ATTACHMENT 2A
LONG ISLAND HURRICANE INFORMATION

Least-Risk Decision Making

Safety is the primary consideration for the American Red Cross in selecting hurricane evacuation shelters. When anticipated demands for hurricane evacuation shelter spaces exceed existing capacity as defined by the preceding standards, there may be a need to utilize less preferred facilities. It is critical that shelter selection decisions be made carefully and in consultation with local emergency management and public safety officials. This process should include the following considerations:

- No hurricane evacuation shelter should be located in an evacuation zone for obvious safety reasons. All hurricane evacuation shelters should be located outside of Category 4 storm surge inundation zones. Certain exceptions may be necessary, but only if there is a high degree of confidence that the level of wind, rain, and surge activities will not surpass established shelter safety margins.
- When a potential hurricane evacuation shelter is located in a flood zone, it is important to consider its viability. By comparing elevations of sites with FIRMs, one can determine if the shelter and a major means of egress are in any danger of flooding. Zone AH (within the 100-year flood plain and puddling of 1-3 feet expected) necessitates a closer look at the use of a particular facility as a sheltering location. Zones B, C, and D may allow some flexibility. It is essential that elevations be carefully checked to avoid unnecessary problems.
- In the absence of certification or review by a structural engineer, any building selected for use as a hurricane evacuation shelter must be in compliance with all local building and fire codes. Certain exceptions may be necessary, but only after evaluation of each facility, using the aforementioned building safety criteria.
- The Red Cross uses the planning guideline of 40-square feet of space per shelter resident. During hurricane conditions, on a short-term basis, shelter space requirements may be reduced. Ideally, this requirement should be determined using no less than 15 square feet per person. Adequate space must be set aside for registration, health services, and safety and fire considerations. Disaster Health Services areas should still be planned using a 40-square feet per person calculation. On a long-term recovery basis, shelter space requirements should follow guidelines established in ARC 3041, *Mass Care: Preparedness and Operations*.

Hurricane Evacuation Shelter Selection Process

General procedures for investigating the suitability of a building or facility for use as a hurricane evacuation shelter are as follows:

- Identify viable sites. Evacuation and transportation route models must be considered.
- Complete a risk assessment on each viable site. Gather all pertinent data from SLOSH and/or SPLASH (storm surge), FIRM (flood hazard) models; determine the facility base elevation; and obtain hazardous materials information and previous studies concerning each building's suitability.
- Have a structural engineer evaluate the facility and rate its ability to withstand wind loads according to ASCE 7-98 or ANSI A58 (1982) structural design criteria.
- Inspect the facility and complete a *Red Cross Facility Survey* (ARC Form 6564) and a *Self-Inspection Work Sheet/Off Premises Liability Checklist*, in accordance with ARC 3041. Note all potential liabilities and the type of construction. Consider the facility as a whole. One weak section may seriously jeopardize the integrity of the building.

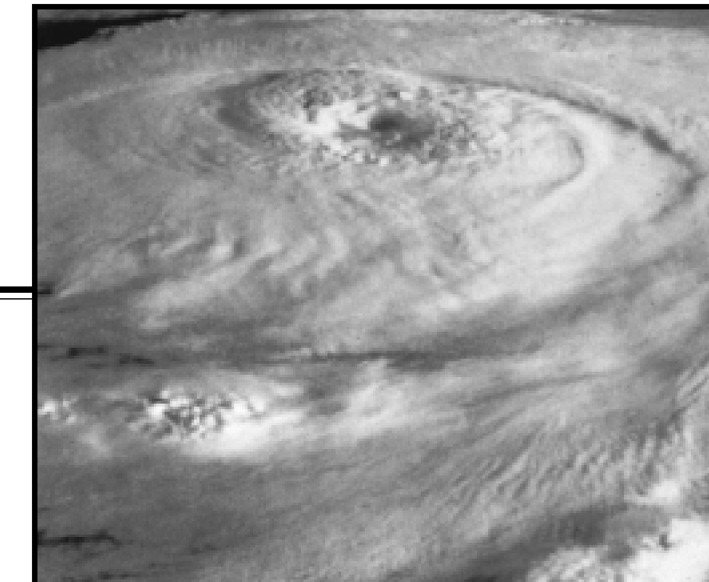
Increasing Shelter Inventory

An annual review of all approved hurricane evacuation shelters is required. Facility improvements, additions, or deterioration may change the suitability of a selected facility as a hurricane evacuation shelter. Facility enhancements may also enable previously unacceptable facilities to be used as hurricane evacuation shelters.

Work with officials, facility managers, and school districts on mitigation opportunities. Continue to advocate that the building program for new public buildings, such as schools, should include provisions to make them more resilient to possible wind damage. Suggest minor modifications of municipal, community, or school buildings, such as the addition of hurricane shutters, while buildings are being planned. Such modifications will make them useful as hurricane evacuation shelters.

Finally, add any new shelters to chapter shelter system and disaster response plans. Share shelter information with local emergency planning partners and the state lead chapter for Disaster Services for inclusion in state disaster response plans.

ARC 4496
Rev. January 2002



Standards for Hurricane Evacuation Shelter Selection

American Red Cross

Together, we can save a life

An interagency group comprised of the Federal Emergency Management Agency, the U.S. Army Corps of Engineers, the Environmental Protection Agency and Clemson University, has developed hurricane evacuation shelter selection standards. These standards reflect the application of technical data compiled in hurricane evacuation studies, other hazard information, and research findings related to wind loads and structural problems. These standards are supplemental to information contained in ARC 3041, *Mass Care: Preparedness and Operations* concerning shelter selection.

Planning considerations for hurricane evacuation shelters involve a number of factors and require close coordination with local officials responsible for public safety. Technical information contained in Hurricane Evacuation Studies, storm surge and flood mapping, and other data can now be used to make informed decisions about the suitability of shelters.

In the experience of the American Red Cross, the majority of people evacuating because of a hurricane threat generally provide for themselves or stay with friends and relatives. However, for those who do seek public shelter, safety from the hazards associated with hurricanes must be assured. These hazards include—

- Surge inundation.
- Rainfall flooding.
- High winds.
- Hazardous materials.

The following standards address the risks associated with each of these hurricane-associated hazards.

Surge Inundation

In general, hurricane evacuation shelters should not be located in areas vulnerable to hurricane surge inundation. The National Weather Service has developed mathematical models, such as Sea, Lake, and Overland Surges from Hurricanes (SLOSH) and Special Program to List Amplitudes of Surges from Hurricanes (SPLASH), that are critical in determining the potential level of surge inundation in a given area.

- Carefully review inundation maps in order to locate all hurricane evacuation shelters outside of Category 4 storm surge inundation zones.
- Avoid buildings subject to isolation by surge inundation in favor of equally suitable buildings not subject to isolation. Confirm that ground elevations for all potential shelter facilities and access routes obtained from topographic maps are accurate.
- Do not locate hurricane evacuation shelters on barrier islands.

Rainfall Flooding

Rainfall flooding must be considered in the hurricane evacuation shelter selection process. Riverine inundation areas shown on Flood Insurance Rate Maps (FIRMs), as prepared by the National Flood Insurance Program, should be reviewed. FIRMs should also be reviewed in locating shelters in inland counties.

- Locate hurricane evacuation shelters outside the 100-year floodplain.
- Avoid selecting hurricane evacuation shelters located within the 500-year floodplain.
- Avoid selecting hurricane evacuation shelters in areas likely to be isolated due to riverine inundation of roadways.
- Make sure a hurricane evacuation shelter's first floor elevation is on an equal or higher elevation than that of the base flood elevation level for the FIRM area.
- Consider the proximity of shelters to any dams and reservoirs to assess flow upon failure of containment following hurricane-related flooding.

High Winds

Consideration of any facility for use as a hurricane evacuation shelter must take into account wind hazards. Both design and construction problems may preclude a facility from being used as a shelter. Local building codes are frequently inadequate for higher wind speeds.

- If possible, select buildings that a structural engineer has certified as being capable of withstanding wind loads according to **ASCE (American Society of Engineers) 7-98** or **ANSI (American National Standards Institute) A58 (1982)** structural design criteria. Buildings must be in compliance with all local building and fire codes.
- Failing a certification (see above), request a structural engineer to rank the proposed hurricane evacuation shelters based on his or her knowledge and the criteria contained in these guidelines.
- Avoid uncertified buildings of the following types:
  —Buildings with long or open roof spans longer than 40 feet.
  —Unreinforced masonry buildings.
  —Pre-engineered (steel pre-fabricated) buildings built before the mid-1980s.
  —Buildings that will be exposed to the full force of hurricane winds.
  —Buildings with flat roofs or built with lightweight materials.
- Give preference to the following:
  —Buildings with 10°-30° pitched, hipped roofs; or with heavy concrete roofs.
  —Buildings no more than 60 feet high.
  —Buildings in sheltered areas (protected from strong winds).
  —Buildings whose access routes are not tree-lined.

Hazardous Materials

The possible impact from a spill or release of hazardous materials should be taken into account when considering any potential hurricane evacuation shelter.

All facilities manufacturing, using, or storing hazardous materials (in reportable quantities) are required to submit *Material Safety Data Sheets* (emergency and hazardous chemical inventory forms) to the Local Emergency Planning Committee (LEPC) and the local fire department. These sources can help you determine the suitability of a potential hurricane evacuation shelter or determine precautionary zones (safe distances) for facilities near potential shelters that manufacture, use or store hazardous materials.

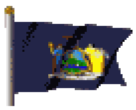
- Facilities that store certain reportable types or quantities of hazardous materials may be inappropriate for use as hurricane evacuation shelters.
- Hurricane evacuation shelters should not be located within the ten-mile emergency planning zone (EPZ) of a nuclear power plant.
- Chapters must work with local emergency management officials to determine if hazardous materials present a concern for potential hurricane evacuation shelters.

Interior Building Safety Criteria During Hurricane Conditions

Based on storm data (e.g., arrival of gale-force winds), determine a notification procedure with local emergency managers regarding when to move the shelter population to pre-determined safer areas within the facility. Consider the following:

- Do not use rooms attached to, or immediately adjacent to, unreinforced masonry walls or buildings.
- Do not use gymnasiums, auditoriums, or other large open areas with long roof spans (longer than 40 feet) during hurricane conditions.
- Avoid areas near glass unless an adequate shutter protects the glass surface. Assume that windows and the roof will be damaged and plan accordingly.
- Use interior corridors or rooms.
- In multi-story buildings, use only the lower floors (no higher than 60 feet) and avoid corner rooms.
- Avoid any wall section that has portable or modular classrooms in close proximity, if these are used in your community.
- Avoid basements if there is any chance of flooding.

HURRICANECITY est 1997 With LIVE audio broadcasting and video



Long Island's history with tropical systems

(br)=brush (ts)=Tropical Storm (bd)=Back Door,meaning coming from over land from opposite coast.Not all names are noted,also storms before 1950 were not named.Not every stat on every storm description is given(since 1871).

Years within 60 miles

1874bdts,1879br,1882ts,1888ts,1888br,1893,1893bdbr,1894ts,1897ts,1934ts,1938extrop,1944
1954,1955bdts,1960tsbr,1960,1961ts,1971tsbr,1972ts,1976,1985,1991br,1996tsbd,1999ts,2004ts
25 times in 135 yrs end of 2005

Names from list above

carol,connie,brenda,donna,doria,agnes,belle,gloria,bob,bertha, floyd,Charley,

How often Long Island gets affected?

brushed or hit every 5.40 years

Average years between direct hurricane hits.(usually within 40 miles to include small hurricanes)

(5h)once every 27.00 years

Statistically when long Island should be affected next

before the end of the 2010 season

Last affected by

2004 Aug 15th T-Storm Charley hits with 40mph winds

This areas hurricane past

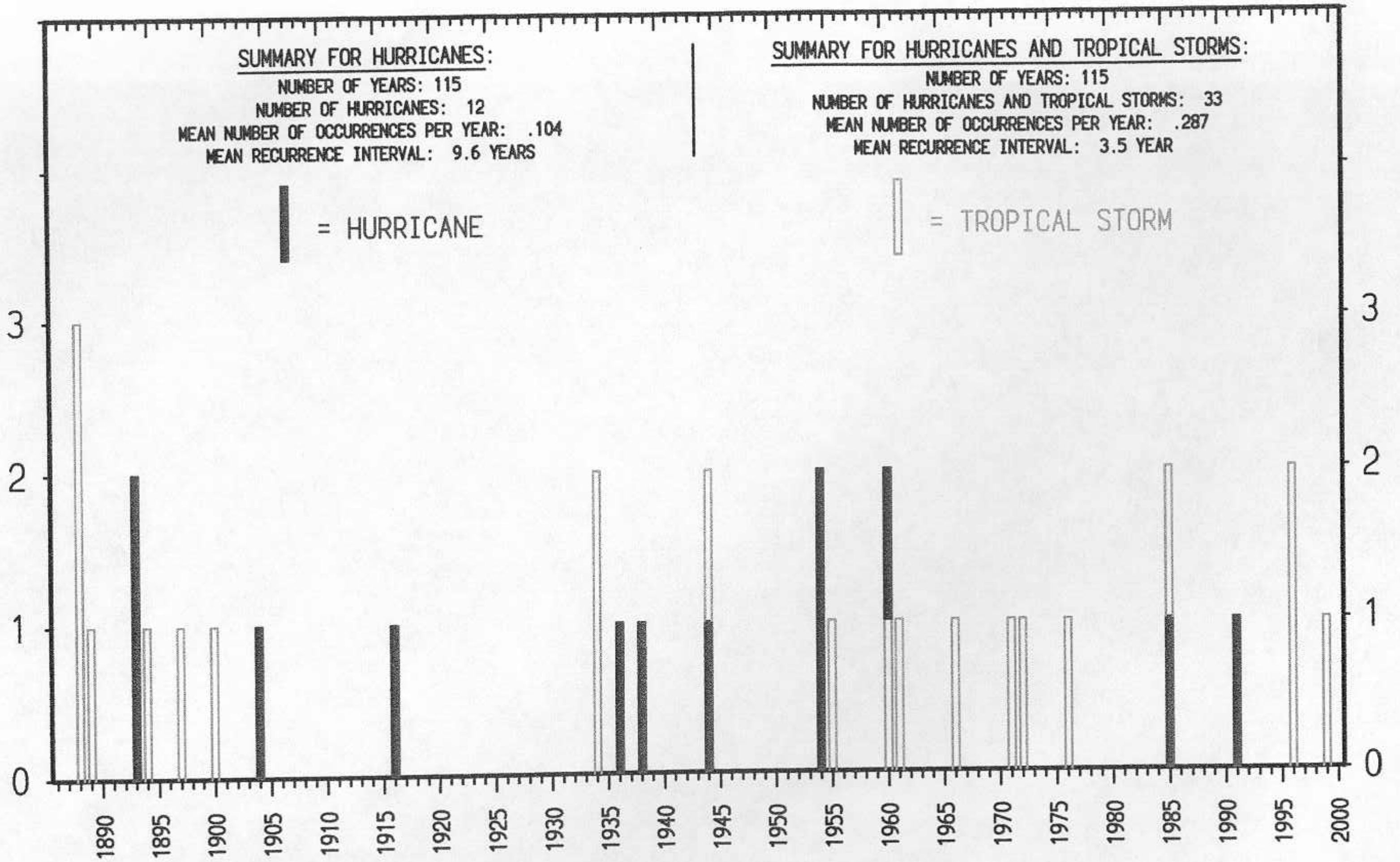
1825 june 4th a hurricane badly damaged long island
1893 a cat 2 hits N.Y city in late august causing heavy damage. It was traveling 30-36mph as it passed along this portion of the coast.
1938 sept 21st Long island express caused storm surge flooding 3 miles inland as a cat 3 in central & East long island.Reports of a 40ft wall of water destroyed approx 14,000 homes.50 killed on Long Isl with over 500 killed in states further north,.In NYC ,Empire

state building swayed as much as 4" with gusts to 100mph but the strongest winds were well east of here.Pressure at Bellport 27.94,many warnings were put up too late. | Newspaper article#1 | #2 | #3 | #4
1944 a cat 1 hits central long island on sept 15th early morning just a shade west of where the 1938 system came ashore.more on the long island express here
1954 hurricane carol hits central long island as many homes were splintered by gusts to 130mph in august. Newspaper article
1960 sept 12th donna hits central long island with gusts to 125mph, sustained at 100mph on eastern end
1976 Belle hits Aug 10th peak gust 95mph system was weakening 24 hrs prior to landfall with a forward speed of up to 25mph.
1985 hurricane gloria gives area gusts to 115mph shuts down NYSE area reported many pre mature births due to low pressure.Being low tide at landfall may have saved many lives. (moderate damage)Newspaper article #1 | #2 | #3 | #4 | #5 | more on Hurricane Gloria here
1991 hurricane bob brushes just east by 65 miles area got 95mph windsbob also dumped heavy rain as area n.e of here suffered the worst damage up to 1.5 billion dollars in damage.killing 18, .

Info for this City

See what cities get affected most by tropical systems

Home | Links | Live Broadcast page | Back to city Database



TROPICAL CYCLONES PASSING WITHIN 75 N.MI. OF MONTAUK PT, NY 1886-2000

(Note: Storm intensity is determined at time of closest approach to site)

CHART 4

Hurricane Information

Long Island Hurricanes and Tropical Storms with 100,000 or More Customers Affected 1975 to 2003

Storm Name/Type	Dates	# of Customers	Duration (hrs)	Restoration (days)
Hurricane Belle (Cat-1)	08/09/76	533,000	112	4.7
Hurricane David (Tropical)	09/06/76	216,000	61	2.5
Hurricane Gloria (Cat 2-1)	09/27/85	750,000	279	11.6
Hurricane Hugo (Tropical)	09/22/89	107,000	40	1.7
Hurricane Bob (Cat 2)	08/19/91	477,765	112	4.7
Hurricane Floyd (Tropical)	09/16/99	149,000	35	1.5

Hurricane Categories and Estimated Electric System Damage and Restoration Time

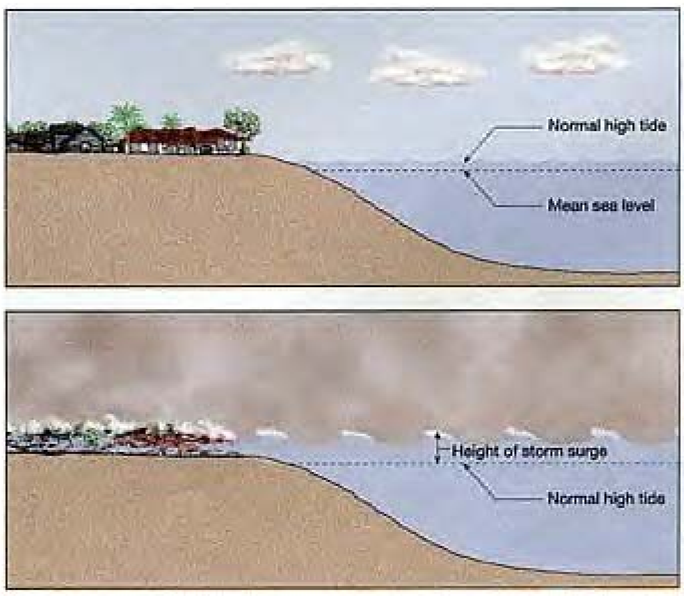
Storm Type	Winds (mph)	Estimated Outages (thousand)	Estimated Restoration (days)
Tropical	39-73	100 to 250	1 to 3
Cat-1 Hurricane	74-95	250 to 500	3 to 6
Cat-2 Hurricane	96-110	500 to 750	10 to 15
Cat-3 Hurricane	111-130	750 to 1,000	15 to 30
Cat-4 Hurricane	131-155	1,000 plus	30 plus

Storm Center
Information & Resource
Online Outage Reports
Safety and Preparedness Tips
• Heat Storms
• Hurricane Season
• Lightning Storms
• Wind Storms
• Winter Storms
• Plan Now. Be Prepared
LIPA is Prepared
Power Outage FAQ
Storm Preparedness Links

[clickable map]

[Montauk, Long Island Lighthouse]

Some of the key observations about hurricanes if they hit Long Island:



Lutgens & Tarbuck, *The Atmosphere, 7th ed.*

[More Details]

Category 1 hurricanes inundate just about all of the immediate south shore of the Island, including the north side of Great South Bay locations and both sides of the north and south forks.

Montauk Highway (RT. 27A) is completely covered by flood waters during a Category 3 hurricane. Therefore, this road would be considered impassable during the storm.

The highest storm surges (Category 4) would occur in the following regions:

Amityville Harbor - 29 feet

Atlantic Beach & Long Beach areas - 24 to 28 feet

South Oyster Bay, Middle Bay, & East Bay areas - 24 to 28 feet

Montauk Point is completely cut off from rest of south fork during a category 1 storm.

Much of the north and south forks are entirely under water during a category 3 hurricane.

A category 4 hurricane inundates the entire towns of: Amityville, Lindenhurst, Babylon, West Islip, East Islip, Bayshore, Gilgo Beach, Cedar Beach, Great South Beach, Fair Harbor, Cherry Grove, Cupsogue, Westhampton Beach, Watermill Beach, Wainscott Beach, Plum Island, Gardiner's Island, Orient, Shelter Island (except for a few high points), Greenport, North Haven, Amagansett Beach, Napeague Beach, Montauk, Woodmere, Valley Stream, Linbrook, Long Beach, Atlantic Beach, Freeport, Merrick, Wantagh, Lido Beach, Jones Beach, and Tobay Beach.

The Great Hurricane of New York of 1938

What's In Store For New York's Future?

A major obstacle to overcome is public complacency. Approximately 78.5% of current New York State coastal residents have never experienced a major hurricane (Hughes). One must remember that in 1938, Long Island was mostly undeveloped. The next time a major hurricane hits, it will be impacting a highly-urbanized region. The last two hurricanes were mild in comparison to the Great Hurricane of 1938. August 19, 1991, Hurricane Bob (category 2) brushed the eastern tip of Long Island and moved into southeastern New England. Because most of Long Island was on the western side of the storm, winds were category 1 strength and the storm surge was minimal. September 27, 1985, Hurricane Gloria (category 1) moved across the center of Long Island causing much tree damage and beach erosion. In informal surveys, most people believe that this was a "strong hurricane" in the category 2 or 3 class when in fact it was a weak category 1 event. Therefore, there is a misguided sense that Long Island can withstand "strong" hurricanes with only minor inconveniences because few have ever experienced a major hurricane.

Christopher Landsea, a meteorologist at the Hurricane Research Division, and Roger A. Pielke, a social scientist at NCAR, looked at the most destructive U.S. hurricanes on record and predicted the cost if these storms were to hit today. The diagram to the right shows quite clearly that the northeast U.S., especially the Long Island and New York City regions, would suffer greatly. Of the 15 "worst" storms, Long Island would be affected by five of them and the 1938 hurricane today would be considered the 6th costliest of all time. In 1998 dollars, the damage would be nearly $18 billion. Of all the natural disasters in the United States, hurricanes account for about two-thirds of the insured property losses (USGS, 1998).

Coastal New York state is second only behind Florida for the amount of insured coastal property (Insurance Institute for Property Loss Reduction (IIPLR) and Insurance Research Council, 1995) so

future hurricanes may have severe economic impact.

Experts now believe that after Miami and New Orleans, New York City is considered the third most dangerous major city for the next hurricane disaster. According to a 1990 study by the US Army Corps of Engineers, the city has some unique and potentially lethal features. New York's major bridges such as the Verrazano Narrows and the George Washington are so high that they would experience hurricane force winds well before those winds were felt at sea-level locations. Therefore, these escape routes would have to be closed well before ground-level bridges (Time, 1998). The two ferry services across the Long Island Sound would also be shut down 6-12 hours before the storm surge invaded the waters around Long Island, further decreasing the potential for evacuation.

A storm surge prediction program used by forecasters called *SLOSH* (Sea, Lake, and Overland Surge from Hurricanes) has predicted that in a category 4 hurricane, John F. Kennedy International Airport would be under 20 feet of water and sea water would pour through the Holland and Brooklyn-Battery tunnels and into the city's subways throughout lower Manhattan. The report did not estimate casualties, but did state that storms "that would present low to moderate hazards in other regions of the country could result in heavy loss of life" in the New York City area (Time, 1998).

Some of the key observations from the storm surge maps for Nassau and Suffolk Counties:

- **Category 1 hurricanes inundate just about all of the immediate south shore of the Island, including the north side of Great South Bay locations and both sides of the north and south forks.**
- **Montauk Highway (RT. 27A) is completely covered by flood waters during a Category 3 hurricane. Therefore, this road would be considered impassable during the storm.**
- **The highest storm surges (Category 4) would occur in the following regions:**
  - **Amityville Harbor - 29 feet**
  - **Atlantic Beach & Long Beach areas - 24 to 28 feet**
  - **South Oyster Bay, Middle Bay, & East Bay areas - 24 to 28 feet**
- **Montauk Point is completely cut off from rest of south fork during a category 1 storm.**
- **Much of the north and south forks are entirely under water during a category 3 hurricane.**

Given public complacency, the amount of people needed to evacuate, the few evacuation routes off Long Island, and the considerable area affected by storm surge, more lead-time is needed for a proper evacuation than in other parts of the country. However, east coast hurricanes are normally caught up in the very fast winds aloft, called the *jet stream*, so they can move up the coast at great speeds - much faster than hurricanes that impact the southern U.S. In fact, the 1938 Hurricane moved at forward speeds in excess of 60 mph. To this day the *Long Island Express* holds the forward speed record for any Atlantic hurricane.

All of these factors point to a possible future disaster.

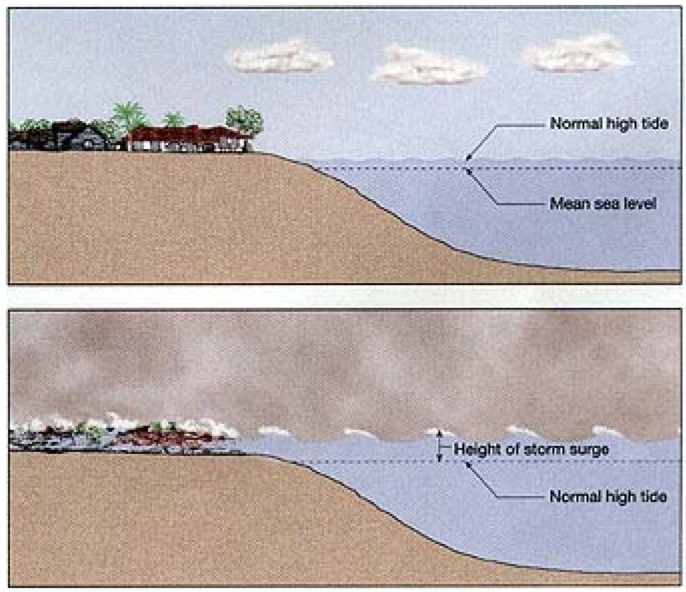
Hurricane Climatology Index References

Other Airports

Other International Airports

Long Island South Shore Hurricane Storm Surge Maps

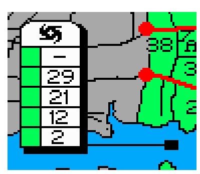
Hurricane storm surge causes approximately 90% of all storm deaths and injuries and much of the damage, therefore it is important for residents of Long Island, New York to be aware of the areas that will be affected by the storm surge. The southern shore of Long Island is most vulnerable to storm surge inundation because hurricane landfall will first occur there and the low elevation will allow sea water to move well inland.



Lutgens & Tarbuck, *The Atmosphere, 7th ed.*

See the effects of storm surge from Camille, a 1969 Category 5 hurricane in Louisiana

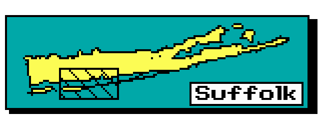
The height of maximum storm surge is a function of storm strength, location of eye landfall, tidal time of landfall, elevation, and speed of storm. The images below represent the various regions of the southern shores of Long Island as well as the north and south forks as they would be affected by storm surge from various strength hurricanes. The images are derived from *HURREVAC*, a DOS-based software application that uses historical storm data and Long Island regional topography to estimate areas that would be inundated by water. *(It should be noted that category 5 storm surges are not predicted by HURREVAC since there is little probability of such storms and no historical data exists for reference.)* Each zone assumes landfall within that zone at normal tidal height. For high tide landfall, one would need to add 1/2 normal tide height to the predicted surge, while landfall at low tide would require a subtraction of 1/2 normal tide height from the predicted surge. The animated image was created using *Microsoft GIF Animator* and shows a loop of all maps within the zone with a five second interval between images.



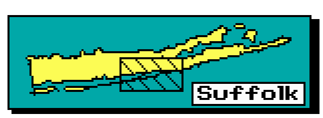
Storm Surge Heights

The key appearing above indicates maximum storm surge height in that region for each category strength. For this example, the storm surge height for a category 4 hurricane would be 29 feet above normal sea-level.

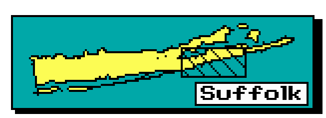
- No Hurricane
- CAT 1 Hurricane
- CAT 2 Hurricane
- CAT 3 Hurricane



- No Hurricane
- CAT 1 Hurricane
- CAT 2 Hurricane
- CAT 3 Hurricane



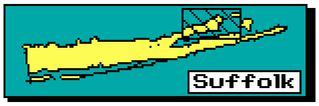
- No Hurricane
- CAT 1 Hurricane
- CAT 2 Hurricane
- CAT 3 Hurricane



- No Hurricane
- CAT 1 Hurricane
- CAT 2 Hurricane
- CAT 3 Hurricane

- CAT 4 Hurricane

- All Maps Animation

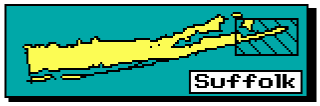


- No Hurricane
- CAT 1 Hurricane
- CAT 2 Hurricane
- CAT 3 Hurricane
- CAT 4 Hurricane

- All Maps Animation

- CAT 4 Hurricane

- All Maps Animation

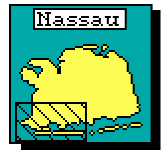


- No Hurricane
- CAT 1 Hurricane
- CAT 2 Hurricane
- CAT 3 Hurricane
- CAT 4 Hurricane

- All Maps Animation

- CAT 4 Hurricane

- All Maps Animation



- No Hurricane
- CAT 1 Hurricane
- CAT 2 Hurricane
- CAT 3 Hurricane
- CAT 4 Hurricane

- All Maps Animation

- CAT 4 Hurricane

- All Maps Animation

- No Hurricane
- CAT 1 Hurricane
- CAT 2 Hurricane
- CAT 3 Hurricane
- CAT 4 Hurricane

- All Maps Animation

The 1938 Hurricane was a category 3 storm that made landfall near Bellport, New York. Therefore, the three surge maps that best represent what may have occurred in 1938 are:

- Bellport Zone
- Westhampton Beach Zone
- Southampton Zone

Some of the key observations from the above include:

- Category 1 hurricanes inundate just about all of the immediate south shore of the Island, including the north side of Great South Bay locations and both sides of the north and south forks.
- Montauk Highway (RT. 27A) is completely covered by flood waters during a Category 3 hurricane. Therefore, this road would be considered impassable during the storm.
- The highest storm surges (Category 4) would occur in the following regions:
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  - Montauk Point is completely cut off from rest of south fork during a category 1 storm.
  - Much of the north and south forks are entirely under water during a category 3 hurricane.
  - A category 4 hurricane inundates the **entire** towns of: *Amityville, Lindenhurst, Babylon, West Islip, East Islip, Bayshore, Gilgo Beach, Cedar Beach, Great South Beach, Fair Harbor, Cherry Grove, Cupsogue, Westhampton Beach, Watermill Beach, Wainscott Beach, Plum Island, Gardiner's Island, Orient, Shelter Island (except for a few high points), Greenport, North Haven, Amagansett Beach, Napeague Beach, Montauk, Woodmere, Valley Stream, Linbrook, Long Beach, Atlantic Beach, Freeport, Merrick, Wantagh, Lido Beach, Jones Beach, and Tobay Beach.*

Introduction to Hurricanes

Home

Weather History of '38 Hurricane

IT HAPPENED ON LONG ISLAND


PHOTO: CORBIS

1954: Hurricane Carol Batters Long Island

On August 31, 1954, Hurricane Carol, the season's third hurricane, battered Long Island. Winds reaching 100 miles per hour tore through both Nassau and Suffolk Counties, causing $3 million worth of damage. Basements flooded, thousands of trees were uprooted, boats capsized and sunk, and chimneys blew down. Some 275,000 homes lost electricity, and eastern Suffolk lost telephone service. Service was disrupted on the Long Island Rail Road and ferry service between Bay Shore and Fire Island was suspended. Communities on both the north and south shores were evacuated, including the beachfront areas from Westhampton Beach to Montauk Point. At Jones Beach, the boardwalks flooded and the Marine Stadium suffered substantial damage. At Mitchel Field in Garden City, the Air Force tied down planes or rolled them into hangars. Yet no deaths or injuries were reported. Sunrise Highway near Babylon is shown here in a photo taken on August 31, 1954. —Cynthia Blair

TOMORROW: BOB COSTAS IS COMMACK SOUTH HIGH GRAD

SCIENCE/TECHNOLOGY
- Aviation
- Air Disasters
- Computing
- Natural Disasters
- Space
- 1980s

HURRICANES
- '70 Celia
- '71 Ginger
- '72 Agnes
- '74 Carmen
- '74 Fifi
- '75 Eloise
- '76 Belle
- '77 Anita
- '79 Bob
- '79 David
- '79 Frederic
- 1980s

Hurricane Belle

By NOAA

Hurricane Belle left 12 dead and caused $24M in damages in the Eastern United States between August 8-10, 1976. Most of the damage was caused to coastal communities in North Carolina, New Jersey, Connecticut, Vermont, and New York.

Though it was only a Category 1 hurricane, it was the most damaging to hit Long Island since Hurricane Carol in 1954. More than 150,000 were left without power in New Jersey.

Background

Belle formed as a depression early on August 6th just east of the northern Bahama islands. While a depression, Belle's position remained about 250 miles northeast of Nassau in the Bahamas as the system did a small cyclonic loop. Belle was upgraded to a tropical storm on the evening of 6th and shortly thereafter starting moving northwest.

Belle reached hurricane strength during the late afternoon of the 7th. Movement continued to be northwest and toward the Carolinas before turning to the north on the 8th and passing within 100 miles of the Outer Banks.

Belle continued to intensify through the 9th when the central minimum pressure dropped to 957 mb and maximum sustained winds reached 120 mph. Weakening commenced later on the 9th and continued through the 10th when the storm made landfall on the south coast of Long Island as a category one storm.

In the Carolinas the highest sustained wind was 37 mph at Cape Hatteras. The highest estimated gust was 75 mph as both Frisco and Hatteras Place on the Outer Banks. 3.70 inches of rain fell at Cape Hatteras.

Source: NOAA.

Share Your Memories!

What do you remember about Hurricane Belle? Have you any compelling stories to share? Share your stories with the world! (We print the best stories right here!)

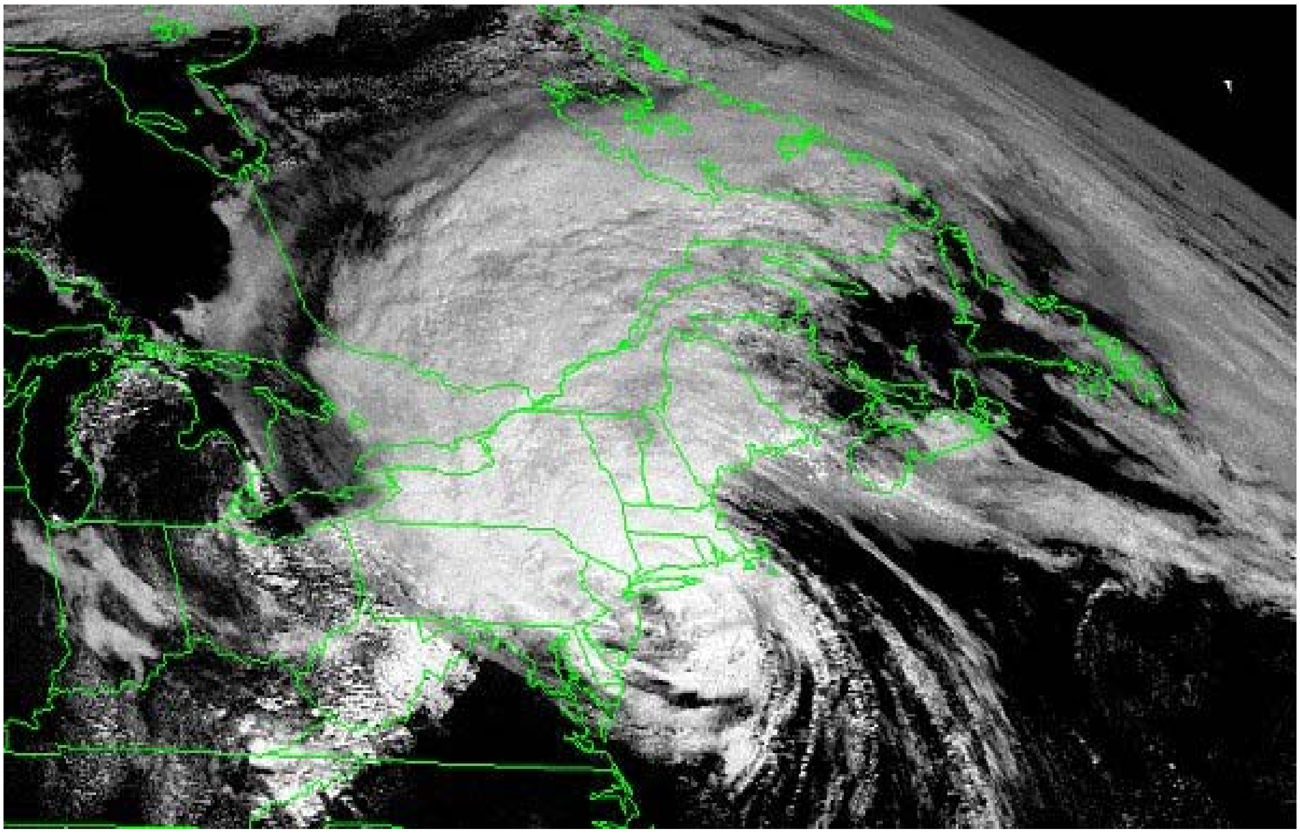
DISASTER DETAILS

Hurricane Belle southeast of Charleston, South Carolina on August 8, 1976.
Courtesy of NOAA

- Date(s): August 8-10, 1976
- Location: Northeastern U.S.
- Deaths: 12
- Injuries:
- Damage: $24M

HURRICANE GLORIA - September 27, 1985.

WINDS: **85-mph (moving at 40-mph).**
PRESSURE**: 28.37 inches/961-mb.**
STORM - SURGE**: 4 - 7 feet above Mean Tide.**



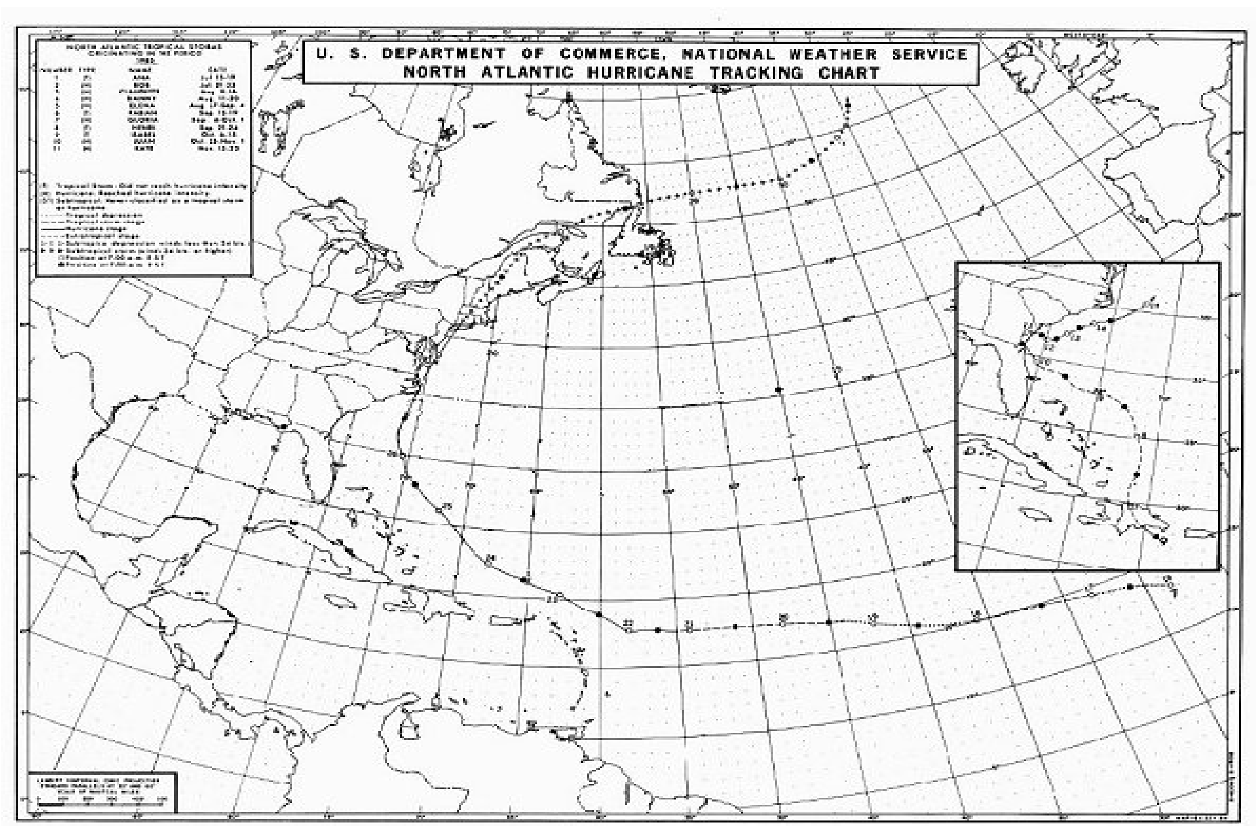
Hurricane Gloria makes landfall on Long Island, New York with sustained winds of 85-mph (gusts to 115-mph) in September 1985. (Photo courtesy NOAA).

One of the most intensely reported events of the 1980's, Hurricane Gloria hit Long Island, New York and southern Connecticut as a moderate hurricane in September 1985. At the time of landfall on Long Island - Gloria had sustained winds of around 85-mph. However, Gloria was moving forward at 40-mph when it struck land. This combination of sustained winds and rapid forward motion - produced peak winds of at least 111-mph across a narrow area of eastern Long Island. Thus, Gloria is considered a major hurricane on Long Island. In Connecticut, Gloria is considered a category 2 hurricane.

Gloria was considerably more damaging to Long Island and Connecticut than Hurricane Belle of 1976. Although Gloria's strength had slowly lessened as it approached the Northeast Atlantic states, isolated areas on Long Island reported some moderate coastal flooding and structural damage. In Connecticut, damage was confined to falling trees - little structural damage or storm surge flooding was reported. Rhode Island and southeastern Massachusetts escaped the storm almost unscathed. Unfortunately, Gloria proved deadly, six persons were killed by falling trees, including a six year old girl in Connecticut.

Gloria was a classic Cape Verde hurricane, traveling hundreds of miles across the open Atlantic in late September 1985. By September 22, Gloria had reached hurricane strength as it neared the Leeward Islands. Slowly curving toward the northwest, the storm moved just to the east of the Bahamas while intensifying rapidly. **When Air Force hurricane hunters reached the storm late on the 24th, Gloria had a central pressure of 919 mb (27.13 in.), and sustained winds of 150 mph** - making Gloria one of the most intense storms ever observed in Atlantic Basin.

As Gloria continued to head toward the United States mainland the storm steadily weakened. As Gloria brushed the North Carolina Outer Banks near midnight on September 27, the winds fell to 105-mph, although the barometric pressure was still extremely low (27.83/942 mb). *The Diamond Shoals light tower sixteen-miles off the North Carolina coast recorded sustained winds of 98-mph with a gusts to 120-mph.* The cyclone continued to accelerate northward off the United States Atlantic coastline, crossing Long Island, New York about 10 miles east of Kennedy International Airport. Gloria then crossed the Connecticut coast near Bridgeport about 40-minutes later with sustained winds around 80-mph.



The track of Hurricane Gloria (1985) from the far tropical Atlantic to landfall along the coast of the Northeastern United States. Gloria's track was similar to the 1938 and 1944 hurricanes (track NHC).

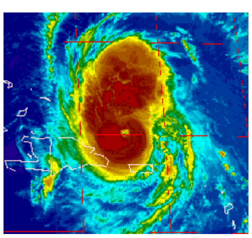
METEOROLOGICAL CONDITIONS

As Hurricane Gloria crossed Long Island, N.Y, Air Force hurricane hunter aircraft reported a central pressure of **28.37 inches (961 mb)** and **sustained winds of 85-mph**. The National Weather Service at Kennedy International Airport recorded a minimum pressure of 28.57 inches, while Sikorsky Airport in Bridgeport,

Preliminary Report
Hurricane Bertha
05-14 July 1996

Miles B. Lawrence
National Hurricane Center
9 November 1996

PRELIMINARY REPORTS
Tropical Storm Arthur
Hurricane Bertha
Hurricane Cesar
Hurricane Dolly
Hurricane Edouard
Hurricane Fran
Tropical Storm Gustav
Hurricane Hortense
Hurricane Isidore
Tropical Storm Josephine
Tropical Storm Kyle
Hurricane Lili
Hurricane Marco



Bertha was an early-season Cape Verde Hurricane that moved across the islands of the northeastern Caribbean Sea as a category 1 hurricane on the Saffir/Simpson scale and made landfall on the North Carolina coast near Wilmington as a category 2 hurricane. Bertha's one-minute winds reached their maximum value of 100 knots on 9 July, while located to the north of Puerto Rico. The last Hurricane to reach this strength, this early in the season, was Alma in 1966 (117K GIF) in the eastern Gulf of Mexico with 110 knots. Bertha is responsible for an estimated eight deaths and $250 million in U.S. damages.

a. Synoptic History

Bertha originated from a tropical wave which moved from Africa to the Atlantic on 1 July. A weak circulation was first detected on satellite imagery on 3 July, centered about 500 n mi south of the Cape Verde Islands in the far eastern Atlantic Ocean. The track of the circulation center begins on 5 July, when the circulation is believed to have reached the surface and become a tropical depression, in the central tropical Atlantic. This track is displayed in Fig. 1 (102K GIF) and listed in Table 1.

Bertha followed a fairly smooth curved path around the western periphery of the Atlantic subtropical high pressure ridge. This ridge changed little during Bertha's existence and a weak mid-level trough persisted in the western North Atlantic. For three days, the depression moved toward the west-northwest at the fast forward speed of 20 to 25 knots and strengthened to a hurricane with 1-min. maximum sustained winds of 75 knots on the 8th as the center moved across the Leeward and Virgin Islands of the northeastern Caribbean. The center moved between Antigua and Barbuda at 0600 UTC on the 8th, across St. Barthelemy, Anguilla, and St Martin, just north of St. Thomas, and over the British Virgin Islands by 1800 UTC.

The track gradually turned northwestward on the 9th and maximum sustained winds reached 100 knots at 0600 UTC. Bertha was centered 120 n mi north of Puerto Rico at this time, but earlier passed within 30 n mi of this island. The strongest winds were located in the northeast quadrant of the hurricane and most of Puerto Rico experienced only tropical storm conditions, except for Culebra, over which hurricane-force winds might have occurred.

Moving northwestward at a slower forward speed of 15 to 20 knots, the center of Bertha moved parallel to the Bahama islands, passing 40 to 60 n mi northeast of the Turks and Caicos islands, San Salvador, Eleuthera and the Abacos. Again, the strongest winds were located to the northeast of the center, but 65-knot sustained winds might have reached some of the above mentioned islands.

Continuing on its gradual turn, the track became north-northwestward on the 10th and 11th and the center moved parallel to the coast of Florida and Georgia at a distance of 150 to 175 n mi offshore. During this time, the forward speed slowed to about 8 knots. Moving northward and re-accelerating to a forward speed of 15 knots, Bertha made landfall at 2000 UTC on the 12th on the coast of North Carolina, with the center crossing the coast midway between Wrightsville and Topsail Beaches. The hurricane had been gradually weakening since its top speed of 100 knots on the 9th to 70 knots on the 11th. Then, in 12 hours just before landfall, the winds increased to 90 knots, which is the estimated maximum 1-min. wind speed at landfall. Bertha quickly dropped below hurricane strength when it moved inland over eastern North Carolina.

It then moved northeastward along the U.S. east coast, producing 40 to 50 knot sustained winds over land from northern North Carolina to New England and 60 knot winds over nearby Atlantic waters. Bertha was declared extratropical on the 14th when the center moved from the Maine coast to New Brunswick, Canada. The extratropical storm brought 40 to 50 knot winds to the Canadian Maritime Provinces and was tracked to just south of Greenland on the 17th.

b. Meteorological Statistics

Figures 2 and 3 (64K GIF) show a plot, versus time, of the various data used to estimate the minimum central sea-level pressure and the maximum 1-min. wind speed, 10 m above ground. Included are data from reconnaissance aircraft and satellite Dvorak-technique wind speed estimates. Table 2 lists selected surface observations of lowest pressure, peak wind, storm surge and rainfall values. Table 3 lists ship reports of 34 knots or greater that were associated with Bertha. The minimum pressure of 960 mb occurred at 0600 UTC on the 9th and is based on a dropsonde measurement. The best track maximum sustained wind speed of 100 knots at the same time is based on a 700-mb flight-level wind speed of 122 knots, measured 19 n mi east-northeast of the center.

Observations are incomplete from the Leeward and Virgin Islands, but because the circular eyewall was 20 - 30 n mi across, it is believed that hurricane conditions with sustained wind speeds to 75 knots, could have occurred on Antigua, Barbuda, Nevis, St. Eustatius, St. Bathelemy, Anguilla, St. Martin, and from St. Thomas northward through the U.S. and British Virgin Islands. Experience with Hurricane Marilyn in 1995 suggests that even higher sustained winds can occur over mountainous terrain as is found on many of these islands. Winds of 35 to 40 knots were experienced over portions of Puerto Rico as indicated by the San Juan observations in Table 2.

A reconnaissance aircraft flight level wind speed of 110 knots in the northeast quadrant of the circulation several hours before landfall is the basis for estimating sustained surface winds of 90 knots on the coast at landfall. The lowest sea-level pressure observed at landfall was 977 mb at Surf City, North Carolina and a value of 974 mb is assumed to be the minimum pressure at landfall.

Storm total rainfall amounts ranged from 5 to 8 inches along a coastal strip from South Carolina to Maine.

Coastal storm surge flood heights, from Florida through New England, ranged from 1 to 4 feet, but values to 5 feet were estimated on the North Carolina coast from Cape Fear to Cape Lookout. A storm surge of 6 feet or a little higher is indicated near Swansboro, where 5 to 6 feet of water was "inside of businesses on the waterfront".(from Newport, North Carolina National Weather Service Forecast Office Preliminary Storm Report).

Seven tornadoes have been confirmed, and these occurred during the passage of an outer rain band. There were five tornadoes in Virginia, one in North Carolina and one in Maryland.

c. Casualty and Damage Statistics

Twelve deaths have been related, in some way, to Hurricane Bertha. One, in Florida, was from an evacuating military jet crashing into a house. One death from an auto accident occurred in North Carolina and another drowned in rip currents. A surfer died in New Jersey. In Puerto Rico, two died in an automobile accident and another died while surfing. On the French half of St. Martin, one person was electrocuted and one fell off a boat.

The U.S. Virgin Islands, along with North Carolina, has been declared a federal disaster area. Surveys indicate that Bertha damaged almost 2500 homes on St. Thomas and St. John. For many, it was a second hit in the ten months since Hurricane Marilyn devastated the same area.

It is likely that there was beach erosion on the north coast of the Dominican Republic as Bertha passed to the north. The Bahamas were also affected by the weak side of the hurricane, but there are no damage figures available from either of these locations.

The primary effects in North Carolina were to the coastal counties and included storm surge flooding and beach erosion, roof damage, piers washed away, fallen trees, and damage to crops. A survey indicated over 5000 homes damaged, mostly from storm surge. A Federal Emergency Management Agency (FEMA) estimate of the number of persons in South and North Carolina who evacuated is 750,000. Minor wind damage and flooding also spread along the path of the storm all the way to New England.

The American Insurance Association reports an estimate of $135 million dollars in insured property damage, primarily along coastal North Carolina. A conservative ratio between total damage and insured property damage, compared to past land falling hurricanes, is two to one. Then the total U.S. damage estimate is 2 times $135 million or $270 million dollars. No figures are available from the Caribbean.

d. Forecast and Warning Critique

Bertha moved on a fairly smooth track. The average official track forecast errors for Bertha ranged from 80 n mi at 24 hours (32 cases) to 147 n mi at 48 hours (29 cases) to 224 n mi at 72 hours (27 cases). These errors are 15 per cent, or more, lower than the previous ten-year averages of the official track errors and are from 15 to 40 per cent lower than the CLIPER forecast errors for the same cases.

Overall, the track model guidance also performed very well. However, the 0000 UTC Aviation Model run on the 9th, when Bertha was located just north of Puerto Rico, (inexplicably?) showed the track recurving significantly further east than the previous run. All of the track guidance models that use the Aviation Model as a background environment also showed a similar track. This resulted in rather large official track forecast errors on the 9th, with a 613 n mi 72-hour error on the 1200 UTC forecast. The Aviation Model and some of the track guidance models recovered to an excellent forecast only 12 hours later. Fortunately, this guidance problem occurred three days prior to landfall in North Carolina and did not have a significant impact on U.S. warnings or on warnings for the Bahamas.

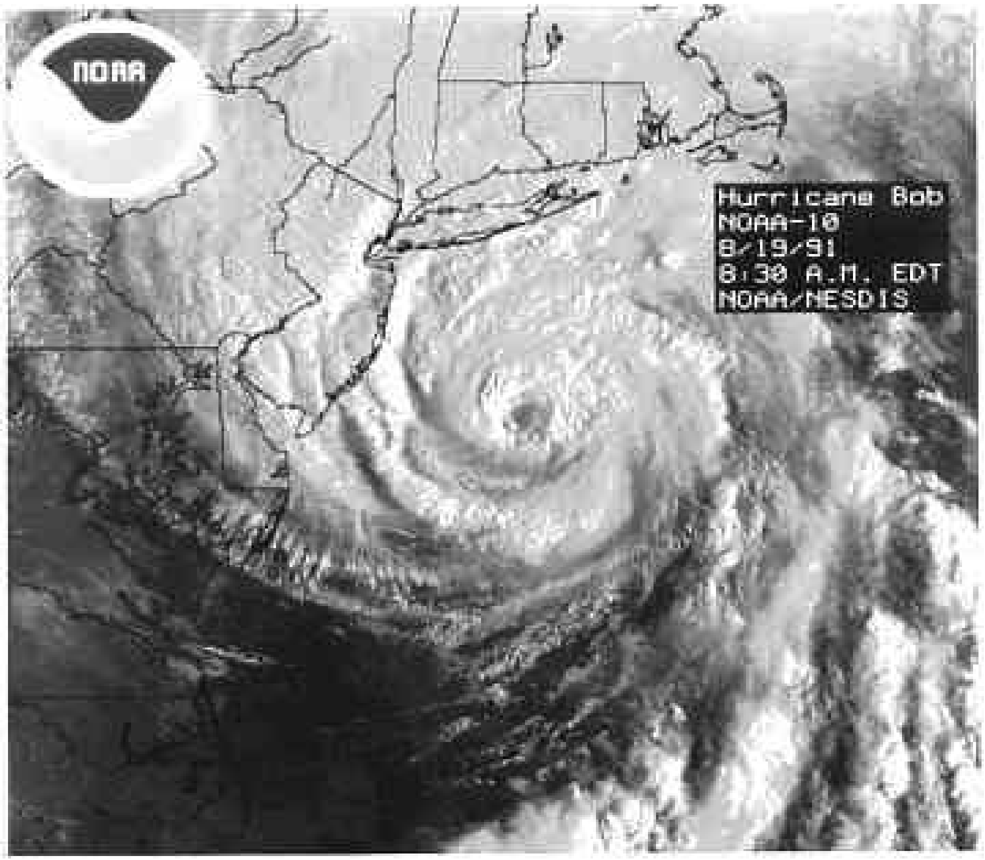
Table 4 lists the various watches and warnings that were issued. Hurricane warnings were issued from Sebastian Inlet, Florida to Chincoteague, Virginia as well as for the Bahamas and for the islands of the northeastern Caribbean Sea from Antigua through Puerto Rico. Tropical storm warnings were issued from Sebastian Inlet to north of Deerfield Beach, Florida and from north of Chincoteague to Watch Hill, Rhode Island. Almost all of the U.S. east coast was involved with some watch or warning and this is the result of the storm track's expected close passage to the southeast U.S. coast. The hurricane watch for the North Carolina landfall area was issued 65 hours before landfall and the hurricane warning was issued 47 hours before landfall. This is far more than the 36- and 24-hour lead times that the National Hurricane Center strives for and is the result of the forward motion decreasing at a faster rate than expected.

Table 1. Best track, Hurricane Bertha, 5 - 14 July, 1996 (updated 4 August 1996)

Date/Time (UTC)	Position		Pressure (mb)	Wind Speed (kt)	Stage
	Lat. (°N)	Lon. (° W)			
05/0000	9.8	34.0	1009	30	tropical depression
0600	10.2	36.3	1008	30	"
1200	11.0	39.0	1007	35	tropical storm
1800	12.0	41.2	1006	35	"
06/0000	12.7	43.9	1005	35	"
0600	13.1	46.6	1004	35	"

HURRICANE BOB - August 19, 1991.

WINDS: **105-mph.**
PRESSURE**: 28.40 inches (962 mb) -Block Island, Rhode Island only.**
STORM - SURGE**: 6 to 10-feet above mean tide.**



Hurricane Bob approaching the Rhode Island coastline in August 1991 (Photo courtesy NOAA).

Hurricane Bob hit Rhode Island and southeastern Massachusetts as a moderate hurricane in 1991. Bob was small in size - but concentrated great power in isolated areas. Fortunately, a northeasterly track kept most of Long Island, Connecticut, and western Rhode Island on the weaker side of the hurricane. This was fortunate, since Bob was stronger than Gloria in 1985. Unlike Gloria, which arrived at low tide - the storm surge from Bob was more significant, and several areas reported extensive wind and storm-surge damage. However, the effects of Bob were in small beach towns in Rhode Island and southeastern Massachusetts, thus media coverage was minimal. Nevertheless - damage in several areas *was at levels not seen since Hurricane Carol in 1954*.

Hurricane Bob developed from a persistent area of clouds just to the east of the Bahamas. By August 17th, Bob was located about 200-miles east of the central Florida coast, with winds of 75-mph. By the 18th, Bob begin turning in a more northerly direction, continuing to intensify. As the storm swept past the North Carolina Outer Banks - the Diamond Shoals Light buoy recorded sustained winds of 99-mph and a peak gust of 123-mph. Bob continued to intensify early on August 19th - reaching major hurricane strength about 80-miles east of Virginia