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CONTENTS

Articles

Reports

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EDITORIAL COMMENT

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This issue of The North Carolina Geographer, much like its predecessor, represents the broad perspectives of research and application in geography and related disciplines. Even so we have here a pronounced tilt in emphasis toward North Carolina's environmental conditions and concerns; this especially as regards climate, water resources and environmental management. This is complemented by explorations into recent General Assembly decisions affecting life and land in the state. As always, the Journal includes shorter articles on more specialized matters, as well as a brief account of this issue's cover.

Walter Martin of UNC-Charlotte leads off with a study of folk perceptions of coastal storm hazards. Long term residents appear to possesss much relevant information about specific localities frequented with greater impact by coastal storms. These hazard zones have subsequently been corroborated by scientists to the point to where it might be advisable to listen more closely to locals when considering issue relating to coastal management.

One of the major pieces of environmental legislation passed recently by the General Assembly was the Water Supply and Watershed Management Act. Bill Holder of Knoxville's Metropolitan Planning Commission and Mike Mayfield of Appalachian Stae University team to explore the utility of Geographic Information System technology as a tool in establishing the drainage parameters of stream buffer zones. In this case the New River watershed in Ashe County provides a highly effective example of the junction of GIS technology and watershed management needs.

If it is raining in Burlington what then is the likelihood that it will be raining also in Charlotte? Surely this question suggests one of the problem issues in local and regional weather forecasting. Here it is given a penetrating look by Peter J. Robinson of UNC-Chapel Hill. In a comparative study of mountain and lowland weather stations he finds that indeed the probability of rain in one particular place, given its actual occurrence in another, can be determined. Jack Hidore of UNC-Grensboro follows with an account of weather hazards. In focusing on the Nor'easters he discovers this prevailing winter-early spring storm to be persistently one of the state's major atmospheric hazards.

Doug Eyre of UNC-Chappel Hill weaves a fine web in detailing the evolution of the series of geographically convoluted redistricting plans proffered by the major parties in their attempts to reconcile self interests and Voting Rights Act expectations. The most recent plan was implemented in time for the 1992 presidential elections, and is now being contested in the courts.

This Journal's Reports include a survey of the utility of using a computer speadsheet software package to ease problems of data manipulation and presentation. Garry Cooper of Appalachian State University demonstrates this software's knack at stimulating creativity in generating complex and useful visuals. And in support of the continually enriched palette of tools available to geographic research Tim Johnson provides a close look at the function and projects of the North Carolina Center for Geographic Information and Analysis.

Art Rex provides a description of this year's four color cover. Art is the project director of the GIS applications of the Upper Catawba Drainage Basin Project, itself directed out of the Western Piedmont Council of Governments with offices located in Hickory.

The North Carolina Geographer continues to seek the results of current findings of academic and applied geographers, and of those who feel that their work and interest is in some way defined within the broad spectrum of this field. But we areawowedly committed to presenting exclusively material that reflects or has a direct bearing on North Carolina's conditions, past, present and future; this is a state journal! Any and all are invited to submit materials of interest to a readership that we expect to range from academicians, to planners and local and state decisionmakers, to school teachers, and to any member of the public at large who find facination with the intricacies of our state's multifaceted geography. Articles submitted will be refereed by peers prior to acceptance for publication. Though this issue characterizes the style adopted by the Journal, all prospective authors may wish to contact the Editor for detailed guidelines on manuscript preparation. All articles should reach the Editor prior to January 31st of the year of publication. For the foreseable future we will be publishing The North Carolina Geographer on an annual basis as the journal of the North Carolina Geographical Society.

The Society wishes herewith to express its deep appreciation to those who have labored in the production of its Journal. Every other year we will acknowledge the support of the readers who freely provide their expertise and recommendations to prospective authors on the basis of their submitted work. So we thank the following individuals, John Florin, D. Gordon Bennett, Jack Hidore, Jonathan Phillips, Bill Rogers, Robert Reiman, William Imperatore, Tyrel Moore, Neal Lineback, Michael E. Lewis, Gerald L. Ingalls, Roger Winsor, Peter Soule , Brooks Cates, W. Frank Ainsley, Art Rex and Melinda Meade. In addition the appearance on the street of this particular issue owes much to the following, Kim Heinz and Paul Maney, Appalachian Graduate Assistants; John Craft, who spent much of his weekend clearing up some of the mysteries of Pagemaker, and the faculty and staff of the Department of Geography and Planning at Appalachian.

STORM HAZARD ZONES ALONG THE OUTER BANKS OF NORTH CAROLINA; CULTURAL AND PHYSICAL PERSPECTIVES

Walter E. Martin

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Knowledge of storm and erosion hazard zones along barrier islands is crucial for public safety and informed land use. In this study hazardous areas along the Outer Banks which have been identified by earth scientists in the literature of coastal zone management are compared with native folk perceptions. Long-term residents who have observed several decades of environmental change can complement scientific delimitation of hazard zones.

Introduction

Local folk perceptions of storm and erosion hazards along North Carolina's barrier islands is here compared to the findings of earth scientists

Early European settlements were established on the islands of Bodie, Roanoke, Hatteras, and Ocracoke by 1720. Since then the resident population has accumulated considerable experience in dealing with the storm-related hazards of living on a barrier island. As historically isolated from the mainland settlements of North Carolina by Albemarle and Pamlico Sounds, residents of the Outer Banks developed a rich body of folklore about their land and history. Traditional assessments of storm hazard provide a baseline for pre-modern storm hazard mitigation and planning strategies. Awareness of both real and perceived storm hazards along barrier islands continues to play an important role in public safety and informed land use decisions. This paper compares traditional culturally defined hazard zones with recent systematic physically defined assessments of hazard zones along the Outer Banks.

After bridges across the Alligator River and Oregon Inlet were completed in 1959 and 1963 the region entered a new era: tourism would replace fishing as the leading economic activity. Land development, real estate, and rental property became big business. Patterns of traditional land use adjusted to the new economy with waves of beach-front development. Construction within high risk areas, such as the ocean-side flood and erosion zone, has been driven almost exclusively by tourist demand. Today, with more than 37 percent of the barrier islands developed for residential or recreational use, poor location or inappropriate construction leave the coast increasingly vulnerable to storm damage (Gade, Stillwell, and Rex, 1986). The conflicts inherent in ocean-side and beach-front development has prompted vigorous debate about coastal zone management policies (Furuseth and Ives, 1984; Ives and Furuseth, 1988; Pilkey, 1987; Sturza, 1987).

During the present century sea level rose nearly a foot along the North Carolina coast and another two-foot rise is likely by the year 2100. Along the North Carolina coastal plain each one-foot rise in mean sea level can be expected to relocate the shoreline 1,000 feet inland. Knowledge of storm and erosion hazard zones along barrier islands such as the Outer Banks will continue to be crucial for both public safety and formulation of prudent land use policies. Ignorance of coastal zone processes such as beach erosion, storm surges, barrier island overwash, and inlet formation threatens everyone from vacationers to taxpayers who often get the bill for coastal zone mismanagement. Brower points out that a major obstacle to growth management in many coastal communities is the "mythical absolute freedom of property owners to do as they wish with their land" (Brower and Beatley, 1987). A critical first step in achieving consensus depends on an acceptable hazard zone classification. This survey suggests that long term residents who have observed several decades of environmental change can play a valuable role in validating hazard zones.

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Data

Sixty-two residents from Kitty Hawk to Ocracoke were interviewed between 1972 and 1990. Forty-three interviews were conducted during 1972 and nineteen during the years since. Eighty-three percent of the respondents were older than 50 at the time of the interview and most were retired. Respondents were carefully selected to provide as much information as possible about pre-modern storm related traditions and perceptions. With minor exceptions, respondents were lifelong residents of the Outer Banks who represented many of the prominent native families. Among them notable contributions were made to this survey by Lawrence Austin, Hatteras; Jesse Eldred Baum, Kitty Hawk; Bernice Ballance, Buxton; Asa Gray, Waves; W. W. Harvey, Manteo; Wahab Howard, Ocracoke; Archie Scarborough, Frisco; and Gage Williams, Wanchese. Austin was 16 when the "San Ciriaco" hurricane of August 1899 struck Hatteras, and he lived to see most of the storms that struck the Outer Banks during this century. The perceptions described here are drawn from statements of those who faced the storms of the past century.

This survey suggests that long term residents who have observed several decades of environmental change can play a valuable role in validating hazard zones

Analysis

How had the native residents perceived their environment prior to the recent benevolent invasion of tourists? What did they identify as dangerous? How would that knowledge compare with what is known today about coastal processes and hazards? Respondents were asked to identify areas with ocean-side or sound-side erosion problems. Each was also asked to identify areas that they perceived to be dangerous or hazardous duringstorms. Nativeperceptions of hazard zones will be compared with physically defined hazard zone assessments by Pilkey and Neal (1980) and Pilkey and Bush (1993).

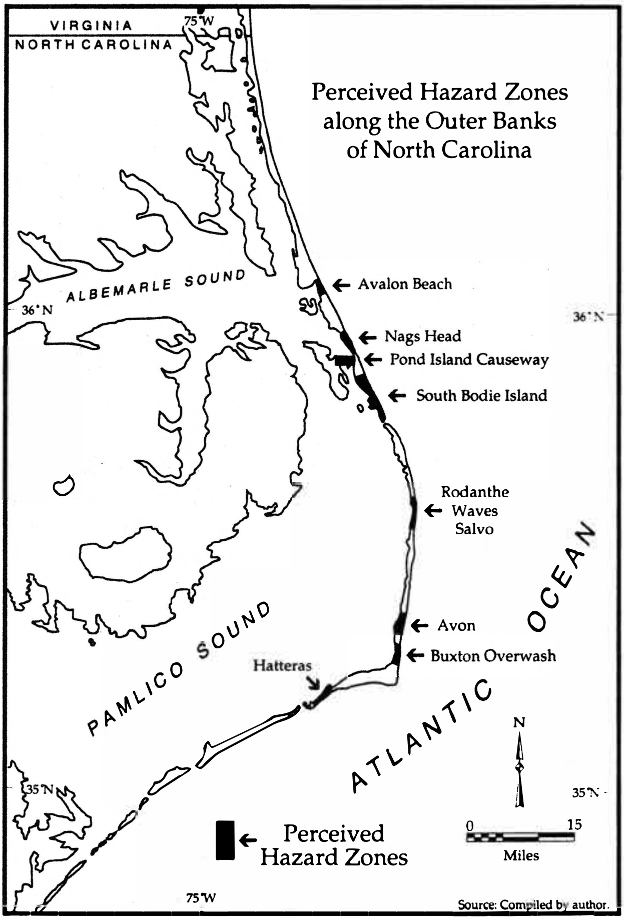

Figure 1. Perceived Hazard Zones along North Carolina's Outer Banks

<u>Perceived Hazard Zones</u>

Eight zones were identified by native respondents as relatively hazardous. From north to south they are: Avalon Beach; South Nags Head; the Pond Island Causeway; South Bodie Island; the villages of Rodanthe, Waves and Salvo; Avon; the Buxton Overwash; and Hatteras Village (Figure 1). Although protection from high winds and wind-blown debris was frequently cited as a major priority during severe weather, identification of these flood-prone areas suggests an acute awareness of the greater risks associated with flooding. Each of these areas is threatened by oceanic overwash, sound-side flooding, or beach erosion. Generally respondents identified the narrow low-elevation island segments as the most hazardous. Here they are treated in order of percieved hazard.

During the 1970s the Pond Island Causeway was a low

During the 1970s the Pond Island Causeway was a low segment of paved fill that connected Roanoke Island with Bodie Island. Some segments of causeway were less than 20 meters in width and only one meter above lunar high tides in Roanoke Sound. Tropical cyclones with little more than 50-knot winds were sufficient to flood the roadway and the contiguous undeveloped flat appropriately known as Pond Island. Both Pond Island and the causeway were perceived to be at risk because they were vulnerable to sound-side flooding whenever tropical cyclones moved northward near the barrier islands. As tropical cyclones approach from the south, onshore winds from the counterclockwise circulation serve to temporarily impede the flow of riverine water through Albemarle Sound. As the storm passes to the north, backing winds drive water from the engorged Albemarle sound through Roanoke and Croatan Sounds and onto the sound-side settlements of Bodie and Hatteras Islands.

During the 1980s Pond Island was completely developed primarily for housing despite long standing knowledge among the native population that this was not the most prudent location for housing (Martin, 1973). In recent years some risk to Pond Island and the south Bodie Island developments has been reduced with completion of the new Virginia Dare Washington Baum bridge, which provides a more dependable evacuation route. Parts of the causeway connecting Nags Head with the new bridge, however, remain dangerously low and vulnerable to sound-side flooding.

Eight hazard zones have been identified by local residents. North to south they include: Avalon Beach; Nags Head; Pond Island Causeway; South Bodie Island; the villages of Rodanthe, Waves and Salvo; Avon; Buxton Overwash and the village of Hatteras

Of the old village sites, both Avon and Hatteras have been considered relatively high risk locations because of their potential for sound-side and overwash flooding. Avon residents traditionally responded to the flood hazard in several ways. Several families permanently relocated from Avon to Manteo in the aftermath of severe hurricanes that struck Hatteras Island in 1899, 1910, and 1944. One neighborhood in Manteo, "Little Kinnakeet," was known for its ancestral connection with the village of Kinnakeet, or Avon as it is known today. Prior to construction of the ocean-side barrier dune system between 1935 and 1945, oceanic overwash was a frequent occurrence during Northeasters each winter. In response to the inconvenience and high risk to life and property from overwash, Avon residents attempted an engineering solution. They constructed an unbroken overwash barrier dune that surrounded the entire village (Figure 2). Although the efficacy of this structure in protecting the village from overwash is undocumented, it allegedly contributed to elevated and prolonged flooding during sound-side flooding events. During Hurricane Gloria in 1984 and again with Emily in 1993 parts of Avon, Buxton, Frisco, and Hatteras were flooded from the sound to depths of five and six feet. Even though the Avon overwash barrier was abandoned and the dune was breached at the road entrance to the old village several decades ago, the relic structure still stands six meters wide and nearly two meters high.

The low narrow neck of land between Avon and Buxton known as the Buxton Overwash has traditionally been perceived as one of the most dangerous segments along the entire Outer Banks. The Buxton Overwash zone has historically been prone to oceanic flooding and inlet formation. Mid-latitude cyclones that sustain strong northeasterly winds through several successive high tides have eroded and overwashed barrier dune ridges with pre storm heights of more than three meters. The linkages between storms, oceanic overwash, and inlet formation are complex (Baker, 1977; Fisher, 1962; Langfelder et. al., 1974), but the extreme risks are clear from eyewitness accounts of the formation of Hatteras Inlet in 1846 (Stick, 1958): "to their great surprise, in the morning they saw the sea and the sound connected together, and the live oaks washing up by the roots and tumbling into the ocean." Most storm cut inlets quickly silt up and disappear naturally but several can be opened by a single hurricane. Six new inlets were formed along the Outer Banks during the Great Atlantic Hurricane of 1944.

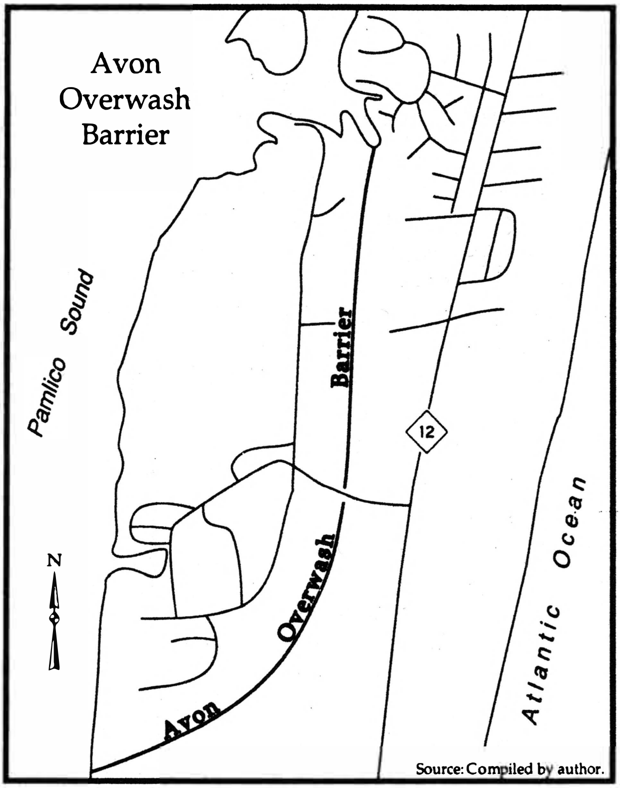

Figure 2. The Avon Overwash Barrier

Many respondents asserted that the Buxton Overwash zone is particularly prone to inlet formation. Historically, a deep water trough known as the Cape Channel led up to the Buxton Overwash and focused high wave energy toward the low narrow island segment. During severe storms, overwash from the Atlantic could open a new inlet. Although several relatively minor overwashes have occurred since then, the last major breach of the Buxton Overwash took place during the Ash Wednesday Storm of 1962. Land transportation and telephone service for the villages of Hatteras, Frisco, and Buxton were immediately severed. South of the Buxton Overwash, then known as Buxton Inlet, residents were distressed and eager to have the inlet filled or bridged. Residents of Avon, adjacent to the inlet on the north side, although sympathetic, were quite satisfied with their more convenient access to the sea.

A temporary one lane wooden bridge was constructed to serve until the inlet silted in naturally. But the inlet did not fill in, rather it eroded southward, and transportation was again severed. An organized effort was mounted in Buxton and Hatteras to retard the inlet's growth and migration by using old automobile bodies to armor the channel of the new inlet. After this failed, a dredge was brought in to fill the inlet with pumped sediment in 1963. By this time the inlet had become so deep and swift that a single dredge was insufficient and a second dredge was contracted. The two dredges were able to close the breach eighteen months after it had formed.

Like Avon, Hatteras and the low narrow reaches to the southwest were also identified as prone to sound-side flooding during major storm events, but flooding from the sound-side rarely presents the level of danger or structural damage which accompanies oceanic overwash, inlet formation, or high rates of erosion. Although traditionally perceived as flood prone, the width of the island and its vegetative cover at Hatteras were thought to reduce threats from strong winds and overwash. Respondents suggested that the spit southwest from Hatteras village is easily overwashed and represents a high hazard zone (Figure 1).

Rodanthe, Salvo, and particularly Waves were identified as areas subject to interior flooding along roads and lower elevations. Respondents pointed to frequent flooding between the surf zone and N.C. Highway 12 as evidence. This was actually relatively minor episodes of overwash that linger on roadways and impede transportation. Overwash flooding exacts far more damage from corrosion by salt than does typical riverine flooding.

In South Nags Head many locals well understood the benefits of building on the sound side with its wide and well vegetated areas. But they were bewildered by the building of homes along the rapidly eroding beach

The land area between the surf zone and N. C. Highway 12 at Avalon Beach, Nags Head, and at South Nags Head, as well as the entire southern segment of Bodie Island were identified as being at risk from flooding or beach erosion. This assessment was prevalent among the native population at least a decade prior to intensive beach-front development in South Nags Head, mainly between Juncos Street and McCall Court. Many natives of the Outer Banks were bewildered by decisions to build or purchase homes along this rapidly eroding beach front during the late 1970s and early 1980s.

Orrin Pilkey has noted that most of those areas designated safe were also locations of the older 'native' communities on the Barrier islands

Many natives well understood the benefits of building on the sound side where the island was wide and vegetated. In part, the National Seashore exists because residents sold cheaply or generously donated tracts that were perceived too low, too narrow, or too close to the ocean, and therefore too hazardous for settlement. Despite being flooded on occasion, the old villages along the Outer Banks were deemed to be relatively secure from storm hazard compared with ocean-side development. Lifelong residents accepted the inevitable periodic flooding from severe storms. Traditionally they chose not to evacuate even though it was understood that a direct hit from a severe hurricane could decimate most of the villages if it moved very slowly or stalled.

Pilkey notes: "Most of the areas designated as 'safe,' interestingly enough, are also the locations of the older 'native' communities on the barriers! These areas are generally very high, on the wide portions of the barrier, with fairly heavy vegetative cover of maritime forests. On the other hand, much of the more recent development and that currently taking place occurs in areas of highest hazards. Why? Because most of the 'safe' areas have already been developed; areas with serious natural hazards are the last available." (Pilkey et al., 1980).

The Pilkey Hazard Zones

Much of the settlement along the Banks occurs below the ten feet contour and often less than 1,000 feet from the waters edge. High tides driven by gale force winds have frequently flooded the roadways, villages, and new housing developments. Although some structures are located within stable coastal zones, others are located where erosion rates are four feet or more per year; where the island is less than a mile wide; and where flood water from the ocean can overwash the island with sufficient force to erode a cross-sectional slice of sand and create a new inlet.

Several leading works provide us with very sensible guidelines for apprasial of coastal hazard zones (Pilkey and Bush, 1993; Pilkey and Neal, 1980; Pilkey et al., 1980). These works document the conflicts inherent in building in an environment as dynamic and risky as along barrier islands. As an aid to builders, developers and especially buyers in choosing (or avoiding) specific building sites the authors evaluated the risk along the shoreline "from Currituck to Calabash." Each segment is classified as belonging to one of three land use categories: "safe," "caution," and "danger." Classification was based on eleven specific factors: 1) the average rate of shoreline erosion and accretion; 2) slope and width of the beach and character of the nearshore continental shelf; 3) character of the first dune row; 4) degree and extent of overwash; 5) width and height of barrier dune; 6) size and extent of overwash; 7) nature and extent of vegetative cover; 8) size and shape of back barrier estuary; 9) extent of marsh development on sound side of island; 10) estuarine shoreline erosion rates; and 11) inlet history and potential for development of new inlets

Developers and buyers are encouraged to apply the risk categories of 'safe,' 'caution', and 'danger' to a set of eleven land use factors

The criteria were selected to reflect the interdependent processes that link topography, drainage, soils, dune fields, vegetation, inlets, and estuaries. The authors emphasize the advantages of recognizing, accepting, and working within the limits of a balanced natural system so that the beauty and value of our beaches can be preserved indefinitely. Applying these criteria to the northern Outer Banks the authors identify six areas as dangerous building sites: near Corolla, Sanderling, Nags Head to Oregon Inlet, Rodanthe, Buxton overwash to Cape Point, and near Hatteras (Figure 3).

At one time Corolla was the largest village on the Outer Banks between Kitty Hawk and Virginia, but after the second World War the population declined sharply until only a dozen families remained by the late 1950's. After Carolina Power and Light Co. extended service as far north as Corolla in the late 1950s both Duck and Corolla witnessed increasingly rapid growth driven by tourism. In 1990 one of the smaller rental companies for example, Twiddy & Company, boasts in their rental brochure "No one knows the Outer Banks better than we do and the property we manage amounts in value to more than 90 million dollars." Erosion rates near Corolla are six to eight feet per year, the danger of overwash from the ocean to the Albemarle Sound is great during severe storms, and the potential for inlet

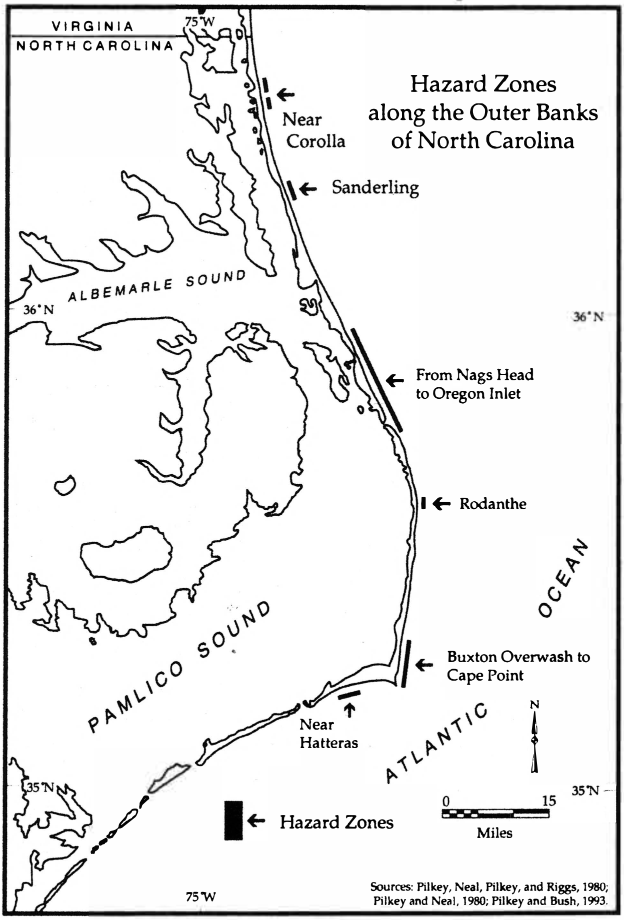

Figure 3. Hazard Zones Along the Outer Banks of North Carolina

formation is high according to Pilkey and Neal (1980).

The Sanderling Hotel at Sanderling is a luxury resort complex built along the lowest and narrowest segment of the North Banks. Formerly Caffey' s inlet, the potential for complete overwash and reestablishment of the inlet is very high during a severe storm. Although the long term risks are great, short term risks are acceptable: erosion rates at Sanderling are only two feet per year.

In the early 1830s Nag' s Head was selected as a summer vacation site by a Perquimans county planter. Since then it has developed into a gateway resort for the million visitors that drive through the Cape Hatteras National Seashore each year. The beaches experience moderate erosion rates (two to four feet per year). There is danger of complete overwash, and the potential for inlet formation is very high near Whalebone junction. South Nags Head has the highest erosion rate of any recently developed area (between four and nine feet per year). Further south and within the Cape Hatteras National Seashore, Coquina Beach looses beach sand at the excessive rate of ten to 22 feet per year. The areas adjacent to the Oregon Inlet are threatened by rapid rates of both erosion and accretion.

The Rodanthe segment has lost as much as 16 feet of beach in a single year, though typical rates are closer to 12 feet per year. Overwash and inlet formation potential are both high. Pilkey reports rates of erosion decrease quickly to the south and overwash potential decreases rapidly to the north.

North of the Cape Hatteras light, the Buxton overwash remains highly susceptible to oceanic overwash. It is still extremely narrow, and endures erosion rates of six to ten feet per year. South from the Cape Hatteras Lighthouse, erosion is removing nearly ten feet per year except immediately adjacent to the Lighthouse where heroic efforts to protect the structure are creating a promontory. The lighthouse would have fallen into the ocean before now had it not been for the dumping of a nearby parking lot onto the beach during a previous major storm. Finally the narrow isthmus between Hatteras Village and Frisco is also vulnerable to overwash and inlet formation.

Findings and Conclusions

Interviews with lifelong residents along the Outer Banks suggest that native perceptions can complement scientific analysis. The perception of hazard zones along the barrier islands of North Carolina are not identical but similar to the legitimately dangerous settlement areas identified by Pilkey and Neal (1980), and Pilkey and Bush (1993). Because the original native settlements were located along the sound side of the islands concern about rates of beach erosion appear to be generally less important to the respondents than might be expected from newcomers with recently purchased beach-front property. Native respondents identified hazardous areas as those with a potential for swift moving flood water, especially overwash and inlet formation. They pointed out the hazards of building permanent structures on Pond Island or along the beach front at South Nags Head long before those areas were developed. Many of the respondents had witnessed the failure engineering solutions such as the Avon Overwash Barrier and the beach-front barrier dune.

By virtue of their observations and knowledge of pervious storms, some of the oldernative residents can provide community leadership and support for hazard zone assessment and prudent growth management policies. As a resource for anyone interested in educating themselves or their students about the implications of storm hazards for land use planning, coastal zone management, or personal safety, the native resident population can be a fascinating and insightful place to begin.

A critical finding of this study is that some older native residents can provide leadership and support for hazard zone assessment and management

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GIS BASED DETERMINATION OF EFFECTIVE STREAM BUFFERS

William J. Holder and Michael W. Mayfield

Introduction

According to the U.S. Environmental Protection Agency (EPA), nonpoint sources of water pollution are among the leading causes of decreased water quality in the United States. Nonpoint sources are the most important source of water pollution in six of the ten EPA regions (EPA 1985). The leading contributor to nonpoint pollution is agriculture, but urban runoff, mining, forestry, and construction produce substantial amounts of as well. It has been estimated that nonpoint pollution costs the nation over $6 billion per year in lost productivity and direct costs of water cleanup (Batie 1985). There are also many associatedsocial and environmental costs that are not amenable to cost estimates.

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Because of rapidly degrading surface water supplies and rapid development of riparian zones of many critical watersheds, the State of North Carolina recently promulgated stringent regulations governing riparian land use in watersheds which supply water for public water delivery systems. This legislation is known as the Water Supply and Watershed Classification and Protection Act. It does not attempt to account for local variations in riparian soils, but rather specifies maximum housing densities in zones adjacent to streams.

In order to protect critical water supply streams and to enhance water quality in stream courses, methods are needed to design effective control techniques for reduction of sediment, nutrient, and chemical loading of streams from nonpoint sources. Vegetated stream buffers have been recognized as useful tools in protecting water quality. Vegetated stream buffers with forest or grass cover have been shown to be highly effective in attenuating nonpoint pollutants in a variety of settings (Field 1985). These strips have been shown to be effective in removing sediment, nutrients, and organic chemicals.

North Carolina's recently enacted law regulating watershed protection is here considered in the context of forest and grass cover as stream buffers

While it has been widely recognized that vegetated buffer strips are effective in a variety of settings, it is difficult to determine how wide such buffers must be in order to achieve specified levels of performance. Phillips' Riparian Buffer Delineation Equation (RBDE) has been shown to be effective in the lowlands of eastern North Carolina (Phillips, 1989a, 1989b, 1989c). The RBDE predicts the effectiveness of vegetative stream buffers in attenuating pollution by

Hydraulic Model

$$B = (K_b/K_r)(Lb/L_r)^{0.4}(S_b/S_r)^{-1.3}(n_b/n_r)^{0.6}$$

Detention Time Model

$$B = (n_b/n_r)^{.6}(L_b/L_r)^{2}(K_b/K_r)^{0.4}(S_b/S_r)^{-0.7}(C_b/C_r)$$

B = buffer effectiveness ratio
K = saturated hydraulic conductivity (centimeters/hour)
C = soil moisture storage capacity (centimeters)
L = slope length or buffer width (meters)
S = slope gradient (percent)
n = Manning roughness coefficient (dimensionless)
b = proposed buffer
r = reference buffer

Table 1. Riparian Buffer Delineation Equations
Source: Phillips, 1989a

examining a variety of physical and edaphic conditions within the buffer area (Table 1). The conditions considered include soil moisture storage capacity, slope gradient, saturated vertical hydraulic conductivity, and surface roughness. This equation could help local areas determine operational buffer widths in their area and the implementation of its findings could help improve water quality in designated areas (Phillips 1989a, 1989b, 1989c).

The first purpose of this project was to extend the use of the RBDE to a far different setting with substantially different topographic and edaphic conditions. Ashe County, North Carolina was selected as a study area because of concerns with local water quality in the New River, a National Wild and Scenic River. The second purpose was to test the use of a Geographic Information System (GIS) to simplify the process of determining the effectiveness of vegetated stream buffers. The utilization of GIS in solving this equation makes it simpler and more powerful than conventional methods, as site-specific terrain variations and soil characteristics can be considered.

Countywide Association-Level Modeling

Buffer effectiveness was first modeled in a general form for the soil associations of all of Ashe County. This preliminary analysis gave a very generalized view of the entire county. Each of the six soil associations in Ashe County was evaluated on the basis of its most prominent soil. Using values provided in the soil survey for slope and hydraulic conductivity, each soil association was tested against a reference buffer.

Reference buffer specification was based on selection of a soil type that had conditions typical of those soils found within the study area. Although the selection of a specific soil type determines the specic values of the RBDE in a study, soils will yield the same ratio of effectiveness to one another regaardless f the reference buffer that is chosen. For this study Toxaway loamwas chosen. It is a soil found commonly in the county, primarily as a floodplain soil along major streams (U.S. Department of Agriculture, 1984). Relevant properties of the Toxaway Loam are listed in Table 2.

Variable	Units
Buffer Width	30 meters
Roughness (Manning's n)	0.45
Slope	11 percent
Hygraulic Conductivity	3.3 cm/hr

Table 2. Reference Buffer Characteristics

Representative slope values for the soil associations were chosen by taking an intermediate value in the slope range for the dominant soil in each soil association from the soil survey. The hydraulic conductivity for each soil association was chosen by taking an average value in the range for the dominant soil in each soil association. As was the case throughout the study, surface roughness was held constant at 0.45 because the county is primarily covered by pasture and forest. In addition, it is assumed that any vegetated buffer would be covered by either grass or forest.

Results of the county level equation are shown in Figure 1. Of the six soil associations, four had buffer effectiveness ratios greater than 1.0, which indicates that these soils were more effective buffers than the reference buffer. The most effective soils were those of the Braddock dominated association, with an effectiveness ratio of 4.7. Other soil associations with ratios greater than 1.0 were the Clifton, Edneyville, and Watauga dominated associations.

Figure 1 shows that the most effective soils are located in the center of Ashe County. These are of Braddock dominated associations with an effectiveness ratio of 4.7

Porters and Evard soil associations had ratios below 1.0, indicating that they are less effective than the reference buffer. The Evard dominated soil association had a very low ratio of 0.27. This is consistent with the steep slopes and low hydraulic conductivity of these soils. The Evard soil association consists primarily of soils on narrow ridgetops and side slopes, and is not favorable for row crops and urban development (U.S. Department of Agriculture, 1984).

Laurel Springs Quadrangle Soil Series Level Modeling

After the very general county-wide buffer effectiveness model was completed, the next step was to incorporate USGS Digital Elevation Model (DEM) data to find more precise slope values. Instead of relying upon average slope values, site-specific slopes were evaluated. These slope values were employed to find buffer effectiveness ratios for the soil series data for a smaller study area, the Laurel Springs quadrangle in Ashe County. For this smaller area, soil series and phases were utilized.

A slope gradient variable was derived by overlaying the slope layer with the soil layer. Three different values were produced. A value for the median slope of every soil series was calculated as well as values for the slopes in the tenth and nintieth percentile for every soil series. Each of these three values for each soil was inserted into the Riparian Buffer Delineation Equation (RBDE).

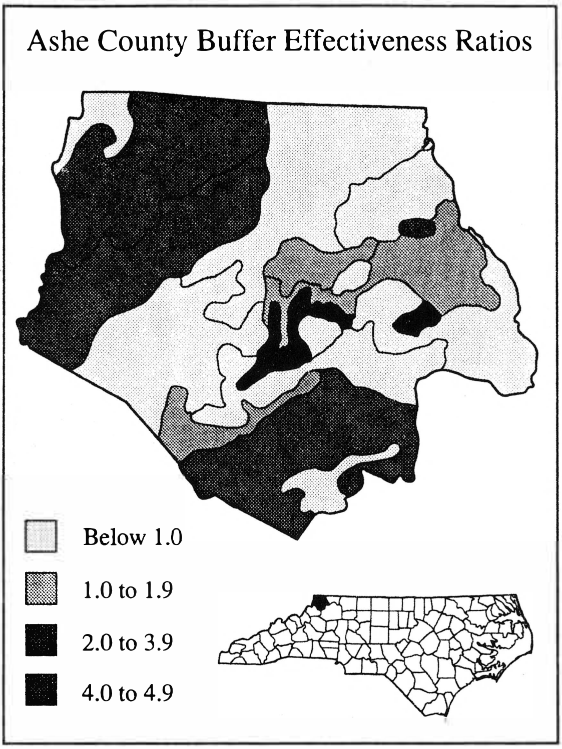

Figure 1. Ashe County Buffer Effectiveness Ratios

Buffer effectiveness ratios were computed for the remaining 17 soil series and phases in the Laurel Springs Quadrangle. Buffer width was held constant with the reference buffer width for this portion of the study. Effectiveness of a buffer with a median slope was modeled first. Of these 17 soils, 12 had a buffer effectiveness ratios greater than 1.0, which indicates that these soils are more effective in buffering pollutants than the reference buffer soil (Table 2). All of the 12 soils that had ratios greater than one have high hydraulic conductivity values (10.16 or 8.38 cm/hr). The buffer effectiveness ratios ranged from a low of 0.27 for the Tusquitee moderate phase to a high of 4.70 for the Colvard fine sandy loam. Colvard soil, being a nearly level floodplain soil, is well suited to agriculture. Its gentle slope suggests why it has a high buffer effectiveness ratio (U.S. Department of Agriculture 1984). The four remaining soils that had buffer effectiveness ratios of less than 1.0 had hydraulic conductivity values that were appreciably lower, at 3.3 cm/hr. A Tusquitee moderate phase soil, which has very steep slopes and low hydraulic conductivity, had the lowest value recorded.

Slopes that fell into the bottom ten and top ten percent of each soil series were next used to compute a buffer effectiveness ratio. The

	Slope Percentile		
	10th	50th	90th
Braddock	16.67	2.87	1.62
Chandler	3.08	1.17	.61
Clifton (g)	6.77	2.06	1.01
Clifton (m)	6.77	1.75	.84
Colvard	28.24	4.67	1.06
Evard Stony	2.48	1.06	.54
Evard (m)	1.30	.49	.27
Evard (s)	1.13	.43	.22
Fannin (g)	6.77	2.25	1.06
Fannin (m)	5.54	1.62	.80
Toxaway	5.41	1.00	.96
Tusquitee (g)	2.20	.67	.28
Tusquitee (m)	.53	.27	.19
Tusquitee/Spivey	2.48	1.51	.64
Watauga (g)	6.77	2.25	.96
Watauga (m)	4.00	1.62	.84
Watauga (s)	3.48	1.33	.68

phases
g = gentle m = moderate s = steep

Table 3. Buffer Effectiveness Ratios
Source: U.S.D.A. Soils Conservation Service, 1984

slope values for this tenth percentile were appreciably lower than the median, and thus buffer effectiveness ratios were higher (Table 3).Only one soil, the Tusquitee moderate phase, had a buffer effectiveness ratio that was less than 1.0. The high value was once again the Colvard fine sandy loam, with a buffer effectiveness ratio of 28. The slopes of the nintieth percentile were studied for each soil. These slope are steeper than the median slopes, and thus buffer effectiveness ratios are lower. In this computation only 4 of the 17 soils had buffer effectiveness ratios greater than 1.0. This confirms that the steeper the slope, the less effective a riparian buffer will be at attenuating pollutants.

There is a substantial range of buffer effectiveness ratios under all slope conditions, for the most and least effective soils. This indicates that no set standard vegetative buffer would be effective in all situations unless it was a worst-case buffer. A buffer of typical Evard soils would have to be well over 100 meters wide to be as effective as a 30-meter Tusquitee or Toxaway soil. The cost of uniformly choosing such a wide buffer would be prohibitive and it is rarely necessary.

Pixel Level Buffer Delineation

The next step in the study was to overlay the slope file, created by manipulating a Digital Elevation Model, with a layers representing the remaining variables in the hydraulic version of the RBDE. An ERDAS program, GISMO (GIS MOdeling), was employed to do the computations (ERDAS, 1991). The output file created in the GIS gave buffer effectiveness values for each pixel. These values ranged from a low of 0.1 to a high of 67.0. The values were then lumped into four categories to facilitate interpretation. The new categories placed all pixel values with buffer effectiveness ratios below 1.0 in the first category, 1.0 to 1.9 in the next category, values from 2.0 to 5.9 in another, and values above 6.0 in the final category.

Some significant patterns emerged from the resulting map. A cluster of effectiveness values above 6.0 is located in the Colvard dominated area near the confluence of the South Fork of the New River and Peak Creek. Another cluster of high buffer effectiveness ratios is located near where Cranberry Creek meets the South Fork. A third cluster is located near Laurel Springs, where Wolf Branch meets Cranberry Creek. All three of these areas are in the floodplains of streams and have Colvard soils. There is a fourth area of near-level slopes at the confluence of Peak Creek and a tributary stream near the community of Transou. Because it is dominated by Toxaway soils, which have much lower hydraulic conductivity values, it has lower buffer effectiveness ratios. There are also patterns of low buffer effectiveness ratios which correspond to the areas near mountain peaks, such as Rattlesnake Mountain and Peach Bottom Mountain. Both slope and hydraulic conductivity exert considerable influence over buffer effectiveness, as areas with low hydraulic conductivity or steep slopes have consistently low buffer effectiveness values.

Stream Corridor Study

One of the purposes of this study was to determine if the soils near streams would function as effective buffers. The last phase of the study involved isolating the 100-meter riparian corridor. A buffer map was created by first digitizing all of the perennial streams in Ashe County, as indicated by solidblue lines on a 1:24,000 quadrangle maps. Next, a search program created a 100 meter buffer around each of the streams. This file was overlaid with the file of the recoded four category buffer effectiveness ratio map. By doing this, the area within the buffered area could be highlighted and studied.

An important issue for this study is whether soils near streams will serve as effective buffers. On the following page Figure 2 demonstrates significant variation in buffer effectiveness

Figure 2 represents a subset of the pixel-level analysis of the 100-meter riparian corridor in the Laurel springs Quadrangle. There are a few areas within this corridor that have clusters of buffer effectiveness ratios below 1.0. These clusters occur primarily near the South Fork of the New River, rather than the adjacent tributary streams. The largest cluster was located near the South Fork as it was leaving the Laurel Springs quadrangle toward the north. This cluster emerged for two reasons. The part of the cluster on the south and east sides of the South Fork produced low buffer effectiveness values because the slopes in that area were quite steep, approaching 80 percent. Hydraulic conductivity did not have any effect on the low buffer effectiveness values because the Evard stony loam soils which dominate the area have high hydraulic conductivity values. The north and west sections of the South Fork in this small area also had buffer effectiveness ratios below 1.0, but the slopes on that side of the stream were much gentler. The reason for the low values was that the Tusquitee and Evard soils have much lower hydraulic conductivity values than the other soils.

Christmas tree farming in Ashe County and the related herbicide usage increases the possibilities for chemically polluted streams

Detention Time Model Study

Because of the increased land area devoted to Christmas tree farming in Ashe County and associated herbicide usage, there are increasing possibilities for chemical pollutants to enter streams. The detention time version of the Riparian Buffer Delineation Equation (RBDE) is "...based on how long a given imposed flow is detained within a buffer, and is applicable to nonconservative pollutants such as nutrients, bacteria, and oxygen demand" (Phillips 1989a). Subsurface flow is considered in this version. In the detention time version, subsurface flow is analyzed through the use of soil moisture storage capacity, which is an indicator of the ability of a buffer to assimilate infiltrated water. The equation is based on a buffer' s ability to attenuate pollution by detaining or delaying it in the soil.

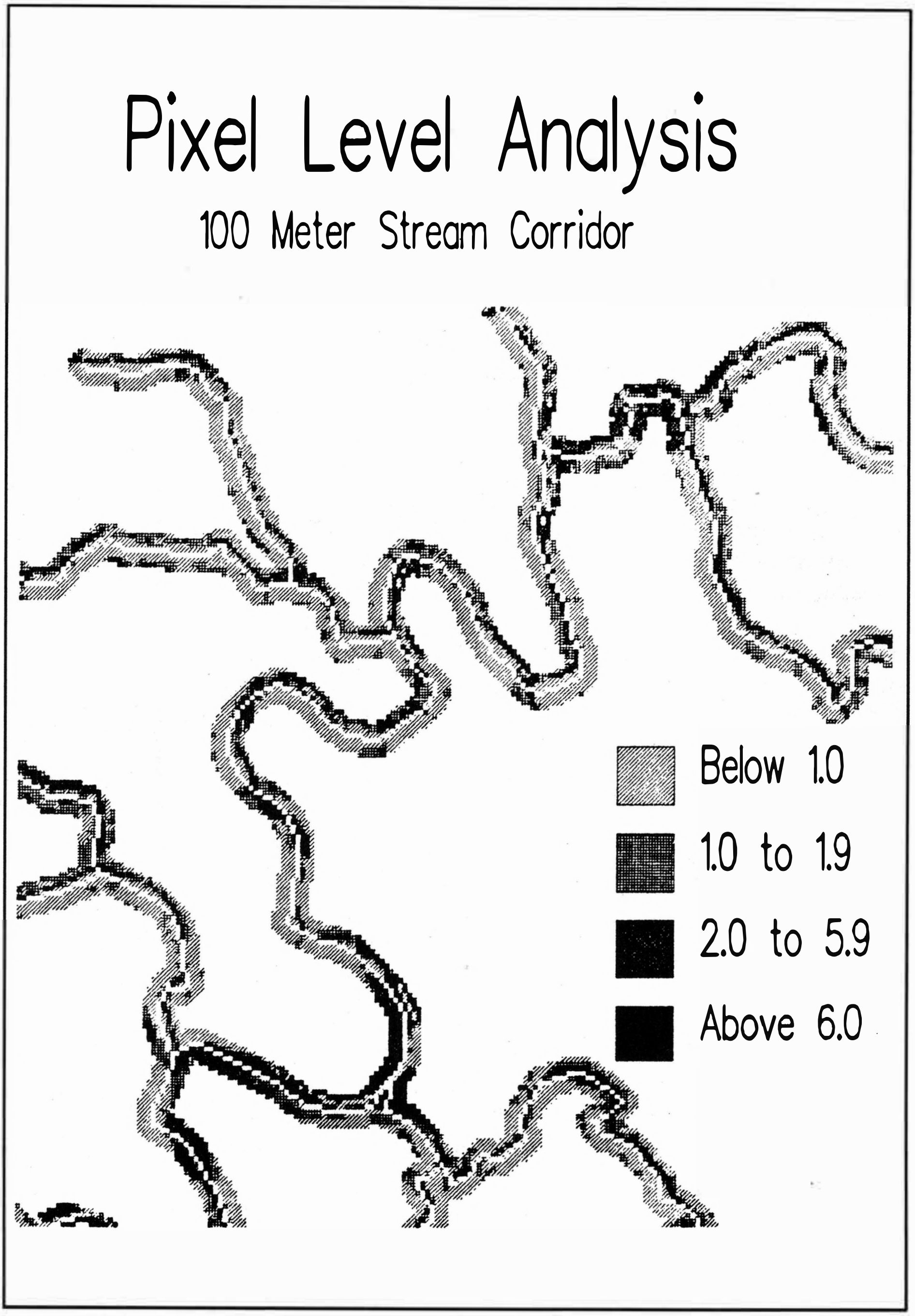

Figure 2. Pixel Level Analysis, Laurel Springs Quadrangle

A pixel level calculation of the detention model was made using the 100-meter area near the perennial streams. Using this version of the equation, few areas had buffer effectiveness ratios above 1.0. The buffer effectiveness ratios for the detention time version range from values just below 1.0 to values of approximately 5.0. The range of values is much lower for the detention time version than the hydraulic version. This reveals that most of these soils are ineffective as buffers of such pollutants as agricultural herbicides.

Conclusions

This approach to modeling riparian buffer effectiveness ratios in a mountain setting has shown that there are significant variations in buffer effectiveness. These differences are due to the substantial variations in terrain and edaphic factors present in any mountain setting. Utilization of Geographic Information System techniques has provided a high level of precision in in specification of site-specific topographic and edaphic variables. In addition, spatial patterns of buffer effectiveness became apparent because the RBDE equation was solved on a pixel by pixel basis.

In planning for the protection of aquatic resources, these variations must be accounted for and incorporated into the decision making process in order for riparian buffers to be effective. Operational buffer widths must be situation specific, depending on the edaphic and topographic conditions.

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THE SPATIAL SCALE OF DAILY PRECIPITATION IN NORTH CAROLINA

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Introduction

One of the major geographical characteristics of precipitation is its spatial pattern. Many studies have described and explained the spatial variation of monthly and annual precipitation totals in various regions. For North Carolina these patterns, clearly demonstrating such phenomena as the orographic effect or the influence of sea breezes or coastal storms, are well established and underpin much of our concept of the climate of the state (e.g. Kopec and Clay, 1975). Much less is known, however, about the pattern of precipitation on the daily time-scale. Individual daily conditions are routinely considered by the National Weather Service for forecasting purposes, and this has led to an informal classification of precipitation into two types (Robinson and Henderson, 1992). First are the cyclonic days associated with widespread, often gentle rainfall from travelling depressions. Second are the convective days with localized, frequently intense, precipitation from short-lived thunderstorms. The relatively infrequent visits of tropical systems to the state are frequently a mixture of these two types, and are not considered separately here. It can be suggested that the cyclonic days should dominate in winter, and that there should be a mixture of cyclonic and convective activity in summer (Epperson et al., 1989). In addition, topographic effects should lead to differences between the mountains and the rest of the state. Thus, on the average, there should be different patterns of daily precipitation between winter and summer and between the mountains and the lowlands. The focus of this paper is to investigate these seasonal and topographic differences in daily precipitation patterns. In more personal terms, it considers the question "If it is raining at my location, what is the probability that it is raining at another place in the state which is of interest to me?"

On the average there should be different patterns of daily precipitation between winter and summer and between the mountains and the lowlands. This paper looks at these seasonal and topographic differences

On a more personal level the question considered here is: "If it is raining at my location, how likely is it that it is raining somewhere else in the state in a place of interest to me"

The spatial pattern of daily precipitation is established through consideration of the conditional probability of precipitation at two stations a known distance apart. This, extended to include all of the stations in North Carolina, allows two direct measures of the spatial pattern. First, by development of a relationship between probability and inter-station distance it is possible to determine the overall probability that it will rain on the same day at any two points a known distance apart. This indicates the spatial scale of the daily precipitation. The second approach is to consider conditions at a single selected station and map the probability that it will rain anywhere in the state on a day when it is raining at the selected station. Both approaches are considered here. Neither consider the amount of precipitation which might fall, only whether or not any falls on that particular day.

Data and Methodology

In order to investigate the influence of topography on daily precipitation patterns, the state was divided into "mountain" and "lowland" zones. The eastern edge of the Blue Ridge portion of the Appalachian Mountains provided the primary separation, with the mountain zone to the west. Traditionally the area to the east is geographically divided into the rolling Piedmont sloping gently eastward for approximately 200 km before reaching the much flatter and low-lying Coastal Plain. Nevertheless, both of these regions are distinctly flat and low-lying in comparison to the western mountains and were treated as a single region here.

Precipitation information was obtained from "Climatological Data" published by the National Climatic Data Center (NCDC) (Hatch, 1983). Analyses were undertaken on a seasonal basis, with summer (June, July, August) and winter (December, January, February) being used here. The year for the winter is that of the appropriate December, with the addition of January and February from the following year. Stations with more than 4 missing daily observations for the season were excluded from

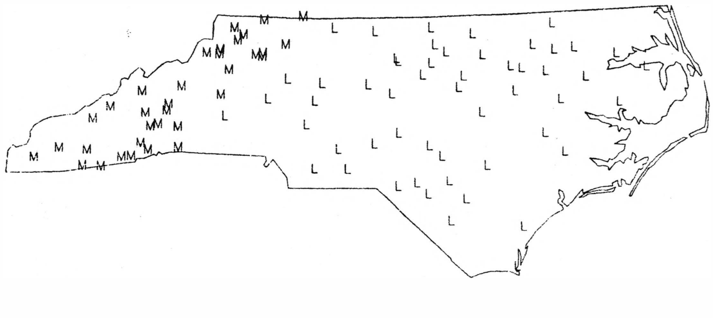


Figure 1. Location of North Carolina Climatological Test Stations for This Study

the analysis. Days with a "trace" of precipitation were included as wet days. Only those stations taking observations within an hour of 7 a.m. were usedhere (Figure 1). Data for the 1980-1985 period were used. All stations with data for at least five of these six years were used. Thus the amount of information used was maximized, although as a result the station distribution did not come close to approaching a uniform grid. In particular, the station density in the mountains is much greater than that in the eastern part of the state. However, it was anticipated that the errors introduced by this were smaller than those which would occur if a more regular grid of stations with a mixture of observations times were used. The topographic separation was established by using the Climate Division information provided by NCDC. Each Division is a collection of observing stations which represent an area of relatively homogeneous climate. In North Carolina, Divisions 1 and 2 represent the mountain climates, and stations in these divisions were assigned directly to the mountain region. The actual number of stations in each region varied slightly with time, but there were about 2750 station pairs in the lowlands and 1500 in the mountains.

The 1980-1985 period was chosen since it had a reasonably stable station network and also provided a wide range of wet and dry periods. Rankings (Table 1) were determined using the seasonal climatic division precipitation averages for the 1890-1990 period. The rankings were expressed in deciles to give general indications of precipitation amounts since, given the varying number and location of stations used in the development of the relationships here, more refined ranking were not appropriate.

Year	Summer		Winter	
	Mts.	Low.	Mts.	Low
1980	1	1	1	1
1981	1	5	10	10
1982	5	5	7	8
1983	1	1	9	9
1984	6	5	2	4
1985	8	8	1	1

Table 1. Deciles of Precipitation Amounts Derived From 100 Years of Record (1890-1990)
(1=driest; 10=wettest)

The first step in the analysis was the identification of the conditional probability of precipitation for each station pair. For each season the number of days with precipitation at both stations, pb, the number of days with precipitation at station 1 only, p1, and the number at station 2 only, p2, was determined. The probability of precipitation at station 2, given that it is raining at station 1, P12, was given by

$$P12 = pb/(pb + p1)$$

Similarly: $P21 = pb/(pb + p2)$

In order to determine the spatial scale of daily precipitation all station pairs were analyzed as a function of distance d between stations. Inter-station distance was determined using standard techniques from the station latitude and longitude coordinates given in Climatological Data. The nature of the relationship between the probability Pij of precipitation at station j, given that precipitation is occurring at i, and the station separation distance dij is not well established. Some tentative results based on correlations of daily amounts have been suggested (e.g. Berndtsson, 1989) but there is no recognized model for the simple rain/no rain approach required here. A preliminary analysis, using both a subset of the present data and a comparable data set for Colorado, indicated that a logarithmic function was appropriate (Robinson, 1993). Not only did this reproduce the distance decay shape at short distances, but it also indicated a nearly constant probability at large distances. This latter probability approached values around 0.5. Without any consideration of conditional probabilities, individual stations have a probability of precipitation of approximately .30, so that the slightly higher values for the conditional probabilities at large distances suggested by the logarithmic model appear reasonable. Consequently a model of the form:

$$P_{ij} = a + b \ln(d_{ij})$$

was used for the analysis of the full dataset.

We selected individual stations with at least some rain measurable for a day and with the probability of precipitation at all other stations

The spatial pattern of daily precipitation was determined using straightforward mapping techniques. A single station was selected as the prime station and the probability of precipitation at all other stations, given that it was raining at the prime station, was determined. Probability contours were then calculated and the results mapped. The mapping procedure used the SURFER software package on an IBM PC. This uses a three stage process. In the first the irregularly spaced station data were converted into a regular grid of points. This provides an opportunity to minimize the influence of the irregular station spacing, with its tendency to have a wider spacing in the east of the state. Thus several grid spacings and interpolation procedures were tested, before a 25 x 20 grid with an inverse distance weighting scheme was chosen. In the second step these gridded data were smoothed using a cubic spline an attempt to reduce further the impact of the irregular network and to minimize the influence of any single, possibly aberrant, station. Finally, an inverse distance weighted interpolation was used to develop the contours from the smoothed gridded data. Although these procedures minimize the influence of an irregular network of stations, they do not eliminate it completely. Thus, for example, while it can be anticipated that spatial patterns will be smoother in the southeast than in the northwest because of topographic differences, part of this may arise from network density differences. The results must be regarded as general estimates, not as definitive statements.

No distinction was made in this spatial analysis between the mountain stations and the others. Theoretically any station could be chosen as the prime station. Here, there were two overriding concerns, investigation of the differences in patterns between mountain and lowland sites, and investigation of the stability of the patterns when comparing closely spaced stations. Consequently two groups of three stations were chosen for analysis. In the mountains these were Banner Elk, Boone, and Blowing Rock, while Enfield, Scotland Neck, and Tarboro were used in the lowlands.

Results

Rainfall probability within shorter distances from where it is actually falling is about the same for mountains and lowlands for the winter. But for the summer, as shown in Figure 2, the probability for the mountains decreases more rapidly with increasing distance

For North Carolina as a whole, there was a distinct difference in the spatial structure of daily precipitation between summer and winter (Figure 2). The probability of precipitation occurring at a point a given distance away from a station where precipitation is already occurring was higher in winter than in summer. The two seasons were closest at the shortest distances, with differences increasing rapidly at distances up to about 75 km and more slowly thereafter. This was consistent with the hypothesis that winter has more raindays, giving the overall higher probabilities, and that cyclonic rainfall, giving more widespread rain, is more prevalent. The only differences between the mountains and the lowlands in winter was at short distances, where the mountains had lower probabilities. It can be postulated that topography served to produce a more scattered precipitation pattern within the overall widespread rainfall than was the case in the lowlands.

In summer, however, the topographic differences were much more marked. The lowlands had a very high probability at short distances, but a very rapid decrease. These clearly reflect a localized, convective dominance. The mountain conditions were rather similar to those for winter, except that the lower overall probability reflected the lower number of raindays. In general topographic effects appeared to overshadow seasonal ones in the mountains whereas the opposite was the case for the lowlands

The year-to-year differences can be investigated by considering he results of the model for a specific inter-station distance. A convenient example is a spatial scale of 300 km, since this is near the upper limit of the actual observations while also being sufficiently large that the model is likely to be approaching a nearly flat condition (Figure 2). The year-to-year scatter of points was much smaller in winter than in summer, again

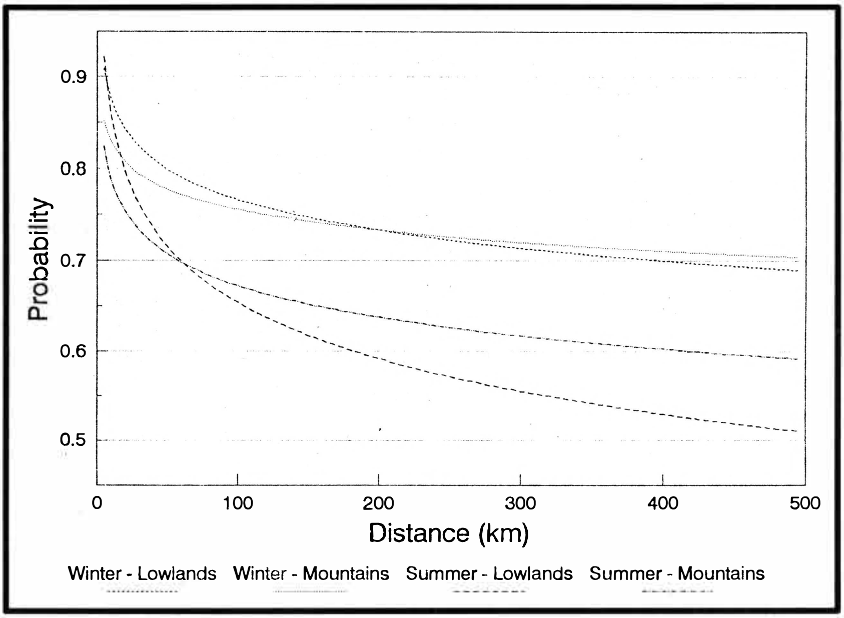
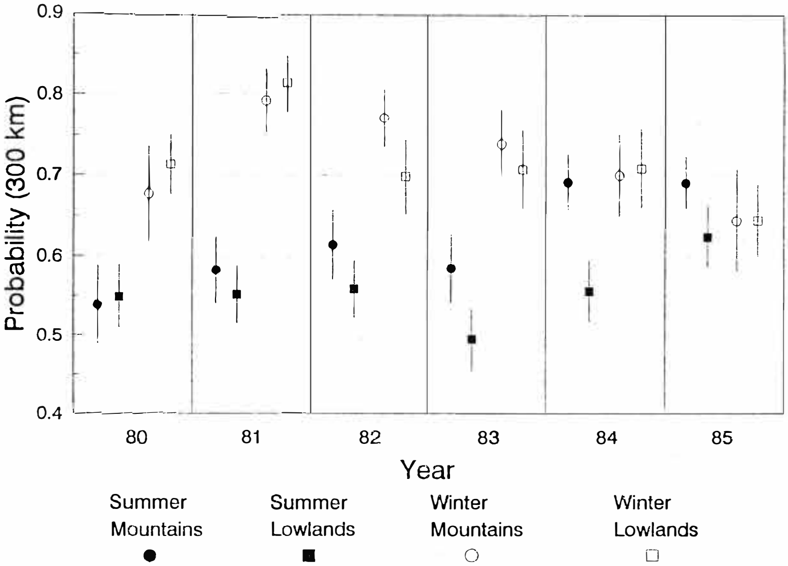


Figure 2. Probability of Precipitation With Increasing Distance From a Point Where Precipitation is Actually Occurring; North Carolina by Season and Topography

in accordance with the observation that summer precipitation is more variable (Epperson et al., 1989) and the concept that pseudo-random localized convective events have major importance in this season. Thus the probability of precipitation at any point given that it is raining 300 km away was commonly in the 0.5 - 0.7 range in summer, 0.7 - 0.8 in winter (Figure 3). In virtually all summers the probabilities were higher in the mountains than in the lowlands. Several differences were considerably greater than the range of Pij given by incorporating the standard error of the estimates of a and b, indicating a highly significant topographic contrast. This reinforces the suggestion that orographic effects in summer lead to widespread uplift and precipitation in the mountains, a process absent in the lowlands. The least difference occurred in 1980, a major dry year in both areas. The differences between topographic regions in winter were much less marked, and varied in direction. Only in 1982 was the difference significant, with the lowlands once again having a lower probability. This was a reasonably wet year, but other years with similar amounts did not give similar differences. Again this supported the hypothesis that the winter precipitation events are more widespread and evenly distributed across the state irrespective of topographic considerations.

The spatial distribution of the probabilities of precipitation given



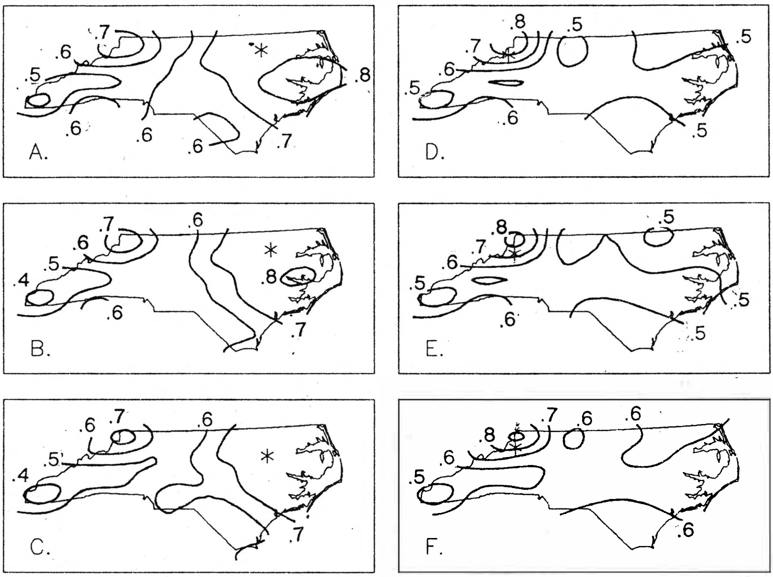
Vertical lines represent the range indicated by the standard error of the logarithmic regression

Figure 3. Probability of Precipitation 300 Km From a North Carolina Station Where Precipitation is Occurring.

that it is raining at a selected station obviously depends on the station chosen and the season and year used. Conditions for 1982, when both summer and winter were neither particularly wet nor particularly dry (Table 1), were used with the six primae stations as an example here. Examination of other years indicated that 1982 was a reasonably typical year.

In summer the three lowland stations (Figure 4, a-c), located in the north central portion of the lowlands, all indicated probabilities above 0.7 for virtually the whole of the eastern third of the state. Values generally decreased westward, but in the mountainous western third there was a distinct north-south gradient, with high probabilities in the northwest and low ones in the southwest. The pattern for each station was similar suggesting that the results are of applicability through a region much wider than that of a single station. All displayed the general decrease in conditional probability with distance, producing a longitudinal gradient through much of the state, with a marked latitudinal one in the mountains.

The three northwestern mountain stations showed a rapid decrease in probability towards the southwest in summer (Figure 4, d-f). This distribution was reminiscent of that of the lowland stations. Further, all the mountain stations also gave relatively uniform probabilities throughout the lowlands. Values were below 0.5 in the southeast and northeast, and slightly above this in the center. The pattern differences between the three stations were somewhat greater than for the lowland sites, as would be anticipated given the addition of orographic influences in the mountains. Nevertheless, the mountains results indicated a decrease in probability



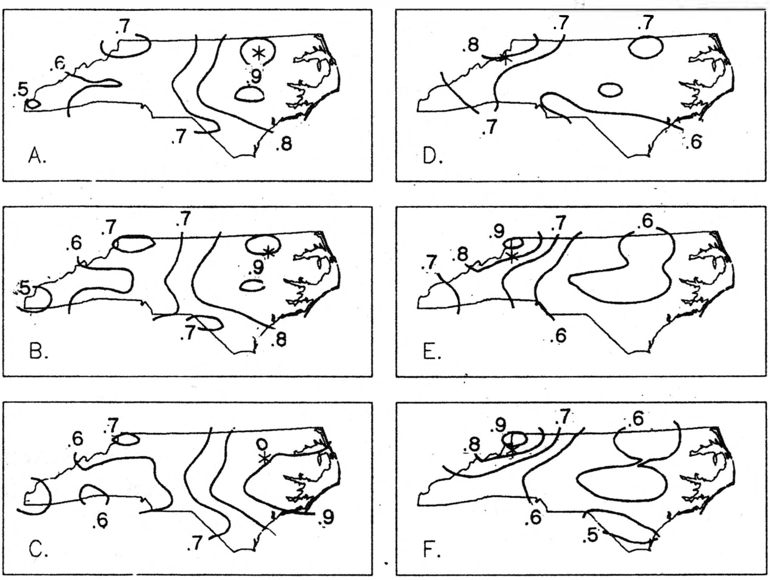
Stations, marked by asterisks, are: (A) Enfield; (B) Scotland Neck; (C) Tarboro
(D) Banner Elk); (E) Blowing Rock; (F) Boone

Figure 4. Spatial Distribution of the Probability of Precipitation on the Same Day

with increasing distance, but superimposed on this was an east-west alignment of the probabilities, possibly reflecting the tendency for storms to cross the state from west to east.

In winter the east-west alignment was much less marked and the overall probabilities were higher throughout the state. The three lowland stations had values in excess of 0.8 for much of the eastern third, and above 0.6 for the whole of the lowland region (Figure 5, a-c). The north- south gradient in the mountains as found in summer was also apparent, but less steep, in the winter.

commonly were below 0.6, but there appeared to be a slight rise in the central portion of the lowlands. Other years (not shown) also suggested this slight rise. This could be the result of a preferred location and track for winter storms, a track possibly induced by the alignment of the Appalachians, or it could be an artifact of the station distribution and interpolation schemes used. This seeming anomaly, however, needs



Stations, marked by asterisks, are: (A) Enfield; (B) Scotland Neck; (C) Tarboro
(D) Banner Elk); (E) Blowing Rock; (F) Boone

Figure 5. Spatial Distribution of the Probability of Precipitation on the Same Day in Winter, 1982, Given the Occurrence of Precipitation

further investigation.

In both seasons the three stations in the mountain group had similar patterns, as did the three stations in the lowland group. The minor differences within each group were most marked in summer, when the spatial scale of the precipitation is shorter, and hence such differences could be anticipated. Further the patterns for all stations were similar, indicating that the probabilities are rather stable, with steep gradients in the mountains, much less steep ones in the lowlands. It would appear, therefore, that the selection of a particular station is not too critical and that the present results can be generalized to suggest the probabilities of precipitation in one area given that it is raining in another.

Conclusions

The development of conditional probability distributions for the occurrence of precipitation on a daily basis is a straightforward process. The present results indicated that there was a logarithmic relationship between the conditional probability and inter-station distance. The method, and the resultant relationship, constitutes a convenient method of quantifying and summarizing the spatial scale of individual daily precipitation events. In North Carolina precipitation is likely to be much more localized in summer than in winter. Moreover, particularly in summer, widespread precipitation is much more likely to occur in the mountains than in the lowlands. While these conclusions could be anticipated from a consideration of the general climatology of the state, the present results extend this by indicating that topographic effects are more important than seasonal differences in the mountains whereas seasonal variability dominates in the lowlands.

The topographic division of the state appeared to exert relatively little influence on the pattern of probability of precipitation given that it was raining at a particular station. For mountain stations in winter there appeared to be some steepening of the rate of decrease in probability with distance was the lowlands were approached. In summer there were also indications that regions of high probabilities were elongated in an east- west direction, possibly a result of the location of the common storm tracks. While no firm conclusions can be reached when only six stations for one year are analyzed, it appears that the patterns are stable, and that it is possible to determine the probability of rain in one area given that it is raining in another.

In spite of the relatively small sample of six stations it is possible to conclude, that the probability of rain in one area given that it is raining in another can be determined

Year-to-year variability in the spatial scale and distribution of the precipitation is considerably more marked in the summer than in the winter. From the small sample investigated here, it is difficult to establish relationships between the patterns and either the global atmospheric flow patterns which produce them or the total precipitation amounts which result. Nevertheless a fuller analysis should provide insights leading to increased understanding of the nature and causes of the spatial distribution of precipitation in North Carolina.

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NORTH CAROLINA NOR'EASTERS AND THEIR RELATED STORM HAZARDS

Jack Hidore

Introduction

Some natural events occur in our environment which last but a short time, with a life span of days or even seconds. When these unusual events affect humans adversely we refer to them as natural hazards. Most hazards fall into two categories, those resulting from the dissipation of energy in the earth's interior and those resulting from atmospheric imbalance of energy. Geologic hazards, such as earthquakes and volcanic eruptions are not such a problem in North Carolina since the state lies over a relatively stable crustal plate. Many small earthquakes occur but there are no known injuries recorded from earthquakes in the state. There have been no active volcanoes in the region since long before the time the human species evolved.

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In North Carolina the natural hazards which cause the greatest number of casualties and greatest dollar damage are atmospheric (Hidore, 1993). There are four main storms which affect North Carolina. They are the tropical cyclone, the extratropical cyclone, the tornado, and thunderstorm. Tropical cyclones have caused more deaths and more damage than the other storms (Table 1). This is changing rapidly in terms of casualties. Forecasting of life threatening storm systems is becoming more reliable. In the last several decades casualties due to tropical cyclones has dropped rapidly. In the United States, there are good detection and warning systems for both tropical and extratropical cyclones. North Carolina benefits from these warning systems. There are several days advance warning on the approach of hurricanes, and usually a day or two warning of the approach of a severe extratropical cyclone. The last major hurricane to severely affect North Carolina was Hugo in 1989. The path of the storm took it across the west-central part of the state from near Charlotte north-west to the Virginia border. Substantial warning time was made available to those living along the coast of North and South Carolina. As a result of the warnings and requests to evacuate, a large part of the population did leave the coastal region and move inland. It was unfortunate in one respect that many of those evacuating coastal areas traveled to Charlotte which was itself severely impacted by the storm. Even under these circumstances there were a minimal number of deaths and injuries. These storms continue to be the leading cause of damage.

North Carolina's major natural hazards are its storms, including tropical cyclones, extratropical cyclones, tornados, and thunderstorms

The Nor'easter-Physical Characteristics and Hazards

One of these four storms, the extratropical cyclone occurs more frequently than hurricanes and consistently causes death and destruction. Extratropical cyclones are depressions that develop along the subpolar front. They also develop over warm currents of water in midlatitudes particularly along the east coasts of North America, Asia, and South Africa. Many of these low pressure systems form over the Great Plains east of the Rocky Mountains in Texas and Oklahoma or over the Gulf of Mexico. They track eastward fed by latent heat of evaporation from the relatively warm Gulf. The storms are carried eastward over the Appalachian Mountains and then northward along the Atlantic Coast. These east-coast lows are also called Hatteras lows or Nor' easters. They are again fed by large quantities of energy from the Atlantic Ocean through the latent heat of evaporation. The Blizzard of 1993 was the result of such an extra-tropical storm. The storm began as a weak low-pressure system over the western Gulf of

Fatalities		
1955	August 7-21	Hurricane Diane. 400 fatalities, many in North Carolina.
1940	November 11-12	Blizzard. 144 casualties, many in North Carolina.
1984	March 28	Tornadoes in North and South Carolina. 67 fatalities and over 800 injured.
1955	August 12-13	Hurricane Connie. 43 fatalities.
1993	March 12-14	Blizzard. 16 fatalities.
1936	April 2	Tornado in Greensboro. 13 fatalities and 144 injured
1989	September	Hurricane Hugo. Two fatalities and an unknown number of injured in the state.
Damage		
1989	September	Hurricane Hugo. $1 billion in North Carolina.
1977	November 6	Floods in the Appalachian Mountains. $280 million.
1954	October 15	Hurricane Hazel. $136 million.
1984	March 28	Tornadoes. $100 million.
1993	March 12-14	Blizzard. $100 million.
1972	June 21-26	Hurricane Agnes

Table 1. Significant Natural Hazards in North Carolina Base on Fatalities and Damage

Mexico on March 12. It intensified quickly as it moved eastward. The center of the low pressure system crossed the panhandle of Florida and moved northeastward over the mid-Atlantic States. Figure 1 shows the path of the storm and its position at six hour intervals.

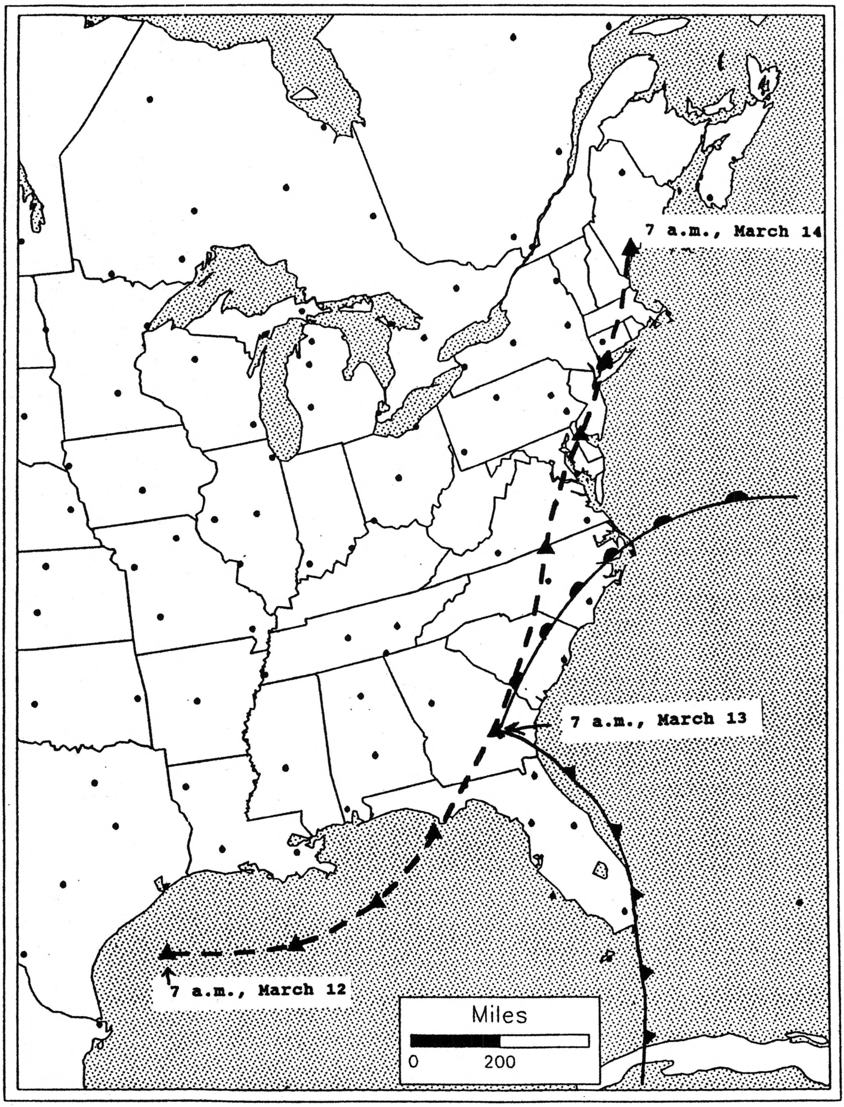


Figure 1. Track of the Storm Resulting in the Blizzard of 1993, and the Location of the Fronts on March 13 and 14.

Because of the intensity of these storms they develop elements which become hazardous. Table 2 enumerates some of these attributes. These storm elements subsequently often have a very serious impact on the state of North Carolina. In terms of frequency of fatalities and damage the impact of these storms is substantial. The primary reason for this is that there are more of these storms than there are hurricanes. Over a period of 42 years over 1300 nor' easters were identified along the Atlantic Coast. This averages about 31 storms each year. For instance, the year 1992 was an unusual year for catastrophic loss in the United States. Average insurance payouts for catastrophic losses in recent years has been about $5 billion. Insured losses in 1992 totaled a record $22 billion. Much of the damage was caused by Hurricane Andrew, but December nor' easters cost the insurance industry over $1 billion (Snyder, 1993).

High wind velocities
High waves on the coast
A high storm surge along the coast
Excessive rain and flooding
Flooding
Heavy snowfalls
Ice storms
Severe Thunderstorms
Thundersnows or snow blitzes
Blizzards
Severe cold

Table 2. Hazards Associated With Extra-Tropical Cyclones

Most individual nor' easters do not affect the entire Atlantic Coast, but some do. The ones most likely to affect the length of the coast are the Hatteras lows. Many nor' easters affect North Carolina, and some affect all parts of the state. They can cause severe problems from the Atlantic Coast to the Appalachian Mountains. Table 3 itemizes some of ways in which these storms impact the state.

Fatalities
Injuries
Beach Erosion
Damage to beach front property
Airport closings
Highway closings
Power outages
Telephone outages
School closings
Business and industry closings
Livestock losses
Structural damage due to winds and heavy snow
Loss of trees and shrubs
Damage to roads and bridges

Table 3. Impact of Extra-Tropical Lows in North Carolina

Wind Velocity and Wind Damage

When upper atmospheric conditions support the development of the extratropical low, the system can develop the structure of a tropical cyclone, with very low pressures in the center and even a recognizable eye. The storm producing the blizzard of 1993 was just such a storm. Record low pressures were recorded along the track of the low. Table 4 provides some of the pressures that were recorded during the passage of the storm over the state. Note that most of them are below 29 inches. Some pressures were less than those recorded from hurricanes that have affected North Carolina. The average station pressure at Raleigh/Durham

Airport is 29.6 inches. Records of pressure have been kept there since 1951. At 2:30 PM, Saturday, March 13, the pressure at the airport dropped to 28.6 inches. This is the lowest pressure recorded since records began. The previous low was 28.75" set in October 1954 when Hurricane Hazel passed over the area.

High velocity winds are produced by the steep regional pressure gradient and by severe thunderstorms and tornadoes imbedded in the system. As a result of the steep pressure gradient around the center of the low, winds of hurricane velocity may be generated. Even though the wind may have a sustained velocity below 75 miles per hour, gusts may go substantially higher. The high wind velocities and persistent direction of the wind produce hydraulic surges and high waves which cause excessive damage to beaches and to beach-front property.

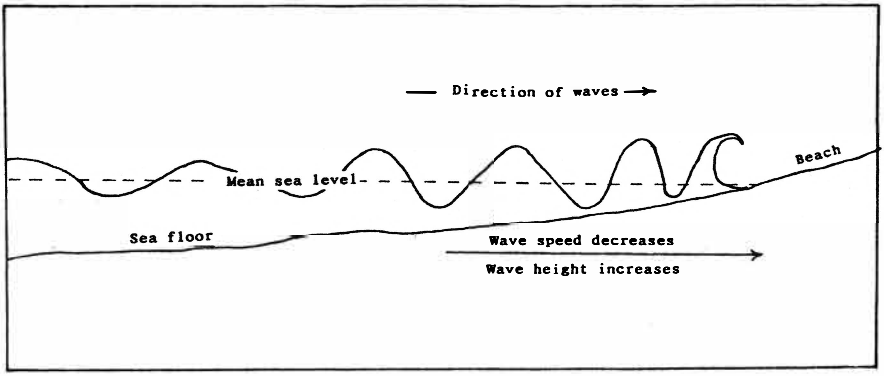
	Saturday 10 AM	Saturday 11 AM	Sunday 10 AM
Western			
Ashville	M	28.90 F	30.02 R
Hickory	28.94	28.87 F	30.02 R
Central			
Charlotte	28.81 F	28.73 F	30.02 R
Greensboro	28.95 F	28.83 F	29.94 R
Raleigh-Durham	28.88 F	28.82 F	29.96 R
Fort Bragg	M	28.64	29.97 R
Fayetteville	28.82 F	28.73 F	30.00 R
Northeast			
Elizabeth City	29.09 F	M	29.82 R
Manteo	29.22	29.03 F	M
Cape Hatteras	29.15 F	29.05 F	29.89 R
Southeast			
Goldsboro	M	28.76 F	29.95 R
Kingston	28.95 F	28.80 F	29.96 R
New Bern	28.88 F	28.90 F	29.97 R
Cherry Point	M	28.86 F	29.92 R
Jacksonville	28.82 F	28.83 F	30.00 R
Wilmington	28.88 F	28.80 F	30.01 R

Table 4. Barometric Pressure on Saturday, March 13 and Sunday, March 14, 1993

Nor'easters may result in waves up to 20 feet above the storm surge with a related sea floor effect that is dramatized in Figure 2

The storm surge is a characteristic of both the hurricane and the extratropical cyclone. It is perhaps best known in conjunction with the tropical cyclone, but it is equally significant in connection with the extratropical cyclone. The storm surge is an elevated sea surface that may reach up to 20 feet in extreme cases. This storm surge occurs near the center of the storm and in the sector where the winds are moving in the same direction as the storm. Surges result from several processes including wind set up, decrease in atmospheric pressure in the storm center, the speed of the storm system, the wind speed within the storm, the steepness of the continental shelf, and the shape of the coastline. Storms surges in excess of three feet are common along the Carolina coast.

High waves are also a characteristics of nor' easters. Waves of up to 20 feet occur. These are built on top of the storm surge. One of the reasons these storms cause so much damage along the North Carolina coast is that the sea floor has such a low gradient. As the waves move up the continental shelf, friction with the sea floor slows the water at the base. Since momentum must be conserved the waves increase in height (Figure 2).



Waves build in height as they approach shore. When the depth of the water becomes less than half the wave length friction begins to slow the wave. In order to maintain momentum as the wave speed decreases wave height must increase

Figure 2. The Wave-Shore Relationship

The primary damage caused by nor' easters is to barrier islands and structures on the islands. Damage to the barrier islands comes in the form of erosion of the dunes and damage or destruction of structures. About a fourth of all nor' easters cause dune erosion and property damage. An average of at least one storm a year does substantial beach erosion and local property damage. These once-a-year storms generate waves which reach to nearly 11 feet, and last some 34 hours. In general, the more severe the storm, the longer the damaging winds last.

Severe Thunderstorms and Tornadoes

Due to the great amount of heat added to the atmosphere through condensation, and the rapid lifting of the air in the center of these nor' easters, severe storms and tornadoes are frequent associated with them. In the March 1993 storm, lines of severe thunderstorms moved across some parts of the state. They moved rapidly and in at least one case along the coast they were moving at 60 miles per hour. This storm also spawned many tornadoes. Some 26 were confirmed in Florida. A tornado was also reported over Hyde County, North Carolina about 8:50 AM, EST on Saturday, March 13. Trees were damaged and a 20 foot boat was missing. Power lines were broken but no injuries reported. The touchdown was in the Outer Creek area near Swanquarter. A second touchdown was reported minutes later near Lake Mattamuskeet.

Precipitation

These storms produce heavy precipitation in a variety of forms because of the large amounts of moisture being drawn in from the Gulf of Mexico and Atlantic Ocean. Rainfall may be widespread as well as intense. The entire state may receive precipitation from a single storm and totals may run to 5 inches or more.

In winter it is snowfall, particularly in the Appalachian Mountains where elevation reduces the temperature. In the typical extratropical storm over North Carolina the heaviest snowfalls, and in fact most of the snow, falls west of the center of the storm. This is because the cold air is being drawn into the system from the northwest and it is mixed with the warmer and more moist air from the Atlantic Ocean. Due to the topography of North Carolina there are variations in the extent of snow or ice from a storm. The most severe snow storm occurred on January 17, 1930. This storm system reached blizzard status over part of the state. Fourteen and seven-tenths inches of snow fell in Greensboro from this storm. The state was crippled by the snow. During the Blizzard of 1993 many new snowfall records were set. Mount Mitchell received 50 inches of snow by Sunday morning and there were drifts of 12 to 14 feet. Once the cold front passed through Saturday night, temperatures plummeted and at the ranger station it was 7° below zero on the morning of March 14.

Mayhem caused by a Nor'easter may well extend to the North Carolina mountains. The Blizzard of 1993, for example, dumped 50 inches of snow on Mount Mitchell with up to 14 feet in drifts

Traffic delays and accidents are a big problem when snow comes to the area. When snow first hits, the public gets out and goes to the grocery stores, the malls, or to family and friends houses. This in itself causes traffic to be very heavy. Then when the snow or ice begins to stick to the roads, the problem escalates. Snow and ice sticking to roads and highways causes the roads to be very slick. This situation is the main cause of "fender-benders" that occur during snow and ice storms. Visibility is also hindered due to blowing and drifting snow which adds to the danger.

Snow also has a widespread impact on construction, manufacturing, agriculture, retail sales, power supply, communication and recreation. Public health and safety services can also endure heavy financial losses either in terms of mitigation costs or direct damage and disruption.

Ice storms are a part of winter nor' easters. Ice storms occur when precipitation begins aloft as rain and falls through air near the surface that is below freezing. This causes the rain to freeze as it falls on trees, shrubs, and power lines. This takes place along the warm front as moist air rides upward over the colder air behind the low. A severe ice storm occurred on February 16-19, 1979. This storm hit an area from Burlington to Winston-Salem, with the worst in Greensboro. For three days, Greensboro was immobilized. At one point there were as many as 10,000 homes without electricity. Some of these power outages lasted for two days. Ice forming on trees caused power and phone lines to fall and break. It was not until the nineteenth ofFebruary that the temperature rose enough to melt the ice cover.

Some North Carolina Nor'easters

The Ash Wednesday Storm of 7 March,1962

The extra-tropical storm which traveled northward along the Atlantic Coast in early March of 1962 is considered by many to be the most severe ever recorded. The storm center traveled parallel to the coast some 60 miles off the shore and never actually crossed the coastline. The storm traveled along the coast for a period of some four days from March 5 through March 8, driving a storm surge that ranged from 3 to 6 feet in height. Waves often exceeding 12 feet formed on top of the storm surge and were driven onto the shore. Waves on the open ocean were estimated to be as high as 33 feet (Davis and Dolan, 1993).

Up to the time of this storm there had been practically no control of building along the offshore islands. Damage from this storm was tremendous perhaps exceeding $300 million. Whole towns were obliterated. Fortunately, the casualties were low because most structures were summer cottages and unoccupied at the time of year the storm struck. Damage to the barrier islands themselves was immense. Beach retreat ranged from 30 to 300 feet, and varied greatly over very short distances. This storm was far more destructive of the barrier islands than any hurricane has ever been. However, subsequent small storms began to return the sand to the beaches so that in the long run much of the damage to the islands was repaired.

Damage from the Ash Wednesday Storm was so great that it influence the founding of a new school of coastal morphology and engineering

The damage from the storm was so immense that like the Lisbon tsunami of the Middle Ages, it resulted in a major change in thinking about natural hazards. In this case, in the United States it brought about a new school of coastal geomorphology and coastal engineering. The federal government began supporting research into the processes of barrier island formation and beach erosion. State laws regarding minimum setback from the shoreline date from this time.

Storm of March 16 -17, 1983

The Grand Strand (Garden City/Surfside Beach area) was hit by a Nor' easter that began March 16 and continued through March 17. The storm released five inches of rain causing numerous evacuations, flooding and beach erosion. By March 18 the Waccamaw River had risen two feet above flood stage due to runoff draining into the river. The river rose above 10 feet by March 20. Fifty homes were evacuated along the river, and necessary precautions were taken as the river continued to rise. Some homes, especially these at Surfside Beach, had two to three inches of water in them. The city' s new sewer system was also damaged by the flooding.

Storm of December 2-4, 1986

During the beginning of December, 1986 a Nor' easter hit the coast from Charleston, South Carolina to Wilmington, North Carolina. The resultant high tides caused extreme beach erosion. Northeasterly winds began on December 2 and continued until December 4. Winds were 15 to 40 miles per hour. Tides were 6.4 feet above normal and waves splashed at least 40 feet up on some buildings.

Garden City reported the greatest loss. Beachfront property damage was extensive. Seawalls around four high-rise condominiums were destroyed along with their oceanfront swimming pools, and the beach was eroded to the foundations of several high rise buildings.

The storm also brought severe weather to the northwestern part of the state. High winds and freezing rain knocked down trees and left about 1,500 residents of Watauga County without power.

Storm of January 1, 1987

On January 1, 1987, traditional New Year' s celebrations were not the order of the day for parts of coastal Carolina. A severe storm which began earlier in the week as a low-pressure system in the Gulf of Mexico coupled with a once in 16 year astrological phenomenon created a storm for the coast which rivaled that of Hurricane Hazel in 1954. This storm passed off Beaufort South Carolina early on the morning of January 1st and moved slowly north up the Carolina coast at the worst possible time. The timing coincided with tides already being pushed to an extraordinary level (approximately 9.5 feet above normal) by the alignment of Earth, Sun and Moon, called Syzygy (Figure 3). These unusual high tides and harsh, northeasterly winds gusting at 50 to 60 mph combined to wreak havoc and cause massive damage on beach areas that had just begun recovery from an early December nor' easter. Included in the damage were the following:

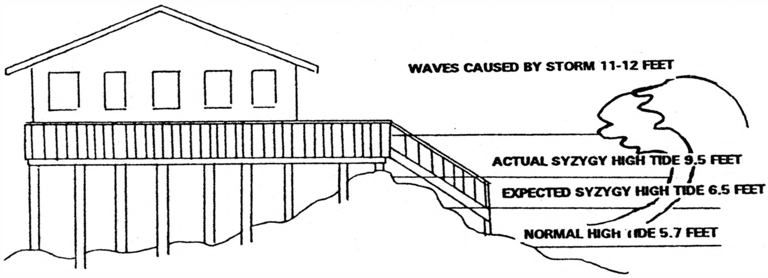


Figure 3. Tidal Effects of the Syszygy During the January 1, 1987 Nor'easter

1. County and state highway work crews had to scrape two to three feet of sand off the area highways and parts of the main north-south highway had to be closed for repair.
2. Sand replenishment projects were eliminated.
3. Parts of Carolina Beach Fishing Pier collapsed.
4. Every street on the north end of Pleasure Island was flooded. Many cars and homes flooded.
5. At Wrightsville Beach most roads were considered impassable due to flooding. Water was three to four feet deep in many homes and apartments.
6. At Topsail Beach water flattened a one-mile section of sand dunes. This included artificial dunes recently created through a sand replenishment project.
7. At Atlantic Beach tides reached seven feet above normal.
8. At Long Beach some estimated 40 to 50 homes were damaged.

Storm of March 8, 1989

Wednesday, March 8, 1989, was the beginning of a two day storm that pounded the Outer Banks unrelentingly. With winds gusting up to 60 mph and waves reaching 15 feet, there was considerable damage and destruction to structures; extensive beach erosion; and flooding of low-lying areas.

Dare County received the most damage before the slow-moving storm moved on out over the Atlantic. There was an average of 35 feet of beach erosion.

Highway 12, along the Outer Banks, was subjected to overwash as the storm wore away the beaches and dunes. As with any storm that hits the Outer Banks, officials become concerned that Bonner Bridge, which connects Nags Head with Hatteras Island, might suffer damage.

Storm of October 30-31, 1991

On the evening of October 30 and the morning of October 31, 1991, the coast of North Carolina was pounded by high winds, high seas, and torrential downpours. Just as coastal residents and tourists had breathed a sigh of relief from the narrow escape from Hurricane Grace, a mid-latitude low pressure system left land and gained astonishing power as it mixed with the remnants of the hurricane. This produced 50 mph winds and 21 foot waves. After the storm system had passed, the entire Dare County area had been placed in a state of emergency. On Hatteras Island, 500 feet of the Rodanthe dam had been washed out by high tides. Transportation was almost impossible because there was, in some places, up to four and five feet of sand and water covering some roads. Worst hit was the section of N.C. 12 between Kitty Hawk and Nags Head. At Nags Head, five permanent homes were completely destroyed and 34 suffered major damage. Residents at Kitty Hawk were also hit hard as the storm damaged more than 200 homes.

Coastal residents and insurance assessors had just begun the colossal task of surveying the damage left by the violent nor' easter, when a second storm hit. While this storm did not have the intensity nor the duration of the previous storm, it covered major roadways with thirty inches of sand and water. Cape Hatteras was closed from Pea Island to north of Rodanthe.

Storm of March 13-14, 1993

North Carolina was fortunate in the late 1980s and early 1990s to have been spared major snow and ice storms. However, the winter storm came back with a vengeance with the blizzard of 1993, which occurred March 12-14. Seven deaths in North Carolina were attributed to the storm and damage estimates exceeded $100 million.

Winds were recorded at 101 mph on Flattop Mountain. At Wilmington Saturday morning at 10 am the wind was out of the south at 40 mph and gusting to 57 mph. By 11 am Saturday morning the storm surge had reached 3.5 feet. At Duck Cove Pier waves of 14 feet were reported. Unofficial reports of waves of up to 12 feet were common.
Saturday morning, March 13, severe thunderstorms were spread over eastern North Carolina. Some of the storms were moving at 60 miles per

hour. At one point during the storm different parts of the state were experiencing thunderstorms, sleet, freezing rain and snow. Blizzard conditions exist when sustained wind velocities are 35 mph or higher, and visibility is less than 1/4 mile due to blowing snow for a period of three hours or more. At the height of the storm most the western half of the state was under blizzard conditions.

A major search and rescue operation was conducted in the Great Smokey Mountains. Some 120 students and faculty from Kingswood Academy in Bloomfield, Michigan had gone into the mountains on Friday on a camping trip. Many of them walked out of the mountains on Saturday or Sunday, but others had to be brought out by rescuers. By Monday all were rescued. A few eventually needed to have toes amputated.

Transportation networks were nearly completely shut down. Most airports in the state were closed Saturday. Interstate routes 77,85,81, and 40 were all closed over the mountains. With the slick roads traffic accidents were abundant. By 6 p.m. Saturday, March 13, the State Highway Patrol reported over 300 accidents in the Triad area near Greensboro, Winston-Salem, and High Point. In Greensboro police had investigated 110 accidents by 8 p.m. the same day. The scene was repeated over much of the state since the roads were either wet with rain or snow and ice covered.

The western portion of the state will remember the storm for the large amount of snow and school closing which lasted for a week in some cases. The eastern part of the state will remember the wind, rain, storm surge, thunderstorms and tornadoes.

Summary and Conclusions

The natural hazards which have taken the most lives and resulted in the most dollar damage in North Carolina are atmospheric storms. Among the storms which are a major hazard to the state are Nor'easters. These storms are extratropical cyclones which cross the coastline as they travel eastward or form off the coast and travel northward along our coast. The storms are large enough and move slow enough so that they can be accurately forecast. The primary hazard consists of flooding from the storm surge and high waves. At the present time it is not possible to eliminate or reduce the hazard. Since the frequency of extra-tropical cyclones is as high as it is, the probability of Nor'easters affecting North Carolina is very high. If reduction of fatalities and damage is to take place it will necessitate coastal zone management regulations not now in place.

Though Nor'easters are quite predictable as to when they can be expected and where they might hit, they are still some of the most damaging for North Carolina

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CONGRESSIONAL REDISTRICTING IN NORTH CAROLINA, 1991-92

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Each American state has sets of electoral districts from which representatives are sent to the state legislature and the U.S. House of Representatives. Every ten years, following the completion of the federal census, the electoral districts must be redrawn to reflect changes in population numbers and distribution over the prior decade. This exercise in political cartography is of critical importance because it identifies the foundation building blocks on which democratic representative government rests. At first glance, redistricting appears a relative mechanical exercise, but in reality it is complex and time-consuming, complicated by political competition and legal challenges, and usually produces a plan that is controversial in some part. It is a process in which political, legal and geographical elements intermesh. The goal is fundamentally geographical, to create acceptable new districts that are shaped around regional variations in population numbers, racial composition and political party affiliation. However, in operation, redistricting is inherently political in nature, with the political party in power doing its best to maximize its power base, to protect its incumbents and to further its chances for political gain at the expense of its opponents. The process also involves state and national laws, their interpretation and enforcement, and legal procedures.

Redistricting is inherently political in nature, with the political party in power doing its best to maximize its power base, to protect its incumbents and to further its chances for political gain at the expense of its opponents

Congressional redistricting falls within the broad scope of political geography, a relatively small subfield of geography that is commonly defined as "the spatial dimension of political activity", or "the relationship between political activity and the territory within which it occurs." The text by Glassner (1992) is a useful survey of the range of topics included within political geography at national and international levels. Brunn (1974) shows how many of these topics and approaches are applicable to the U.S. specifically, including the design of Congressional and legislative districts and other areal units of governance. Political Geography, a monthly specialty journal, is a main publication outlet.

Morrill (1981) has produced the major survey of political (Congressional) redistricting by a geographer. It considers gerrymandering, criteria for redistricting, and redistricting methods. Case studies of Congressional redistricting in Mississippi and Washington and a comprehensive bibliography are included. For North Carolina, Orr (1970) provides a thorough analysis, supported by district maps and a useful bibliography, of how Congressional districts have been reshaped until 1970. Although now dated, it is a foundation upon which this and later studies build.

Background

During the 1980s, North Carolina had eleven members in the U.S. House of Representatives. Their electoral districts, created in 1982, extended numerically in two general east-west tiers; the 1st to 6th and, farther south, the 7th to 11th (Figure 1). The 1st, 3rd and 7th were in the Coastal Plain; the 2nd incorporated segments of the Coastal Plain and Piedmont; the 4th, 6th, 8th and 9th were in the heavily urbanized and

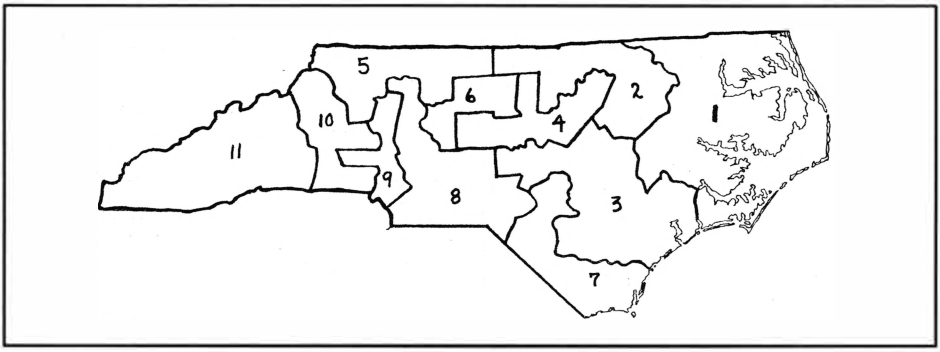

Figure 1. North Carolina Congressional Districts, 1982. District Lines are Generalized

populated Piedmont; the 10th and 11th were in the western Mountains; and the 5th straddled the Mountains and Piedmont. Reflecting regional party strengths in the Democratic east and Republican west, Republicans were in office in the 6th, 9th, 10th and 11th and Democrats were in the other seven districts in 1990.

The 1990 Census returns showed that North Carolina had increased almost 13 percent since the last census to a new total of 6,628,637 persons, making it the tenth largest state in population and qualifying it for an additional, or twelfth, Congressional seat in the 1992 elections. This meant a recasting of the 1982 Congressional districts by the Democrat-controlled North Carolina General Assembly. In June, 1991, the General Assembly approved a Democrat-sponsored redistricting plan that left most incumbents unthreatened, created one new district with a black majority and another with a Republican majority, and introduced novel configurations for some of the distrticts. An unsuccessful Republican-sponsored plan was highlighted by the creation of two new districts with black majorities based upon the state' s 22 percent black population.

In response to challenges by Republicans and civil rights groups of black under-representation, the U.S. Department of Justice reviewed the plan, found it unacceptable and returned it to the General Assembly for modification. A new version, accepted by the federal authority in February, 1992, featured two predominantly black districts and was used in the November, 1992 national elections. However, the plan remains under fire by its opponents and a case claiming that the 12th District is unconstitutional was submitted to the U.S Supreme Court for judgement in April, 1993. Two months later, the Court ruled in favor of the plaintiffs and sent the case back to the U.S. District Court for trial.

Objective

This paper focuses upon the redistricting strategy and cartographic results, with a cursory look at political and legal aspects, of the 1991-92 redistricting process. It includes a review of the guidelines and technology used in redistricting; the main features of the Republican-sponsored plan, the 1991 plan approved by the General Assembly but rejected by the federal authorities, and the federally approved 1992 plan; and objections to the 1992 plan. Confined to Congressional districts, the paper does not consider the reshaping of North Carolina' s State Senate and House of Representatives districts by the General Assembly during the same time period.

Confined to Congressional Districts this paper provides a review of the redistricting technicalities and process which led to a number of politically inspired plans and a court challenge

Redistricting Guidelines

A redistricting bill follows the same course through the General Assembly as does any piece of legislation, and it must be approved by the full body. Maps and statistics used in the redistricting process are important to the evaluation of proposal plans and their compliance with legal requirements. Legislators faced with both legislative and congressional redistricting face a formidable body of historical precedents and legal regulations in addition to furthering their political interests. To prepare and assist them, the Legislative Services Office of the General Assembly issued a study, Redistricting 1991: Legislator' s Guide to North Carolina Legislative and Congressional Redistricting, that reviews key legal issues and their historical background and information about Census data and the computer technology available in Raleigh in redrawing district boundaries. The following section is extracted from that legislative guide.

Population Equality

The principle of "one person-one vote", set by the U.S. Supreme Court in 1962 (Baker vs. Carr) and in subsequent court decisions, requires that each member of a political body represent substantially the same number of persons. The population equality standard for Congressional districts is much stricter than for legislative districts. North Carolina' s 1961 Congressional redistricting plan and the revised 1966 plan were found to be in violation of the "one person-one vote" standard and had to be redrawn to reduce population inequity among districts. The initial 1981 Congressional redistricting plan was also redrawn in 1982 in response to federal objection. A major difficulty is that there is no specifically acceptable range of population deviation for Congressional districts. North Carolina' s approved 1982 plan fell within the two percent overall range.

Contiguity and Compactness of Territory

The North Carolina Constitution requires that the territory of legislative districts be contiguous, but there is no such explicit standard for Congressional districts. The fact that a district is considered contiguous if part of its territory touches another part at some point can produce some wildly strung out units. Neither North Carolina nor federal law requires districts to be compact, and there are no measures of compactness that have been recognized as judicial standards of judgement. Compactness can be defined by such criteria as territorial shape, population distribution, community of interest, and physical economic, social or other shared features.

A relatively new development that bears upon district configuration is the splitting of counties to comply with more demanding population exactness standards. The North Carolina Constitution does not take a position on county splitting, yet the general tendency prior to 1991 was to avoid such division and to achieve redistricting by shuffling entire counties. In fact, the 1982 redistricting involved the splitting of only four counties (Avery, Johnston, Moore and Yadkin) to keep the population deviation within the two percent range.

Partisan Gerrymandering

Continuing redrawing of partisan districts, with its frequently appearing strange shapes and ithe absence of underlying clear standards opens the door to court challenges

"Gerrymandering" is the term applied to the purposeful manipulation of electoral districts for partisan advantage. In many past instances, the result has been the creation of districts of fantastic shape that provide maximum voting support. However, districts of more conventional block-like configuration can also achieve the same result. Recognizing redistricting as a partisan political process, the courts were unwilling to consider redistricting cases until the 1960s. Only since a 1986 U.S. Supreme Court decision (Davis vs. Bandermer) have challenges to partisan gerrymandering been deemed appropriate for federal court review. The 1986 decision requires proof of both intentional discrimination and an actual discriminatory effect. The former is easier to prove than the latter. To date, no redistricting plan has been overturned by the U.S. Supreme Court for discrimination against political parties, but the continued redrawing of partisan districts, the often strange shapes of districts through county splitting, and the absence of clearly stated standards for judgement open the door to future challenges.

Minority Voting Rights

The Voting Rights Act of 1965 injected a new, important legal requirement to redistricting. The Act was created to insure minorities that their rights to vote, as guaranteed by the Fifteenth Amendment, is not abridged by government by the use of literacy tests, poll taxes or other discriminatory electoral devices. The U.S. Congress amended the Act in 1982 to make clear that a redistricting plan is in violation of Section 2 of the Act if it has a discriminatory effect on minorities. Discrimination may be established by such measures as the extent to which elections are racially polarized, the success rate of minorities in getting elected and the extent to which racially restrictive devices are used.

Section 5 of the Act requires that North Carolina and other designated states submit their legislative and Congressional redistricting plans to the federal government to prove there is no intent or effect of abridging minority voting rights in any counties where abridgement was identified when the act became law. There are 40 of these so-called "covered counties" in North Carolina (Figure 2). Federal approval of a redistricting plan is obtained by either preclearance judgement by the U.S.

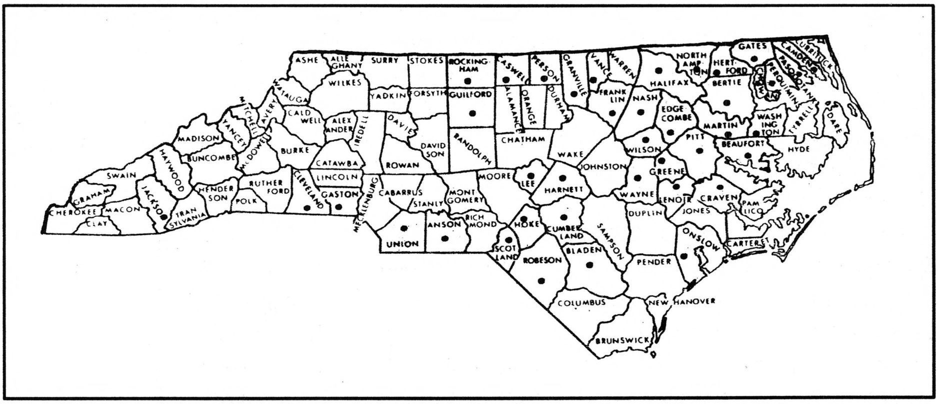

Figure 2. North Carolina "Covered Counties" by the Voting Rights Act of1965
Source: North Carolina General Assembly, Legislative Services Office

Department of Justice or, less commonly, by a declaratory judgement by the federal district court for the District of Columbia.

Under the preclearance process, the redistricting plan approved by the General Assembly, with supporting documents, is sent to the U.S. Department of Justice, where it is either precleared or an objection is filed. In the latter case, the General Assembly has the opportunity to resolve the objection. If preclearance is not given, the challenged portion of the plan cannot be put into effect until the State gets approval by the federal district court to the District of Columbia. Even a precleared plan is subject to litigation under Section 2 of the Act.

Redistricting Technology

The computer age makes possible the handling of more census and voting data, and the division of counties in a short time period. Legislation in the 1985 General Assembly authorized all North Carolina counties with a 1980 population over 55,000 to participate in the Census Bureau's 1990 Census Redistricting Data Program. Under this program, precinct boundaries in the counties were made to conform to new Census Bureau units shaped around geographical features. The participation of 48 North Carolina counties enabled the General Assembly to receive population data for each of the precincts and facilitated county splitting in creating a new electoral district. The computertized boundaries also allow the analysis of voter registration data and prior election returns while redistricting is in progress.

Four sets of data, voter registration, population, boundaries and prior election returns, are integrated in a computerized Mapping and Redistricting Information System (MARIS). This sophisticated technology has considerably improved on the accuracy of drawing new districts

Four sets of data - boundaries, population, voter registration and prior election returns - are integrated in a computerized Mapping and Redistricting Information System (MARIS), which was used to redraw legislative and Congressional districts in 1991. MARIS allows users to display any section of North Carolina on a computer screen at any level of census geography (census tracts, block numbering areas and census blocks) and political geography (counties, townships, cities and precincts). It can also calculate such information as population numbers, minority population and deviation from the ideal size for each district as it is created or altered. MARIS is available at only a few expensive workstations in Raleigh and requires a demanding training schedule. Needless to say, these technical advances spread the redistricting process and make it more accurate than prior to 1990. They also help to explain the upsurge in county splitting in the 1991-92 redistricting efforts.

The 1991 Redistricting Plan

In June, 1991, the General Assembly approved a Democrat-sponsored redistricting plan that divided North Carolina into 12 new Congressional districts with mathematical precision (Figure 3). Seven

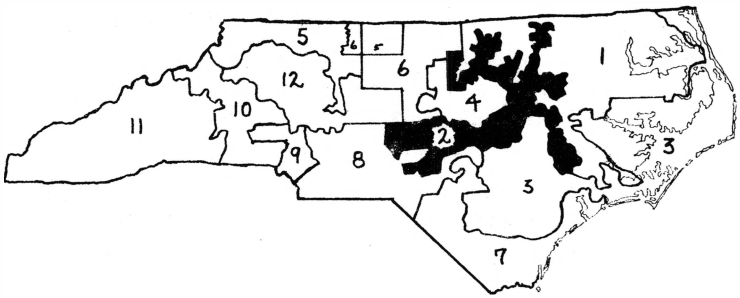

Figure 3. The North Carolina 1991 Congressional Redistricting Plan. District Lines are Generalized

Source: North Carolina General Assembly, Legislative Services Office

of the districts had 552,386 residents apiece, while the other five had only one additional person. In order to achieve this high degree of numerical similarity, county splitting was the order of the day. The new map split 34 counties to some degree, a drastic increase from the four split counties in 1982. The new district alignment protected the interests of incumbents and the Democratic Party. The eleven incumbents all remained in separate districts where they did not have to run against each other. In general, incumbents managed to retain the precincts in which they received strong support in earlier elections. However, the reworked Congressional map showed some radical changes in district configuration, especially in eastern North Carolina, due in part to an effort to have at least one black member of Congress.

In the northeast, a smaller 1st was created from parts of the old 1st and 2nd specifically to give better representation to its large (55.8%) black population. A tentacle extended to the southeast to encompass a large block of black voters. The new 2nd had the most remarkable shape, like a pinwheel with irregular arms jutting in different directions. Its main body consisted of parts of the old 2nd and 3rd, while its arms came from siphoning off blocks of white voters from the fringes of the new 1st in order to guarantee a black electorate in Roanoke Rapids. The city of Kinston was divided by the district boundary between its heavily black east and the heavily white west.

The new 3rd consisted of two large areas joined by a narrow corridor. One area was from the eastern and southern margin of the old 1st, and the other was the bulk of the old 3rd. The new 4th, shaped around the

Research Triangle counties, was smaller and shaped differently than earlier. Trimming the western extension of the old 4th meant substracting a large number of Republican voters and thus strengthening the Democratic incumbent's chances. The old 5th remained largely intact except for the one-half of Stokes County, which was awarded to the new 6th. The much larger 6th jutted northward into old 2nd territory, encompassing more Democratic voters and thus posing more of a threat to the incumbent Republican. The plan originally called for the eastern one-half of Rockingham County to join the new 6th, but Rockingham objections led to the inclusion of eastern Stokes County instead. In an unusual alignment, Rockingham County joined the new 5th and Stokes County joined the new 6th only where they met at a common corner.

Republican incumbents already represented the three western districts, and Republican voter registration and voter support in the central and western Piedmont had increased markedly during the 1980s. The Democratic strategy was to create a new GOP-leaning 12th from major parts of the old 8th and 9th. This move subtracted some Republican strength from the old 6th and the Republican incumbent, and provided a greater margin of safety for Democratic incumbents in the new 4th and 8th. The new 9th was more narrowly shaped around the Charlotte metropolitan area. The 10th, which has elected Republican Congressmen since 1952, was expanded by the addition of Mitchell County and three Avery County precincts, all with strong Republican voting records. The intent was to subtract Republican strength from the 11th, which otherwise remained intact, giving a Democratic challenger a somewhat better chance in the 1992 elections.

"The Bug Splatter" was Republican governor James Martin's derisive comment on seeing the redrawn 2nd District (See Figure 3)

Republican governor James Martin, the only American governor without veto power, led his party's charge in unsuccessful opposition to the new political map, which one newspaper headline called "political pornography". Looking at the map through partisan glasses, he commented derisively on the unusual district shapes. "1st District: If turned upside down, it looks like a bull moose swimming; 2nd District: That's the bug splatter; 3rd District: About the only description you can put on that one is it looks like a roadkill; 4th District: A happy guppy swimming east; 5th and 6th Districts: Really absurd; 8th District: Shark swimming west; and 12th District: Rampaging bull elephant headed west" (Raleigh News & Observer, July 19, 1991).

The Republican Plan

An unsuccessful redistricting plan representing Republican interests had three noteworthy qualities. One, it boosted Republican voter strengths whenever possible, even by a few percentage points. Two, it split counties aggressively, 49 in all, and created several districts with wildly meandering boundaries. Third, it broke new political redistricting ground by creating two districts with a black population majority (2nd and 12th). Like the Democratic plan, it had mathematical precision; only one district had one more than 552,386 persons.

Comparing the reworked districts with the 1982 map, the 1st and 2nd occupy roughly similar positions but the 1st is smaller and the 2nd is larger (Figure 4). Created with a majority (57.43%) black population, the 2nd poked arms eastward into the 1st in search of black voter blocks. The

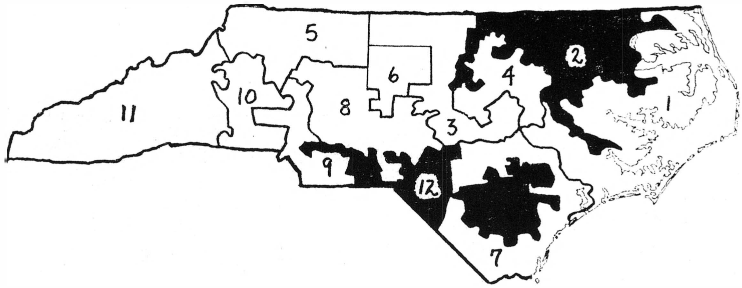

Figure 4. Republical Plan for North Carolina 1991 Congressional Redistricting

Source: North Carolina General Assembly, Legislative Services Office

3rd involved a major displacement. Instead of extending to the southeast, it was moved northward to include three counties and part of a fourth county bordering on Virginia that were part of the old 2nd and 5th. The 4th was smaller and more irregular in shape, while the 6th reinforced Republican voting strength.

The 7th remained in the southeast but extended much farther inland in a doughnut shape with a very erratic interior boundary. Perhaps the most striking boundary contortions belonged to the reworked 8th, which retained the northern part of the old 8th and flailed northward and eastward to incorporate more Piedmont Republican areas and enhance Republican election chances. The 9th, 10th and 11th were somewhat modified but clearly identifiable. The new 12th was bilobate, formed of a western portion from the old 8th and an eastern portion derived mainly from the old 3rd. The latter was encircled except for a narrow corridor westward by the new 7th. With a narrowly majority (48.06%) black population, the 12th was designed as a second district to give greater political representation to black voters.

The Reworked 1992 Plan

The 1992 redistricting plan that was approved by the General Assembly failed to gain approval by the U.S. Department of Justice in preclearance review. Rejection was based upon a perceived manipulation of black voter areas in order to protect white incumbents. Also, it was noted that the Republican proposal had shown that two predominantly black, districts could be created to represent the black population more proportionally.

Reworking the 1991 plan was a top priority when the General

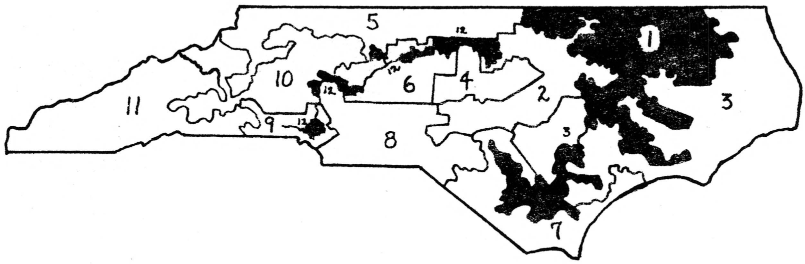

Figure 5. The North Carolina (Reworked) 1992 Congresional Redistricting Plan, District Lines are Generalized

Source: North Carolina General Assembly, Legislative Services Office

Assembly recovened in early 1992. The fruit of its efforts was an early February map (Figure 5) that had numerically equal districts and two districts, the 1st and 12th, with black majority populations. The two districts combined had 43% of the state's 1.4 million blacks. However, the shape of three districts (1st, 10th and 12th), even more radical than in the 1991 plan, pushed North Carolina's political cartography to new imaginative levels. Even as the 1992 plan made its way successfully through the legislature, some Democratic supporters publicly expressed wonderment over its geographical audacity and doubts about its legality.

The 1st extended from a compact northeastern area southward through much of the Coastal Plain in a disjointed series of arms that incorporated black voter clusters, including black precincts in Fayetteville and Wilmington. Consequently, it had a black majority of 53.4 percent in all or part of 28 counties, many of them "covered counties" under the

Voting Rights Act. The 2nd, 3rd, 4th, 8th and 11th occupy the same general location as in the 1991 plan but with modified boundaries. The long linear continuity of the 5th along the Virginia boundary, farther east than in either 1982 or 1991, was restored. As a result, the expanded 6th was moved south nearer its 1982 location. The 9th acquired a more distinct east-west layout.

The 10th became a multi-armed, strongly Republican district composed of the 1991 10th and 12th, with addition of precincts in the 5th and 11th and transfer of its southern slice to the 9th. The 12th was the most bizarre creation of all (Figure 6). Sinuously eccentric, it wove for 160 miles through 10 counties. Incorporating black precincts in Durham, Greensboro and Winston-Salem, it then followed a corridor southward along Interstate 85 to pick up black precincts in and around Charlotte. It had a 53.3 percent black population and, in contrast to the other more rural black district (1st), it was essentially urban. With the black vote usually overwhelmingly Democratic, the new 12th had the potential to enhance black representation and, as a by-product, to create a Democratic enclave in the Republican heart.

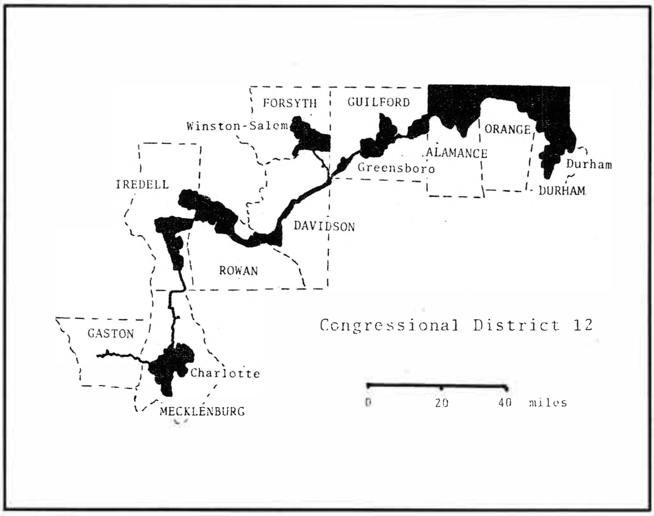

Figure 6. The 12th Congressional District of 1992, District Lines are Generalized

Source: Modified Version of Map From New York Times, April 16, 1993.

The U.S. Department of Justice quickly gave its approval in early February, 1992 to the revised Congressional redistricting plan. This decision, which indicated that the plans met the requirements of the Voting Rights Act, came in time to allow completion of the process leading up to the November elections. In those elections, the Democratic redistricting strategy was proven sound. Democratic candidates emerged victorious in the same pre-1992 districts and won an additional seat in the new 12th. While Republicans made some gains in voting strength, they were unable to expand their pre-1992 four seats. Equally important, black candidates victorious in the new 1st and 12th placed black members in North Carolina' s Congressional delegation for the first time in the twentieth century.

A Legal Challenge

The 1992 Congressional redistricting plan, as well as the plans for the state legislature, provoked a chorus of complaints from many quarters on many issues. Republican complaints centered early on the plan's failure to draw compact districts and to honor prior communities of interest. Another change was that partisan gerrymandering diluted GOP voting strength by concentrating Republican voters in these districts. More widespread criticism that cut across political party lines centered upon the creation of predominantly black districts that may promote racism and decrease black influence in other districts because white leaders there may feel free to ignore black issues. On the defensive, Democratic legislative leaders admitted to drawing some unprecedented, odd-shaped North Carolina Congressional districts but said they were drawn in compliance with the Voting Rights Act and the judgement of the U.S. Department of Justice.

Most bizarre creation of the new districts was the 12th, which sinuously eccentric wove for 160 miles through 10 counties

Objections took legal form in a suit (Shaw vs. Reno), filed in March, 1992 by five white voters, after federal judges dismissed a Republican charge of political discrimination. The suit was also rejected the following month, leading to an appeal to the U.S. Supreme Court in April, 1993. Briefly, the appellants claimed that the General Assembly violated constitutional principles when it created the new 12th District to guarantee the election of persons of a specific race. Further, they claim that the redistricted 12th is an act of racial gerrymandering that violates the Voting Rights Act by giving them less opportunity to participate in the political process and thus violates their 14th Amendment equal protection rights. The objection was not using race as a factor, but as the deciding or only factor, in redistricting. North Carolina's legal representative argued before the Court that the General Assembly was following U.S. Department of Justice guidelines and that the five plaintiffs failed to prove that the redistricting was done with blatant discriminatory intent.

The case has caught national attention because "after the 1990 Census, dozens of state legislatures designed Congressional and legislative districts with black or Hispanic majorities. Depending upon how broadly it is worded, a decision for the plaintiffs could throw some or all of those districts in question."

"So Shaw vs. Reno will be argued amid a cacophony of "friend of the court" briefs from both national political parties and from civil rights, civil liberties and conservative groups. In general, Republican and conservatives are supporting the plaintiffs; Democrats and Liberals are supporting the North Carolina plan. On both sides there is talk that this case could be among the two or three in a decade in which the High Court chooses to assert itself in some broad and significant way in redistricting and voting-rights cases" (New York Times, April 16, 1993).

In late June, 1993, the Supreme Court ruled in a 5-4 decision that the oddly shaped new (1st and 12th) districts, created to favor one racial group, violated the constitutional rights of other voters to participate in a color-blind electoral process. Writing for the Court majority, Justice O' Conner stated in part:

> "We believe that reapportionment is one area in which appearances do matter. A reapportionment plan that includes in one district individuals who belong to the same race, but who are otherwise widely separated by geographical and political boundaries, and who may have little in common with one another but the color of their skin, bears an uncomfort able resemblance to political apartheid....It reinforces racial stereotypes and threatens to undermine our system of representative democracy by signaling to elected officials that they represent a particular racial group rather than their constituency as a whole." (Raleigh News & Observer, June 29, 1993).

Justice White dissented, stating in part:

> "Lack of compactness and contiguity, like uncouth district lines, certainly is a helpful indicator that some form of gerrymandering (racial or other) might have taken place or that "something may be amiss"...They have no bearing on whether the plan ultimately is found to violate the Constitution. Given two district maps on similar, race-based grounds, the one does not become more injurious than the othersimply by virtue of being snake-like" (Raleigh News & Observer, June 29, 1993).

The North Carolina General Assembly now finds itself caught in a legal grey zone between the strengthening of minority representation and the protection of other voter's electoral rights

The Supreme Court sent the case back to the U.S. District Court for trial. This move could involve the state in a lengthy court battle with the outcome uncertain, or could prompt the General Assembly to redraw the objectionable districts voluntarily in a plan acceptable to the courts in time for the 1994 Congressional elections. In either course of action, the General Assembly finds itself caught in a legal grey zone of permisiveness between the strengthening of minority representation under the Voting Rights Act and the protection of other voters' electoral rights. One new legal signal that comes from the Supreme Court' s decision is that geographical compactness and community of interest, however defined, must be considered when North Carolina' s Congressional districts are redrawn.

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MY FAVORITE ANALYTICAL TOOL THE SPREADSHEET

Garry Cooper

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The toolbox of geographers and planners contains many different items. We all have our favorites. Mine is the spreadsheet. Although not one of the older tools, it is an exceptionally versatile tool.

First developed by Daniel Bricklin in 1979, spreadsheet programs are now available from several major software companies, for use on all types of computer operating systems. My favorite program is Microsoft Excel. This is available for both the Macintosh and the DOS operating systems and, like most such programs, even has built-in tutorials as well as charting and data base capabilities.

Familiarity with spreadsheets varies considerably from one professional to another. Most microcomputer classes at colleges and universities today introduce students to spreadsheets. However, many professionals, although familiar with spreadsheets in general terms, lack understanding about spreadsheets in actual practice.

My personal experience with the spreadsheet is both academic and professional. As a community and regional planning teacher at Appalachian State University, several opportunities exist for spreadsheet applications in both my planning techniques and my project management class. Because my overall computer proficiency is only average, initial selection of a spreadsheet program required that it be something not too complex (i.e., for me to grasp), and easy to apply in the classroom. Several of my students each semester are unfamiliar with spreadsheets when classes begin. Therefore, it is necessary to make these students feel comfortable with the program and appreciate its applications by the end of each semester. This goal has consistently been met, and by the end of each semester, even students initially intimidated by computers are able to integrate spreadsheets in a variety of planning applications. In addition, a few students each semester generally surpass my knowledge about certain functional computer program capabilities, thereby teaching me something new about both the program and its applications.

Many think of the spreadsheet as only a number crunching tool. Although numerical data applications are something a spreadsheet manages very well, it has other applications. Demography, economics, land use, environment, transportation, and housing are just a few examples of categorical planning and geographical topics where opportunities for spreadsheet applications are abundant. Figures 1-4 illustrate the versatility of spreadsheets in each of these topical areas.

Spreadsheet graphics for both presentations and reports include line, bar, column, and pie chart options (Figure 1). Three dimensional appearance is an additional option with most programs. Most programs create axes values and legends automatically. Just add titles, and label axes. Built-in formulas allow computation of predicted values using linear regression analysis.

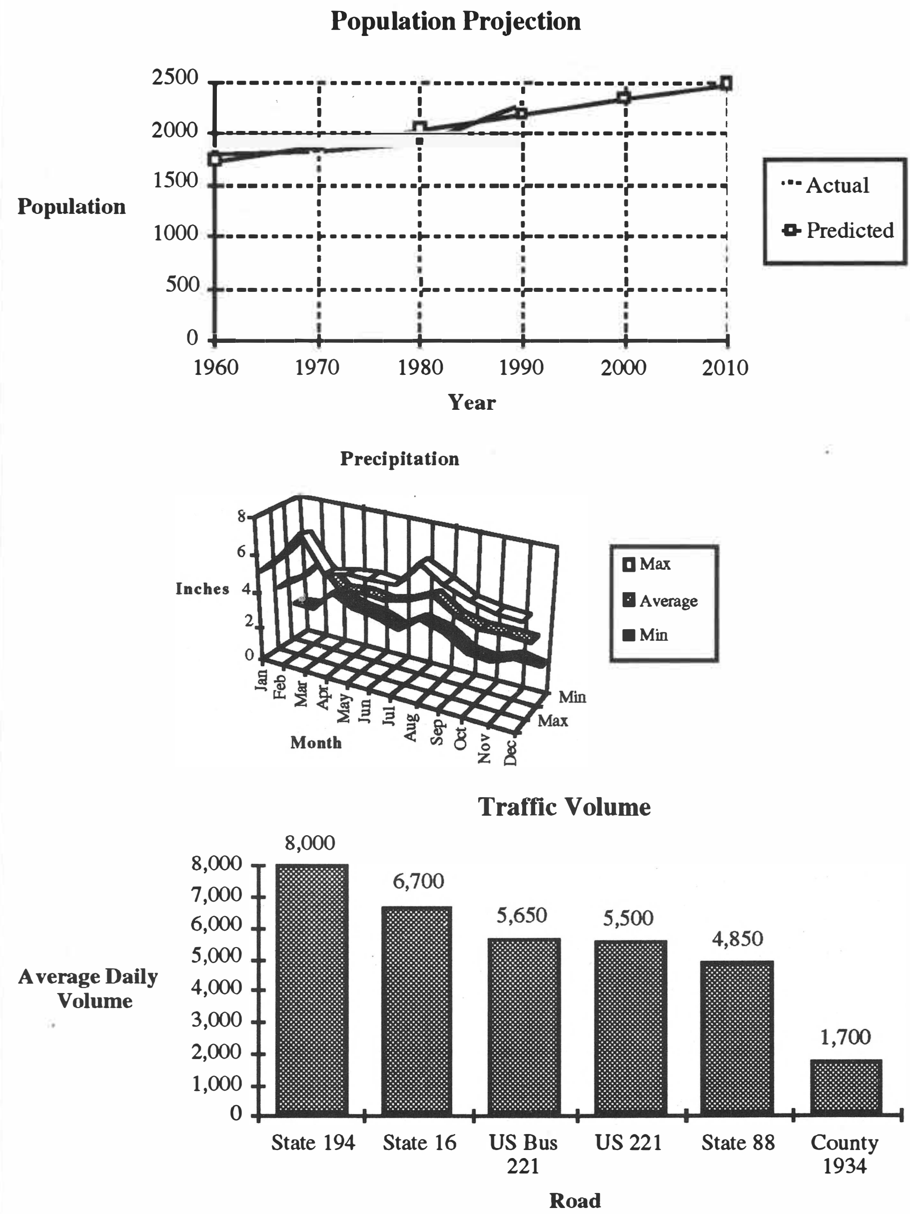

Figure 1. Line, Bar, and Column Charts

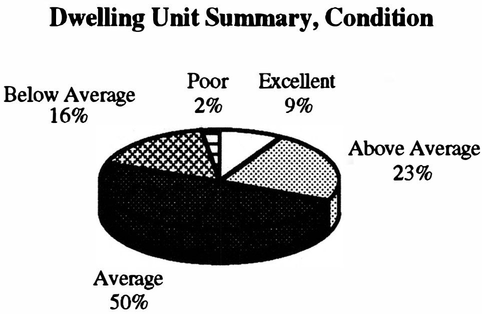

Figure 1 (continued). Pie Chart

Matrix charts neatly summarize tabulated data. Spreadsheet functions include automatic formulas as well as alphanumeric text, shading, and outline capabilities useful in creating matrix charts. Automatic formulas calculated all functions in the Figure 2 matrix charts: totals, percentages, ratios, and future requirements data

Employment Summary

Employee Range	Number of Employers	Percentage of Total	Number of Employees	Percentage of Total
1 - 10	261	78.9%	823	16.1%
11 - 49	54	16.3%	1,313	25.7%
50 - 99	7	2.1%	462	9.0%
100 - 499	8	2.4%	1,813	35.5%
500 or more	1	0.3%	700	13.7%
Totals	**331**	**100%**	**5,111**	**100%**

Figure 2. Matrix Chart

The spreadsheet is also useful in creating scheduling charts. Gannt charts utilize the shading, underlining, and justification capabilities of spreadsheet programs (see Figure 3).

Any Town, USA

Land Use Classifications	Land Use Acres	Percentage of Total Land Use	Ratio of Land Use Acres/ Present Population	Land Use Acres Required for Change in Population	x1.25 to Accommodate Choice and Constraints
Residential	9,600	30%	0.79	1,354	1,693
Commercial	1,600	5%	0.13	223	279
Industrial	1,600	5%	0.13	223	279
Institutional	1,600	5%	0.13	223	279
Roads, streets, highways	6,400	20%	0.53	908	1,136
Parks, recreation, open space	11,200	35%	0.92	1,577	1,971
Totals	**32,000**	**100%**		**4,508**	**5,635**

Existing land area (acres)	32,000
Present population	12,143
Forecast population	13,857
Change in population	1,714

DWELLING UNIT SUMMARY, CONCENTRATIONS

DISTRICT	ZONE	CONDITION OF DWELLING UNIT EXCELLENT	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	POOR	TOTAL DWELLING UNITS
STUDY AREA TOTALS		176	442	956	318	45	1,937
Percentage of Study Area		9.1%	22.8%	49.4%	16.4%	2.3%	
1	1	15	52	129	49	8	253
1	2	22	49	115	50	9	245
1	3	0	1	137	61	3	202
1	4	7	40	46	7	1	101
1	5	2	19	19	11	0	51
1	6	0	7	16	2	0	25
District 1 Totals		46	168	462	180	21	877
Percentage of District		5.2%	19.2%	52.7%	20.5%	2.4%	
Percentage of Study Area		2.4%	8.7%	23.9%	9.3%	1.1%	
2	6	11	67	172	31	10	291
2	7	60	63	22	16	1	162
2	8	22	43	80	9	0	154
2	9	1	23	77	29	3	133
2	10	1	23	43	16	3	86
2	11	24	22	17	10	7	80
2	12	0	11	38	14	0	63
2	15	2	8	24	2	0	36
2	16	7	8	10	7	0	32
2	17	2	6	11	4	0	23
District 2 Totals		130	274	494	138	24	1,060
Percentage of District		12.3%	25.8%	46.6%	13.0%	2.3%	
Percentage of Study Area		6.7%	14.1%	25.5%	7.1%	1.2%	

Figure 2. Matrix Charts (continued)

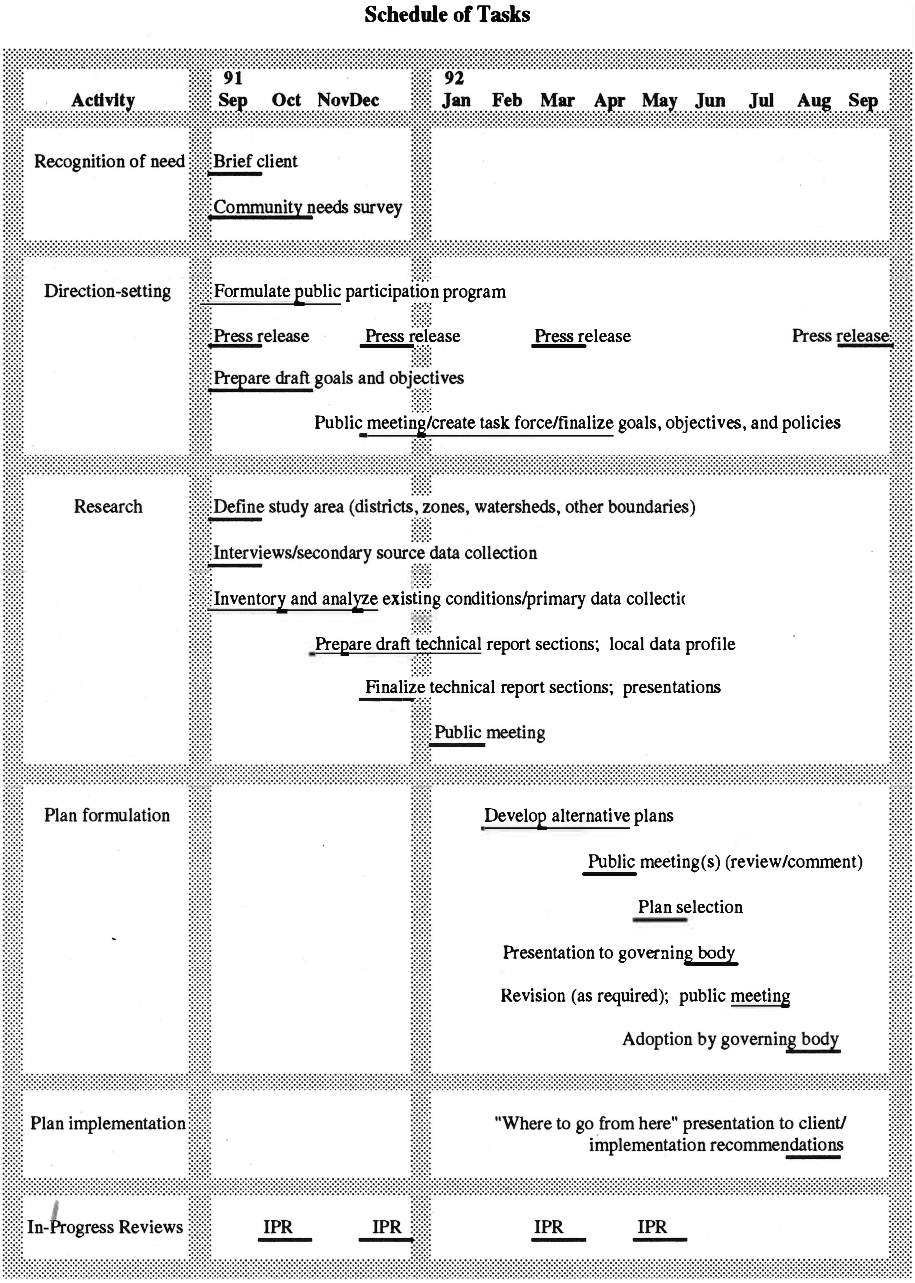

Figure 3. Gannt Chart.

In summary, the spreadsheet can serve a number of purposes. It is an excellent anal;ytical tool; it is a great communication tool; and it adds to creativity and research efficiency. To those who think that the spreadsheet is of value for others but not for yourself, my response is similar to what Dr. Seuss had to say about green eggs and ham. Try it, you may like it!

References

Grauer, Robert T. and Paul K. Sugrue. (1987) *Microcomputer Applications*. New York: McGraw-Hill.

Dr. Seuss. (1960) *Green Eggs and Ham*. New York:: Beginner Books.

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THE NORTH CAROLINA CENTER FOR GEOGRAPHIC INFORMATION AND ANALYSIS

Tim Johnson

Tim Johnson is an analyst with the North Carolina Center for Geographic Information and Analysis

Geographic information is increasingly being used as a decision support tool in both public and private sector organizations. Geographic information systems (GIS) technology is extending the use of this information as the movement continues from paper maps and statistical tables to the digital world. This trend is expected to continue as geographic data becomes more readily available and technological advances enable access to the data in a faster and less expensive manner. North Carolina is a national leader among the states where this trend is concerned.

The North Carolina Center for Geographic Information and Analysis (CGIA) is an agency in the Office of State Planning within the Governor' s Office. CGIA is the lead coordinating agency in state government for geographic information. CGIA was established in 1977 as part of the Land Policy Act under the name of Land Resources Information Service. CGIA implemented one of the first fully operational state geographic information systems in the country. Its traditional mission has been to build and maintain a statewide database of digital geographic information and to provide GIS services to a broad list of clients including other state government agencies, local government and regional organizations, the private sector, and academic institutions.

The CGIA is the lead agency in state government for geographic information. As such it provides GIS services to the private sector as well as to academic institutions

The agency changed its name to CGIA several years ago to reflect a broadening mission beyond its beginnings in land resources management. In 1991, a GIS Task Force recommended that CGIA be moved to a central organization in state government to meet the growing need for coordination of geographic information development and use. The mission of CGIA was affirmed through executive order and expanded to include support for a formal GIS coordination initiative in North Carolina. Governor James B. Hunt, Jr., reaffirmed this support of coordination of geographic information by signing a new executive order earlier this year. The coordination initiative recognizes that: (1) geographic information is a strategic resource for North Carolina; (2) decisions involving geography are increasingly complex and involve overlapping governmental responsibilities; and (3) limited financial resources demand that agencies work together to develop and utilize geographic information.

CGIA has 31 full time technical professionals and supportstaff to support its mission. The staff is organized into five operational units:

client services, technical services, production services, database administration, and system administration. The organization is totally receipt-supported. CGIA maintains a network of workstations and personal computers utilizing two primary software packages: ARC/INFO and Imagine. ARC/INFO, produced by Environmental Systems Research Institute, is the primary GIS package. Its functions include the ability to capture, manage, analyze, and display geographic data. Imagine is produced by ERDAS and provides tools for manipulation of satellite imagery and other raster data files for analysis in combination with other data. Together, these tools provide the capability to produce custom maps and to inventory resources, but more importantly, to perform custom geographical analyses, such as water quality modeling, site suitability studies, routing and distribution projects, and trend analysis.

Over the past 16 years, CGIA has been involved in several hundred projects that have used geographic information and custom analyses to support decision making. These projects range from the development of single map products to development of regional or statewide databases to meet the needs of a client. Early projects focused on natural resources and environmental applications. In the mid-1980s, the organization was a major contributor to the state' s site proposal for the Superconducting Super Collider. More recently, CGIA has served as the data management agency for the Albemarle-Pamlico Estuarine Study (APES) funded by the Environmental Protection Agency as part of the National Estuary Program. The APES effort has involved building a database of geographic features that are critical to effective resource management in the areas draining into the Albemarle and Pamlico Sounds. Land use/land cover, submerged aquatic vegetation, coastal marinas, and fisheries nursery areas are just a few examples of the data contained in this portion of the database. CGIA is currently in the outreach phase of the project where users are encouraged to access the database remotely as a tool for resource management.

CGIA is currently in its outreach phase of the Albemarle-Pamlico Estuary Study. Now users are encouraged to access the comprehensive data base remotely as a tool for resource management

The largest current project at CGIA involves a major expansion of the state' s GIS database through a cooperative effort with the North Carolina Department of Transportation. The goal of this project is to build a statewide database of geographic information to support the environmental review process related to highway planning. As a result of the Transportation Improvement Program funded by the General Assembly in the 1989 session, state leaders viewed GIS as a tool for assisting the environmental review process early in a highway project. Two pilot areas were chosen and a pilot project was conducted to test the concept. CGIA along with the Departments of Transportation, Environment, Health, and Natural Resources, and Cultural Resources jointly proved that GIS would be an effective tool in highway planning. The database development effort is focused on 15 GIS data layers that are key to the environmental review process. These layers are being developed statewide and include land use/ land cover, detailed soils, hydrography, transportation, historic and archaeological sites, and wetlands, among others. Aside from database development, custom software is being developed as another tool for use by the environmental review specialists in state government. Projected completion of this effort is 1995. Many users of geographic information in North Carolina will benefit from this database upon its completion.

With the Transportation Improvement Program the CGIA is generating 15 GIS data layers, each providing a key to the environmental review process

Taking the broad view of database development and use is one of the keys linking CGIA projects to the coordination part of its mission. CGIA refers to the database under development as the state's "corporate database" for GIS. It will be viewed as a strategic resource for the state when complete because it will consist of data layers that are significant to an extensive user group and must be maintained to be of continuing benefit for many types of decision making. Responsibility for the corporate database will be distributed but it will be regularly maintained through formal agreements with data providers. These "data custodians" are agencies with program responsibility for data sets that make a commitment to maintain the data in the GIS environment. For example, the Department of Transportation is the data custodian for the transportation data layers and the Department of Administration-State Property Office will be the custodian for the state lands and buildings layers.

Development, use, and maintenance of the corporate database will be enhanced by the upcoming communications advances in state government. A wide area communications network (WAN) has been established linking GIS user agencies in the state government complex. The Departments of Agriculture, Environment, Health, and Natural Resources, and Transportation, along with CGIA, are currently part of the network. This network will expand in the next few years to other state government agencies. Further expansion of communications capabilities supporting GIS will occur with implementation of the North Carolina Information Highway (NCIH). This effort will bring high-speed, fiber optic communications to the GIS user community in every part of the state by the end of the decade. Local governments, regional organizations, utilities, academic institutions, and other organizations will eventually become a part of NCIH. CGIA is serving on a work group to ensure that the communications needs of the GIS user will be met by the NCIH.

Implementation of the North Carolina Information Highway will bring high speed fiber optic communications to the GIS user community in every part of the state by the end of the decade

With full implementation of NCIH and the development of digital geographic databases throughout North Carolina, the promise of distributed GIS across the state is expected to become a reality. Data sharing and partnerships between all of the GIS users in the state will be facilitated by the technical advances mentioned above. New major applications such as economic development and health care planning will bring geographic information and GIS to the forefront once again as tools for the decision maker. The geographer must play a leadership role by using geographical analysis to approach these issues. The role of CGIA will continue to evolve as not only a data development agency but one of greater leadership in geographical analysis. Current and new users of GIS technology need the continuing education that the geographer can offer.

New developments in fields such as health care planning and economic development will need the tools of geographic information systems and the leadership role provided by the geographer

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ABOUT THE COVER: DIGITAL IMAGE PROCESSING, TIGER FILES, AND GEOGRAPHIC INFORMATION SYSTEMS

Art Rex

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Geographic Information Systems (GIS) have been greatly enhanced by a wide range of available data sources. The availability of digital data through a variety of public and private vendors are playing a critical role in the implementation of the Watershed Management Act in North Carolina. Regulation of minimal environmental standards of these geographic regions have been entrusted to local governments, who in turn are utilizing the many capabilities of GIS.

Location is one of the fundamental characteristics of geographic data and the ability to locate geographic features accurately is a primary function of a GIS. Geo-referencing allows the features of different data layers to overlay appropriately. Displaying a variety of layers simultaneously allows users to view the spatial relationships between phenomena. This feature is a fundamental function of a GIS and this function has helped local governments acquire visual information to help identify and manage watersheds.

Technical Issues

Cost of data input has often been a prohibitive factor to many local governments acquiring GIS capabilities, however, recent availability of digital data at a relatively low cost is a viable alternative, if one can work with the input scales of the data. These limitations are generally not a concern when dealing with watershed management activities.

Both covers of the journal were created with the combination of several different digital data sources. ARC/INFO and ERDAS (Earth Resource Data Analysis System) were the geoprocessing software packages utilized on a SUN IPX workstation.

The front cover consists of a TM (Thematic Mapper) satellite image that was classified within ERDAS to map land cover categories. This file was transferred to the vector based ARC/INFO system and was clipped using the drainage basin cover supplied by the USGS (United States Geologic Survey). The hydrography or surface water was then draped over the land cover file to help enhance the visual impact of the watershed. This file was acquired from the USCB (United States Census Bureau) TIGER (Topologically Integrated Geographic Encoding and Referencing) database for Burke and Caldwell Counties in North Carolina. The utility of a digital layer of land cover is valuable for many for watershed models, and can easily be handled by most GIS packages.

The back cover utilized the TIGER files almost exclusively. The only layer that is not from TIGER is the actual basin boundary (USGS). This cover clearly demonstrates the types of data that are within the TIGER files. These files are generally free of charge if you do your own processing and are available on CD's (Compact Disks) from most university map libraries. The diversity of layers (roads, railroads, hydrography, transmission lines, county lines and incorporated areas) are amazing and can be coupled with other data sources to enhance the capabilities of local governments in watershed management.

These covers depict one sub-basin of the Upper Catawba Drainage Basin Project being directed by Mike Struve and Dee Blackwell at the WPCOG (Western Piedmont Council of Governments). This project is a cooperative effort between WPCOG, ARC (Appalachian Regional Commission), USGS, Duke Power, the North Carolina Nature Conservancy, North Carolina Center for Geographic Information and Analysis, Appalachian State University and numerous local and county governments.