HURRICANE FLOYD:
CAUSES AND CONSEQUENCES

(Activities Integrating Geography, Science, and Mathematics)

North Carolina Geographic Alliance
2002
Forward

The North Carolina Geographic Alliance is a grass-roots organization of teachers and professional geographers dedicated to promoting and enhancing geographic education in our state. Through its summer institutes, workshops, curriculum monographs and newsletters, it has enlisted thousands of teachers and administrators. Its newsletter, received by every school in the state and nearly 5,000 teachers, announces Alliance events, provides lesson plans, book reviews, geography quizzes, maps, and other articles of help and interest to teachers. The Alliance hosts an annual meeting in Burlington, NC, each October and is an active participating member of the North Carolina Council for the Social Studies.

The Alliance’s instructional materials development efforts include one major curriculum project each year. This year’s monograph, *Hurricane Floyd: Causes and Consequences*, is the result of an Alliance Summer Institute funded jointly by the Eisenhower Foundation, the Alliance, and the Humanities Extension/Publications Program of North Carolina State University.

This activity book provides lesson plans and activities that integrate geography, science, and mathematics. It also integrates the North Carolina Standard Course of Study and the Six Essential Elements of Geography for Life—the national geography standards.

For information about the activities and publications of the North Carolina Geographic Alliance please contact Dr. Derek Alderman at East Carolina University, 252-328-4013, or Dr. James Young at Appalachian State University, 828-262-2689.
Preface

This monograph is the result of a summer institute for teachers held on the campus of East Carolina University in 2001. Two years earlier eastern North Carolina suffered the consequences of the state’s worst natural disaster when Hurricane Floyd swept across the area flooding much of the coastal plain and disrupting the region’s economy and shattering the lives thousands of its citizens, including the deaths of more than 50 people.

The disaster raised many questions for teachers and students and presented area scientists with an opportunity to study the consequences of one of nature’s great forces. Dr. Paul Gares of the Geography Department assumed the leadership role for the institute and received Eisenhower Foundation funds that were supplemented with monies from the Alliance and NC State’s Humanities Extension Program. Twenty teachers, consultants, geographers and science curriculum specialists exchanged ideas, identified appropriate materials and web sites, and shared life experiences in an effort to develop model lesson plans that would examine Hurricane Floyd and its consequences from a geographic perspective.

Institute participants, who developed the instructional materials, are identified throughout the text. The materials were collected, edited, and formatted into lesson plans by Nancy Bray, a local science teacher and institute participant. We trust the monograph will serve as an instructional model for many years to come.

I wish to thank all teachers who took time from their busy summer schedules to attend our institute. Without their contributions this publication would not have been possible. Finally, I am grateful to Dr. James Clark of North Carolina State University who was an early supporter of this effort.

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Useful Web Sites
1. Climatic and Hydrologic Systems of Eastern North Carolina – (Filename: Hydro & Climate systems.doc)

This Microsoft Word document is a copy of the paper by Paul Gares that is included in the beginning of the Hurricane Floyd: Causes and Consequences Monograph. It may be reproduced freely.

2. Climatic and Hydrologic Systems of Eastern North Carolina – (Filename: Hydro & Climate systems.ppt)

This is a PowerPoint document. This poster by Paul Gares was presented at the 2nd Hurricane Floyd Conference held at ECU in May, 2001. It includes all the figures from the paper of the same title, in color. There are several additional figures that are pertinent to the topic that were not included in the paper. Each figure is presented as an individual slide that may be copied. The entire presentation may be shown as a slide show either on the monitor screen or attached to a projector and projected onto a large screen.

3. Effect of Hurricane Floyd Flooding on Pamlico River Estuary Water Quality and Fishes- (Filename: Estuary Water Quality.ppt)

This is a PowerPoint document. It represents a poster prepared by Joseph Luczkovich of East Carolina University, with Larry Ausley, Chris Pullinger, Gercy Ward and Katy West of NC Dept. of Environment and Natural Resources. This poster was presented at the 2nd Hurricane Floyd Conference held at ECU in May 2001. It reports on the concentration of certain nutrients and on the incidence of fish diseases in the Pamlico River following Hurricane Floyd. Like the other PowerPoint, the images on this one appear on individual slides. They may be reproduced from the picture or the entire show may be presented.

4. Miscellaneous Photographs of Hurricane Floyd - (Filename: Floyd Photos.ppt)

The photographs were taken by Paul Gares and by friends of his who shared them with him. Some photos are from web pages.

5. Princeville’s Pride: A History of Floods and Freedom - (Filename: Princeville.ppt)

This is a PowerPoint presentation by Dr. Ron Mitchelson of ECU with historical narrative and supporting graphics which illustrates Princeville’s history of devastating floods and the community’s courage and persistence.

6. Princeville, Images of the Flood of the Century – (Filename: Princeville2.ppt)

This is a PowerPoint presentation of photos taken immediately after the Floyd event showing property damage, impacts on animals and dangerous situations in the Tarboro and Princeville area.
Climatology and Hydrology of Eastern North Carolina and Their Effects on Creating the Flood of the Century
Paul A. Gares
East Carolina University

Abstract: Hurricane Floyd crossed eastern North Carolina on September 15 and 16, 1999, causing the largest disaster in the State’s history. The majority of the damage was caused by flooding associated with heavy rainfall rather than by high winds or coastal erosion. The rainfall produced a flood that exceeded the predictions for the 100 year event, catching most of the resident to the region by surprise. The general perception was the region had seen hurricanes of that magnitude before and they had not produced such extreme floods. This particular flood occurred because hurricane Floyd arrived less than two weeks after hurricane Dennis, which dropped up to 10 inches of rain on the region, saturating the soil and raising water levels to the bankfull stage. When hurricane Floyd dropped an additional 6-16 inches, the likelihood of a severe flood was enhanced. There are a number of physical features of eastern North Carolina that contributed to making this flood so severe. These include: the shape of the drainage systems; the topography of the coastal plain; the characteristics of the soils; and the land-use on the coastal plain. These factors combine with precipitation to produce hydrologic conditions that are highly variable, as these factors vary in time and space. When these factors come together in certain unique ways, extreme events, such as the flood associated with hurricane Floyd, occur.

Introduction

On September 16, 1999, hurricane Floyd made landfall on the coast of North Carolina in the vicinity of Wrightsville Beach. Residents of coastal areas along the southeast coast of the United States had been following the progress of this hurricane for several days as it moved through the Caribbean, across the Bahamas and along the Florida coast. As with all hurricanes, the National Weather Service predicted landfall over a rather broad section of coast, this time ranging from Charleston, South Carolina to Morehead City, North Carolina. Of greater concern early on was the speed of the winds associated with the storm which were reaching 150 mph, making it a category 5 storm. As Floyd moved north, however, the wind speeds diminished, so that by the time it crossed the coast maximum winds were around 100 mph. To the residents of eastern North Carolina, the storm had become more of a nuisance, not even measuring up to the force of hurricanes Bertha and Fran which had followed nearly the same path in 1996. What people did not realize was that this storm was going to create widespread havoc throughout the region.

By the morning of September 17, 1999, hurricane Floyd had already moved far enough north that rainfall had ceased in the southern part of the state. The sun appeared during the early afternoon across all but the northern-most part of the region. The heavy rains overnight had caused localized flooding along small creeks, but these waters quickly passed through the system. Residents began hearing warnings of possible flooding along the major rivers that afternoon, and indeed water levels began to rise that evening. When people awoke on Friday September 18th, residents of the floodplains of the Tar, Neuse and Cape Fear Rivers found water lapping at their doors. Widespread evacuations began, and people looked in incredulously as water rose in their living rooms destroying treasured possessions. There was a general sense of amazement that such a disaster had developed from this rather innocuous storm. Yes, rainfall had been significant, but people recalled other
storms that produced as much rainfall and no flooding. It turns out that a rather unique set of circumstances combined to create this flood.

The purpose of this paper is to examine the climatic and hydrologic conditions of Eastern North Carolina with the purpose of explaining how this flood occurred. In order to accomplish this, a review of factors that affect flooding in this region will be undertaken and then rainfall and river stage data will be provided to characterize the magnitude of the event. There are five factors that affect river flow in general and flooding in particular: 1. The amount of precipitation and its intensity; 2. The shape of the drainage basin; 3. The topographic characteristics of the drainage basin; 4. The characteristics of the soils within the drainage basin; and 5. The land use characteristics of the region. Each of these factors will be discussed within the context of eastern North Carolina.

**Eastern North Carolina**

Eastern North Carolina coincides with the region called the coastal plain. It consists of a flat, relatively featureless plain that slopes gently from the Piedmont to the ocean, losing about 200 feet in elevation over its 75-100 mile width. The flat appearance of the plain leads to the conclusion that runoff and surface erosion is minimal. Recent research by Phillips et al (1993; 1999) and Slattery et al (1997) suggests that this is not true.

![Map of North Carolina with precipitation data](image)

**Figure 1:** North Carolina annual rainfall and monthly distribution of rainfall for the Coastal Plain.

Rainfall across Eastern North Carolina ranges from 45-65 inches per year (Figure 1), with the higher amounts concentrated along the coast, mainly in the southern two-thirds of the region. Rainfall is highly seasonal, with maximum amounts of 5-7 inches during June, July, August and September. There are four precipitation mechanisms responsible for the rain: 1. Cold fronts that cross the state from west to east and that dominate from fall to spring;
2. Thunderstorms produced by convective systems that develop during the hot, muggy summer months; 3. Coastal rain associated with northeaster storms that develop off the Cape Hatteras coastline; and 4. Tropical storm systems that track north from the Caribbean, often developing into hurricanes. Hurricanes are most likely to affect the region in late summer and early fall. This is a period of the year when monthly rainfall drops from about 4.5 inches in September to about 3 inches in November.

Four large river systems flow across the coastal plain (Figure 2). The shape of drainage basins is significant as they are elongated in a northwest-southeast direction, with the main trunks of the rivers running mainly along the southern margins of the watersheds. The location of the rivers with respect to their floodplains is significant because higher ground is generally located on the southern side of the rivers whereas broad, flat floodplains lie to the north. This configuration explains the fact that the most extensive flooding occurred north of the rivers with sections of Tarboro, Greenville, Goldsboro and Kinston among other local communities being completely inundated.

![Drainage systems of the Coastal Plain of North Carolina.](image)

There is a general perception that the soils of the coastal plain are predominantly sandy with silt/clay soils located in marshy or low-lying areas. The particle size characteristics of soils are an important component of the hydrologic system because they determine to a certain extent the amount of precipitation that can infiltrate into the soil, and therefore the amount of water that runs off across the surface. The infiltration/run-off relationship determines the rate at which the river discharge increases following the beginning of rainfall, and the length of time over which increased discharge occurs. A soil survey of Pitt County (Soil Conservation Service, 1974), located approximately in the middle of the coastal plain, reveals that about 63% of the land has soils characterized as poorly- or extremely poorly-drained, and the remaining 37% are equally divided between moderately
well- and well-drained. Infiltration experiments conducted on two fields in southern Pitt County reveal the degree to which the particle size characteristics affect infiltration. The first field consisted primarily of soils of the Wagram series, characterized as well-drained loamy sand soils with an A horizon approximately two feet in depth. The second field consisted of Lenoir Series soils described as poorly drained loams with a shallow A horizon at about 8 inches depth. The infiltration data (Figure 3) reveal sharp differences between the soils. The first set of infiltration runs took place in late April, 1996 after a long period without rain. Gravimetric soil moisture on the Wagram field was 0.7% and on the Lenoir field 6.4%. The second infiltration run was done in September, 1996, after hurricane Fran. Gravimetric soil moisture was 31% on the Wagram field, but not measured on the Lenoir field. On the dry fields, the initial infiltration rate is very high on the Wagram field, but it falls off to an equilibrium value of 10.8 inches/hour after 15 minutes of running time. Infiltration is lower on the Lenoir field, starting at 25 in/hr and achieving equilibrium at 2.4 in/hr. Under wet conditions, the infiltration rates are very low - 5.2 in/hr on the Wagram field and 0.4 in/hr on the Lenoir field. Given these observations, we could expect infiltration rates of 5-10 in/hr on about 18% of Pitt County, and rates of 0.5-2.5 on about 63% of the County. It seems safe to conclude that the 18% defined as moderately well-drained would have infiltration rates in the 2.5-5 in/hr range.

Figure 3. Infiltration on two Coastal Plain agricultural fields.

Land use in Eastern North Carolina is dominated by agriculture (Figure 4). Land classified as agricultural makes up about 15% of the image shown in Figure 4. The primary crops grown in the region are tobacco, cotton, corn and soy. The planting schedule can be important to hydrological processes as fields are left bare for certain parts of the year. Tobacco is generally planted in early spring and harvested by mid-summer, whereas cotton and soy are planted in late spring or early summer and harvested in mid to late fall. Fields
are generally left bare over the winter, although in recent years there has been an increase in the number of fields planted with a cover crop such as rye.

![Land Use - % of Total Land](image)

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<td>Extractive</td>
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<tr>
<td>Forest</td>
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<tr>
<td>Agriculture</td>
<td>27.75</td>
</tr>
<tr>
<td>Wetland</td>
<td>22.02</td>
</tr>
</tbody>
</table>

**Figure 4.** Land use in Eastern North Carolina. White represents agricultural land; light grey is wetland; medium grey is forest; dark grey is urban; nearly black is water.

**Hurricane Floyd**

On September 7th, 1999, a tropical depression was identified by the National Weather Service, located some 950 miles east of the Leeward Islands. By early on September 8th, the storm had gained sufficient strength to be classified as a tropical storm, and it became hurricane Floyd on September 10th, when the eye of the storm was located some 190 miles east of Barbuda. At that point, Floyd was moving in an east-northeast direction at 10 mph. On September 14th, Floyd crossed the Bahamas, moving at a speed of 14 mph toward the coast of Florida. Maximum sustained winds were 150 mph, making it a very strong category 4 storm on the Saffir-Simpson scale. Experts observed that Floyd had developed into a very large storm in which hurricane force winds (>74 mph) extended 125 miles out from the eye. The cloud cover associated with Floyd extended about 750 miles in a north-south direction, and 650 in an east-west direction. By contrast, comparable measurements made for
hurricane Andrew when it was in approximately the same location, some 350 miles east of Miami, reveals a more compact storm, some 250-280 miles wide.

Figure 5. Precipitation recorded at Kinston, NC., September 14-16, 1999. Also shown are rainfall intensities for selected periods during the storm.

As Floyd progressed through the eastern Caribbean, forecasters believed that the storm would turn to the north. However, Floyd confounded the experts by continuing on an westward course and evacuations were carried out along the entire coast of Florida. Late in the evening of September 14th, Floyd finally began the long-awaited turn to the north. At this time, the outer bands of the hurricane began to cross the North Carolina coastline, coming into contact with a strong cold front that was moving across the southeast. The stalled cold front produced 0.5 to 1.0 inches of rain across eastern North Carolina on September 14th, and into the early morning of September 15th (Figure 5). At 5AM on September 15th, the eye of the storm was centered 100 miles east of Cape Canaveral, moving forward at 14 mph, with maximum sustained winds of 140 mph. By 1pm, the eye was located about 150 miles east of Jacksonville. Maximum sustained wind speed had diminished to 125 mph, hurricane force winds (>74mph) still extended out to 140 miles from the eye, and tropical storm force winds (>39mph) extended out 230 miles. At this time, Floyd was about 250 miles south of Wilmington, NC. The heavier rain bands were beginning to move across the North Carolina coastal plain, producing heavy precipitation during the afternoon of September 15th (Figure 5). Tropical storm winds began to be felt along the NC shoreline from Wilmington to Morehead City.

By 5pm on September 15th, the storm center had moved to within 215 miles of Wilmington. The storm's forward speed had increased to 17 mph, while the maximums sustained winds had dropped to 115 mph. The hurricane force winds still extended 140 miles out from the eye. By 11 pm that night, the storm center was 100 miles south of Wilmington.
Hurricane Floyd finally made landfall at 3 am on September 16th, at Cape Fear. Maximum sustained winds at that time were 110 mph. The National Weather Service continued to call for 6 to 12 inches of rain along the hurricane path, as it had been doing for the previous 24 hours. The hurricane was moving faster as it passed over the coast, advancing northward at 20 mph. At 7 am, the center was approximately over New Bern, moving at 24 mph. Maximum sustained winds had dropped to 100 mph. By 11 am, the storm was passing over Virginia Beach, moving offshore again. Maximum winds speeds were 80 mph.

The primary impact of this storm was the rainfall associated with the storm. Whereas the National Weather Service had been predicting 6 to 12 inches of rain, preliminary data indicate that 10 to 18 inches of rain actually fell over much of eastern North Carolina (Figure 6). This amount of rainfall is unusual for this region, representing 15-25% of the annual total, and exceeding the average monthly rainfall for September by 6-12 inches. However, the region has experienced heavy rain before, having had recent experiences with hurricanes Bertha, Fran, and Gloria. Inhabitants of eastern North Carolina were, therefore, surprised when many small creeks in the region suddenly grew, overflowing their banks and flooding extensive areas adjacent to the streams. Residents woke up on Friday September 17th, to find that the main stems of the region's rivers were predicted to reach flood stage during the course of the day and that the rivers would continue to rise for several days. Stage data for the Tar River at Greenville typify the river's conditions throughout the region (Figure 7). At this point, discharge data are not yet available from the USGS, but the agency estimates that the discharge will rank the flood in the 200 year recurrence interval range. This is significantly different from the 500 year level that many have cited, but this estimate is based on the stage data which have inherent inaccuracies.

The Hurricane Floyd Flood

All information about hurricane Floyd suggests that this storm should have produced moderate flooding. Rather, Floyd created the worst disaster in the history of the state of North Carolina. Indeed, some estimates indicate that 50,000 homes were affected by the flood waters and that total losses will exceed $6 billion. The question on many people's minds is: what made Floyd such a devastating storm?

The answer to the question is found in the topics reviewed above. The primary factor was the fact that not two weeks prior to Floyd's arrival, hurricane Dennis moved over the Outer Banks and then stalled offshore. The result was several days of rain throughout the region with rainfall totals reaching 8-12 inches (Figure 5). In fact, this amount of rain was sufficient to raise the rivers to bankfull stage. The rivers had only just begun to recede when Floyd arrived. The precipitation totals for the two storms are depicted in Figure 5. The map shows that much of eastern North Carolina received at least 13 inches of rain, with some places receiving over 20 inches. It is useful to consider the rainfall in terms of the infiltration data presented in Figure 3 and in terms of the nature of the soils that predominate in eastern North Carolina. Given that poor drained soils make up the majority of the soils of the region, and given infiltration rates of these soils we can assume that rainfall intensities greater than about 0.5 inches per hour will result in nearly all the rain running off the land. These intensities occurred several times during the passage of Floyd. Using Pitt County as an example, about 270,000 acres are poorly drained. If we assume no infiltration on this land, and we estimate that 12 inches of rain fell during Floyd, there would be 11.8 billion cubic feet
Figure 6. Distribution of rainfall during Hurricanes Dennis and Floyd. Also shown is total precipitation from the two events. (Note: Date for Dennis and Floyd were obtained from the State Climate Office of North Carolina; precipitation total data are from the National Climate Data Center.)
of water to dispose of. Given that the Tar River drainage system comprises about seven counties, if we assume that comparable amounts of water were generated in each county, there would be nearly 100 billion cubic feet of water to move through the system.

![River stage data graph](image)

**Figure 7.** River stage data for the Tar River at Greenville, September, 1999 (data from USGS Regional Office, Raleigh, NC).

The runoff situation in Eastern North Carolina is modified by the land use characteristics of the region. The heavy agricultural usage means that the vegetation cover is modified at certain periods of the year when the harvest occurs. The tobacco harvest typically occurs in late July through August. The result was that when Dennis and Floyd moved through eastern North Carolina many fields were covered only with crop residues. The absence of this vegetation can be expected to increase the intensity of rainfall impact on the surface and to increase run off.

From a hydrological standpoint, it could be argued that the flood associated with Floyd could have been worse had the storm track and the river basin orientations not been perpendicular to each other. There is evidence that discharge is intensified when a storm tracks along the axis of a drainage basin, but it is attenuated when the storm passes across drainage basin perpendicular to its axis. This was the case in this storm. Although there was considerable rain at the upper ends of the coastal plain drainage basins, it took several days for the peak flow to move downstream. This at least allowed evacuations to occur with some time to spare.

**Conclusions**

We have learned many lessons from this particular storm. It is clear that we do not completely understand all the interactions involved in environmental events at least while they are occurring. If we did, we would have seen that the environmental factors that existed in eastern North Carolina prior to the storm were likely to lead to a catastrophic situation. The
flood associated with Floyd was the product of a set of conditions that were relatively unique. The most important of these factors was the heavy rainfall that occurred just 10 days earlier when hurricane Dennis passed across the region. The rainfall associated with Dennis was spread across several days and increased soil moisture. The wet soils then inhibited infiltration when the rainfall from Floyd fell. The high percentage of poorly draining soils in the region combined with pre-existing moisture conditions to limit infiltration. This and the intense rainfall that occurred during the storm led to high run off. The relatively rapid rise of the Tar River suggests that surface or sub-surface run-off was quite significant in this storm. All these conditions are also influenced by the absence of vegetation on the tobacco fields. The biggest problem for inhabitants of the coastal plain, and for the managers of the occupied areas, is that it is virtually impossible to quantify the combinations of these factors to produce reliable probability of occurrence data. Thus, the link between the operation of the physical system and the management of human systems will be very difficult to establish with a high degree of certainty.

References Cited


The Flood of '99
in eastern North Carolina
and the Five Themes of Geography
by
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Location: "All places possess absolute and relative location."

Location answers the question: Where? Location can be absolute; i.e., a grid system such as latitude and longitude. It can also be relative; i.e., locations in reference to where other things are located, or relative to surrounding places.

1. Absolute location: Eastern North Carolina is situated on the Atlantic coast midway between Eastport, Maine and Key West, Florida (between Lat. 34 --36 30'N and Long. 75 30'--84 W). The Coastal Plain extends westward from the Atlantic Ocean to the Fall Line, a distance that varies from 100 to 150 miles. The maximum north-south distance between the Virginia and South Carolina boundaries is 190 miles. The region's elevation ranges from sea level to an average 400 feet along the Fall Line. The Coastal Plain is covered with a veneer of sands and clays and is, as its name implies, a relatively flat area.

2. Relative location: The eastern point of the state (the Outer Banks) lies directly south of Philadelphia, Pennsylvania. The Coastal Plain region of eastern North Carolina can variously be considered an Eastern, Southern, Southeastern, Middle Atlantic, or Atlantic Seaboard region. It lies east of the Piedmont region and contains 45 percent of the state's area and can be divided into two parts: The Outer Coastal Plain, or Tidewater region, and the Inner Coastal Plain. The Outer Coastal Plain lies next to the ocean and is extremely flat and is characterized by marshes and swamps. The Inner Coastal Plain is higher and better drained. A line through the settlements of Gatesville, Plymouth, Washington, New Bern, Jacksonville, Burgaw, and Wilmington marks the boundary between the two sub-regions.
Place: "Every landscape possesses physical and human elements."

All places have special features that distinguish them from other places. All places have their own distinguishing physical and cultural characteristics. Different people have different perceptions of places.

1. Physical

The Outer Coastal Plain is bounded on the east by a chain of barrier islands named the Outer Banks which extend along the coast from Virginia to South Carolina. Beautiful beaches, many covered with sand dunes, are located here. Three capes jut out from these islands: Cape Hatteras, Cape Lookout, and Cape Fear. Off the shores of these capes lie shallow reefs which have caused many shipwrecks--"the Graveyard of the Atlantic."

To the west of the Outer Banks is an extensive body of water consisting of five major sounds: Core, Bogue, Albemarle, Currituck, and Pamlico. The mainland west of these sounds contains lakes, ponds, and fresh and salt water marshes and swamps. The largest of these are Lake Mattamuskeet and the Dismal Swamp. Extending across the Outer Coastal Plain is a zone containing a number of elliptical and oval scars known as Carolina Bays. Many of these shallow depressions are occupied by lakes. Lakes Mattamuskeet, Phelps, White, and Waccamaw are examples. They are thought to be meteorite scars or solution depressions but their true origin is still unknown.

The Inner Coastal Plain occupies the position between the Outer Coastal Plain on the east and Piedmont on the west. Its width varies between 70 and 100 miles while its elevation ranges from about 50 feet above sea level to a maximum of 740 feet at Candor in Montgomery County. The prominent relief features in the area are the Sandhills--so named because of their deep sandy soils and rolling topography. Elevations in the Sandhills vary between 500 and 740 feet above sea level. In general, the slightly rolling topography of the Inner Coastal Plain offers better natural drainage of the land surface than is found in the flat Outer Coastal Plain. Nevertheless, wetlands characterize much of the area.
One peculiar aspect of the Inner Coastal Plain is that swampy areas may be found in upland areas, or the divides between adjacent streams. In eastern North Carolina, these swamps are called *pocosins*, an American Indian word meaning "swamp on a hill."

The Coastal Plain enjoys a Humid Sub-tropical type of climate. Nearness to the Atlantic Ocean and adjacent sounds modify the climate of the Tidewater area while the rest of the eastern region enjoys a climate characterized by a long frost-free season, abundant rainfall, warm humid summers, and mild winters. These climatic characteristics support a variety of vegetation with forests and a varying undergrowth of shrubs and tidal marshes. Today pines occupy about 70 percent of the forested portions of the Coastal Plain with loblolly the most abundant species.

Eastern North Carolina averages about 48+" of rainfall a year. Seasonal variation in precipitation occurs with summer rainfall usually the greatest, with July the wettest month. Autumn is the driest season and October the driest month. Floods may occur at any season, but are most frequent in early spring, summer, and early fall. Rains associated with hurricanes are the main cause of late summer and fall floods.

A hurricane is a large, extremely powerful, low pressure storm which forms over warm ocean waters near the Tropic of Cancer. At the center of these storms, which average 400 miles in diameter, is the eye, an area of calm. Swirling around the eye are winds which exceed 75 miles per hour and often reach 100 miles per hour or more. Heavy rain, abnormally high tides, and winds of devastating force accompany the arrival of hurricanes to the North Carolina Coastal Plain. North Carolina's beaches, and man-made structures on the Outer Banks and along the immediate coast, are especially prone to damage from these storms. While the hurricane "season" lasts from June 1st until November 30th, some years pass without any hurricanes visiting North Carolina; during other years several hurricanes may threaten the region as Hurricanes Dennis and Floyd did in September, 1999.

A river system consists of a main river and the numerous tributaries which flow into the main river. All the area drained by a
river and its tributaries is referred to as that river's drainage basin. Streams originating in the Coastal Plain and eastern Piedmont have wide valleys and flat slopes. The eastern part of the Coastal Plain has swampy areas with very flat stream slopes. The dominant drainage basins in eastern North Carolina are the Roanoke, the Tar-Pamlico, and the Neuse which flow eastward and discharge into area sounds. The Cape Fear flows southeastward into the Atlantic Ocean.

The source of ground water is precipitation. Water is held in underground rock formations, usually porous layers of sedimentary rock called aquifers. Aquifers, like rivers, are an important source of water for North Carolinians. Many municipal water supplies come from wells which reach deep into the aquifers for fresh water. In the sedimentary rocks of the Coastal Plain the sand, clay, and limestone are mostly unconsolidated and water moves through the pore space between the grains.

2. Human

Eastern North Carolina has traditionally been an area of important agricultural activities with tobacco, corn, soybeans, cotton, sweet potatoes, and peanuts being dominant crops. The area also has witnessed an expansion of livestock activities, especially enormous increases in the raising of hogs, chickens, and turkeys. Forestry continues to remain an important element of the Coastal Plain's economy. In the early 1950s large deposits of phosphate were discovered adjacent to the Pamlico River in Beaufort County and continue to be mined. With 1,000 miles of tidal shoreline, 15,000 square miles of continental shelf, and 2,500 square miles of bays and sounds, commercial and recreational fishing activities contribute to the local economy.

Manufacturing in eastern North Carolina is diverse and includes the traditional tobacco and food processing, lumber and wood products industries, and apparel and textiles. Newer industries include the manufacture of electrical and non-electrical industries, chemical and allied products, diesel engines, automotive components, pharmaceuticals, and medical supplies just to mention a few.

Eastern North Carolina is characterized by a large number of small and medium sized towns and villages; yet with a very dense
rural population where the averaged sized farm is small, less than one-third the size of the average U.S. farm of 450 acres. The Coastal Plain contains nearly half of the state's rural population. Indeed, several eastern counties are 100% rural. Small farms and a dense rural population partly mirror the nature of tobacco farming. Tobacco is the world's most labor intensive crop and family farms involved in this crop must by their very nature remain small. The growth in many of our coastal counties is in sharp contrast to rural eastern counties that have lost population and experience much out-migration, especially by minority populations. The growth of our coastal counties mirrors increased tourism, attraction of the beach and other coastal amenities to retirees, and to those seeking second homes with a recreation orientation. Of the ten fastest growing counties in North Carolina, six are coastal counties.

Nearly 25% of North Carolina's population is minority (this figure compares to 13% for the US as a whole). African Americans are the state's largest minority and they live primarily in our larger urban areas and the agricultural Coastal Plain counties of the east where they average about 35% of the population and are the majority population in several eastern counties such as Warren, Bertie, Northhampton, Hertford, and others.

North Carolina has the largest Native American population of any state east of the Mississippi River with the Lumbees and other smaller tribes located in the east. Native Americans, the increasingly visible Hispanics (especially in agricultural/food processing and construction jobs), and Asians, each represent about 1% of the state's population.

Human/Environment Interactions: "We are shapers of the landscape."

This theme deals with how the natural environment affects human activity, how people adapt to various physical environments, and how human activities have changed the physical environments. This theme could be called "human ecology" or the two-way relationship between people and their physical environment.

Humans variously respond to weather phenomena depending upon its type. In the case of hurricanes, this can vary from carrying
an umbrella to thousands of people evacuating their homes. A predicted hurricane landfall in coastal North Carolina is often preceded by a frenzy of activity as people board up their homes and businesses and as thousands of tourists pack up and leave their favorite vacation spots. Hurricanes Dennis and Floyd ruined many family’s summer vacations.

Humans have always responded to their natural environments in one way or another. Human modification of the landscape in eastern North Carolina has resulted in cultivated fields long cleared of their natural vegetation. Here, ditches and canals are characteristic landscape modifications of a flat landscape--designed to facilitate drainage of water off of cultivated fields. Both these changes and lax regulations allowed urban sprawl (with encroachment onto floodplains) to contribute to the human modification of drainage systems. Urban development has changed the movement of water.

The sketch below is a cross section of a coastal river's floodplain:

North Carolina has hurricane damages that average $235 million per year. The state ranks fourth after Florida, Texas, and Louisiana. Such damages normally include coastal flooding and inland wind damages. Flooding is related to the infiltration rate, the rate at which soil can absorb water which is determined by the amount of pre-existing water. In this case, Hurricane Dennis had already soaked the area prior to the arrival of Hurricane Floyd. The Flood of '99 racked eastern North Carolina with one-half of a year's rainfall (28") in two weeks (Dennis=6-8" & Floyd=15-20") causing flooding so severe that it has been called North Carolina's worst natural disaster. The total cost, yet to be determined, is estimated at more than $2 billion dollars.
Lessons learned? There are a number of myths that limit the general public's access to understanding flood frequency. These are grouped here into four general flood frequency concepts. The first two concepts are statements of the obvious; the last two are more subtle. Each, however, reflects the nature of probability statistics and the pitfalls of relatively small data sets.

Flood Frequency Concept #1: *The probability that a 100-year flood will strike a river in North Carolina is the same every year, regardless of how long it has been since the last 100-year flood.*

Flood Frequency Concept #2: *It is not a certainty that the 100-year event will occur sometime in the next 100 years (although it is pretty likely).*

Flood Frequency Concept #3: *In North Carolina, where historic data sets are small, the 100-year floodplain is likely to grow following a major flooding event.*

Flood Frequency Concept #4: *It is a virtual certainty that the defined 100-year floodplain is not the actual 100-year floodplain.*

The flood demolished man’s best planned infrastructure—those elements of a modern industrialized society that allow us to enjoy creature comforts: electric power was disrupted; water treatment and sewage disposal facilities were overtaxed and at times inoperable; pumping stations were under water; airport terminal buildings, planes, and rental cars were under water; roads and bridges were flooded and washed out leaving many eastern NC communities inaccessible urban islands. Even our city and county landfills could not absorb all the debris produced by this catastrophe.

Not all our communities remained islands, however. Princeville and Tarboro were submerged by the Tar River. Here enormous amounts of floodplain waters covered most houses as well as the dike designed to protect Princeville. The rushing waters were even forceful enough to pick up and move some of the houses. Perhaps the saddest scene, and certainly one of the most agonizing, was the one of cemetery caskets being dislodged from their resting places and floating downstream.
Much of eastern North Carolina is farmland and nearly 15% of the state's farms were put out of business because of the flooding. More than 100,000 hogs and 2 million chickens and turkeys either starved or drowned. Hog lagoons overflowed and fueled an ongoing dispute over large hog farms.

The flood waters became a murky soup of raw sewage, animal waste, chemicals, farm and lawn fertilizers, petroleum, and vegetation. These polluted waters flowed into our sounds disrupting marine life and coastal fishing. The organic matter is mostly trapped because the barrier islands of the Outer Banks convert the sounds into nearly closed lagoons. Studies are underway to determine whether or not oxygen-poor "dead zones" will develop in the Pamlico Sound. As the water warms in the spring, accumulated pollutants could suck oxygen out of the water through two processes--1) by decomposing and 2) by providing food for algae, which in turn rob oxygen when they die and decay. Some scientists fear an ecological time bomb as the weather warms up. One said, "Next summer is going to tell the tale."

Finally, the human toll. Fifty-one deaths have been attributed directly to this disaster in one way or another.

The only good news is that after Floyd automobile accidents dropped by 50 percent.

Movement: "We all resist the tyranny of place and distance."

Mobility of people, goods, and ideas. Movement includes travel, communication, diffusion, international trade, and global interdependence.

Hurricane Floyd spawned the largest mass evacuation in U.S. history. Both tourists and local residents fled the onslaught of Hurricane Floyd. During the flood, as waters began rising at unprecedented rates, residents fled their homes with little more than the clothing on their backs. Some were trapped and had to be airlifted by military helicopters with some 1500 such rescue efforts taking place. Thousands of ECU students fled their low-lying riverside apartments leaving books, computers, and clothing behind.
Some, using canoes, ingeniously paddled through their flooded second-story windows to rescue their pet cats and dogs. A total of more than 15,000 homes were destroyed or were made uninhabitable; 43,000 homes were damaged. The flood was widespread and affected 73 communities. The hardest hit, however, were Rocky Mount/Tarboro/Princeville; Greenville; Goldsboro; and Kinston.

Government and relief groups came into the communities with food, clothing, and financial assistance. Many church groups from across the nation arrived with military precision, set up tents and cooking facilities in church yards, and began taking thousands of hot meals to those displaced folks living in temporary shelters set up in many of the area's public schools.

Private donations as well as state and federal monies began to flow into the area. FEMA (Federal Emergency Management Agency) established emergency housing that consisted of hastily constructed camper-trailer villages across the area. Because many of the displaced lived in the flood plain they are now faced with the decision to either sell their homes at pre-flood values or have them elevated to a secure height. The government's buy-out program is aimed at reclaiming the flood plains. Thus, for many the dilemma is: Stay or go! The Princeville Town Council recently elected to stay and rebuild their community in its present location.

It is likely that many people, unwilling or unable to rebuild their homes and their lives, will elect to leave eastern North Carolina. But, rebuilding will go on as money begins to flow into the area to help repair houses, schools, farmsteads, businesses, washed out bridges and roads, and water treatment plants.

While the flood may cause some out-migration from the region, the area will continue to experience an influx of migrants from other areas of the nation. Some will be natives returning to home areas after a lifetime of living elsewhere. Others are young professionals taking advantage of new economic opportunities in the region, especially in the health-care fields. Still others are retirees who are moving to coastal areas, university communities, or areas offering recreational amenities.
Regions: "These are human constructs that promote understanding."

Areas on the surface of the Earth that are defined by certain unifying and homogeneous characteristics. These characteristics may be physical or human, and they may be defined by one feature or by multiple features. A region is a mental construct, or an organizational tool, used to define, examine, describe, explain, and analyze the physical and human environment.

Eastern North Carolina may be viewed as a region because of its many homogeneous physical and human characteristics. The area is recognized primarily as a flat coastal plain region with sandy soils, abundant precipitation, perennially flowing streams, and characteristic vegetation made up of coniferous and deciduous trees. The area's climate is subtropical and includes hot summers and mild winters.

The area's light sandy soils and climate have long encouraged farming and eastern North Carolina is known as an agricultural region characterized by a large number of small (by national standards) farms devoted primarily to the growth of tobacco, corn, and soybeans. The expansion of livestock production, especially large hog and poultry operations, represents a fairly new dimension to the region's agricultural picture.

The region's human landscape also is characterized by a large number of small and medium sized towns, many of which serve as market service centers for surrounding rural areas. Many of the area's largest urban areas are given over to port, military, and university activities.

The region also exhibits a multi-cultural human landscape that includes African-Americans as the largest minority group. Other minority groups include Native Americans, Asians, and a growing Hispanic population. Protestant churches dominate the religious landscape with small country churches and adjacent cemeteries commonplace throughout the region.