lot of trouble up river that has not been touched on this chart.

Doescher: What about the point sources. What do you have.

Rader: At this point all we have is permitted point sources. We're trying to distinguish permitted from discharging. There are some areas where agricultural drainage is effectively point source discharge, but that's not addressed through the permitting system.

Doescher: Let's turn to the other side of the chart. What do we mean by water quality patterns?

Khorram: Spatial and spatial/temporal distribution of water quality parameters of interest.

Doescher: What are some of those water quality parameters of interest?

Participants: Temperature, salinity, turbidity, chlorophyll A, suspended solids.

Doescher: In my opinion, this is defiritely classification level II or III. What resolution do we need to monitor these patterns?

Participant: Resolution is more than spatial resolution. There's also radiometric resolution.

Doescher: O.K., so we need to add characteristic called Spectral Response. Now, let's look at each of these parameters and you tell me which I can get with various sources? What can I get with AVHRR?

Askari: Temperature and cholorphyll.

Participant: Turbidity and total suspended solids.

Doescher: So all I'm missing with AVHRR is salinity. What can I pick up with MSS?

Askari: There are questions about temperature and salinity.

Doescher: What about TM?

Participant: All five, with a question about salinity. Salinity is the hardest one on both the MSS and the TM.

Doescher: What about aircraft.

Askari: All, better than satellite.

Participant: It's more expensive though.

Doescher: Are there other kinds of sources.

Askari: CZS. (Coastal Zone Scanner)

Doescher: That's out of date.

Askari: It can give us (historic) trends.

Doescher: How far back do we want to go with historic data?

Participant: As far back as the land data.

Doescher: I think you do want your trends so you can compare it with your land-use change. What about the monitoring issue? How frequently do you need your data in terms of water quality monitoring.

Askari: Biweekly.

Doescher: All year?

Participant: In the Chesapeake Bay they monitor twice monthly from March to October and then, if they don't see anything happening, once monthly through the winter.

Rader: For some parameters of interest 20 minutes is too long.

Stewart: We're talking about patterns, though.

Doescher: What about accuracy?

Khorram: Depends on the parameter of interest and your objectives. You can have two boats side by side measuring chlorophyll, and if you get 75 percent accuracy between the two, you're doing well. However, if you're talking about turbidity, if you don't get more than 90 percent, you're missing the boat. So the accuracy should be a range from 75 to 90 percent.

Participant: The accuracy is also a function of the number of point samples that are taken. If we have very few point samples, they better be right.

Khorram: You really need to couple the two in order to be able to associate any accuracy with the monitoring.

Doescher: When we get down to costs, too, we have to always remember that data cost includes the original cost and support data. Let's try to target a source in terms of water quality. I'd aim at AVHRR.

Participant: It won't give you what you want in terms of spatial resolution.

Participant: When we say bi-weekly on the water quality sampling, it doesn't mean we need satellite overpasses to coincide with the sampling. The biweekly sampling would be used to draw biological trends and the data to highlight critical time periods where overpasses are appropriate to get the larger spatial distribution.

Doescher: Can I couple TM for monitoring with AVHRR for trends?

Khorram: I really think you need to approach this like land cover. You need both. You need either AVHRR or TM to give you the overall patterns and trends, then you need TM coupled with surface measurements, in addition to the stationary water quality monitoring stations to give you what you want. Even then, I'm not sure you're going to get a lot of useful information out of it. I am sure AVHRR will not give you the spatial resolution that you need.

Siderelis: I think we have to consider the cost when we start talking about coupling TM with biweekly monitoring.

Doescher: I think what he's saying is look at (fairly inexpensive) AVHRR for your trends, then when you have specific identified problems that you want to analyze, look at TM.

Tribble: Let me ask this. AVHRR has to be processed on a daily basis. How expensive and time-consuming is that going to get to be.

Doescher: This is not very high resolution data and it can be processed fairly quickly.

Askari: I'd like to emphasize the point made by the gentleman from the University of Delaware. You are really going to get more for your money as far getting water quality parametes from a boat, if you nail the physics of the system down. You need to study the optics. If you just keep sending a boat out everytime a satellite passes over, you are going to calibrate one image at a time. Your algorithms are going to break down in time and in space. It will be much more cost effective in the long term when you're establishing the monitoring system, if you go out two or three times during typical conditions and once and for all nail the optics down and find out what the spectral distribution of light in the water column is.

Doescher: In all this, we're taking chances. I don't think the program can afford this level of fundamental research.

Participant: One of the things we haven't talked about that affects all these other factors is precipitation. We need to think about some kind of climatological study. We're going to need it for base run-off studies, for a lot of different things.

Tribble: There are a number of layers of data that will be involved in the study that won't be acquired through remote sensing.

Khorram: That's a good point, though. In order to use land-use/land-cover studies and do water quality studies and couple them together, you must have a watershed characterization baseline to build on.

Participant: I don't mean just precip for a time period. I mean a basin study of hydrologic events, of runoff curves, and so forth. These kinds of things will really help in our modeling to tie erosion potential to land-use activities.

Doescher: I don't know if we've come up with any real solid recommendations. I think we have have scoped the level down, narrowed the focus. Please send any additional thoughts and recommendations you have to the workshop coordinators.

Recommendations for Utilization of Remote Sensing and a Geographic Information System in the Pamlico-Albemarle Estuarine Study

Carolyn Clark

PROJECT PLANNING

1. Define the problem

   Identify the conditions that will be managed for, i.e. pristine conditions, maximum unchecked utilization (and resultant degradation), the best compromise between utilization and conservation of environmental and ecological integrity, restoration if degradation has been severe, etc.

2. Characterize current status of land use, land cover, and water quality.
3. Characterize trends in water quality and living resources.
4. Identify environmentally significant changes/problems.
5. Identify probable causes of environmentally significant changes.
6. Determine remote sensing data requirements, i.e., scale, resolution, frequency of coverage, multi-sensor combinations.
7. Determine data processing and digitizing requirements.
8. Determine other data needed for inclusion in GIS (Vector format) needed to do modeling.
9. Develop interactive models based on observations and measurements.

GIS AND REMOTE SENSING REQUIREMENTS

Since LRIS will do data management for the APES and will develop, operate, and maintain a statewide GIS, the APES GIS should be compatible in every way with the State GIS to effect efficiency and cost effectiveness.

It is suggested that project planners review the October 1987 issue of Photogrammetric Engineering and Remote Sensing. In addition, it is suggested that project planners contact the Mississippi Institute of Technology Development, Center for Remote Sensing (Scot Madry, 601-688-2864) and/or the Earth Resources

Laboratory, NASA, at NSTL, MX (David Brannon, 601-688-2042). They have developed the digitizing, registration and overlay capabilities to effect a good GIS, and have cooperative work mechanisms set up. Planners should confer with Geobased Systems of Research Triangle Park and have them use some existing data for demonstration of their capabilities.

DATA COLLECTION

A. Based on APES goals and objectives, assemble all available data:

1. Existing aerial photo coverage from the National Cartographic Information Center (1-800-USA-MAPS)

2. USGS 30" series, orthophoto maps, and 7 -1/2" quads and digitized soils maps

3. National Wetlands Survey (1:24,000 scale maps)

4. NHAP photos (most current)

5. EPA base maps (1:100,000)

B. Determine compatibilities and usefulness of information.

C. Determine gaps in information.

D. Determine resolution of remote sensing data needed to map, inventory, detect change, and model the processes that cause problems.

REMOTE SENSING SUGGESTIONS

1988 Aerial color infrared photography (1:24,000 to 1:32,000) preferable. A summer acquisition and a winter acquisition in 1988 would be best for land cover/land use, however, one acquisition at a smaller scale would suffice.

1988 A summer TM acquisition processed for a full resolution, false color infrared image. The digital image should also be processed (classified and labeled) and entered into the GIS.

1988 AVHRR data processed the same as the TM to see "the big picture." MSS is not recommended because it has no thermal data.

--- Use subsequent AVHRR acquisition to detect change.

--- Use subsequent TM (quarter scenes) to analyze change. Aerial color infrared photography (1988) can also be used to study change.

--- Aerial CIR photography can be used when doing ground in situ sampling of any environmental parameters, to select and locate sample sites, to map aggregated sample data, etc.

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Remote sensing of water conditions/quality should be utilized if continuing research shows feasibility.

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MODELING

Identify the kinds of changes that may occur. Quantify the amount of change in one factor required to effect change in other factors.

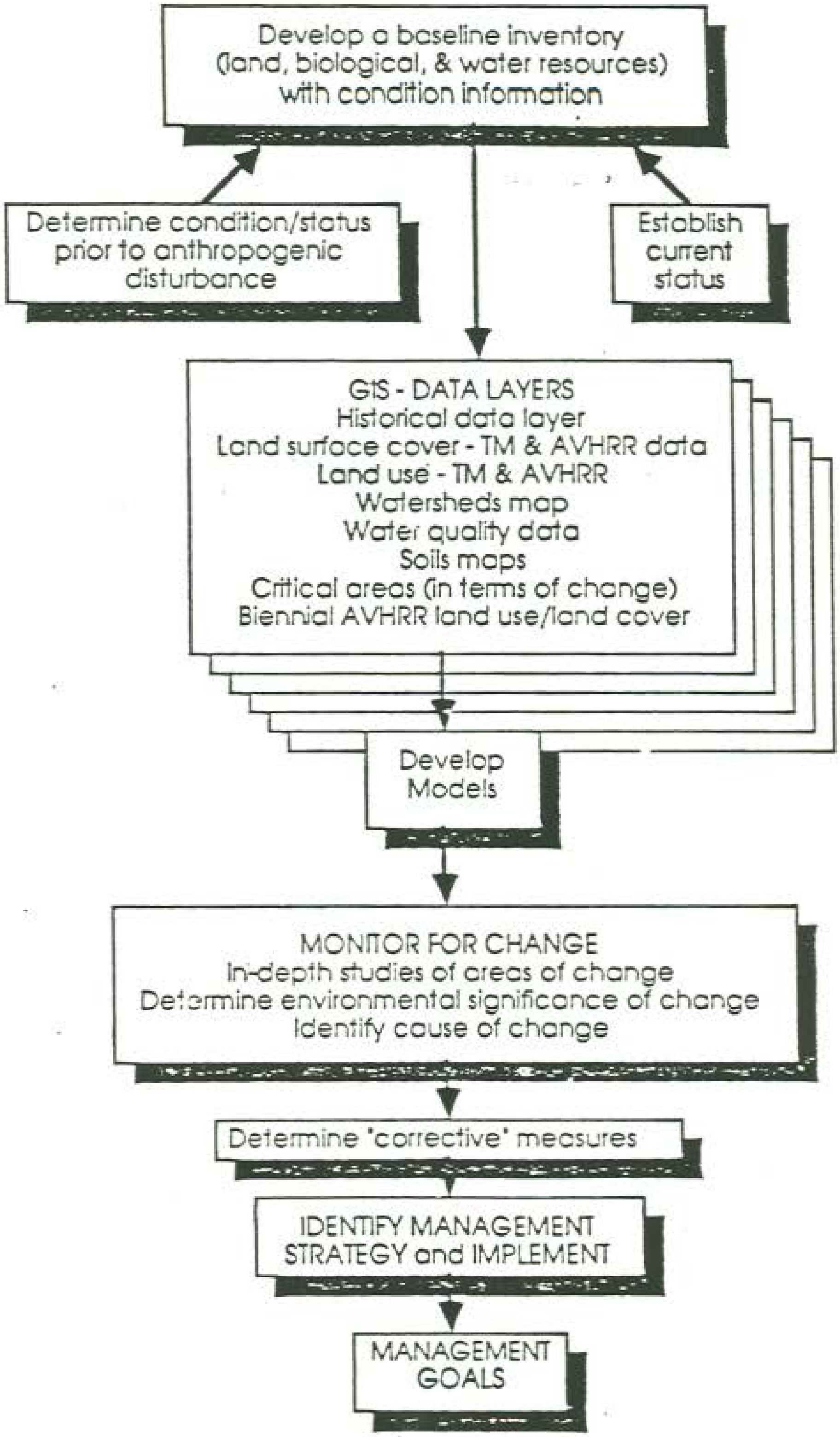

Figure 15 - Flowchart for utilization of remote sensing and a Geographic Information System in the Albemarle-Pamlico Estuarine Study

WORKSHOP ON REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEMS
NOVEMBER 9-10, 1987

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