LEGISLATIVE

RESEARCH COMMISSION

EMERGENCY MANAGEMENT ISSUES

REPORT TO THE
1993 GENERAL ASSEMBLY
OF NORTH CAROLINA

1994 SESSION

A LIMITED NUMBER OF COPIES OF THIS REPORT IS AVAILABLE FOR DISTRIBUTION THROUGH THE LEGISLATIVE LIBRARY.

ROOMS 2126, 2226
STATE LEGISLATIVE BUILDING
RALEIGH, NORTH CAROLINA 27611
TELEPHONE: (919) 733-7778

OR

ROOM 500
LEGISLATIVE OFFICE BUILDING
RALEIGH, NORTH CAROLINA 27603-5925
TELEPHONE: (919) 733-9390

TABLE OF CONTENTS

STATE OF NORTH CAROLINA

LEGISLATIVE RESEARCH COMMISSION

STATE LEGISLATIVE BUILDING

RALEIGH 27611

May 23, 1994

TO THE MEMBERS OF THE 1993 GENERAL ASSEMBLY (REGULAR SESSION 1994):

The Legislative Research Commission herewith submits to you for your consideration its interim report on Emergency Management Issues. The report was prepared by the Legislative Research Commission's Committee on Emergency Management Issues, pursuant to G.S. 120-30.17(1).

Respectfully submitted,

Daniel T. Blue, Jr.
Speaker of the House

Marc Basnight
President Pro Tempore

Cochair
Legislative Research Commission

1993-1994

LEGISLATIVE RESEARCH COMMISSION

MEMBERSHIP

President Pro Tempore of
the Senate
Marc Basnight, Cochair

Senator Austin Allran
Senator Frank W. Ballance, Jr.
Senator R. L. Martin
Senator J. K. Sherron, Jr.
Senator Lura S. Tally

Speaker of the House of
Representatives
Daniel T. Blue, Jr., Cochair

Rep. Harold J. Brubaker
Rep. Marie W. Colton
Rep. W. Pete Cunningham
Rep. Bertha M. Holt
Rep. Vernon G. James

PREFACE

The Legislative Research Commission, established by Article 6B of Chapter 120 of the General Statutes, is the general purpose study group in the Legislative Branch of State Government. The Commission is cochaired by the Speaker of the House and the President Pro Tempore of the Senate and has five additional members appointed from each house of the General Assembly. Among the Commission's duties is that of making or causing to be made, upon the direction of the General Assembly, "such studies of and investigations into governmental agencies and institutions and matters of public policy as will aid the General Assembly in performing its duties in the most efficient and effective manner" (G.S. 120-30.17(1)).

The Legislative Research Commission, prompted by actions during the 1993 Session, has undertaken studies of numerous subjects. These studies were grouped into broad categories and each member of the Commission was given responsibility for one category of study. The Cochairs of the Legislative Research Commission, under the authority of G.S. 120-30.10(b) and (c), appointed committees consisting of members of the General Assembly and the public to conduct the studies. Cochairs, one from each house of the General Assembly, were designated for each committee.

The study of emergency management issues would have been authorized by Sections 2.1 (5) of House Bill 1319 (2nd edition) which passed both chambers but inadvertently was among the bills not ratified at the end of the 1993 Session. Part II of House Bill 1319 would allow studies authorized by that Part for the Legislative Research Commission to consider House Bill 88 (Senate Bill 75) in determining the nature, scope and aspects of the study. [The Committee is also authorized to study issue of compensation for disaster relief volunteers who are injured during and as a result of their volunteer activities. Section 2.1 (52) of House Bill 1319; (House Bill

1283/Senate Bill 1192)]. Section 1 of House Bill 88 provides in pertinent part that "the Legislative Research Commission may study the State emergency management program's ability in the future to adequately address preparedness, response, recovery, and mitigation for technological and natural hazards as may impact the citizens of North Carolina and their property." The relevant portions of House Bill 1319 and House Bill 88 are included in Appendix A. The Legislative Research Commission authorized this study under authority of G.S. 120-30.17(1) and grouped this study in its State and Local Government Grouping area under the direction of Senator J.K. Sherron. The Committee was chaired by Senator David R. Parnell and Representative Foyle Hightower, Jr. The full membership of the Committee is listed in Appendix B of this report. A committee notebook containing the committee minutes and all information presented to the committee is filed in the Legislative Library.

COMMITTEE PROCEEDINGS

The Committee on Emergency Management Issues met on April 14, 1994 and May 11, 1994 to consider the issue of funding a restudy of hurricane evacuations for coastal North Carolina.

At the April 14, 1994 meeting, the Committee heard from representatives of the N.C. Department of Crime Control and Public Safety, Division of Emergency Management, the Federal Emergency Management Agency (FEMA), and the U.S. Army Corps of Engineers (Corps) on the justification for the restudy.

The original hurricane evacuation study, "The Eastern North Carolina Hurricane Evacuation Study" was initiated in 1984 and completed in 1987. The study was managed by the Corps from its Wilmington District Office. Funding for that study was provided by FEMA ($225,000), the Corps ($240,000), and the State ($100,000).

Since the completion of the original study, population increases and technological advances in computer modeling have rendered much of the data from the 1987 study obsolete. This data is used by emergency officials to calculate clearance times, inundation zones, and evacuation networks. Failure to update this information could endanger the safety of coastal residents and the tourist population.

Among the critical changes that have occurred along the North Carolina Coast are a 20%+ increase in the residential population and a significant growth in the tourist population. Further, advances in computer modeling techniques show that the height of the hurricane storm surge for a fast-moving hurricane, Hurricanes Hugo or Andrew, for example, could be 5' to 10' higher than the values predicted in the original study.

The Corps has issued a Report of Recommendation documenting the need for the hurricane evacuation restudy. A copy of that report is included as Appendix C to this report. At this time work has begun on the mapping part of the project. It is from the completed mapping process that data may be taken and utilized for evacuation planning - such as determining inundation zones, locating shelters, clearance times for barrier islands, etc. After the mapping is completed, the other tasks to be undertaken as a part of the restudy include shelter analysis, vulnerability analysis, transportation analysis,

behavior analysis, and an update of the software used by emergency officials for hurricane evacuation decisions, Hurrevac.

The total cost of the restudy is projected to be $1.7 million dollars and the restudy should be complete in 1997. The Division of Emergency Management has recommended that the State provide $420,000 as the State's share of the costs of the project. Federal monies for hurricane studies are limited and the State's contribution will allow the restudy to be completed as rapidly as possible.

After hearing the presentations on the need for the restudy, the Committee voted to recommend that the General Assembly fund the restudy in the amount of $105,000 per year for the next 4 years. The Committee requested that legislation be drafted appropriating the initial $105,000 for fiscal year 1994-1995.

At the May 11, 1994 meeting the committee reviewed the draft report and proposed legislation. Representative Wright and Mr. Seamon expressed concern that the population figures for the coast included in the Corps report (See Appendix C) may have been understated. In the restudy a close look must be taken at actual population figures and these numbers taken into account in calculating clearance times for the coastal areas. The committee members present voted unanimously to approve the report and forward it to the Legislative Research Commission its review.

FINDINGS AND RECOMMENDATIONS

After a review of the data provided by the Division of Emergency Management, the Federal Emergency Management Agency, and the U.S. Army Corps of Engineers, the Committee on Emergency Management Issues recommends to the General Assembly that $105,000 be appropriated for the 1994-1995 fiscal year as part of the State's share of the cost of the hurricane evacuation restudy. The Committee also recommends that the hurricane evacuation restudy be funded in the amount of $105,000 per year through 1997, bringing the total State contribution to the project to $420,000 of the estimated $1.7 million needed to complete the restudy.

In keeping with this recommendation, the Committee proposes ratification of Legislative Proposal I: AN ACT TO APPROPRIATE FUNDS FOR A HURRICANE EVACUATION RESTUDY OF COASTAL NORTH CAROLINA.

GENERAL ASSEMBLY OF NORTH CAROLINA

SESSION 1993

S/H D

93-ems-01
THIS IS A DRAFT 27-APR-94 09:46:50

Short Title: Funds for Hurricane Evac. Restudy (Public)

Sponsors:

Referred to:

A BILL TO BE ENTITLED

AN ACT TO APPROPRIATE FUNDS FOR A HURRICANE EVACUATION RESTUDY OF COASTAL NORTH CAROLINA.

Whereas North Carolina is one of the most vulnerable of the eastern seaboard states to hurricane strikes; and

Whereas, in 1984 a study on hurricane evacuations was initiated by the North Carolina Division of Emergency Management, the Federal Emergency Management Agency, and the U.S. Army Corps of Engineers; and

Whereas since the completion of the original study in 1987, the coastal population has increased 20%+ and the tourist population has increased significantly; and

Whereas new computer modeling techniques show that the storm surge heights for fast-moving hurricanes could range up to 10' higher than those projected in the original study causing far more extensive flooding and destruction than earlier anticipated; and

Whereas the change in data indicates that current clearance times and flood zones for the State's coastal communities may no longer be valid and emergency management decisions based on the existing, obsolete information may endanger lives; and

Whereas the U.S. Army Corps of Engineers has reviewed the data and recommended that a hurricane evacuation restudy of coastal North Carolina be done; NOW THEREFORE,

The General Assembly of North Carolina enacts:

Section 1. There is appropriated from the General Fund to the Department of Crime Control and Public Safety the sum of one hundred five thousand dollars ($105,000) for the fiscal year 1994-1995 to be used to fund the State's share of the cost of conducting a restudy of hurricane evacuations for coastal North Carolina.

Sec. 2. This act becomes effective July 1, 1994.

APPENDIX A

HOUSE BILL 1319, 2ND EDITION

AN ACT TO AUTHORIZE STUDIES BY THE LEGISLATIVE RESEARCH COMMISSION, TO CREATE AND CONTINUE VARIOUS COMMITTEES AND COMMISSIONS, AND TO DIRECT VARIOUS STATE AGENCIES TO STUDY SPECIFIED ISSUES.
The General Assembly of North Carolina enacts:

PART I.-----TITLE

Section 1. This act shall be known as "The Studies Act of 1993".

PART II.-----LEGISLATIVE RESEARCH COMMISSION

Sec. 2.1. The Legislative Research Commission may study the topics listed below. Listed with each topic is the 1993 bill or resolution that originally proposed the issue or study and the name of the sponsor. The Commission may consider the original bill or resolution in determining the nature, scope, and aspects of the study. The topics are:

(5) Emergency Management Issues -- study continued (H.B. 88 - Hightower, S.B. 75 - Parnell),
(52) Disaster Relief Volunteer Protection (H.B. 1283 - Redwine, S.B. 1192 - Doyle),

Sec. 2.2. Committee Membership. For each Legislative Research Commission Committee created during the 1993-94 biennium, the cochairs of the Commission shall appoint the Committee membership.

Sec. 2.3. Reporting Dates. For each of the topics the Legislative Research Commission decides to study under this act or pursuant to G.S. 120-30.17(1), the Commission may report its findings, together with any recommended legislation, to the 1994 Regular Session of the 1993 General Assembly or the 1995 General Assembly, or both.

Sec. 2.4. Bills and Resolution References. The listing of the original bill or resolution in this Part is for reference purposes only and shall not be deemed to have incorporated by reference any of the substantive provisions contained in the original bill or resolution.

Sec. 2.5. Funding. From the funds available to the General Assembly, the Legislative Services Commission may allocate additional monies to fund the work of the Legislative Research Commission.

PART XI.-----APPROPRIATION FOR STUDIES

Sec. 11.1. From the appropriations to the General Assembly for studies, the Legislative Services Commission may allocate funds to conduct the studies authorized by this act.

PART XII.-----EFFECTIVE DATE

Sec. 12.1. This act is effective upon ratification. Part VI of this act is repealed on June 30, 1995.

GENERAL ASSEMBLY OF NORTH CAROLINA

SESSION 1993

H 1

HOUSE BILL 88*

Short Title: Continue Emergency Mgmt. Study. (Public)

Sponsors: Representatives Hightower; Smith, Gottovi, and Wright.

Referred to: Rules, Calendar and Operations of the House.

February 9, 1993

A BILL TO BE ENTITLED

AN ACT TO AUTHORIZE THE CONTINUATION OF THE EMERGENCY MANAGEMENT ISSUES STUDY.

Whereas, the technical, legal, and economic issues involved in the provision of emergency response to natural and technological disasters are very complex; and

Whereas, the Legislative Research Commission Study Committee on Emergency Management Issues has met numerous times to discuss the varied issues before it; and

Whereas, a majority of the Committee's time was focused on the development of a regional response program for hazardous materials emergencies; and

Whereas, many of the issues that the Commission was directed to study by the 1991 General Assembly have not been fully studied and resolved; and

Whereas, there is a continuing need to study emergency management issues and provide for comprehensive disaster planning and a disaster recovery fund; Now, therefore,

The General Assembly of North Carolina enacts:

Section 1. The Legislative Research Commission may study the State emergency management program's ability in the future to adequately address preparedness, response, recovery, and mitigation for technological and natural hazards as may impact the citizens of North Carolina and their property. In conducting its study, the Commission may consider the program's ability in the future

to address recovery operations during Presidential and Gubernatorial declared disasters, including:

(1) Need for Disaster Recovery Law, Disaster Recovery Fund, and related staffing needs;

(2) Need to expand the Emergency Information System; and

(3) Need to respond and recover from catastrophic disasters, including resource needs at State and local levels such as auxiliary power requirements for vital facilities.

If the Commission conducts the study authorized under this act, it shall report its findings together with recommended legislation, to the 1994 Session of the 1993 General Assembly, or to the 1995 General Assembly, or to both.

Sec. 2. This act is effective upon ratification.

GENERAL ASSEMBLY OF NORTH CAROLINA

SESSION 1993

H 1

HOUSE BILL 1283

Short Title: LRC Study Disaster Relief. (Public)

Sponsors: Representative Redwine.

Referred to: Rules, Calendar, and Operations of the House.

May 7, 1993

A BILL TO BE ENTITLED

AN ACT AUTHORIZING THE LEGISLATIVE RESEARCH COMMISSION TO STUDY PROTECTION OF DISASTER RELIEF VOLUNTEERS.

Whereas, North Carolina's geographic location and climate make it vulnerable to various natural disasters; and

Whereas, the State Division of Emergency Management relies upon volunteers to help the citizens of North Carolina recover from the devastation of such disasters; and

Whereas, the State Division of Emergency Management has requested the assistance of statewide volunteer organizations to provide volunteer labor and donated materials to citizens and communities impacted by natural disasters; and

Whereas, G.S. 166A-14, G.S. 166A-15, and other statutes appear to provide limited liability protection to disaster relief volunteers acting under the auspices of the State, but do not appear to provide protection to disaster relief volunteers who themselves are injured during and as a result of volunteer activities; and

Whereas, the lack of protection, real or perceived, is a powerful deterrent to statewide volunteer organizations to providing or coordinating volunteer services; Now, therefore,

The General Assembly of North Carolina enacts:

Section 1. The Legislative Research Commission may study the adequacy of protection for disaster relief volunteer workers and organizations or those providing other volunteer services to the State.

Sec. 2. The Legislative Research Commission may make a report and recommendations to the 1993 General Assembly, Regular Session 1994, and a final report to the 1995 General Assembly.

Sec. 3. There is appropriated from the General Fund to the Legislative Research Commission fifteen thousand dollars ($15,000) for the 1993-94 fiscal year to fund the study.

Sec. 4. This act is effective upon ratification.

APPENDIX B

EMERGENCY MANAGEMENT COMMITTEE MEMBERSHIP 1993 - 1994

LRC MEMBER:

Sen. J.K. Sherron, Jr.
4208 Six Forks Road, Suite 302
Raleigh, NC 27609
(919)781-8721

President Pro Tempore's Appointments

Sen. David R. Parnell, Cochair
P.O. Box 100
Parkton, NC 28371
(910)858-3521

Mr. Kelly Barnhill
P.O. Box 1904
Greenville, NC 27835

Sen. John B. Codington
624 Forest Hills Drive
wilmington, NC 28403
(910)763-4894

Sen. David W. Hoyle
P.O. Box 2494
Gastonia, NC 28053
(704)867-0822

Mr. Tony Seamon
P.O. Box 3486
Morehead, NC 28557

Mr. Clarence Skinner
Rt. 2, Box 780
Manteo, NC 27954

Sen. R.C. Soles, Jr.
P.O. Box 6
Tabor City, NC 28463
(910)653-2015

Speaker's Appointments

Rep. Foyle Hightower, Cochair
P.O. Box 1063
Wadesboro, NC 28170
(704)694-2515

Rep. Vance Alphin
Route 2, Box 372
Mount Olive, NC 28365
(919)658-9800

Rep. John W. Brown
Route 2, Box 87
Elkin, NC 28621
(910)835-2373

Rep. Zeno L. Edwards, Jr.
212 Riverside Drive
Washington, NC 27889
(919)946-3714

Rep. Hugh A. Lee
Route 3, Box 445
Rockingham, NC 28379
(910)895-2112

Rep. Richard H. Moore
P.O. Drawer 19
Henderson, NC 27536
(919)438-4134

Rep. E. David Redwine
P.O. Box 283
Shallotte, NC 28459
(910)754-4326

Rep. Thomas E. Wright
317 S. 17th Street
Wilmington, NC 28401

(910)343-9842

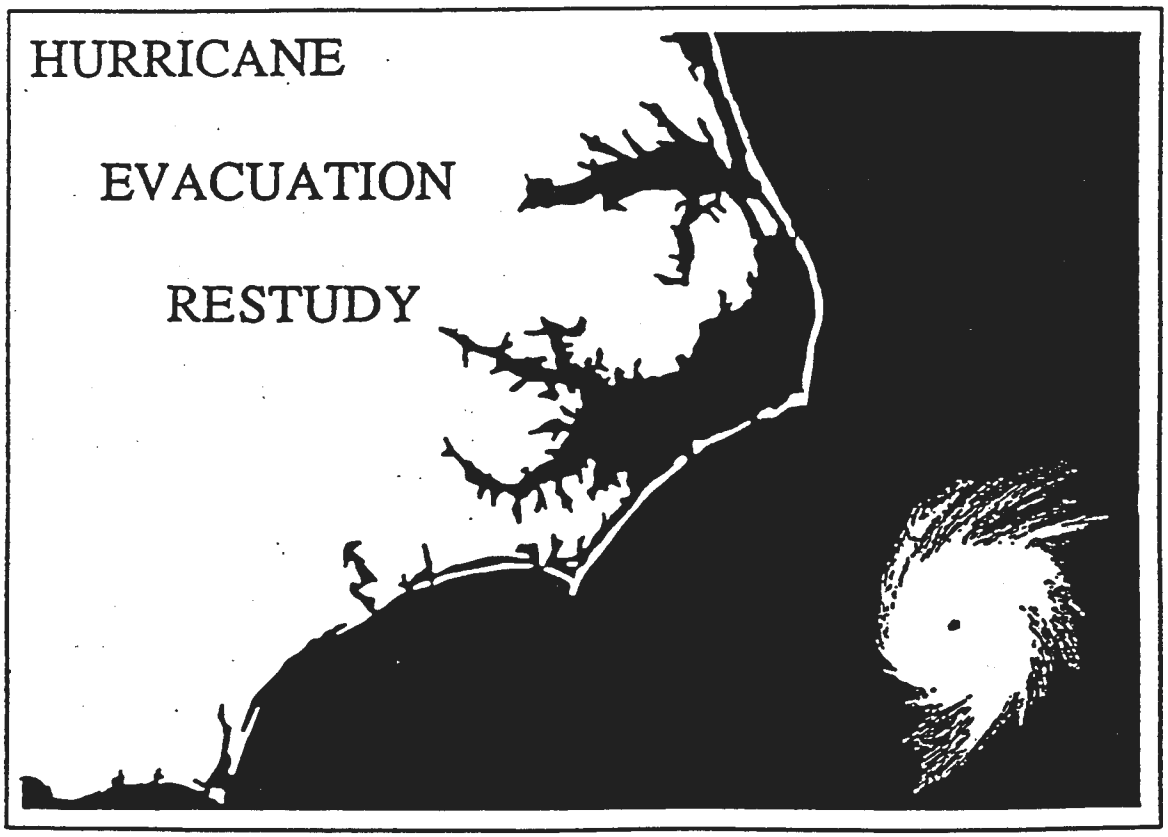
Staff:
Ms. Barbara Riley
Research Division
(919)733-2578

Clerk:
Ms. Doris Allen
621 Legislative Office Bldg
O: (919)733-9349
H: (919)694-6587

REPORT OF RECOMMENDATION

FOR

COASTAL NORTH CAROLINA



U S ARMY ENGINEER DISTRICT
WILMINGTON, NORTH CAROLINA

DECEMBER 1993

COASTAL NORTH CAROLINA
HURRICANE EVACUATION
RESTUDY

REPORT OF RECOMMENDATION

Prepared by: Wilmington District
U.S. Army Corps of Engineers

December 1993

EXECUTIVE SUMMARY

This report has been prepared to determine the changes which have occurred along the North Carolina coast that might effect changes to existing data reported in the North Carolina Hurricane Evacuation Study, published in November 1987. This report was prepared to recommend whether restudy of the North Carolina coast for hurricane evacuation planning is advisable.

Eastern North Carolina is experiencing rapid change with tremendous development and population increases occurring over the past three decades. Much of the development has been on the barrier islands and at or near the coastline. The permanent population in these areas at high risk from hurricanes has increased to 679,000 in 1990, up from 564,000 in 1980. This is an increase of 20.4 percent.

Hurricane Hugo which smashed into the South Carolina coast in 1989 moving at a forward speed in excess of 25 miles per hour highlighted the need to update storm surge information compiled for North Carolina's hurricane evacuation planning. Updated modeling results completed in 1992 by the National Hurricane Center for the four southeastern most counties in North Carolina showed startling results. Surge values for large, fast moving hurricanes were found to be significantly higher (some as much as 10 feet higher) than those reported for similar category storms in the 1987 North Carolina Hurricane Evacuation Study. This up-to-date technical information upon which officials can base critical evacuation decisions is in need of updating for the entire study area and this information needs to be disseminated in order to be useful and effective.

In addition to the increased permanent population and higher surge values mentioned above, there are other reasons why a restudy is essential at this time. These include: (1) a significant increase in the tourist population on the barrier islands in the past 10 to 20 years; (2) essentially little or no significant evacuation aiding improvements to the existing roadway network since the original study was conducted; (3) a greater number of people unknowingly at risk from storm surges; (4) an increase in evacuation times in certain areas by possibly 2 to 4 hours as evidenced during Hurricane Emily; (5) the need to provide a better analysis of both hurricane shelters and special needs shelters in coastal areas; and (6) the need to assess hurricane evacuation traffic control through inland counties, which was not done during the original study, and to evaluate the impact of evacuation into Virginia and South Carolina.

The recommended course of action is a restudy of the North Carolina coast. The restudy would consist of generation of digital storm surge maps (a task already in progress) and conducting new hazards, vulnerability and behavioral analyses. Updates to the 1987 shelter and transportation analyses are also recommended. There are 18 counties in the study area: Beaufort, Bertie, Brunswick, Camden, Carteret, Chowan, Craven, Currituck, Dare, Hyde, New Hanover, Onslow, Pamlico, Pasquotank, Pender, Perquimans, Tyrrell, and Washington. In addition, Martin and Jones Counties will be included in the transportation analysis.

The estimated cost of the restudy is $1,700,000 and it is expected to take about 3 years to complete. It is recommended that a detailed plan for the restudy, which will clearly define responsibilities, timing, and cost for each study product, be prepared in fiscal year 1994. This will be followed in fiscal year 1995 by initiation of the investigation described above. Assuming adequate and timely funding, the Coastal North Carolina Hurricane Evacuation Restudy is expected to be completed in 1997.

COASTAL NORTH CAROLINA

HURRICANE EVACUATION RESTUDY

REPORT OF RECOMMENDATION

Table of Contents

List of Tables

List of Figures

List of Plates

List of Appendixes

PURPOSE

The purpose of this appraisal is to evaluate the need for an update or revision of the 1987 North Carolina Hurricane Evacuation Study. Since completion of the 1987 study, technology advances have been made in the areas of surge level prediction, mapping, and in decision making. Also, advances have been made in the national understanding of hurricane-related data and significant changes in the character of the study area have taken place. Because these variables influence hurricane evacuation planning, changes in them will affect existing plans and the ability of coastal populations to effectively respond to hurricane threats. A map of the study area is shown on Plate 1 (plates are located near the end of this report immediately after the **Recommendations** section).

Based on the significance and level of changes occurring since completion of the 1987 study, established, published clearance times for North Carolina coastal communities may no longer be valid. Such a loss of validity may endanger lives as officials continue to base critical decisions on existing data, much of which is now obsolete.

PRIOR EVACUATION STUDIES

Because coastal North Carolina is one of the more hurricane-vulnerable locations along the coastline of the United States, it was one of the first areas selected for hurricane evacuation study. Forty-seven hurricanes have directly affected eastern North Carolina since 1886. To illustrate this hurricane vulnerability, Figure 1 shows the tracks of historical hurricanes passing within 125 nautical miles of Beaufort, North Carolina.

The original Eastern North Carolina Hurricane Evacuation Study was initiated in 1984. The study was funded by the Federal Emergency Management Agency (FEMA), the U.S. Army Corps of Engineers, and the North Carolina Department of Crime Control and Public Safety, Division of Emergency Management. The total study cost was $565,000. FEMA provided $225,000, the Corps of Engineers $240,000, and the State of North Carolina $100,000. The Eastern North Carolina Hurricane Evacuation Study was authorized by the Disaster Relief Act of 1974 (Public Law 93-288).

National Oceanic and Atmospheric Administration (NOAA) National Hurricane Center (NHC) aided in the study by developing a Sea, Lake, and Overland Surge from Hurricanes (SLOSH) computer model centered on the Pamlico Sound. The Pamlico SLOSH Basin covers the North Carolina coastline from the Virginia border to the Cape Fear region. A total of 266 hypothetical hurricanes were modeled by the NHC for the hurricane evacuation study. The parameters selected for the modeled storms were the intensities, forward speeds, approach directions, and radii of maximum winds then considered to have the highest meteorological probability of occurrence within the Pamlico Basin. A forward speed of 12 miles per hour (mph) was used for northwestward and westward moving hurricanes, and 20 mph for northward, north-northeastward, and northeastward moving hurricanes.

The Maximum Envelopes of Water (MEOW's) were developed from the modeling efforts by the NHC. These MEOW's consisted of computer printouts showing peak surge values developed for each combination of category and approach direction modeled in the study. The values contained on these original MEOW's were the peak surge height values for each model's grid points regardless of where landfall occurred.

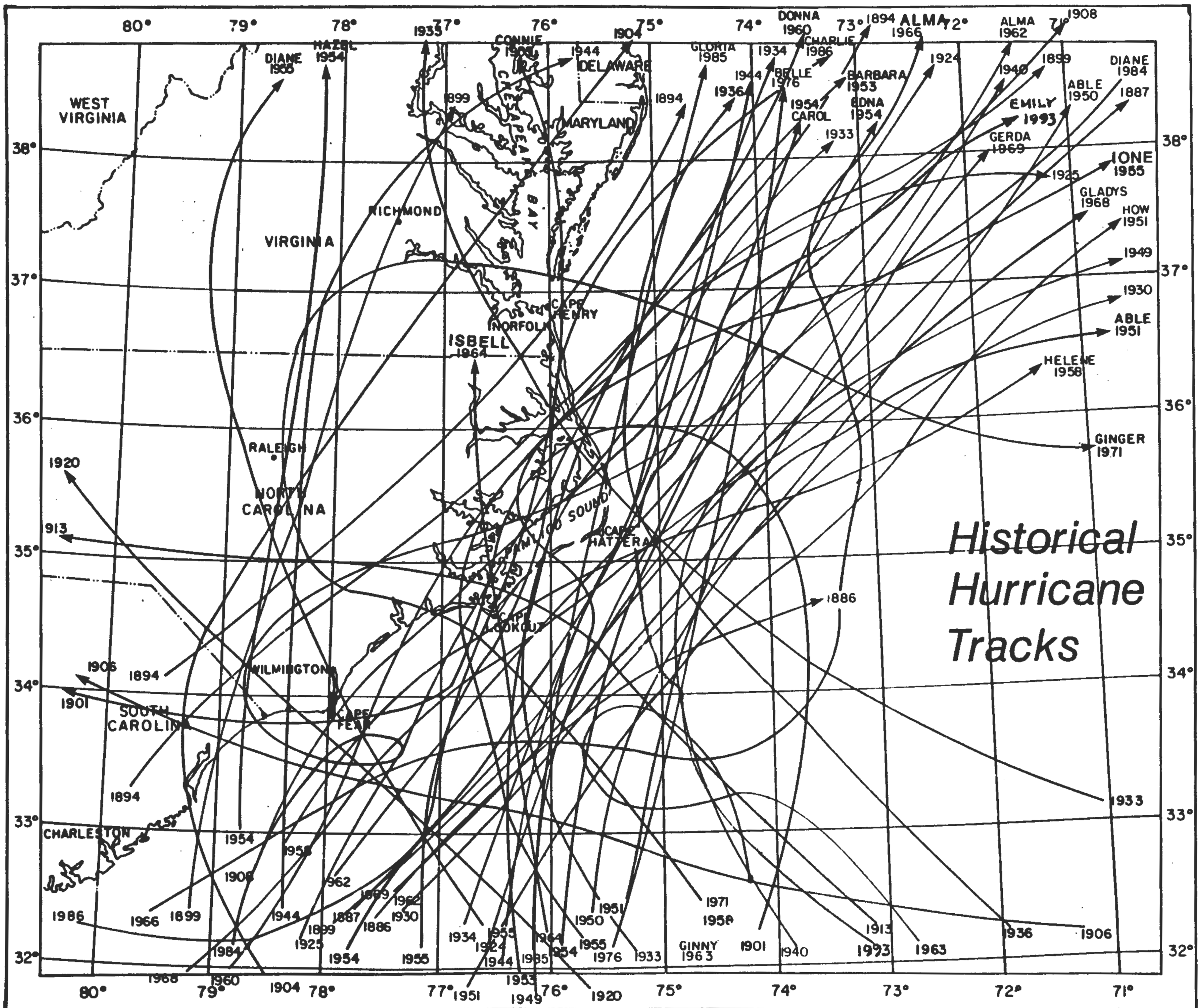

Historical Hurricane Tracks
WEST VIRGINIA
VIRGINIA
RICHMOND
NORFOLK
CAPE HENRY
DELAWARE
MARYLAND
CHESAPEAKE BAY
NORTH CAROLINA
RALEIGH
PAMLICO SOUND
CAPE HATTERAS
CAPE LOOKOUT
WILMINGTON
CAPE FEAR
SOUTH CAROLINA
CHARLESTON
DIANE 1955
HAZEL 1954
CONNIE 1955
DONNA 1960
CHARLIE 1986
ALMA 1966
ALMA 1962
GLORIA 1985
BELLE 1976
BARBARA 1953
CAROL 1954
EDNA 1954
EMILY 1993
ABLE 1950
DIANE 1984
GERDA 1969
IONE 1955
GLADYS 1968
HOW 1951
ABLE 1951
HELENE 1958
GINGER 1971
ISBELL 1964
GINNY 1963
80°
79°
78°
77°
76°
75°
74°
73°
72°
71°
38°
37°
36°
35°
34°
33°
32°

Figure 1

Subsequently, the NHC developed additional Maximum Envelopes of Water (MEOW's of MEOW's) combining all approach directions and grouping the hurricane categories into 1 and 2, 3, and 4 and 5. It is from these that the inundation maps shown in Appendix A of the Technical Data Report were developed. These inundation maps depict the limits from peak storm surge heights potentially generated by the three groups of categories of storm intensity and serve as a basis for the balance of the study. However, these maps were manually drawn and do not lend themselves to modification as more current technological data becomes available.

The Eastern North Carolina Hurricane Evacuation Study was conducted and managed by the Wilmington District of the U.S. Army Corps of Engineers and was completed in November 1987. Products of the study, in addition to the storm surge atlases mentioned above, included hazards, vulnerability, behavior, shelter, and transportation analyses, results of which are included in the Technical Data Report. Copies of that report are still available by contacting Mr. Al Bjorkquist, Plan Formulation Branch, at (919) 251-4596.

CHANGES SINCE THE 1987 REPORT

Since completion of the Eastern North Carolina Hurricane Evacuation Study, many changes have occurred where current applications may affect evacuation planning and execution and established clearance times as reported in the original study.

SLOSH Model

The SLOSH model used for predicting surge levels for the North Carolina base study was developed in the late 1970's by NOAA's National Weather Service. Special techniques incorporated into the model took into consideration the two-dimensional inland inundation, the routing of surges inland when barriers are overtopped, the effect of coastal forests, the movement of the surge up rivers, the flow through cuts and channels, and the flow over hills. Rain, riverine flow, astronomical tide, and shallow water wind waves are other processes tending to change local water levels; however, these factors were not included in the SLOSH computations.

A special polar grid was used for the SLOSH computations. The area covered by the grid was focused on a specific location on the coastline. It was a telescoping polar coordinate system with two functions: (1) to provide increased resolution of the storm surge at the coastline and inside the harbors, bays, and rivers, while decreasing the resolution in the deep water where detail is not required; and (2) to allow economy in computation. However, because the grid used for the 1987 study was centered on the Pamlico Sound, resolution was lost in the extreme southeastern coastal counties of New Hanover, Brunswick, Pender, and Onslow. Plate 2 shows the Pamlico Basin SLOSH Grid.

Today, state-of-the-science for SLOSH modeling, while utilizing the same basic techniques, enables finer resolution of terrain, rivers, and waterways. By using a hyperbolic, or elliptical grid, the model is able to cover a larger geographical area, but with more accurately detailed topography. This new technology permits inclusion of topographical details, such as highways and railroad embankments, causeways, levees, and dikes in harbors. The result is a more refined prediction of inundation zones because the accuracy of modeled surge values increases as the accuracy of the input terrain and storm data improves. Also, the new SLOSH model has been expanded to simulate faster moving storms. Scenarios now range from 5 to 35 miles per hour storms. This expansion was made because of the increased probability of faster moving storms approaching the United States, as was seen in the cases of Hurricanes Hugo and Andrew.

In 1992, the NHC received funding to develop the Wilmington/Myrtle Beach SLOSH model using the latest technology. A report entitled "A Storm Surge Atlas for the Myrtle Beach, South Carolina, and Wilmington, North Carolina" was completed late in 1992. The area covered by the Wilmington/Myrtle Beach SLOSH model grid is shown in Plate 3.

Comparison of surge values at selected points showing surge values for the 1987 study versus the 1992 report are shown in Table 1. The location of the points identified in Table 1 are shown on Figure 2 below. Table 1 shows that 1992 values are generally consistent with those of the earlier report for slower moving storms (up to 15 mph forward speed). However, fast moving (up to 35 mph forward speed) storms of any category generally produce higher surges than those shown in the 1987 report. Surges at different locations vary but generally are from about 5 to 10 feet higher for a category 5 hurricane along the beaches of this four-county area using the 1992 data for fast moving storms. This is truly significant.

Modeling of fast moving hurricanes in other areas of the North Carolina coast has not yet been done. However, it is likely that when modeling is done the results will similarly show higher relative storm surges as compared to the 1987 report.

Figure 2

LOCATION OF POINTS IDENTIFIED IN TABLE 1

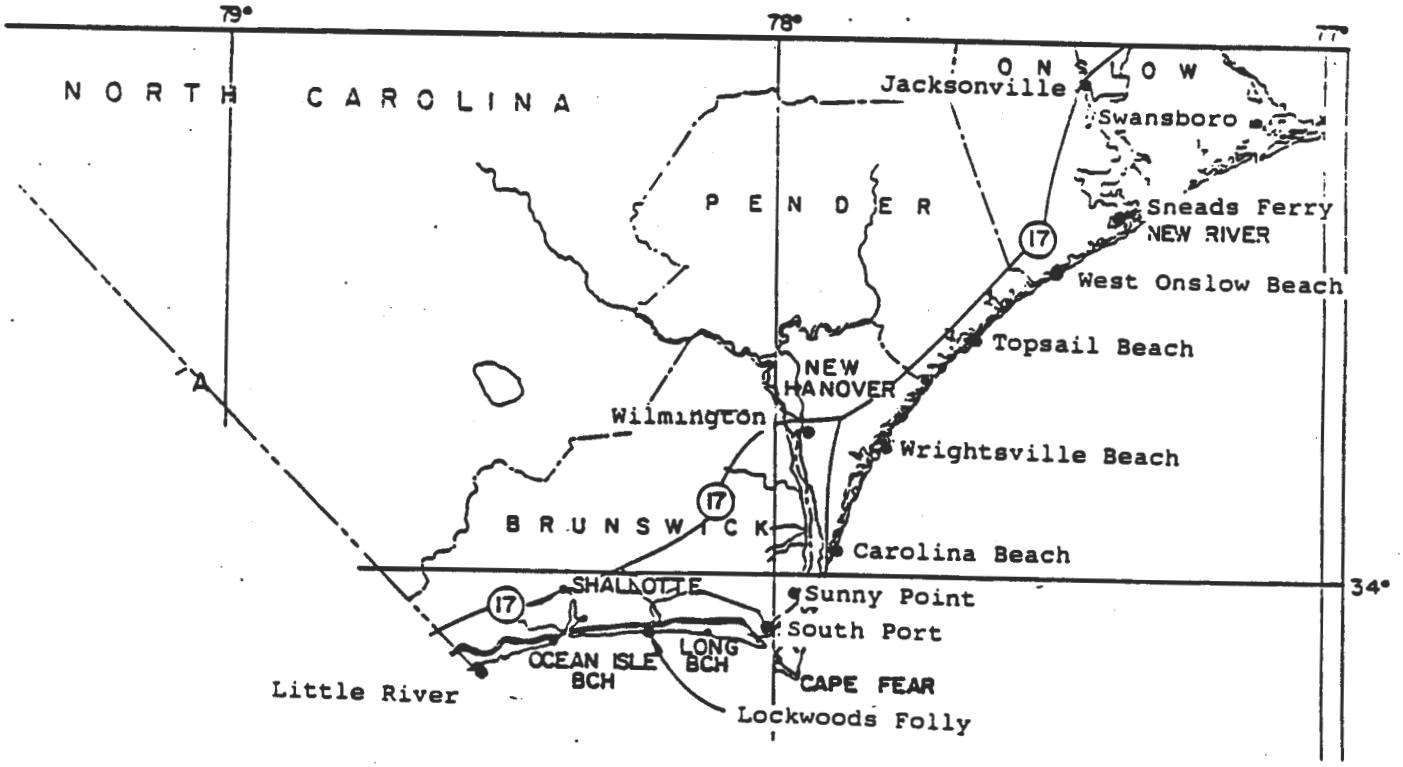


Table 1
COMPARISON OF MAXIMUM SURGE HEIGHTS AT SELECTED POINTS

Location	Category 2 mean tide	Category 2 high tide	Category 2 change from '87	Category 3 mean tide	Category 3 high tide	Category 3 change from '87	Category 5 mean tide	Category 5 high tide	Category 5 change from '87
Swansboro									
1987 report 1/	6.5	8.5		10.0	12.0		16.0	18.0	
1992 slow storms est.		10.0	+1.5		13.0	+1.0		17.0	-1.0
1992 fast storms est.		13.0	+4.5		18.0	+6.0		25.0	+7.0
West Onslow Beach	7.8	9.8		11.2	13.2		17.3	19.3	
		9.0	-0.8		13.0	-0.2		18.0	-1.3
		13.0	+3.2		17.0	+3.8		25.0	+5.7
Sneads Ferry	8.5	10.5		12.3	14.3		18.8	20.8	
		9.0	-1.5		10.0	-4.3		19.0	-1.8
		12.0	+1.5		16.0	+1.7		26.0	+5.2
Jacksonville	5.4	7.4		9.6	11.6		17.8	19.8	
		5.0	-2.4		7.0	-4.6		13.0	-6.8
		6.0	-1.4		8.0	-3.6		16.0	-3.8
Topsail Beach	7.7	9.7		11.4	13.4		17.2	19.2	
		9.0	-0.7		13.0	-0.4		21.0	+1.8
		14.0	+4.3		18.0	+4.6		27.0	+7.8
Wrightsville Beach	7.7	9.7		11.0	13.0		17.0	19.0	
		10.0	+0.3		14.0	+1.0		21.0	+2.0
		15.0	+5.3		18.0	+5.0		26.0	+7.0
Carolina Beach	7.4	9.4		10.3	12.3		16.0	18.0	
		9.0	-0.4		13.0	+0.7		20.0	+2.0
		12.0	+2.6		16.0	+3.7		23.0	+5.0
Wilmington	7.4	9.4		11.9	13.9		20.0	22.0	
		8.0	-1.4		10.0	-3.9		15.0	-7.0
		9.0	-0.4		10.0	-3.9		17.0	-5.0

1/ Table 2-3, page 20, Eastern North Carolina Hurricane Evacuation Study, Technical Data Report, 1987
2/ Numbers shown are in feet mean sea level (msl)
3/ Location of above points is shown on Figure 2

Table 1 cont.
COMPARISON OF MAXIMUM SURGE HEIGHTS AT SELECTED POINTS

Location	Category 2			Category 3			Category 5		
	mean tide	high tide	change from '87	mean tide	high tide	change from '87	mean tide	high tide	change from '87
Sunny Point									
1987 report 1/	8.1	10.6		10.2	12.7		18.0	20.5	
1992 slow storms est.		11.0	+0.4		11.0	-1.7		23.0	+2.5
1992 fast storms est.		13.0	+2.4		14.0	+1.3		25.0	+4.5
Southport	7.0	9.5		10.3	12.8		16.9	19.4	
		10.0	+0.5		13.0	+0.2		21.0	+1.6
		13.0	+3.5		16.0	+3.2		24.0	+4.6
Lockwoods Folly	7.8	10.3		11.0	13.5		17.4	19.9	
		9.0	-1.3		11.0	-2.5		17.0	-2.9
		13.0	+2.7		20.0	+6.5		29.0	+9.1
Little River	8.7	10.7		12.7	14.2		19.5	22.0	
		11.0	+0.3		15.0	+0.8		22.0	0.0
		15.0	+4.3		24.7	+10.5		32.0	+10.0

1/ Table 2-3, page 20, Eastern North Carolina Hurricane Evacuation Study, Technical Data Report, 1987
2/ Numbers shown are in feet msl
3/ Location of above points is shown on Figure 2

Mapping

It is important that the new information be mapped to more accurately predict the surge limits which could be expected from storms approaching the North Carolina coast. This information affects vulnerabilities, evacuation networks, and clearance times as described in the 1987 study. The effect of the newer technology could mean significant increases in the potential inundation areas over those previously published in the 1987 study.

Mapping of the SLOSH model results is an important task. It is only through this function that the data can be utilized for evacuation planning. Map development, presentation style, mapping standards, flexibility in use, and updating capability play important roles in presenting and in maintaining critical hurricane surge data.

In the initial study, information generated by the SLOSH model was displayed in storm surge maps which were printed separately as Appendix A to the 1987 Technical Data Report. Twenty-five computer printouts were developed to illustrate the Maximum Envelope of High Water (MEOW) for hurricanes moving toward the west, northwest, north, north-northeast, and northeast for storm categories one through five, traveling 12 to 20 miles per hour. Ultimately, 18 maps were published displaying the Maximum of the Maximum envelope of high water (MOM) for storm categories one through five. These maps were hand drawn, prepared in hard copy format only.

Because of the large volumes of data involved, handling of the maps is cumbersome. Updating the maps would be expensive and would essentially mean total redevelopment of the maps. Flexibility in use is limited because of the hard copy format.

Today, with the development of more sophisticated computers and software, analyzing large volumes of geographic information has become an inconsequential task. Storm surge data (maps) generated and displayed in electronic format allows more compact storage, manipulation, and retrieval of large quantities of data at greater speeds and lower cost (per unit) over conventional types. The ability to update, maintain, and integrate data from other sources (such as information on highway networks, facility locations, etc.) using computers is unmatched by any manual method.

The advantages of computerized mapping over conventional methods is further emphasized when an analysis is made of the processes required to transform technical data and maps generated during the hurricane evacuation study into local evacuation plans. Generally, local officials reproduced portions of storm surge or evacuation route maps to develop local evacuation and response plans and packages. With maps generated in electronic format, the same maps can be used to accomplish both objectives by simply altering print scales, display functions, etc.

Also of importance is FEMA's current formulation of program-wide standards for map generation and presentation. To comply with the new standards, new data will require electronic generation and a presentation style vastly different from previous formats. It is only through the use of the new technology that compliance in mapping standardization can be achieved.

The most important issue regarding mapping, however, is that to utilize the information from the new SLOSH model runs, the information must first be mapped. Generally, the SLOSH model results cannot be used until they are converted into a more usable format. Evaluating changes in vulnerabilities, evacuation routes, and clearance times which may result from the application of the new SLOSH technology would be impossible without first mapping the SLOSH model results.

Recognizing the importance of the new mapping, the Wilmington District entered into an agreement with the North Carolina Center for Geographic Information and Analysis (CGIA) in late 1992. The purpose of the contract was to develop individual storm surge atlases for Brunswick, New Hanover, Pender, and Onslow Counties. Surge information originating from the NHC's 1992 report is serving as a basis for this mapping. The surge limits are being delineated using automated mapping techniques using a ESRI ARC/INFO GIS.

Because faster moving hurricanes display significantly higher surge levels (see Table 1), and also because slower moving storms are most common, it was decided in meeting with county emergency managers that two scenarios would be mapped. The surge maps being produced by CGIA will be separated into two different volumes. The first will show MOMs for storms having forward speeds of 15 mph or less. Each map will show surges of category 1 and 2, category 3, and category 4 and 5 (i.e., three different colors will be shown on each map).

The second will show MOMs for storms having forward speeds greater than 15 mph up to a maximum of 35 mph. Again, each map will show surges of categories 1 and 2, category 3, and categories 4 and 5 (again three colors, but different from the first set mentioned above, will be shown on each map).

The contract with CGIA has been funded jointly by FEMA and the Corps of Engineers. The total cost for the mapping is expected to be about $200,000. To date, about $81,000 has been committed to that effort. The North Carolina Division of Emergency Management is actively seeking State funding for a portion of the remaining work. Assuming adequate funding from combination sources is available and timely, the surge mapping for the four southeastern North Carolina counties will be completed in 1994. This effort will complete updated surge mapping for four counties in the 18-coastal-county study area.

Renewed National Awareness of Hurricanes

As more research is conducted on hurricanes, advances in the national understanding of hurricanes and hurricane evacuation are made. These advances, then applied, allow officials the opportunity to improve hurricane evacuation planning techniques.

The recent number of hurricanes making landfall within the United States has fostered many lessons learned and has allowed new research to be conducted (and existing research to be tested) through post-storm assessments. A consolidated effort on the part of agencies having the responsibilities to respond to hurricane threats has developed into a flux of excellent recommendations on issues which would improve the technical information provided for hurricane evacuation planning. Much debate and discussion has been made regarding these issues within the national hurricane program community, and it is generally agreed that they generically apply to all areas vulnerable to hurricane strikes.

A brief listing of some of these issues is provided below. Usually, indepth discussion of each has already been made among the national hurricane program participants and agencies.

a. Include results of wind studies in technical data reports to address wind hazards, vulnerabilities, and damage which have been prevalent in recent hurricanes.

b. Take regional approaches for shelter, transportation, etc., studies, as local approaches are not as effective.

c. Incorporate expanded versions of shelter analyses which will address issues such as: (1) long-term care versus "storm refuge;" (2) disease control in shelters; (3) harbors of last refuge; (4) vertical evacuation; (5) sponsoring of shelters by local organizations; and (6) providing refuge for pets and pet owners.

d. Provide more public awareness tools.

e. Identify construction and roof types which have performed poorly during hurricanes.

These issues have generally been raised by individuals who have endured recent hurricane evacuation procedures. They represent those areas where base studies were deficient in addressing the total needs of emergency managers. Incorporating them into future studies and restudies could only increase the depth of technical data reports and fill voids in areas that are equally critical. To not incorporate them into evacuation studies could mean a less than responsible use of existing data which could save lives.

Decision Making Tools

There are two widely recognized approaches available to aid in hurricane evacuation decision making. They are related techniques for determining the time in which an evacuation order or advisory should be given. The Decision Arc Method translates clearance times into distances on a hurricane-plotting chart, and prelandfall hazards times into distances on a two-dimensional hurricane graphic. This combination visually depicts a threatening hurricane situation. Hurrevac, a computer program that operates in a fashion similar to the Decision Arc, integrates data developed in the hurricane evacuation study with information extracted from the National Hurricane Center marine advisories.

Hurrevac is widely used by emergency officials in North Carolina. In fact, most of North Carolina's coastal counties use the tool for evacuation decision making. Using site specific study area characteristics, Hurrevac calculates the local time when an evacuation decision must be made, the time when gale-force winds could arrive in the community, and the time when the hurricane eye could make landfall. The probability values from the National Hurricane Center marine advisories are incorporated into another feature of the program. Using those values, along with the hurricane category, forward speed, and track, the program will select from an array of evacuation scenarios the evacuation decision most often made, historically, under similar circumstances. The Hurrevac program also includes graphic displays of the inundation maps for the study area; past, present and forecast hurricane locations; and the tropical storm wind field.

Hurrevac was provided to North Carolina State and local officials to aid in evacuation decision making after the completion of the 1987 study. The early version of the software, Version 4.0, had crude graphic capabilities and was essentially a compilation of all study results and products. The latest version of Hurrevac, Version 5.0, has a superior display capability which enables officials to better identify potential surge zones. A shelter management feature has also been incorporated into Version 5.0.

Minor updates of Hurrevac databases such as shelter inventories, etc., have generally been accomplished locally, on an as-needed, county-by-county basis. When new information becomes available, such as new storm surge maps, revised evacuation routes, modified clearance times, etc., the existing databases will require updating. Based on the recommendations of this report, the extent of new information becoming available will require a massive revision of nearly the entire existing databases. Such an undertaking will, generally, be beyond local capabilities.

Since completion of the 1987 study, many changes have occurred in the study area that will affect the population's ability to respond to hurricane threats if decision making is based on data from the 1987 study.

Major Hurricane Strike in Neighboring South Carolina

The effects of a recent major hurricane strike in South Carolina can be felt widespread throughout a region, having major effects on future hurricane evacuation and evacuation planning. Physical effects resulting from a major strike, such as damaged buildings and roadways, can influence evacuation planning in areas such as traffic routing and shelter usage. Psychological effects can change behavioral responses of emergency officials in reacting to approaching hurricane threats and the behavior of potential evacuees in responding to official notices. A major hurricane strike also presents a unique opportunity to evaluate and validate the usefulness, or value, of preparedness tools and measures which were used during the planning processes.

On September 21, 1989, Hurricane Hugo invaded the coast of South Carolina and severely affected areas inland to include Charlotte, North Carolina. This event challenged emergency preparedness and left a trail of destruction. The changes in South Carolina and North Carolina which resulted from Hurricane Hugo have affected, and will continue to affect, local hurricane evacuation planning. The effects that these changes will have on existing evacuation plans, and on the technical data upon which these plans are based, cannot be readily assessed without further indepth analysis.

Damage to roadway networks which were used for evacuation routing is important to catalog, as is the unrepaired damage and undocumented vulnerabilities of shelters. Road building, renovation, and new development programs which may have resulted will also affect existing evacuation plans. These factors have significant impacts on emergency planning and preparedness and should be weighed against existing data and considered when contemplating hurricane evacuation studies or study updates.

Changes in the behavioral responses of the vulnerable population are important to research and analyze. Emergency officials, having endured a major hurricane strike, will no doubt modify their behavior based on lessons learned during the strike. For example, emergency officials may realize that the use of a more aggressive public awareness campaign would have been more effective in educating the public on established evacuation routes. Such realizations should be incorporated into future evacuation planning exercises.

The possible changes in the behavioral response of potential evacuees could create an undesirable imbalance in the predicted and actual behavior patterns, as it is the predicted response which forms the basis for evacuation planning. Unless the predicted responses are tested against the actual responses, experts will not be able to validate or revise research data. For example, predicted shelter demand may have been significantly different from actual demand during Hurricane Hugo. Also, since Hurricane Hugo, shelter demand may increase, or decrease, during the next hurricane threat because of the individual Hugo experiences. If shelter capacity is not accurately matched with realistic demand, the results could potentially be dangerous. Analyzing these types of behavior changes is critical for validating or updating the existing research.

Perhaps the most positive effect a hurricane has on an area is the unique opportunity it provides for increasing the storehouse of knowledge about hurricanes and their deadly effects on a coastline. A major strike tests the theories and hypotheses, and through post-storm assessments experts have the opportunity to compare predicted with actual conditions. Unless these lessons learned are documented, combined, and considered, an area, and the nation,

misses its best chance to incorporate actual data and experience into existing plans for better, future evacuation planning.

Changes in Population

Changes in the population of the North Carolina coast, which have occurred since completion of the 1987 study, will affect the results of the behavioral, shelter, and transportation analyses which were reported in that study. The behavioral analysis considered population levels in determining the percentages of the affected and non-affected population which would evacuate under a range of hurricane threat situations. The shelter analysis considered population levels in determining shelter demand for threatened areas. Information from both the behavioral and shelter analyses were used in the transportation analysis to help define evacuation road networks and in estimating clearance times. It can therefore be assumed that significant changes in population levels will affect established clearance times and emergency decision-making abilities.

The population data used in the 1987 base study considered mainly permanent population levels. To get a true estimate of how many people could be in a threatened area at the time of an approaching hurricane tourist population(s) must also be fully considered. Using 1985 as a base year, the initial study computed area clearance times based on the population of a particular area. The 1985 figures used in the base study were extrapolated from 1980 Census Bureau data. Comparing the 1990 population figures provided by the U.S. Census to the 1985 population estimates in the 1987 report, population changes range from a negative 9.8 percent in Hyde County, to a positive 31.5 percent in Dare County. The aggregate population has increased 9.0 percent in the 18-county area from 1985 to 1990. Table 1 shows population changes in the study area from 1960 through 1990.

TABLE 2

TOTAL POPULATION AND CHANGES
IN STUDY AREA COUNTIES 1/

NAME OF COUNTY	POPULATION 1960 CENSUS	POPULATION 1970 CENSUS	PERCENT CHANGE 1960-70	POPULATION 1980 CENSUS	PERCENT CHANGE 1970-80	POPULATION JULY 1985 ESTIMATE	PERCENT CHANGE 1980-85	POPULATION 1990 CENSUS 2/	PERCENT CHANGE 1985-90
BEAUFORT	36014	35980	-0.1	40355	12.2	43500	7.8	42283	-2.8
BERTIE	24350	20528	-15.7	21024	2.4	21400	1.8	20388	-4.7
BRUNSWICK	20278	24223	19.5	35777	47.7	45400	26.9	50985	11.0
CAMDEN	5598	5453	-2.6	5829	6.9	5800	-0.5	5904	1.8
CARTERET	27438	31603	15.2	41092	30.0	49000	19.2	52556	7.3
CHOWAN	11729	10764	-8.2	12558	16.7	13200	5.1	13506	2.3
CRAVEN	58773	62554	6.4	71043	13.6	79400	11.8	81613	2.8
CURRITUCK	6601	6976	5.7	11089	59.0	12900	16.3	13736	6.5
DARE	5935	6995	17.9	13377	91.2	17300	29.3	22746	31.5
HYDE	5765	5571	-3.4	5873	5.4	6000	2.2	5411	-9.8
NEW HANOVER	71742	82996	15.7	103471	24.7	111800	8.0	120284	7.6
ONSLOW	86208	103126	19.6	112784	9.4	123700	9.7	149838	21.1
PAMLICO	9850	9467	-3.9	10398	9.8	11000	5.8	11372	3.4
PASQUOTANK	25630	26824	4.7	28462	6.1	29100	2.2	31298	7.6
PENDER	18508	18146	-2.0	22215	22.4	24300	9.4	28855	18.7
PERQUIMANS	9178	8351	-9.0	9486	13.6	10400	9.6	10447	0.5
TYRRELL	4520	3806	-15.8	3975	4.4	4200	5.7	3856	-8.2
WASHINGTON	13488	14038	4.1	14801	5.4	14400	-2.7	13997	-2.8
TOTAL	441605	447401	8.1	563609	18.1	622800	10.5	679075	9.0
U.S. (MILLION)	179.3	205.1	14.4	227.8	11.1	239.3	5.0	248.7	3.9
GROWTH U.S. 1960-1990 ..... 38.7 PERCENT GROWTH AREA 1960-1990 ..... 53.8 PERCENT									

1/ Source: 1987 North Carolina Hurricane Evacuation Technical Data Report
2/ Source: 1990 Census

12

The tourist population during the summer season has been gradually increasing each year. This can be attributed, in part, to the increase in construction of coastal rental housing units and the enhancement of recreational facilities on the barrier islands and immediate coastal areas. The following 1992 tourist population estimates are based on the number of people who would be occupying rental housing units on any given day during the June, July, or August tourist season.

TABLE 3

1992 TOURIST POPULATIONS AT SELECTED COASTAL COUNTIES 1/

COUNTY	POPULATION
BRUNSWICK COUNTY	44,000
CARTERET COUNTY	34,000
CURRITUCK COUNTY	6,000
DARE COUNTY	42,000
OCRACOKE-HYDE COUNTY	3,000
NEW HANOVER COUNTY	30,000
ONSLOW COUNTY	22,000
PENDER COUNTY	12,000
TOTAL	**193,000**

Note: These figures do not include day visitors or campers. Also, counties estimated 1993 figures were 5 percent higher than 1992 figures shown above.
1/ Source: North Carolina Division of Emergency Management

Tables 2 and 3 show that the permanent and tourist population of the North Carolina coast has increased in most areas. Populations in the actual storm surge flooded areas cannot be accurately estimated until surge mapping is completed. However, enough data exists to conclude evacuation planning may be affected by these changes but cannot be assessed without indepth investigation.

Changes in Shelter Inventories

Because of the importance of shelter availability to a successful evacuation, a current shelter analysis and inventory are critical to emergency preparedness. During the 1987 study, a shelter analysis was conducted to study shelter vulnerability and demand. The analysis resulted in a shelter inventory which is now minimally useful for shelter usage planning. Although updates to shelter inventories have been made locally, the technical information used to determine shelter demand now requires updating which cannot be made at the local level.

Factors which tend to influence the current usefulness of the 1987 shelter analysis include: changes in public attitudes regarding evacuation because of a major hurricane strike in the study area; changes in the Red Cross shelter selection criteria; and physical changes in the study area, such as school (shelter) closings and openings which may have occurred since completion of the 1987 study.

When Hurricanes Hugo and Andrew struck the coast, it affected public attitudes toward many aspects of evacuation. More research is needed to definitize the effect of a major hurricane strike in the study area on future shelter usage. Only through such research can existing behavioral predictions be validated (or invalidated) as representative of future expected behavior.

In July 1992, the American Red Cross published supplemental guidelines for hurricane evacuation shelter selection. These guidelines suggested certain restrictions on the selection of buildings as hurricane shelters, and local incorporation of the guidelines has resulted in a reduction in shelter capacity along the North Carolina coast. Local application of the new guidelines is a prominent factor which makes updating of the 1987 study shelter analysis necessary.

The natural changes in shelter status, such as building and school closings and openings, must also be added to the list of problems with the continued application of the 1987 shelter analysis. Because some shelters have closed and new ones opened, an up-to-date analysis which includes new shelters and deletes abandoned ones will be necessary as characteristic changes of the study area are documented.

Table 4 below indicates the changes in the shelter capacity in the study area after all influences have been taken into account. As shown, some of the decreases are critical and, generally, shelter capacity is not only inadequate for most areas, but the shortage is critical.

TABLE 4

CHANGES IN SHELTER CAPACITY

COUNTY	1987 SHELTER CAPACITY 1/	1994 SHELTER CAPACITY 2/	% CHANGE IN SHELTER CAPACITY
BEAUFORT	3995	4265	+6.8
BERTIE	1802	1802	0.0
BRUNSWICK	6509	10503	+61.4
CAMDEN	1038	688	-33.7
CARTERET	5095	3900	-23.5
CHOWAN	2210	2231	+1.0
CRAVEN	6400	5800	-9.4
CURRITUCK	2400	0	-100.0
DARE	4435	0	-100.0
HYDE	742	0	-100.0
MARTIN 3/	4153	4153	0.0
NEW HANOVER	4741	1550	-67.3
ONSLOW	4901	2549	-48.0
PAMLICO	2900	1000	-65.5
PASQUOTANK	4156	1800	-56.7
PENDER	4136	1633	-60.5
PERQUIMANS	1856	700	-62.3
TYRRELL	460	0	-100.0
WASHINGTON	2164	637	-70.6

1/ Source: N.C. Hurricane Evacuation Study Technical Data Report

2/ Source: Emergency County Preparedness Directors and Local Red Cross Offices - American Red Cross approved hurricane shelters

3/ Included in study area for purposes of the shelter analysis

Because the shelter analysis provides information which is crucial to calculating clearance times, changes in the shelter situation will affect established clearance times for the study area. While minor changes in shelter availability have been handled locally, significant changes in shelter demand and availability are generally too extensive to be handled at the local level. Because this aspect of hurricane evacuation planning is one of the most critical, gathering technical information to update shelter inventories is also critical and will generally be beyond the scope of local capabilities.

Changes in Highway Networks

The overall goals of the transportation analysis performed in the base study were to:

a. Estimate clearance times (the time it takes to clear a county's roadways of all evacuating vehicles).

b. Define the evacuation road network.

c. Look at general traffic control measures that could improve traffic flow along critical roadway segments.

Factors that influence clearance time, and thus overall evacuation order time, include storm scenarios, population-at-risk, behavioral and socioeconomic characteristics, the roadway system, and traffic control. The transportation model used in the base study considered all these factors at their 1987 levels.

Today, most of these factors have changed. Changes in the storm scenarios, population-at-risk, and behavioral and socioeconomic characteristics will greatly influence the reliability of established evacuation clearance times which were calculated during the base study. These variables have been discussed in another section of this report; the impacts will not be reiterated here.

Changes in the roadway system will have important impacts on the results of the 1987 transportation analysis. Without further, more expert analysis, the impacts cannot be definitized because of the level of expertise required.

Because traffic movement associated with hurricane evacuation involves several different patterns (in-county origins to in-county destinations; in-county origins to out-of-county destinations; out-of-county origins to in-county destinations; out-of-county origins to out-of-county destinations; and background traffic), the effect of highway changes is debated by local officials. Some argue that the improvements will help in reducing clearance times, while others argue that they will only aid in faster congestion at out-of-county destinations, thus increasing clearance times. The level of expertise necessary to evaluate the change is far beyond the scope of this report.

Significant changes in the highway networks of communities vulnerable to hurricane threats could immensely affect evacuation routes and clearance times. Unless such changes are additionally matched against changes in expected behavior, hazards, vulnerabilities, and shelter locations, existing evacuation plans may be less than optimal. Another important consideration is the now recognized necessity to expand to a regional scope transportation analysis. The need exists to assess hurricane evacuation traffic control through inland counties, which was not done in the previous study, and to evaluate the impact of evacuation into Virginia and South Carolina.

PRELIMINARY RESTUDY ESTIMATE

Based on the recommendations made in this report, a preliminary study cost estimate is provided below.

TABLE 5

ESTIMATED RESTUDY COSTS

ACTIVITY	COST	REFERENCE NOTE
Plan of Study	$ 30,000	
Mapping	$ 785,000	(1)
Shelter Analysis	75,000	(2)
Vulnerability Analysis	85,000	
Transportation Analysis	150,000	(3)
Behavioral Analysis	90,000	
Update Hurrevac Software and Data Bases	50,000	(4)
Miscellaneous and Contingency	$ 150,000	(5)
Study Management	$ 100,000	(6)
Coordination and Report Preparation	$ 185,000	
Total Study Cost	**$1,700,000**	

Reference Notes:

(1) Figures represent the cost for (color) electronic mapping of the entire North Carolina coast, including some topographic information, with final printing at an approximate scale of 1"=4000'. If the required level of detail decreases and/or electronic printing costs are less or another printing method is used, the cost of mapping will decrease. Also note that about $115,000 not included in this amount will have already been committed to the mapping effort for Brunswick, New Hanover, Pender, and Onslow Counties by 1994.

(2) Figures include $50,000 to update the shelter analysis and approximately $25,000 for surveys to acquire spot elevations of roads, buildings, schools, etc.

(3) Includes $7,500 per county for 20 counties.

(4) North Carolina coastal counties are on Version 4.0. The cost indicated includes upgrading to Version 5.0 and also revising the existing data bases as called for during the restudy.

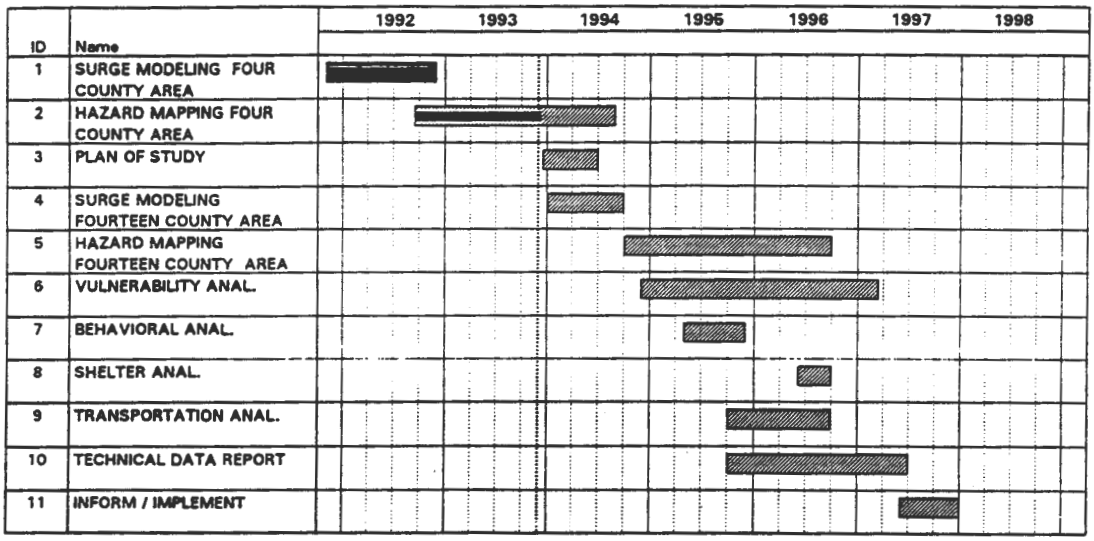
(5) Miscellaneous cost includes items such as evacuation signs (requested by county officials), training of local officials in how to use the electronic maps, and any associated hardware or software, meetings, and travel.

(6) Figures represent the cost of study management if the study is completed in 3 years and equates to 0.25 man-years per year of the study.

PRELIMINARY RESTUDY SCHEDULE

Figure 3 below depicts the preliminary study schedule. This schedule which is contingent upon receipt of timely and adequate funding will be finalized during the preparation of the plan of study which is to be completed in 1994.

Figure 3



CONCLUSIONS

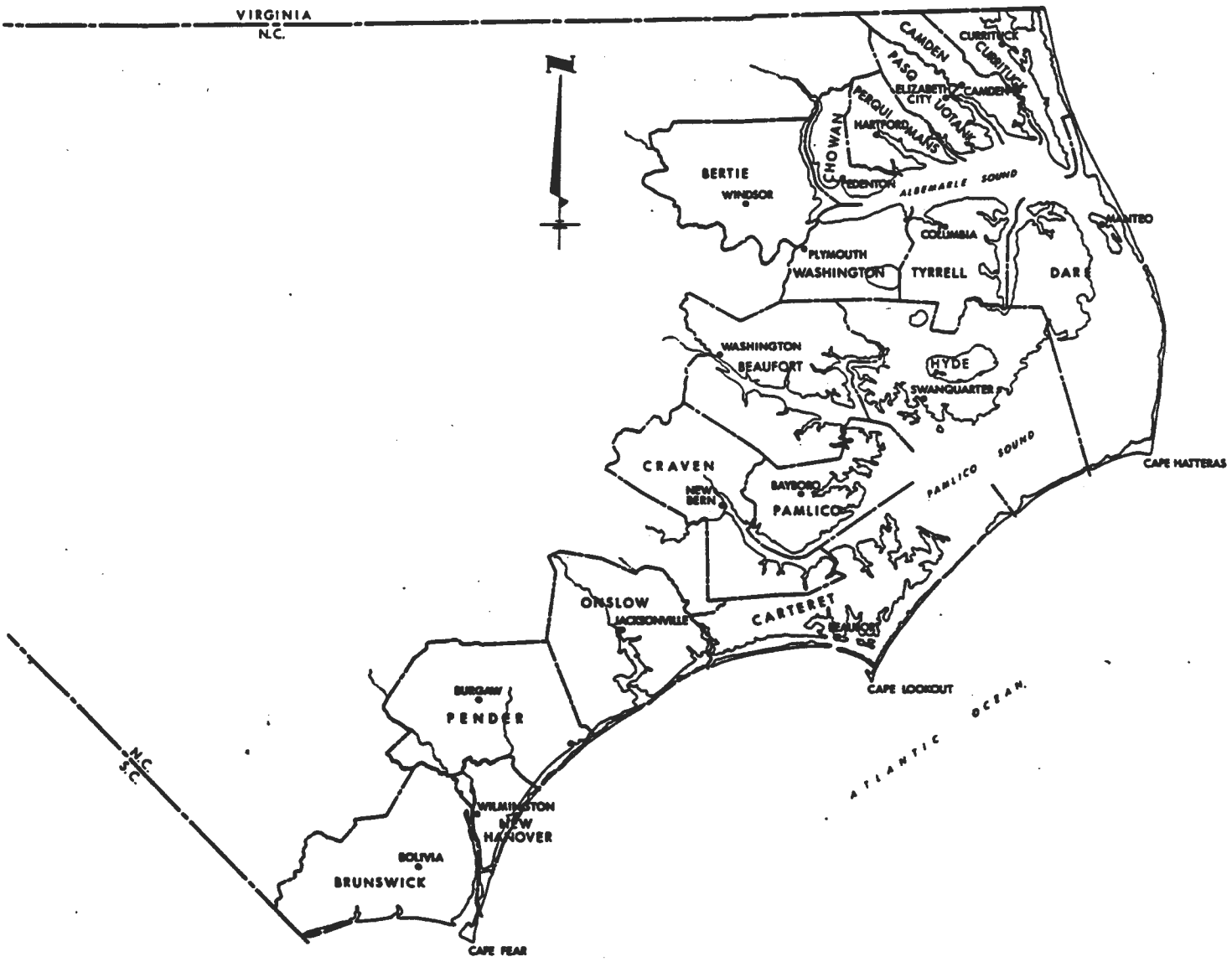
Many changes have occurred in North Carolina which have raised questions concerning the continued use of the technical data compiled during the 1987 Hurricane Evacuation Study for present-day evacuation planning. Technological advances have provided more accurate prediction of storm surge levels. The advances in the national understanding of hurricanes have allowed improvements in the fields of evacuation planning and emergency preparedness. Psychological and physical changes in the study area have also occurred that will influence established evacuation numbers and clearance times. Population increases, changes in shelter inventories, and changes in highway networks make continued reliance on the 1987 data unsafe for North Carolina's coastal population. The level of update to technical data necessary to aid in reliable, accurate evacuation planning is generally beyond local capabilities.

The recommended course of action is a restudy of the North Carolina coast. The recommendation is for generation of electronic storm surge maps and conducting new hazards, vulnerability, and behavioral analyses. Updates to the 1987 shelter and transportation analyses are also recommended. Eighteen coastal counties are included in the recommended restudy area: Beaufort, Bertie, Brunswick, Camden, Carteret, Chowan, Craven, Currituck, Dare, Hyde, New Hanover, Onslow, Pamlico, Pasquotank, Pender, Perquimans, Tyrrell, and Washington. In addition, Martin and Jones Counties will be included in the transportation analysis.

RECOMMENDATION

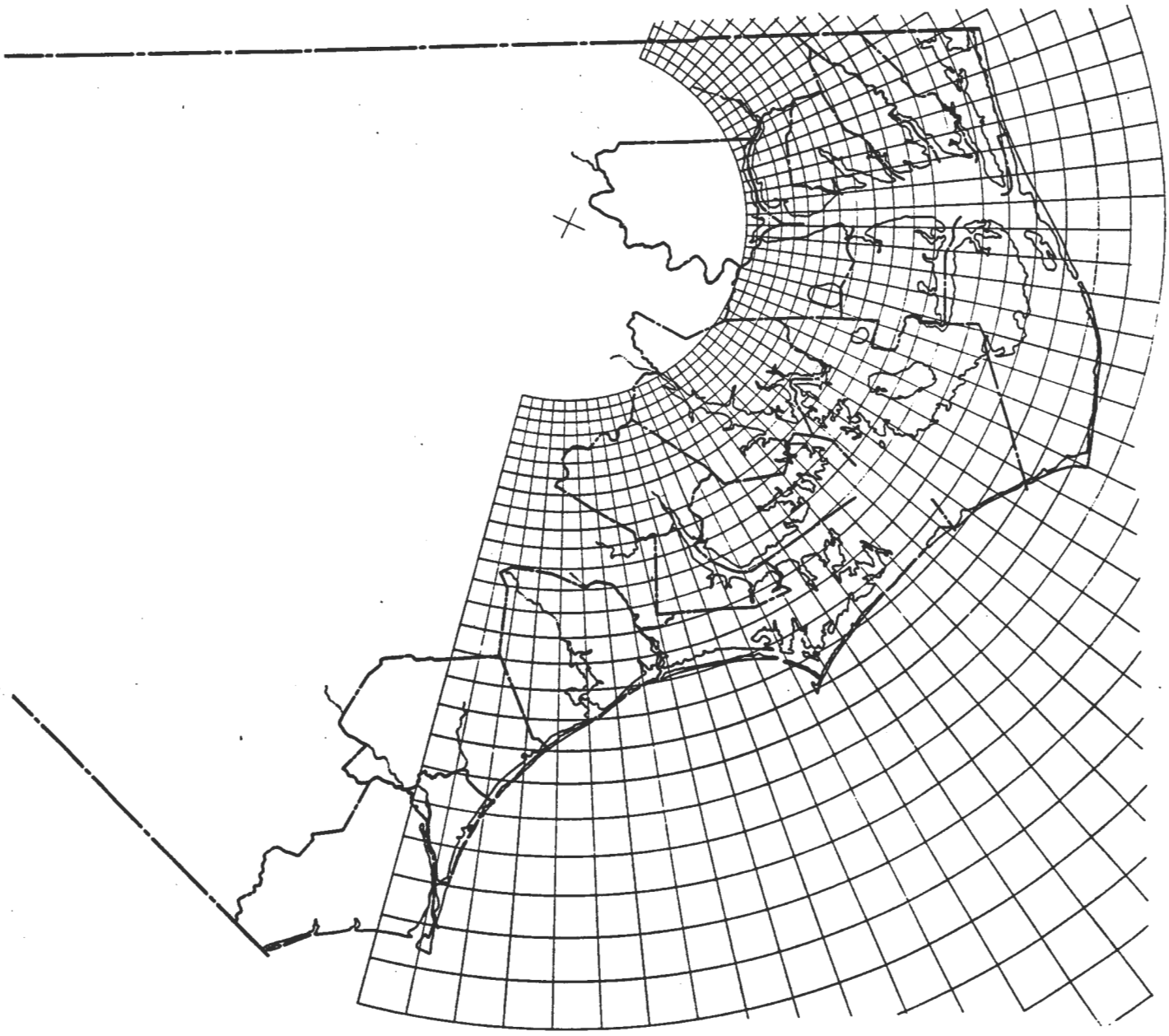
Based upon the above findings, I conclude that this report is favorable and supports further study of the North Carolina coast for hurricane evacuation planning. The State of North Carolina has been apprised of these findings and is supportive. I therefore recommend that this report be approved, a detailed plan of study be prepared and the restudy be initiated.

LAWRENCE W. SAUNDERS
Chief, Planning Division



Study Area

PLATE 1



Pamlico Basin
SLOSH Grid

PLATE 2

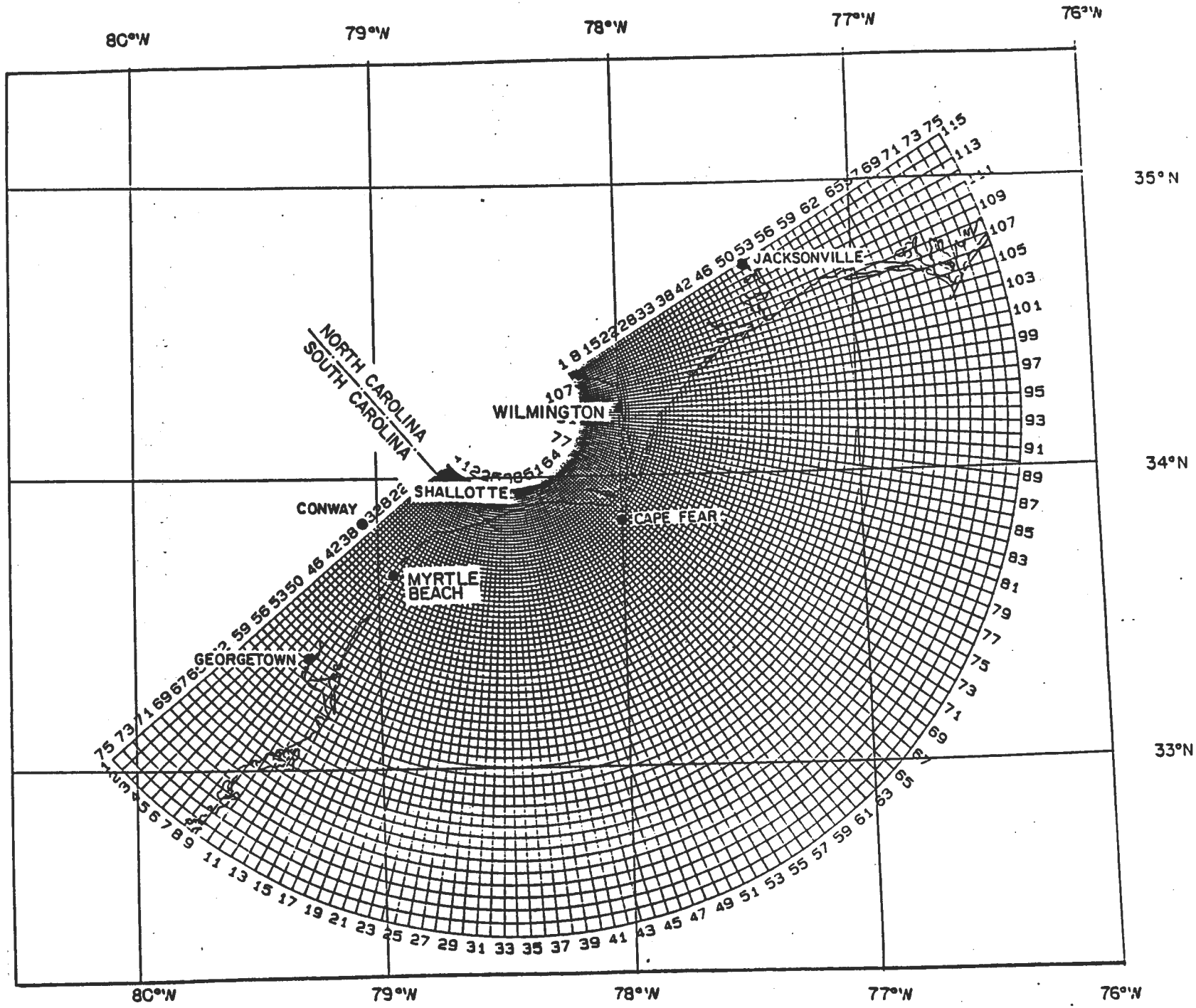

80°W
79°W
78°W
77°W
76°W
35°N
34°N
33°N
NORTH CAROLINA
SOUTH CAROLINA
JACKSONVILLE
WILMINGTON
SHALLOTTE
CONWAY
CAPE FEAR
MYRTLE BEACH
GEORGETOWN

PLATE 3

APPENDIX A COORDINATION

MEMORANDUM FOR RECORD OF 30 NOVEMBER 1993
NORTH CAROLINA HURRICANE EVACUATION RESTUDY
INTERAGENCY COORDINATION MEETING

CESAW-PD-P 2 December 1993

MEMORANDUM FOR RECORD

SUBJECT: North Carolina Hurricane Evacuation Restudy Interagency Coordination Meeting

1. Subject meeting was held in the Wilmington District conference room beginning at 0830 on 30 November 1993. A copy of the attendee list is attached. Also attached is a copy of the agenda for the meeting.

2. After an opening by Mr. Saunders in which he stressed the need for the restudy, Mr. Chesnutt briefly went over the history of restudy efforts. He recalled the first restudy which was done for the Miami, Florida, area. The original study was completed in 1983 using the SPLASH model. Even though many other coastal areas had yet not had an initial study completed, it was decided to restudy the Miami area because of its hurricane vulnerability. This decision to restudy was questioned and criticized heavily by those in areas which had no initial study completed. The restudy for Miami was completed in 1991, and information from that restudy was used extensively for Hurricane Andrew--a fact which in hindsight justified the restudy. Mr. Chesnutt explained that the meeting here was to further develop the process for deciding where restudy effort should be expended and to consider the need for restudy in North Carolina.

3. Mr. Bill Massey, FEMA, Region IV, recapped the history of the hurricane evacuation study program. He made special mention of the fact that North Carolina was one of only three states that have helped to fund hurricane evacuation studies. He indicated that State support was an important factor in selection of study and/or restudy selections.

4. Mr. Billy Cameron, Director of the North Carolina Division of Emergency Management, made a strong statement in favor of restudy in North Carolina. He said that the restudy was the number one priority in his office and that its completion was vital, particularly in light of storm surges during Hurricane Emily which were some 5 feet higher than those which are predicted for a similar storm by the existing SLOSH model. He said that funding for the restudy was included in the 4-year plan and a proposal was before the General Assembly to provide funding toward the restudy in 1994. Mr. Cameron was confident of funding approvals.

5. Mr. Alan McDuffie gave a slide presentation based on the past study which was completed in 1987. The slides graphically displayed the storm surge levels on local landmark buildings in coastal North Carolina. He described how surge levels for similar storms are now much higher using the 1992 SLOSH model results. This is because the "new" model used high tide levels at the time of maximum surge and because faster forward speed hurricanes were modeled during the 1992 SLOSH study.

CESAW-PD-P 2 December 1993
SUBJECT: North Carolina Hurricane Evacuation Restudy Interagency Coordination Meeting

6. Mr. Al Bjorkquist presented a summary of the Draft Report of Recommendation for Coastal North Carolina Hurricane Evacuation Study. A copy of that report, which was given to meeting participants, is attached. A lengthy and mutually informative discussion proceeded. Most attention was focused on the high study cost and particularly on the cost of mapping.

7. Mr. Will Brothers, North Carolina Division of Emergency Management, reasserted the need for the restudy. His statement is summarized in a meeting handout which is attached. As shown on page three of the handout, the State of North Carolina is proposing to provide $390,000 over the 3-year restudy period which would begin in October 1994.

8. During the meeting wrap-up, Mr. Chesnutt stated the need for trimming down study costs, particularly in light of the relatively small amount ($2-3 million annually) that FEMA will be receiving for hurricane evacuation studies nationwide. Although he questioned the need for behavioral reanalysis and again questioned the high cost of mapping, he thought that the justification for the restudy (focused on updated SLOSH results) was adequate and recommendation for a restudy of North Carolina should proceed.

9. Mr. Cameron summarized sentiments of the North Carolina Division of Emergency Management. He said they want the restudy, they have a plan and are budgeting for the restudy, and they are ready to start.

10. The meeting concluded at about 1145.

Albert M Bjorkquist

ALBERT M. BJORKQUIST
Study Manager

4 Atchs

(Atch 3 not included in Appendix A)

NORTH CAROLINA
HURRICANE EVACUATION RESTUDY
INTERAGENCY COORDINATION MEETING

30 November (Tue), 1993
Conference Room, Wilmington District Corps of Engineers

MEETING PARTICIPANTS

NAME	ORGANIZATION	PHONE
AL BJORKQUIST	WILMINGTON DISTRICT COE	910-251-4596
LARRY SAUNDERS	" " "	910-251-4505
Sy Reitman	So. Atl. Div - Atlanta, COE	404-331-6641
CHARLES CHESNUTT	HQ, USACE	202-272-0169
Jennifer Watson	Charleston District, COE	803-727-4785
WILL BROTHERS	NC DIV. OF EMERGENCY MGT	919-733-3627
Joe Gavin	PHILA. DISTRICT, COE	215-656-6547
Nancy Watkins	COE, Wilmington	910-251-4945
Joel Hendrix	COE, Wilmington	910-251-4944, 4946
DAVID GIORDANO	NC Center for Geographic Info. & Analysis	919-733-2090
BILL MASSEY	FEMA - Atlanta -	404-853-4430
Billy R. Cameron	Director N.C. E.M.	919-7333925
Ray Batchelor	COE: Planning	910-251-4729
Don Lewis	PBS&J	904 224 7275
ALLAN McDIFFIE	COE, WILMINGTON DISTRICT	919 251-4724

ATTACHMENT 1

NORTH CAROLINA
HURRICANE EVACUATION RE-STUDY
INTERAGENCY COORDINATION MEETING

30 November (Tue), 1993
Conference Room, Wilmington District Corps of Engineers

MEETING AGENDA

0800	Coffee and Doughnuts	
0830	Welcome	Laurence Saunders Chief Planning Division Wilmington District
0845	National Perspective (Meeting Purpose)	Charlie Chestnut Hurricane Program Manager Office Chief of Engineers Bill Massey FEMA Region IV
0900	Past Study	Alan McDuffie Chief, Hurricane Study Unit Wilmington District
0930	Break	
0950	Discussion on Report of Recommendation	Al Bjorkquist Study Manager Wilmington District
1015	State of North Carolina Perspective	Billy R. Cameron, Director NC Division of Emergency Mgmt. Will Brothers NC Division of Emergency Mgmt.
1045	Wrap up	Charlie Chestnut Bill Massey
1130	Adjourn	

ATTACHMENT 2

North Carolina Department of Crime Control and Public Safety
Division of Emergency Management

James B. Hunt, Jr., Governor

Thurman B. Hampton, Secretary

RESTUDY: EASTERN NORTH CAROLINA HURRICANE EVACUATION STUDY

Background: The original Eastern North Carolina Hurricane Evacuation Study was initiated in 1984 and completed in 1987. The study was funded by the Federal Emergency Management Agency, the U.S. Army Corps of Engineers, and the North Carolina Department of Crime Control and Public Safety, Division of Emergency Management. The direct cost of the study was approximately $500,000 and the indirect costs were over $150,000. North Carolina's share of the direct cost was $100,000.

The hurricane evacuation study area included over 300 miles of open coastline and 1,700 miles of sound and estuary shoreline in eastern North Carolina. There were 18 coastal counties in the original study area. This included: Beaufort, Bertie, Brunswick, Camden, Carteret, Chowan, Craven, Currituck, Dare, Hyde, New Hanover, Onslow, Pamlico, Pasquotank, Pender, Perquimans, Tyrrell, and Washington. Martin County was included in the transportation analysis phase of the study.

The study consisted of several related analyses that provided (1) technical data concerning hurricane hazards, (2) vulnerability of the coastal population to storm surge flooding, (3) public response to evacuation advisories, (4) sheltering needs for various hurricane threat situations, and (5) evacuation decision timing associated with different storm scenarios and hurricane evacuation traffic patterns.

The Pamlico Basin Sea, Lake and Overland Surges from Hurricanes (SLOSH) model, developed by the National Hurricane Center, was the primary computer model used in the evacuation study. The effective coverage area of the Pamlico SLOSH Basin is from near the Virginia border to about the mid-point of Onslow County near the New River Inlet.

From this point in Onslow County, to the South Carolina border in Brunswick County, the National Hurricane Center used an older computer model known as the Special Program to List the Amplitude of Surges from Hurricanes (SPLASH). The SPLASH model provided still-water storm surge heights, but it was limited in that surge heights were only calculated for open coastlines.

ATTACHMENT 4

NEED FOR A RESTUDY: There are several reasons why a restudy is essential. These are: (1) the recent completion by the National Hurricane Center of the Wilmington/Myrtle Beach SLOSH Basin project which reflect higher storm surge values for the four (4) Southeastern coastal counties than previously provided by the SPLASH model; (2) the significant increase in the permanent and tourist population on the barrier islands over the past 10-20 years; (3) essentially little or no significant change or improvements to the existing roadway network since the original study was conducted; (4) greater number of people at risk from the storm surge; (5) increase in the evacuation clearance times by possibly 2-4 hours in certain areas; (6) the need to provide a better analysis of both hurricane shelters and special needs shelters in the coastal areas; (7) the need to route hurricane evacuation traffic through the inland counties, which was not done in the original study, and (8); to evaluate, in more detail, the impact of evacuation into Virginia and South Carolina.

The permanent resident population in the Eastern North Carolina Hurricane Evacuation Study area has increased at a significant rate over the past 30 years. This population increase has occurred primarily on the barrier islands and at or near the coastline. The population figure for the 1980 census was 563,600 and in 1990 the census figure was 679,100.

The tourist population during the summer season has been gradually increasing each year. This can be attributed, in part, to the increase in construction of coastal rental housing units and the enhancement of recreational facilities on the barrier islands and immediate coastal areas. The following 1992 tourist population estimates are based on the number of people who would be occupying rental housing units on any given day during the June, July or August tourist season:

1992 Tourist Estimates

Brunswick County	-	44,000
Carteret County	-	34,000
Currituck County	-	6,000
Dare County	-	42,000
Ocracoke-Hyde County	-	3,000
New Hanover County	-	30,000
Onslow County	-	22,000
Pender County	-	12,000
TOTAL		193,000

Note: These figures do not include day visitors or campers. Counties estimated 1993 figures 5% higher than 1992.

RESTUDY COST - STATE SHARE: $130,000 per year for a three year period is recommended as the cash amount the Department should request the General Assembly provide as the State share. The total State share would be $390,000 and the total study cost is estimated at $1,500,000. The Federal Emergency Management Agency (FEMA) and U.S. Army Corps of Engineers practice has been to give priority consideration to a state that is able to share a portion of the restudy cost. In the original study the direct funding from FEMA and the COE was approximately $400,000 and $100,000 was provided by North Carolina. The decision concerning whether or not the Federal Government should initiate and fund a restudy will be determined by a restudy review and assessment group made up of senior officials from FEMA, the COE, the National Hurricane Center, and possibly a private contractor involved with transportation and traffic control analysis.

If a restudy is approved by FEMA and the COE, it is anticipated the project would be started in October 1994 (FY '95) with State funding for the first year being $130,000. The restudy for coastal North Carolina is estimated to require three years to complete.

APPENDIX B

COASTAL NORTH CAROLINA COMPUTER CAPABILITY ASSESSMENT REPORT

NORTH CAROLINA HURRICANE EVACUATION RESTUDY
COASTAL COUNTIES COMPUTER CAPABILITIES ASSESSMENT

PURPOSE

The purpose of this assessment was to determine the current computer capabilities of emergency management offices of counties involved in the North Carolina Hurricane Evacuation Restudy. Currently, the HURREVAC model is used by most of the counties. In addition, the hurricane evacuation restudy will include generation of electronic maps containing hurricane surge data from the NHC. Adequate computer capability at the county level could possibly obviate the need for multiple hard copies of these maps and significantly reduce the cost of their reproduction.

This assessment was conducted by the North Carolina Division of Emergency Management. A complete copy of their report follows.

North Carolina Department of Crime Control and Public Safety
Division of Emergency Management
James B. Hunt, Jr., Governor
Thurman B. Hampton, Secretary

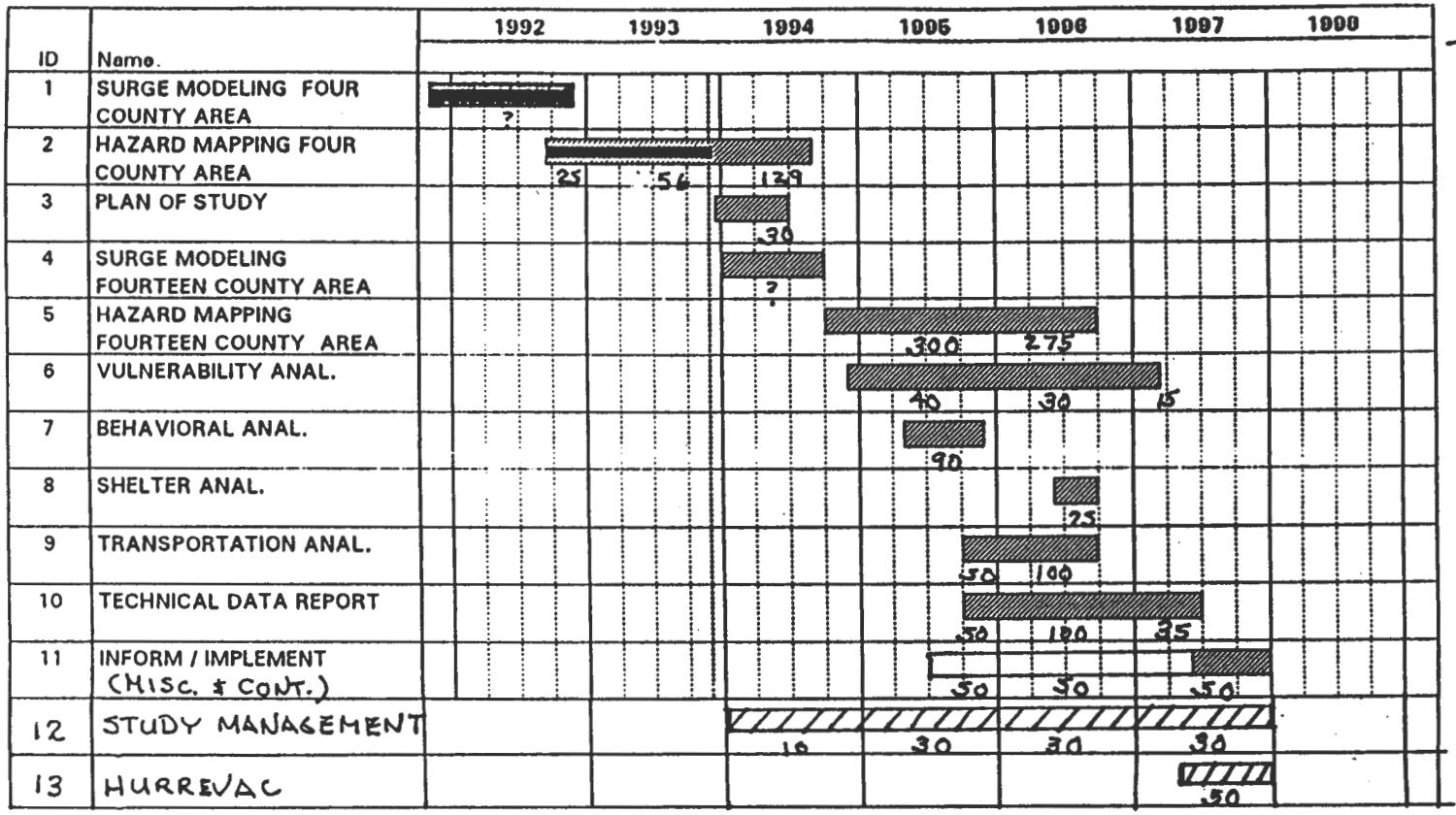
COASTAL NORTH CAROLINA COMPUTER CAPABILITY ASSESSMENT REPORT

County	Computer	Comments
AREA A - Washington		
Beaufort	NCR PC 6	HURREVAC-No
Bertie	NCR PC 6 upgraded to Zenith laptop	HURREVAC-Yes Zenith owned by county
Camden & Pasquotank	NCR PC 6	HURREVAC-Yes; On DG 386 county computer
Chowan	NCR PC 6	HURREVAC-Yes; On county computer
Currituck	NCR PC 6	HURREVAC-Yes; On county computer
Dare	NCR PC 6 upgraded to PC 8	HURREVAC-Yes; on DG 386 county computer
Hyde	NCR PC 6	HURREVAC-Yes; on computer in County Sheriffs Office
Perquimans	NCR PC 6	HURREVAC-No
Tyrrell	NCR PC 6 on loan to Martin County	HURREVAC-No
Washington	NCR PC 6	HURREVAC-Yes; On county computer
Ocracoke (Hyde)	None	HURREVAC-Yes; on county commissioners computer
AREA C - Wallace		
Brunswick	NCR PC 6 upgraded to Novell	HURREVAC-Yes; On county computer
Carteret	NCR PC 6 given to Area C Office	HURREVAC-Yes; On county computer
Craven	NCR PC 6	HURREVAC-Yes; On State Fire Association computer
New Hanover	NCR PC 6	HURREVAC-Yes: On county computer
Onslow	NCR PC 6	HURREVAC-Yes; On county computer
Pamlico	NCR PC 6 given to Area C Office	HURREVAC-Yes; On State Fire Association computer
Pender	None	HURREVAC-Yes; On county computer

(Note: NCR PC 6 does not have a hard drive or color capability required for HURREVAC: The computer capability in each county EM office should be adequate enough to handle HURREVAC without having to "borrow" a computer from another county organization)

116 West Jones Street • Raleigh, North Carolina 27603-1335 • Telephone (919) 733-3867

PRELIMINARY NC RESTUDY SCHEDULE AND COST ESTIMATE



TOTAL STUDY (BY YEAR, $1000's) 25 56 169 610 660 180 #1700

APPROXIMATE ALLOCATION BY YEAR

ACENCY	1992	1993	1994	1995	1996	1997	TOTAL
CORPS	25	41	69	240	265	25	665
FEMA	ϕ	15	70	240	265	25	615
NC	ϕ	ϕ	30	130	130	130	420
TOTAL	25	56	169	610	660	180	1700

State of North Carolina
Hurricane Program

North Carolina Division of Emergency Management

II. History

A. Coastal North Carolina is considered to be one of the most hurricane vulnerable locations along the coastline of the United States. Historically, only Florida exceeds North Carolina in terms of the number of hurricane landfalls among Atlantic coast states. Between 1899 and 1993, North Carolina has received 25 direct hits from hurricanes. Of these, nine were classified as strong hurricanes, i.e., Category 3 or greater on the Saffir/Simpson Hurricane Scale.

North Carolina's Outer Banks are particularly susceptible to the effects of hurricanes due to the projection of the land mass of northeastern North Carolina into the Atlantic Ocean. Even when storms do not make landfall, they are often deflected by inland high pressure systems and are pulled close enough to the coast to have a direct affect on the barrier islands and the immediate coastal mainland.

The following information represents tropical storms since 1899 which were of hurricane strength at the time they reached coastal North Carolina. Storms passing close enough off shore to affect land areas are included, even though they did not make landfall:

1899 August 17: Made landfall in the vicinity of Hatteras. Wind speeds recorded with extreme velocities of 120 to 140 mph before the anemometer blew away. Hatteras covered with water to a depth of from 4 to 10 feet. All fishing piers destroyed. All bridges were swept away. Great proportion of homes on the island were damaged. Ten vessels, including a steamship. were wrecked. In the vicinity of Cape Lookout there was much destruction at Diamond City. Number of lives lost estimated about 25. (CAT 4)

1899 October 31: Made landfall below Wrightsville Beach and followed almost the same path as Hurricane Hazel on October 15, 1954. No wind velocities available from southeastern coastal area. Kitty Hawk reported highest wind there at 72 mph (sustained 5-minute velocity). At Wrightsville Beach, the water was reported to be 8 feet above normal high tide. Wilmington had wharves and streets flooded. New Bern, Morehead City and Beaufort reported flooding and damage. At Southport, it was considered the worst storm ever. 40 mph sustained winds were reported inland to the center of the state, and many trees were uprooted. One person was reported killed and the storm caused considerable damage. (CAT 2)

1901 July 11: Made landfall near Oregon Inlet. Highest sustained wind recorded at Hatteras was 62 mph from the west. Not able to locate record of damages or other related information. (CAT 1)

1903 September 15: Center passed east of Hatteras. Hatteras reported sustained winds at 60 mph from the northwest and Kitty Hawk reported sustained winds at 72 mph from the east. Lack of damage reports probably due to failure of communications on the Outer Banks, which occured frequently during storms. (CAT 1)

1904 September 14: Made landfall near the South Carolina and North Carolina state line, crossed the eastern portion of the state and reentered the Atlantic Ocean near Norfolk, Virginia. Hatteras reported sustained winds from the southwest at 51 mph. Cyclones were reported at Mt. Olive, Faison and Durham. One death was reported and there was considerable damage to crops in eastern and central North Carolina. (CAT 1)

1904 November 13: Center passed near Cape Hatteras. Sustained winds at Hatteras were 68 mph from the southwest. Storm was very severe at Fort Caswell. Four drowned at life-saving station at New Inlet. Four killed when Schooner Missouri wrecked near Washington, NC. Eight men drowned in the sound when a yacht foundered. Several persons drowned at a fishing lodge on Hatteras Island. Two schooners were wrecked near Cape Fear. (CAT 3)

1908 July 30: Center passed east of Hatteras. Highest sustained wind at Hatteras was 58 mph. Considerable water damage to the central and southeastern coastal areas. Wrightsville Beach was evacuated and wind driven water covered the island and destroyed considerable property. Damage was considered immense. There was extensive flooding in eastern North Carolina. New Bern had 10.73 inches of rain in 72 hours and Kinston had 9 inches of rain. The extensive flooding brought all travel to a standstill. (CAT 1)

1913 September 3: Made landfall between Hatteras and Beaufort. Highest sustained wind reported at Hatteras was 74 mph from the southeast. Property and crop damage was heavy in the Pamlico Sound area due to the high water from the sound. In Washington and New Bern, the water was reported to be 10 feet higher than previous high water marks and railroad bridges in both towns were washed away. Wind and rain caused damage as far west as Durham. Five lives were lost and damage was estimated at $3,000,000. (CAT 1)

1920 September 22: Made landfall between Wilmington and Morehead City. A steamship off the coast estimated winds at 90 mph. Winds at the mouth of the Cape Fear River were estimated at 72 mph and it carried a lightship several miles west of where it was anchored. Severe windstorms killed one and injured many in Pitt County. (CAT 1)

1924 August 25: Center passed just east of Hatteras. Sustained winds from Hatteras were reported at 74 mph from the northwest. Two people drowned and Ocracoke was partially flooded. (CAT 1)

1925 December 2: Made landfall between Wilmington and Cape Hatteras. Storm center passed through the northern coastal counties and back into the Atlantic near Cape Henry, Virginia. Hatteras reported a sustained wind of 62 mph from the west. Not able to locate damage reports. (CAT 1)

1930 September 12: Center moved through the coastal waters off the North Carolina coast and east of Hatteras. Sustained winds at Hatteras were reported at 60 mph from the north. Minor wind damage was reported from Atlantic Beach to Hatteras. (CAT 1)

1933 August 22-23: Made landfall at Cape Hatteras and moved into the northeastern counties. Sustained winds at Hatteras were reported at 64 mph. High winds and tides caused considerable damage. There was considerable crop damage as far inland as Granville County. Storm damage estimated at $250,000. (CAT 2)

1933 September 15-16: Made landfall west of Hatteras. Sustained winds at Hatteras were reported at 76 mph before a portion of the anemometer blew away. Winds were estimated at 125 mph in Beaufort and New Bern. Damage was heavy from New Bern to the Virginia line. New Bern streets had 3-4 feet of water. Storm surge in Pamlico and Albemarle Sounds caused 21 deaths and $3,000,000 in damage. In several coastal towns hardly a building was standing. (CAT 3)

1934 September 8: Passed over or slightly east of Hatteras. Sustained winds at Hatteras were reported at 65 mph. Rains of up to 10 inches fell in the Beaufort area. Damage was slight. (CAT 1)

1936 September 18: Center passed over or slightly east of Hatteras. Average 5-minute wind speed of 80 mph reported at Hatteras. Winds of 90 mph reported at Manteo. $55,000 damage to roads, bridges, piers and buildings. The highway from Currituck to Norfolk was washed out. About 35 feet of beach was cut away at Nags Head. Tides were very high at Manteo and Hatteras. (CAT 2)

1938 September 21: Passed off shore a short distance from Hatteras. Sustained winds at Hatteras were reported at 61 mph from the northwest. Heavy rains fell in eastern North Carolina. This storm was "The Great New England Hurricane of 1938". (CAT 1)

1944 August 1: Made landfall near Southport. Oak Island reported winds at 80 mph. Damage at Wrightsville Beach and Carolina Beach was extensive. More than 10,000 people were evacuated from beach areas. Unusually high tide and and heavy seas caused considerable coastal damage. Total damage was estimated at $2,000,000. There was also considerable crop damage in the southeastern coastal counties. (CAT 1)

1944 September 14: Passed slightly east of Hatteras moving northward. Sustained winds at Hatteras were reported at 110 mph. Cape Henry, Virginia reported winds at 134 mph with gusts to 150 mph. On the central and northern coastal areas 108 buildings were destroyed and about 675 damaged at a loss of $450,000. Crop damage was estimated at $1,000,000. There was heavy damage in Nags Head and Elizabeth City. One person was killed. The coast guard cutters Jackson and Bedloe capsized and sank while protecting a Liberty Ship torpedoed off the North Carolina coast. (CAT 3)

1949 August 24: Passed off shore at Cape Hatteras, directly over the Diamond Shoals Lightship. Sustained winds at Hatteras were reported at 73 mph. An estimated $50,000 in property damage occurred, mostly in and near Buxton. Thousands of trees were broken in Buxton woods. Two persons died. (CAT 1)

1953 August 13: Hurricane Barbara made landfall between Morehead City and Ocracoke. Highest winds reported at Hatteras were gusts to 90 mph. Property damage was estimated at $100,000 with the crop damage estimated at $1,000,000, mostly due to corn blown down in fields. One person died at Wrightsville Beach. (CAT 1)

1954 August 30: Hurricane Carol passed just to the east of Cape Hatteras. Highest wind speeds on land were gusts to 55 mph at Wilmington, 65 mph at Cherry Point and 100 mph at Cape Hatteras. Damage along the coast was estimated at $250,000. About 1000 feet of paved highway was undermined on the Outer Banks. (CAT 2)

1954 September 10: Hurricane Edna passed about 60 miles east of Cape Hatteras. Wind gusts were reported at 75 mph on the Outer Banks. A section of the Outer Banks highway was washed out. Damage was minor but widespread in the coastal area. $75,000 for property and $40,000 for crops. (CAT 1)

1954 October 15: Hurricane Hazel made landfall on the North Carolina coast very close to the South Carolina line. From that point northward to Cape Lookout, the ocean front was devastated by storm surge. At Long Beach, 352 of the existing 357 buildings were totally destroyed as no litter or debris remained - it had been swept clean. On Ocean Isle Beach all the buildings disappeared. Holden Beach lost all two hundred of its buildings. Carolina Beach had 475 buildings destroyed and 1,365 damaged. Wrightsville Beach had 89 houses destroyed and 530 damaged. Winds were reported at 150 mph at Calabash, 150 mph at Oak Island, 125 mph at Wrightsville Beach and 100 mph at Morehead City. Miles of grass-covered dunes disappeared. Heavy wind damage occurred over most of eastern North Carolina with wind gusts reported at 120 mph in Goldsboro and 90 mph in Raleigh. Record amounts of rainfall were recorded on the western-half of the storm. There were 19 deaths, most of them at or near the beach. Total coastal and inland damage estimates were $136,000,000. (CAT 4)

1955 August 12: Hurricane Connie made landfall close to Cape Lookout. The slow movement of the storm resulted in coastal and sound flooding. Tides from Southport to Nags Head were about 7 feet above normal while the waters of the sounds and near the mouths of rivers were 5 to 8 feet above normal. Prolonged pounding of the waves along the coast caused tremendous beach erosion, estimated to be worse than Hurricane Hazel in 1954. Hurricane Diane followed in five days and made it impossible to assess the damage caused by Connie. (CAT 3)

1955 August 17: Hurricane Diane made landfall near Carolina Beach and passed over Wilmington. Water was 3-4 feet deep in parts of Belhaven, Washington and New Bern. Winds caused crop damage as far west as Raleigh. Tides were more severe than those with Connie. Diane followed so closely after Connie that it was not possible to assess the damage from each storm. Estimates from the two storms was $60,000,000 in crop damage and $20,000,000 in beach and other property damage. (CAT 2)

1955 September 19: Hurricane Ione made landfall near Salter Path on Bogue Banks. The center passed just west of Cherry Point, Oriental and Belhaven. Sustained winds at Cherry Point were reported at 75 mph from the northeast with gusts to 107 mph. Wind driven tides on the beaches and in the sounds were 3 to 10 feet above normal. Heavy rains of up to 16 inches fell on already waterlogged soil resulting in thousands of acres being flooded and thousands of homes flooded with water up to 4 feet deep. In New Bern the water reached 10 feet with 40 city blocks flooded. Several hundred homes were washed away. Seven people died. Property and crop damage estimated at $88,000,000. (CAT 3)

1958 September 27: Hurricane Helene passed just off the coast from Wilmington to Hatteras. Wilmington reported sustained winds of 85 mph with gusts up to 135 mph. Tides on ocean beaches were 3-5 feet above normal. Tides in southern Pamlico Sound were 8 feet above normal. High winds caused structural and crop damage estimate at $11,000,000. (CAT 3)

1960 September 11: Hurricane Donna made landfall between Wilmington and Morehead City and moved north up the coast. Coastal communities had heavy structural damage from Wilmington to Nags Head, with considerable beach erosion. Maximum winds were reported at 75 mph with gusts at 100 mph. Tides were 4-8 feet above normal. Wind damage to crops, trees and homes up to 50 miles inland. Eight people died. Damage estimated well up in the millions. (CAT 3)

1964 October 16: Hurricane Isbell made landfall near Morehead City and moved north over the northeastern counties. Elizabeth City reported gusts to 75 mph from the northeast. There was some flash flooding. Wet soil damaged the peanut crop. (CAT 1)

1968 October 20: Hurricane Gladys moved northeast along the coast skirting the Outer Banks. The Coast Guard Stations at Hatteras and Ocracoke reported wind gusts to 98 mph. Cape Lookout reported wind gusts at 90 mph, Atlantic Beach at 69 mph, and Topsail Beach at 63 mph. Minor beach erosion was reported. (CAT 1)

1971 September 30: Hurricane Ginger made landfall near Morehead City. Ginger will be noted for its longevity. It was tracked for 31 days and it was a hurricane for 20 days. Wind gusts were reported at Atlantic Beach at 92 mph from the northwest, Cape Hatteras 70 mph from the southeast, Topsail Beach 58 mph from the northwest, and Raleigh 46 mph from the north. Pamlico Sound had storm surge from 4-7 feet and the tides were 6 feet above normal at Washington, Aurora, New Bern and Cherry Point. Rainfall totals were over 10 inches at Bayboro, Belhaven, Aurora and on Roanoke Island. Thousands of acres of corn and soybeans in the eastern counties were lost with damage at $10,000,000. (CAT 1)

1984 September 13: Hurricane Diana made landfall near Long Beach then moved northeast along coastal North Carolina and back over the Atlantic Ocean near Oregon Inlet. Diana was stalled off Cape Fear for about 30 hours before making landfall. Oak Island Coast Guard Station reported a sustained wind of 115 mph on September 11th. Sustained wind was 92 mph when Diana made landfall. Severe beach erosion occurred in New Hanover and Pender Counties along with considerable roof damage on the barrier islands in these two counties. Rainfall amounts of up to 15 inches were reported and three dams failed. There were three deaths and damage in the state was estimated at $80,000,000. (CAT 2)

1985 September 27: Hurricane Gloria made landfall at Cape Hatteras then turned to the northeast. Cape Hatteras had a low pressure reading of 947.5 MB (27.98 inches) making Gloria a Category 3 hurricane. Diamond Shoals tower, about 15 miles from Hatteras, recorded sustained winds of 98 mph with gusts to 120 mph. Storm surge was from 6-8 feet on the Outer Banks with severe beach erosion and coastal flooding. One death was attributed to the storm. Damage was over $8,000,000. (CAT 3)

1986 August 17: Hurricane Charley moved along the coast of North Carolina before it made landfall on the Outer Banks. Charley was classified a hurricane for only 24 hours. Wind gusts of 80 mph were recorded at Swan Quarter in Hyde County and along the Outer Banks. Minimual damage was reported from tidal flooding and downed trees. One death was reported. (CAT 1)

1989 September 21-22: Hurricane Hugo made landfall at Charleston, South Carolina as a Category 4 hurricane. Hugo was estimated to be a minimal Category 3 in Brunswick County, North Carolina. When Hugo hit Charlotte the sustained wind speed was 69 mph with gusts to 87 mph. Wind gusts to 99 mph were reported at the Charlotte International Airport and to 81 mph in Hickory. 28 inland counties received major damage from the tropical storm force winds of Hugo. More than 1,000 boats were destroyed or severely damaged on Lake

Norman. There was considerable damage to marinas and boat houses. Long Beach and Ocean Isle Beach had over 120 homes destroyed. Severe beach erosion occurred in Brunswick County. Moderate beach erosion occurred in New Hanover, Pender and Onslow Counties.There were seven deaths reported. Total damage estimates in North Carolina range from $946,000,000 to $1,100,000,000. (CAT 3)

1993 August 31: Hurricane Emily passed within 20 miles of Cape Hatteras, however the storm's eyewall, which is the area of strongest winds, did move over Hatteras Island. Hurricane force winds with gusts to 107 mph were experienced for over 90 minutes. Storm surge from the sound exceeded 10 feet near Buxton and exceeded 8 feet near the Villages of Frisco and Hatteras. 160 homes were destroyed and 216 received major damage. Two deaths were reported. Damage estimates exceed $10,000,000. (CAT 3)

Note: The storm category from the Saffir/Simpson scale, which is listed after each hurricane, is based on the storm strength at the time of impact on North Carolina and was included in NOAA Technical Memorandum NWS ER-83. Names were given to hurricanes starting in 1950. In 1971, the National Weather Service began using the Saffir/Simpson scale to catgorize hurricanes from 1 through 5. The scale is based on wind speed, storm surge, or central pressure of the hurricane. The scale also gives potential property damage and expected flooding.