

= Hurricane Bonnie (1998) =

Hurricane Bonnie was a major hurricane that made landfall in North Carolina , United States , inflicting severe crop damage . The second named storm , first hurricane , and first major hurricane of the 1998 Atlantic hurricane season , Bonnie developed from a tropical wave that emerged off the coast of Africa on August 14 . The wave gradually developed , and the system was designated a tropical depression on August 19 . The depression began tracking towards the west @-@ northwest , and became a tropical storm the next day . On August 22 , Bonnie was upgraded to a hurricane , with a well @-@ defined eye . The storm peaked as a Category 3 hurricane on the Saffir @-@ Simpson Hurricane Scale , and around the same time , the storm slowed and turned more towards the north @-@ northwest . A large and powerful cyclone , Bonnie moved ashore in North Carolina early on August 27 , slowing as it turned northeast . After briefly losing hurricane status , the storm moved offshore and regained Category 1 @-@ force winds , although it weakened again on entering cooler waters .

Fearing a major hurricane strike , coastal locations from Florida to Virginia performed extensive preparations in advance of the storm . In addition to tropical cyclone watches and warnings , about 950 @,@ 000 people were evacuated from the Carolinas , and the military evacuated and relocated hundreds of aircraft and vessels from the storm 's projected path . Soldiers and guardsmen were deployed throughout those regions .

Hurricane Bonnie made landfall as a borderline Category 2 ? Category 3 storm , with intense wind gusts of up to 104 mph (167 km / h) and rainfall peaking at about 11 in (280 mm) . Reports of downed trees and powerlines , as well as structural damage such as blown @-@ out windows and torn @-@ off roofs , were reported . In coastal North Carolina , the storm washed ashore tens of thousands of tires that had been part of an artificial reef . Crop damage was extensive , but the storm was overall less severe than initially feared . Total damage was estimated at \$ 1 billion (1998 USD) .

= = Meteorological history = =

On August 14 , 1998 , a tropical wave emerged off the west coast of Africa just north of Dakar and moved westward across the Atlantic Ocean . Initially located within cool waters , a strong high pressure area steered the disturbance on a west ? southwest track over warmer waters , and convection started to develop . Several small centers of rotation existed within a broad circulation , and at 1200 UTC on August 19 , the centers consolidated and the disturbance became sufficiently organized to be declared a tropical depression . Despite being poorly organized , winds slightly to the north of the system 's center approached tropical storm strength shortly thereafter . Ship reports revealed a closed circulation , though the center was elongated in a northwest ? southeast oriented manner . Upper @-@ level winds were favorable , which suggested that intensification was likely . The cyclone began moving on a northwestward track , and just hours later the center of circulation appeared to reform close to the convection , an indication of a strengthening storm , as good outflow existed over the western side of the storm . Deep convection slowly developed closer to the center , and at 1200 UTC on August 20 , the depression was upgraded into Tropical Storm Bonnie as it continued its west ? northwest track around the periphery of a high pressure system over the Leeward Islands .

Late on August 20 , the first reconnaissance plane entered the storm and found a minimum central barometric pressure of 1001 mb . The storm brushed the Leeward Islands , although the main thunderstorm activity remained to the north of the storm over the open ocean . Bonnie began to organize its broad circulation early on August 21 , and within the next day the storm began to intensify . The storm began to look strong on satellite images with banding features over the north and west quadrants . The Hurricane Hunters aircraft found a minimum pressure of 987 mb and a nearly complete eyewall early on August 22 , and as a result , the tropical storm was upgraded to hurricane status . Bonnie slowed in forward speed , coinciding with previous forecasts . Later that day , storm was upgraded to a Category 2 on the Saffir @-@ Simpson Hurricane Scale , which

occurred with a substantial 15 mb drop in 8 hours . At the same time , steering currents weakened with the dissipation of the high pressure system ; this , combined with the effect of a nearby trough , caused the storm to turn in a more north @-@ northwestward direction around the western periphery of an anticyclone to the east . Bonnie became a Category 3 storm , a major hurricane , at 1200 UTC the next day , reaching its peak winds of 115 mph (185 km / h) at the same time .

A mid- to upper @-@ level trough slowed the storm almost to a halt early on August 23 , before a drift to the north @-@ northwest began . The next National Hurricane Center (NHC) advisory then reported that the eye was becoming more distinct and well @-@ defined . This strengthening trend abated because the storm had churned up the waters over which it was passing , bringing cooler water to the surface as a result of the slow track . Another inhibiting factor may have been related to the same trough that caused the northward turn , though due to a large anticyclone situated over the hurricane , the weakening effects were not substantial . Despite wind shear , the large and powerful circulation resisted weakening for a time . Early on August 25 , the shear and the entrainment of drier air into the hurricane took its toll on Bonnie , giving it a ragged appearance on satellite imagery , and the eye briefly became cloud @-@ filled .

The storm accelerated somewhat by August 26 , and early that day , it was moving at about 14 mph (23 km / h) . An approaching mid @-@ level trough steered Bonnie north @-@ northeast , and at 2100 UTC on August 26 , the eye passed east of Cape Fear , North Carolina . The hurricane once again slowed , and early the next day , it made landfall near Wilmington , North Carolina as a strong Category 2 or weak Category 3 hurricane . Doppler weather radar displays estimated that maximum sustained winds had quickly weakened to below hurricane intensity , and the storm was briefly downgraded to a tropical storm . However , as the storm turned towards the east in response to the approaching trough , the center neared open waters and the winds began to re @-@ intensify . As a result , the cyclone re @-@ attained hurricane status at 0000 on August 28 . Offshore , the center began drifting roughly eastward . Entering colder waters , hurricane status was lost at 1800 UTC that day , followed by an acceleration to the northeast . The storm began to lose deep thunderstorm activity , and was forecast to lose tropical characteristics and become an extratropical cyclone within days . By early on August 29 , little connection remained over the western semicircle , and only a band of such activity persisted to the southeast of the center . Bonnie became extratropical around 1800 UTC on August 30 , to the southeast of Newfoundland .

= = Preparations = =

On August 20 , a tropical storm watch was posted for the islands of Antigua , Barbuda , Anguilla , St. Maarten , Saba and St. Eustatius , though it was discontinued the next day . Shortly thereafter , a tropical storm warning was issued for the U.S. and British Virgin Islands . Tropical storm warnings and hurricane watches were put into effect for the Turks and Caicos Islands and the southeastern Bahamas . By August 24 , those tropical cyclone advisories were discontinued , and at the same time they were issued for parts of the Southeast United States . A hurricane warning was eventually posted for Murrells Inlet , South Carolina to the North Carolina ? Virginia border . On August 27 , tropical cyclone watches and warnings extended as far north as Plymouth , Massachusetts ; all were discontinued early on August 29 .

= = = Florida and South Carolina = = =

Initially the storm posed a threat to Florida , where military officials kept abreast of the situation . Heavy surf advisories were posted from central portions of the state northward to Georgia , and the National Hurricane Center advised that swimming and boating should be avoided . The Mayport Naval Station ordered 25 ships out to sea in advance of the approaching storm . The Salvation Army was on standby in Jacksonville , prepared to act when needed . Hardware stores in the state reported up to a 75 % increase in the sales of emergency supplies .

Some computer forecast models initially predicted that the storm would move towards South Carolina or Georgia . Before the storm 's arrival in South Carolina , researchers at Clemson

University used Bonnie to test a new method of estimating the damage a storm is likely to cause . In the state , the South Carolina National Guard put about 1 @, @ 512 men on active duty , 1 @, @ 474 being of the Army National Guard . On August 25 , the South Carolina Emergency Preparedness Division activated Level 1 operations , the highest of five levels . That same day , the State Governor declared a State of Emergency , calling for mandatory evacuations of residents east of U.S. Route 17 in Horry and Georgetown counties . Schools were closed throughout the state . Over 200 @, @ 000 people were evacuated from those counties , of which 120 @, @ 000 were tourists . About 6 @, @ 000 sought shelter at schools in Horry County . In a survey , 12 % of respondents in the state took traffic as a significant consideration in deciding if they should evacuate . On the Grand Strand , Bonnie was the first storm where buses were provided to help people evacuate .

= = = North Carolina and Virginia = = =

About 815 guardsmen were called to North Carolina , where they assisted local authorities with the extensive preparations , including evacuating 750 @, @ 000 state citizens . Mandatory and voluntary evacuations were ordered for part of the state . The Outer Banks experienced extensive evacuations ; at least 300 @, @ 000 left , bringing traffic on highways from there to the mainland to a standstill . Active duty armed forces were set to support hurricane recovery missions , and four Defense Coordinating officers were notified . Defense Department emergency centers were opened starting August 21 . Additionally , the U.S. Atlantic Command activated their 24 @-@ hour response cell . Soldiers , sailors , airmen , and Marines evacuated equipment , including hundreds of vessels and aircraft . The North Carolina Department of Environment and Natural Resources closed several state parks , all three state aquariums , and the Division of Marine Fisheries office , with plans to reopen primarily once storm @-@ related damage at any of the locations was properly addressed .

A study was performed on the storm in eight counties in North Carolina to determine the cost of evacuation for hurricanes , and included 1 @, @ 029 households . Another study was performed regarding the actions taken during Hurricane Bonnie evacuations in the state . Tourists were interviewed , and it was found that 90 % of vacationers who were threatened by the hurricane evacuated , of which 56 % went home , 3 % stayed in public shelters , 22 % stayed with friends or relatives , 3 % stayed in hotels and motels , and 16 % stayed elsewhere . In total , 58 % stayed within North Carolina , 12 % went to Virginia , 6 % relocated to South Carolina , and 24 % stayed in other regions . Most of the evacuees left on August 25 ; 80 % left with their own vehicles , and 18 % used rental transportation . Officials in the state opened an estimated 100 shelters to accommodate the evacuating tourists and residents .

In Virginia , where 15 jurisdictions declared local emergencies , local governments took action to inform and protect citizens . Residents in mobile home parks , as well as campgrounds , were advised to evacuate , and 13 jurisdictions opened shelters by August 26 . State Governor Jim Gilmore declared a State of Emergency , and as a result , the State Emergency Operations Center was activated . Beaches and piers were shut down in Virginia Beach , Hampton , and Gloucester counties , where communities canceled some local events due to the threat of Bonnie . Voluntary evacuations throughout the state were issued , and some hotels reached maximum capacity as a result . Roughly 60 Navy ships were ordered to leave port at Norfolk , and ride out the storm far out to sea . The State of Virginia banned swimming along the coast . As Bonnie progressed northward , a tornado watch was posted for much of eastern Virginia .

= = Impact = =

While located north of the Caribbean Sea , Bonnie dropped light rainfall in Puerto Rico . The storm also produced heavy rainfall and gusty winds in The Bahamas , though no significant damage was reported . Along the U.S. East Coast , two swimmers drowned in rip currents ; numerous others were rescued . In the United States , Bonnie caused an estimated \$ 1 billion in damage .

= = = South Carolina = = =

As the hurricane passed to the east of the state , rainfall ranged from 2 to 4 in (51 to 102 mm) , and storm surge was around 2 to 3 ft (0 @. @ 61 to 0 @. @ 91 m) . The highest recorded wind gust in the state was 82 mph (132 km / h) at the Cherry Grove pier , and sustained winds peaked at 76 mph (122 km / h) at the Myrtle Beach Pavilion . Damage was widespread in Horry County , where downed trees and power lines and structural damage was reported . The high winds blew down several trees in Charleston County , and tore the roof off a strip mall in North Myrtle Beach . A 50 @- @ year @- @ old man died near Myrtle Beach ; he was electrocuted while checking his generator after a power outage . Along the coast , a 25 @- @ year @- @ old man died in rip currents at Surfside Beach . Total damage in South Carolina was estimated to be around \$ 25 million (1998 USD) .

= = = North Carolina = = =

Hurricane Bonnie came ashore just at or below major hurricane intensity , bringing with it intense wind gusts of up to 98 mph (158 km / h) in North Carolina , though offshore at the Frying Pan Shoals Light Tower , winds reached 104 mph (167 km / h) . The strongest winds were found in the precursor rainbands , where localized downbursts caused severe damage . Sustained winds officially peaked at 51 mph (82 km / h) at Elizabeth City , where gusts reached 63 mph (101 km / h) . Rainfall was heavy as a result of the storm 's slow movement , peaking at 11 in (280 mm) at Jacksonville , while several totals of over 10 in (250 mm) were reported . However , because the area had been experiencing drought conditions , the flooding was not as severe as it could have potentially been . The most significant flooding occurred near the Cape Fear River , where high waters were reported . The highest storm surge occurred along the beaches of Brunswick County , mostly reaching 5 to 8 ft (1 @. @ 5 to 2 @. @ 4 m) above average . Elsewhere , flooding was mostly limited to locations with poor drainage and low @- @ lying areas . Coastal flooding was not widespread , though surge in the Pungo River flooded several local homes . Other coastal flooding was reported in various harbors and coastal cities . Part of North Carolina Highway 12 was flooded and closed on Hatteras Island due to tidal flooding . At North Topsail Beach , many of the protective dunes constructed after Hurricane Fran in 1996 were destroyed , and along the Bogue Banks , tens of thousands of tires , part of an artificial reef , were washed ashore .

One direct death occurred in North Carolina ; a young girl was killed when a tree fell on her Currituck County home . Throughout eastern portions of the state , trees and powerlines were downed , and there were reports of structural damage . Numerous docks , piers and bulkheads were either damaged or destroyed , including the Iron Steamer and Indian Beach piers , which both lost large sections to the strong wind and surf . Due to the winds , the Brunswick Community Hospital lost about 3 @, @ 000 sq ft (280 m2) . of roof and an air conditioner . The storm left about 500 @, @ 000 people in the state without electric power . In some areas , vegetative and structural debris accumulated in piles several feet deep ; it is reported that thick underbrush prevented the debris from traveling further inland . Wilmington " turned into a disaster zone " , with flooded highways , and downed trees lying across roadways . Crop , particularly tobacco , damage was extensive . According to then @- @ governor Jim Hunt , " You fly along and don 't see much damage to the beach houses , and it 's easy to think we didn 't have much damage . But then you look at the tobacco in fields and you know the damage has been extensive . " The crop losses accounted for much of the overall damage . Forty @- @ seven of those who failed to evacuate in time sought shelter in the Bald Head Island lighthouse as the worst of the storm bore down . Despite the effects , Bonnie 's impact was actually less than originally predicted . Overall , property damage in the state is estimated at \$ 240 million (1998 USD) , with significantly higher crop damages .

Several locations received significant physical impacts . On Wrightsville Beach , North Carolina , Bonnie 's erosion caused an inlet to migrate further south . On the northern end of the inlet , a large sand bar developed , partially due to the storm moving offshore sand . Dune sediments were lost during the storm , exposing boardwalk piling . Similarly , on Topsail Beach , North Carolina , the storm breached 27 sand dunes , destroying 60 % of the dune line . Sediment from storm washover

measured 50 cm (20 in) thick behind the beach . Sections of many eroded dunes were re @-@ built using truck loads of sand . Strong waves ran through the foundation of two stilted homes , both of which were later reinforced to compensate for the lost sand .

= = = Virginia = = =

Bonnie passed just offshore of southeast Virginia , lashing the region with heavy rain and high winds . Sustained winds reached 81 mph (130 km / h) at Cape Henry , and gusts peaked at 104 mph (167 km / h) . There were other reports of winds over 80 mph (130 km / h) along the coast . Numerous homes suffered damage in the Hampton Roads area , and near Virginia Beach , winds blew windows out in hotels . Storm surge was generally around 2 to 4 ft (0 @. @ 61 to 1 @. @ 22 m) with some higher reports , causing some coastal flooding . Rainfall was moderate to heavy , ranging from 1 to 7 in (25 to 178 mm) , with the higher @-@ end totals occurring in the Norfolk area .

Between 320 @, @ 000 and 650 @, @ 000 customers lost power in the state . The power outages led to decreased production in some water and sewer plants , prompting local officials to advise residents to conserve water . In the Ocean View section of Norfolk , the winds tore the roofs off two apartment complexes , and damaged siding on other structures . Along the coast , boats were ripped from their moorings .

Throughout the Tidewater region , there were estimates of thousands of downed trees , and hundreds of homes and businesses were damaged . Of these , about 40 structures were declared uninhabitable . Debris was blown several blocks inland from the coast . Among the hardest hit locations was Sandbridge , where about 12 homes were severely damaged . It is reported that the state was unprepared for the damage , expecting a strike from a weakened tropical storm . About \$ 15 @. @ 3 million (1998 USD) in damage was inflicted in the Virginia Beach and Norfolk areas . Throughout the state , insured losses totaled \$ 95 million (1998 USD) .

= = = Mid @-@ Atlantic , New England and Atlantic Canada = = =

As the storm moved offshore , outer rain bands affected the Maryland coast with gusts of up to 42 mph (68 km / h) at Ocean City , and waves of 10 ft (3 @. @ 0 m) . No damage was reported . Light rainfall was also reported northward into Delaware and New Jersey . In addition , up to 0 @. @ 2 in (5 @. @ 1 mm) of precipitation extended into New York . A person was caught in rip currents and drowned near Rehoboth Beach , Delaware . Along the coast of New Jersey , Bonnie produced strong waves and rip currents , resulting in hundreds of water rescues and eight injuries . The storm was at its closest position to the state on August 28 , as it passed 140 mi (230 km) to the east of Atlantic City , although the rough surf began several days prior , on August 23 . Numerous beaches were closed , and swimming was banned in several communities , as well . The state also reported moderate wind gusts , generally peaking at 35 mph (56 km / h) . Only minor beach erosion occurred . At Point Pleasant Beach , New Jersey , there were reports of a drowning in the rough seas caused by the storm ; however , the man was later spotted onshore with his fiancée , and the two were charged with filing a false police report .

Bonnie moved well to the south of Cape Cod , although a significant outer rain band affected southern Plymouth County , Massachusetts . Torrential downpours produced 4 in (100 mm) of precipitation at Whitehorse Beach , and other locations reported over 1 in (25 mm) . Winds reached 25 to 35 mph (40 to 56 km / h) , although offshore the Georges Bank Buoy reported a 52 mph (84 km / h) gust . A man was killed when his rowboat capsized in rough surf of 1 to 2 ft (0 @. @ 30 to 0 @. @ 61 m) ; his companion safely swam to shore .

On the afternoon of August 29 , Bonnie entered the Canadian Hurricane Centre 's area of responsibility as a tropical storm , and passed south of Nova Scotia and Newfoundland . Precipitation along the coast of Nova Scotia ranged from 15 to 25 mm (0 @. @ 59 to 0 @. @ 98 in) and winds gusted to around 102 km / h (63 mph) . Slightly higher gusts were reported off the coast . On Sable Island , the storm dropped 30 mm (1 @. @ 2 in) of rainfall . An offshore buoy recorded a

wave height of 17 @. @ 9 m (59 ft) .

= = Aftermath and observation = =

Following the hurricane in North Carolina , 10 counties were declared federal disaster areas , while 30 counties became eligible for public and individual assistance . Shelters were opened in 11 counties , and the Raleigh @-@ Durham International Airport briefly canceled all flights . To remove the tens of thousands of tires that washed ashore , hundreds of inmates from state prisons were sent to the Bouge Banks . Some of the tires were buried in sand , and could only be removed during low tide . About 700 more state prisoners were sent around the state to clear debris , and 39 inmate crews were deployed to help farmers salvage the severely damaged tobacco fields . In South Carolina , Horry County was declared a federal disaster area due to the damage . In Virginia , the cities of Chesapeake , Norfolk , Portsmouth , Suffolk , and Virginia Beach became eligible for individual and public assistance programs . After the storm 's departure , a thunderstorm temporarily halted power restoration by Virginia Power company crews . Virginia Governor Jim Gilmore allowed for over \$ 11 million (1998 USD) in state and federal funds to help five cities recover . The storm also contributed to a 13 @. @ 6 % decline in home sales across the southern United States during the month of August by " discouraging potential home buyers " in coastal areas .

Both during and after Hurricane Bonnie 's onslaught , analysis of the storm was extensive ; it was deemed " the most observed hurricane in history . " When examined with Tropical Rainfall Measuring Mission (TRMM) satellite imagery , it was discovered that peak cloud tops surrounding the eyewall rose 59 @, @ 000 ft (18 @, @ 000 m) into the atmosphere , twice as tall as Mount Everest . This was the first time that TRMM had observed such a tropical cyclone structure , according to co @-@ developer of the Saffir @-@ Simpson Hurricane Scale , Bob Simpson . The storm was also used for collection of tropical cyclone research data . For the first time in the Atlantic , a fleet of aircraft investigated the storm 's upper @-@ levels , while other aircraft flew into the low- and middle @-@ levels . A record of over 500 parachute sensors were dropped into the storm while it was active . Each costing \$ 600 (1998 USD) , they sent storm data to research centers via Global Positioning System .

During the storm , the Weather Channel web site experienced substantially increased traffic . Up from an average of three million views per day , 10 million page views on August 26 led to slow download times on the website . On seven major weather providers , page views increased by 123 % from August 24 ? August 26 , compared to an equal period of time during the previous week .