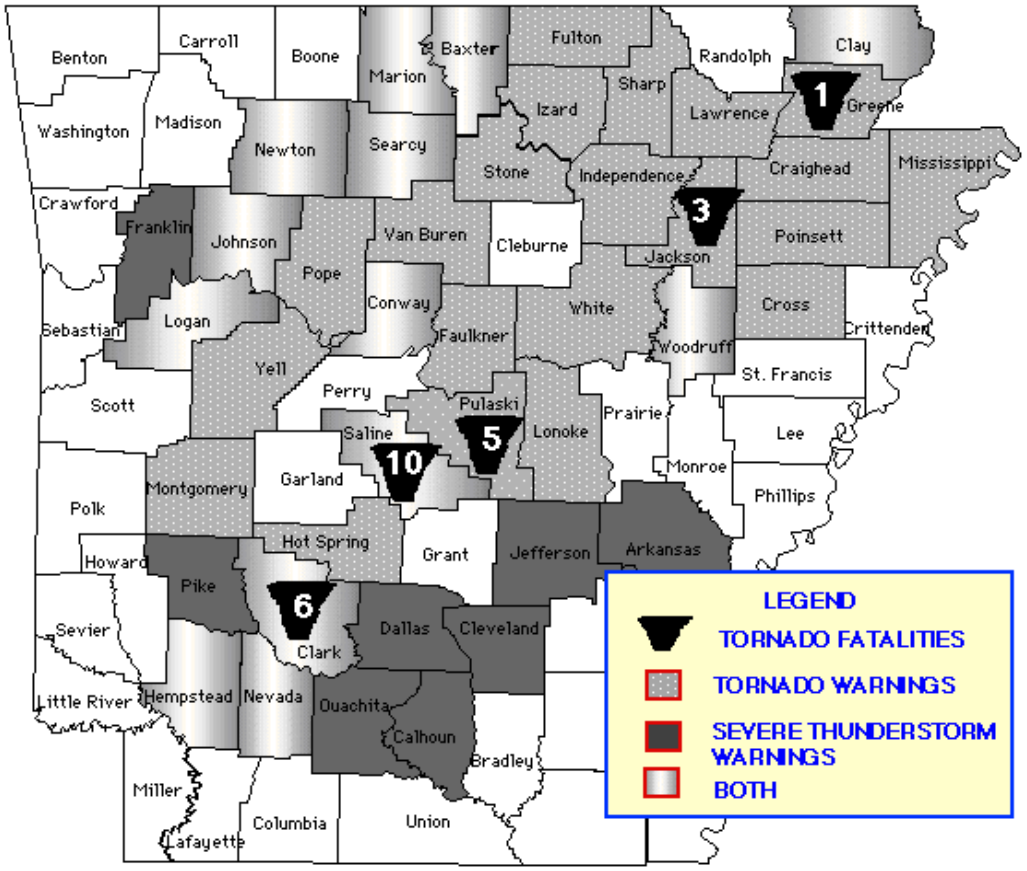
Service Assessment

MARCH 1, 1997, ARKANSAS TORNADO OUTBREAK



U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
Silver Spring, MD

Cover: Outline of Arkansas depicting counties that had severe thunderstorm and tornado warnings issued along with locations of fatalities. Source: Office of Meteorology.

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Preface

The primary purpose of this Service Assessment is to document the National Weather Service's (NWS) performance in fulfilling its mission of providing timely warnings and accurate forecasts prior to and during the tornado outbreak of March 1, 1997, in Arkansas. The NWS's products and services, used by emergency managers, media, and others, are key to public safety with regard to severe weather. The warning process is a partnership between the NWS and all organizations charged with responding to natural hazards. We in the NWS will continue to forge and nurture these relationships to ensure the best possible warning service for our citizens.

Robert S. Winokur
Acting Assistant Administrator
for Weather Services

September 1997

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Acronyms

CWA	County Warning Area
EAS	Emergency Alert System
FEMA	Federal Emergency Management Agency
NEXRAD	Next Generation Radar
NGM	Nested Grid Model
NOAA	National Oceanic and Atmospheric Administration
NWR	NOAA Weather Radio
NWS	National Weather Service
NWSFO	NEXRAD Weather Service Forecast Office
NWWS	NOAA Weather Wire Service
OSF	Operational Support Facility
PUP	Principal User Processor
SPC	Storm Prediction Center
SRH	Southern Region Headquarters
WCM	Warning Coordination Meteorologist
WSH	Weather Service Headquarters
WSR-88D	Weather Surveillance Radar-1988 Doppler

Service Assessment Team

The NWS assembled this Service Assessment Team to analyze the overall warning process and to evaluate the services provided by the NWS to the state, county, and local governments; the media; and the citizens of Arkansas. The team traveled to Arkansas from March 4-8, 1997, collecting information and interviewing the NEXRAD (Next Generation Radar) Weather Service Forecast Office (NWSFO) Little Rock staff members; state, county, and local emergency management personnel; and other officials, media, and the public. Additional information was collected from the Storm Prediction Center (SPC), Southern Region Headquarters (SRH), Weather Service Headquarters (WSH) , and the NEXRAD Operational Support Facility (OSF). All of the information was then compiled and evaluated culminating in this report.

The team was comprised of the following five people:

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Photograph of old concrete and block building in downtown Arkadelphia where major destruction occurred. Flying debris knocked holes in the walls and wooden boards pierced the side of the building. Courtesy of Chris Smith, NWS Southern Region.

Photograph of brick church in Arkadelphia with major roof damage and broken windows. This church was on the edge of the downtown area where major destruction occurred. Courtesy of Chris Smith, NWS Southern Region.

Substantial buildings, such as these brick and block buildings, were completely destroyed from the devastating tornado that struck within a few blocks from downtown Arkadelphia. Courtesy of Chris Smith, NWS Southern Region.

Service Assessment

March 1, 1997,
Arkansas Tornado Outbreak

OVERVIEW

The devastating severe weather that occurred on March 1, 1997, in Arkansas and western Tennessee took 26 lives, injured hundreds, and produced property damage estimated between $115,000,000 and $120,000,000. Of the 26 fatalities, 25 perished in Arkansas and 1 was killed in Tennessee. More than 400 people were injured in both Arkansas and Tennessee. This Service Assessment focused on NWSFO Little Rock's county warning area (CWA), in which 24 of the 25 Arkansas deaths and most of the injuries occurred. In addition, the bulk of the destruction occurred in Arkansas, where property damage was estimated over $115,000,000.

STORM SUMMARY

On the afternoon of March 1, 1997, 16 tornadoes tore through Arkansas, devastating portions of southwest, central, and northeast Arkansas (figure 1). Four of the tornadoes were responsible for all the fatalities and most of the injuries and property damage. All of the tornadoes were produced by four supercell thunderstorms (supercell thunderstorms are rotating storms that are long-lived and typically go through weakening and strengthening phases), and the four killer tornadoes were spawned by two of the supercell thunderstorms which formed ahead of a cold front.

During the early morning hours, atmospheric conditions appeared favorable for the formation of severe thunderstorms and potentially tornadoes. The atmosphere just above the surface was already moderately unstable with strong southwesterly wind, increasing significantly in strength aloft. The low-level air mass over Arkansas was warm and extremely humid for early March, with temperatures mainly between 72 and 75 degrees at 11 a.m. and dewpoint temperatures around 70 degrees. A line of thunderstorms developed along the cold front as it moved into northwestern Arkansas during the morning hours. Several of these storms produced damaging tornadoes. Another line of thunderstorms, including the two supercell thunderstorms, developed approximately 50 miles ahead of the cold front and moved northeast (figure 2).

The first killer tornado produced damage along its 67 mile path. It touched down near Hope in Hempstead County at 1:55 p.m. and moved northeast through northern Nevada County (figure 3). It caused considerable damage in rural areas of these two counties but no

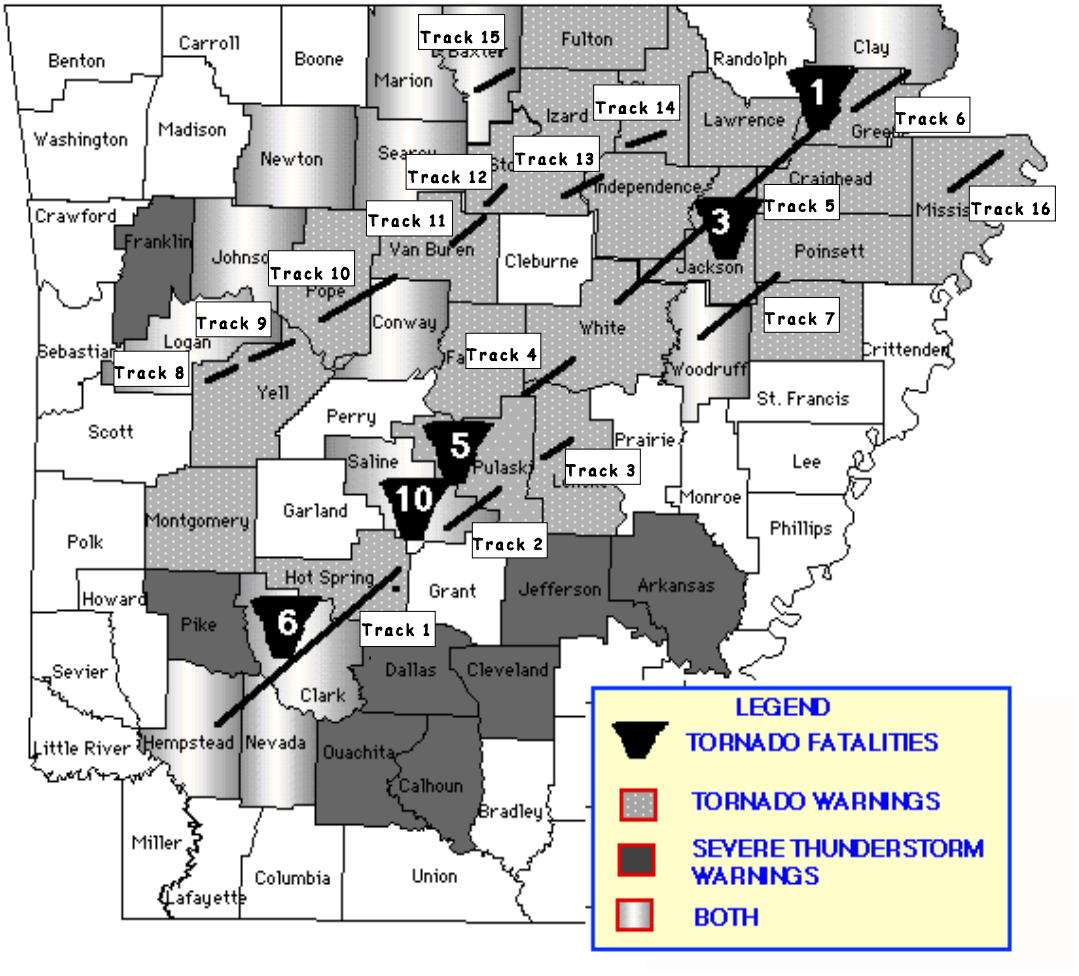

Figure 1. Outline of Arkansas depicting counties that had severe thunderstorm and tornado warnings issued along with locations of fatalities and the 16 tornado tracks. Source: Office of Meteorology.

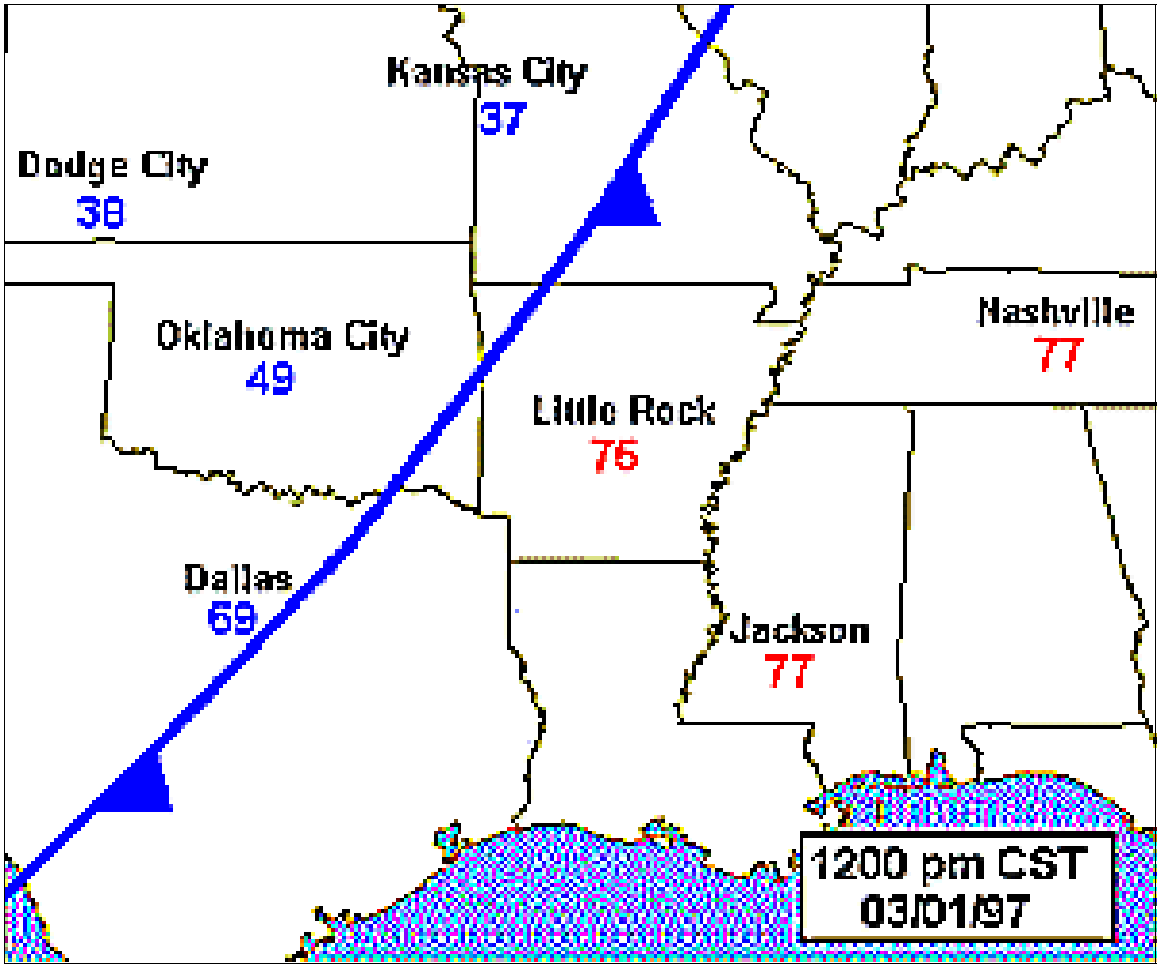

Figure 2. Cold front moving southeast is located in northwest Arkansas at 12 p.m., CST, March 1, 1997. Source: John Lewis, NWSFO Little Rock, Arkansas.

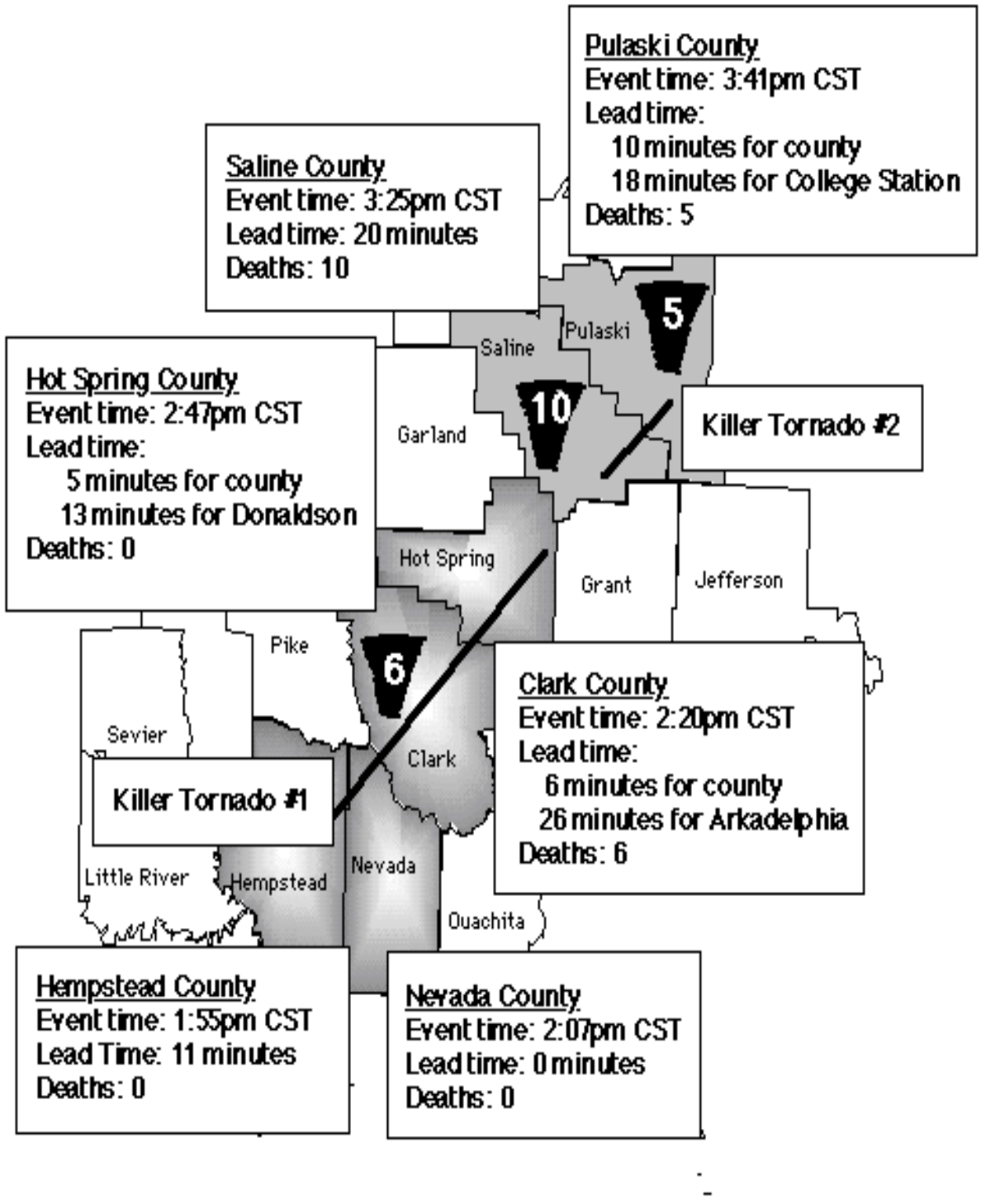

Figure 3. Tornado tracks in Arkansas depicting fatalities associated with the tornadoes in each affected county. Source: Office of Meteorology.

fatalities. The tornado continued its northeast track into Clark County, where it produced F4 damage (refer to the Fujita F-scale in appendix A), six deaths, and numerous injuries in the Arkadelphia area around 2:40 p.m. Five of the deaths occurred in town and one was in a vehicle on Interstate 30. The tornado continued into Hot Spring County where it produced significant damage in the Donaldson area. The tornado lifted about 4 miles east of Malvern around 3:10 p.m.

The second killer tornado produced a damage path 27 miles long. The same supercell thunderstorm that produced the first killer tornado spawned this one as well. The tornado touched down 3 miles southeast of Benton in Saline County around 3:25 p.m. and moved northeast as it strengthened (figure 3). This tornado was the largest of the day, with a path width of 8/10 of a mile and numerous areas of F4 damage. Ten fatalities occurred in Saline County, mostly in the Chicot, Vimy Ridge, Oak Ridge, and Shannon Hills areas. The tornado continued into southern Pulaski County at approximately 3:35 p.m. It produced F2 and F3 damage and five deaths in the College Station area just south of Little Rock. The tornado moved into Little Rock around 3:40 p.m. and lifted along I-440 about 4 miles east of Little Rock.

The third killer tornado produced a damage path 75 miles long (figure 4). It first touched down at 3:15 p.m., 10 miles northeast of Searcy in White County, and moved northeast as it strengthened. The tornado moved quickly into Jackson County, crossing highway 167 about 3 miles south of Denmark (between Velvet Ridge and Denmark) where it produced F2 damage. Two people who had fled their mobile home for shelter in a ditch were killed by a tree falling on them. The mobile home they had been in was also demolished. The tornado continued moving northeast, producing F1 and F2 damage along the way. As it moved through the Jacksonport area at 3:43 p.m., another person was killed in a mobile home. The tornado continued to produce F1 and F2 damage as it moved through Craighead County, passing near Egypt, about 10 miles northwest of Jonesboro at 4:15 p.m. It continued on its northeast track, passed through the southeast part of Lawrence into Greene County, and lifted about 18 miles northeast of Paragould.

The fourth killer tornado touched down in the northeast part of Greene County and was spawned by the same thunderstorm that produced killer tornado number three. This tornado moved northeast for approximately 20 miles through northeastern Greene County and southeast Clay County (figure 4). The tornado moved through the center of Marmaduke, where it produced F3 damage and killed one person. The tornado continued northeast and lifted near Rector in Clay County.

All locations where the deaths and most of the injuries occurred were covered by tornado warnings with lead times of 9 to 28 minutes.

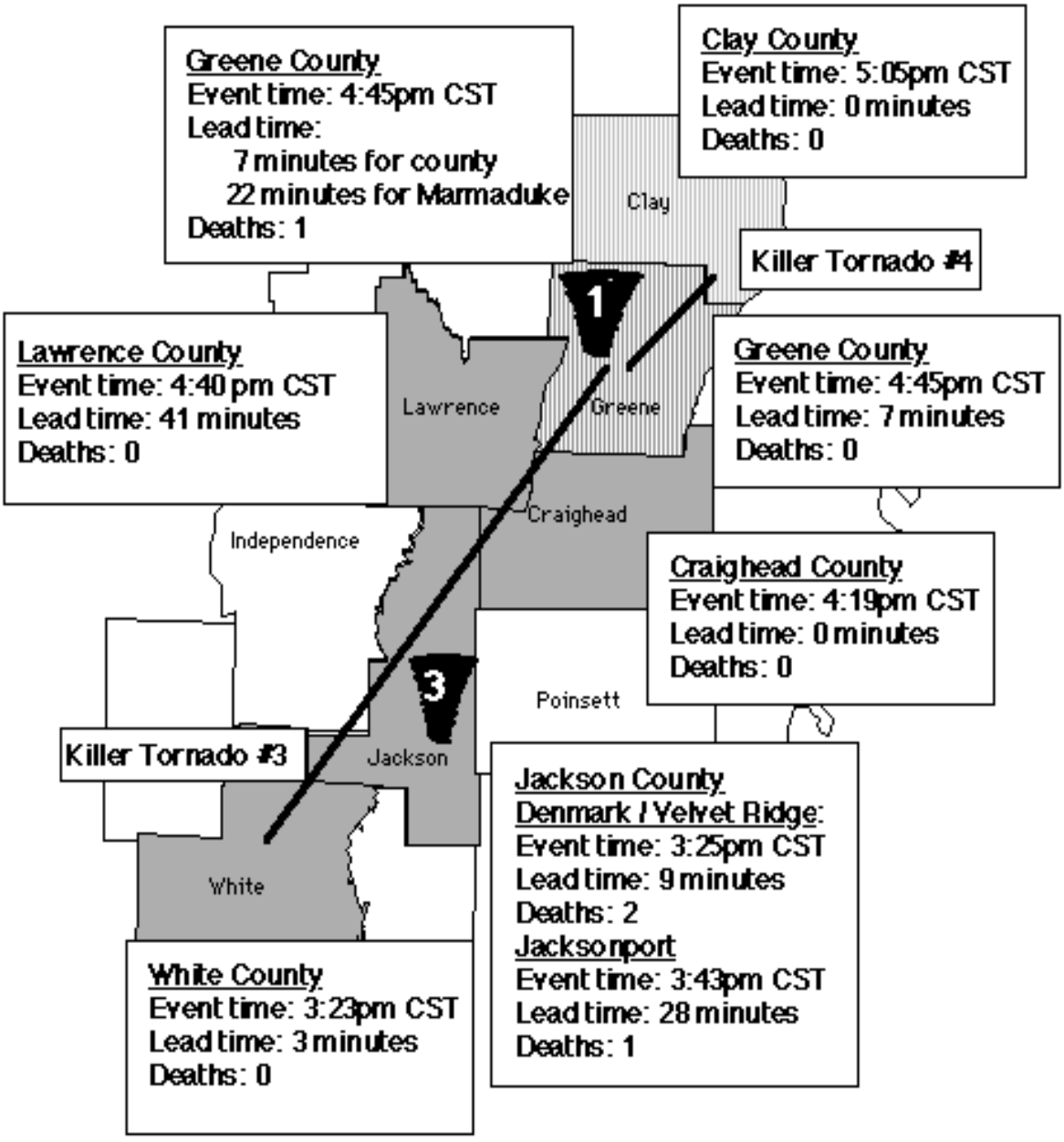

Figure 4. Tornado tracks in Arkansas depicting fatalities associated with the tornadoes in each affected county. Source: Office of Meteorology.

ANALYSIS OF PERFORMANCE

Indications of potential severe weather on Saturday, March 1, 1997, came early to NWS forecasters as well as to media weathercasters in Arkansas. The NWS's SPC issued its Convective Outlook and Second Day Severe Storms Outlook products at approximately 12:08 a.m. CST, Friday, February 28. The Day 1 forecast, which covered the period from 6 a.m. CST, Friday, February 28, to 6 a.m. CST, Saturday, March 1, indicated a slight risk for severe weather in Arkansas. A moderate risk for severe weather was forecast for much of Arkansas in the Day 2 product which covered the period from 6 a.m. CST, Saturday, March 1, to 6 a.m. CST, Sunday, March 2. Subsequent updates from SPC maintained this general forecast. All the Outlooks discussed a higher probability of tornadoes over the area where the bulk of the subsequent fatalities, injuries, and property damage occurred. SPC issued a Mesoscale Discussion at 8 a.m. CST, Saturday morning, which highlighted increasing atmospheric shear and instability over portions of Arkansas. Tornado Watch No. 75 was issued at 11:34 a.m. CST, which covered western and central portions of Arkansas in addition to portions of several other states, approximately 2 ½ hours before the first tornado occurred.

NWSFO Little Rock forecasters were well aware of the potential for severe weather on March 1, based on the SPC guidance as well as numerical model data on Friday and Saturday. In addition, the public forecaster used local atmospheric diagnostic tools to give as clear a picture as possible of the small-scale features which would influence the atmosphere over Arkansas that Saturday.

All available observational tools were used by the Little Rock forecasters. Prior to and during the early development stages of the storm system, satellite imagery was very useful in observing and analyzing larger mesoscale and synoptic-scale features. The Wind Profiler at DeQueen in southwestern Arkansas was also valuable in observing the evolution of the vertical wind pattern over Arkansas. Once the storm system had developed, the Weather Surveillance Radar-1988 Doppler (WSR-88D) at NWSFO Little Rock was used exclusively and was considered by forecasters the most valuable tool. All of the warnings issued were based on radar data. Due to intermittent problems with a component of the receiver chain, which affected reflectivity products, the radar reflectivity display only occasionally indicated intensities typical of supercell storms. However, the velocity display, not affected by the attenuator problem, did an excellent job of detecting storm-scale areas of rotation. Other important factors included the use of innovative Principal User Processor (PUP) color schemes, severe weather staffing, and staff training.

Trained storm spotters played a vital role during the entire severe weather event. Storm information flowed from the spotters to the NWSFO and visa versa. The confirmation of severity received from spotters in Arkadelphia influenced the Little Rock staff's warning decisions for the remainder of the event. One side benefit from this was that many people in rural communities listen to the "ham network" as well as law and fire agencies on scanners during times of threatening weather to get the latest information regarding their area.

From 12:04 p.m. to 6:52 p.m., NWSFO Little Rock issued 57 severe weather warnings—34 were tornado warnings and 23 severe thunderstorm warnings. In addition, flash flood warnings, numerous statements, and short-term forecasts (Nowcasts) were issued. The most active time occurred between 2:04 p.m. and 3:54 p.m., when 14 tornado warnings and 2 severe thunderstorm warnings were issued. This averages one warning product approximately every 5 minutes. All severe weather events occurred in areas covered by the tornado watch and nearly all were under warnings. The average warning lead time for all events was 18 minutes. For the four **counties** in the Little Rock CWA where the 24 deaths and the bulk of the injuries occurred, tornado warning lead times ranged from *6 to 20 minutes*. However, lead times for tornado warnings for the **communities** within these counties where all the deaths and the majority of the injuries occurred was *9 to 28 minutes*. The other death in Arkansas occurred in Greene County which is in the NWSFO Memphis CWA. NWSFO Memphis issued a tornado warning 7 minutes before the tornado touched down in Greene County and 22 minutes prior to the tornado striking Marmaduke where the fatality and five injuries occurred.

All indications are that NWSFO Little Rock provided excellent service to their CWA in Arkansas. The media; state, county, and local government agencies; and the entire emergency management community credited the timely warnings from the NWS with saving many lives. The NWS's direct warning process worked well as did the overall warning process. Media broadcasters provided constant updates to the public with the latest information available. Sirens were sounded in a timely manner in areas where they existed. The tornado warning provided such a long lead time to Clark County that the sirens were sounded a second time, and continuously, when the tornado was sighted as it bore down on Arkadelphia. Sirens were sounded in Pulaski County when the warning was received, and even though the College Station community did not have a siren, residents heard the sirens from Little Rock, about 1 ½ miles away, 15 to 20 minutes prior to the tornado arriving in College Station.

Three potential problem areas have been identified within the overall warning system. First, an apparent problem with the Emergency Alert System (EAS) was identified in the areas south of Little Rock. Broadcasters indicated that they did not get EAS information in Clark and Saline Counties. Reasons for this are unclear; however, potential areas of failure exist with the transmitters, receivers, and programming of equipment at the receiving stations. Second, although there was no failure of the National Oceanic and Atmospheric Administration (NOAA) Weather Wire Service (NWWS) provided by GTE to customers during the event, it was noted by the media and the state government customers that the system had failed earlier that morning. They indicated that they frequently have this problem and have to call the company to get their systems restarted. There is no alert which indicates a problem, and the only way they have of knowing that the system has stopped is to physically check it. Third, even though long lead-time warnings were given, and an active severe weather education effort has existed in Arkansas for many years, numerous residents still did not respond properly to the warnings. These areas are addressed in the findings and recommendations section.

This photograph shows the tornado damage in the Vimy Ridge area of Saline County. All of the homes were damaged and nearly all of the mobile homes and frame houses were destroyed. Pictured is a destroyed home with only a chimney and parts of two walls remaining. Courtesy of Chris Smith, NWS Southern Region.

Following the devastating tornado at College Station in Pulaski County, a cleanup crew works on this home across the street from the church where 20 to 30 people were holding choir practice when the tornado struck. None of the people in the church were injured. Courtesy of Chris Smith, NWS Southern Region.

This photograph shows a broad view of the tornado destruction in a section of College Station, Arkansas. Courtesy of Chris Smith, NWS Southern Region.

Facts/Findings/Recommendations

OBSERVATIONS

Fact 1: NWSFO Little Rock used Micro-SWIS to view and interpret satellite data and found it very useful in observing important cloud features as they developed and moved into and across portions of Arkansas. Satellite data was of limited value once severe weather began in Arkansas.

Fact 2: Wind Profiler data, from DeQueen, Arkansas, was used to evaluate the vertical wind profile over Arkansas during the morning and to observe the evolution of the vertical wind pattern preceding and during the severe weather episode. The SPC used Wind Profiler data from DeQueen and Okolona, in northeast Mississippi, in combination with WSR-88D wind profile information from radars in several states to assess the three dimensional wind field. This aided them in determining that a tornado watch would be necessary.

Fact 3: Confirmation of the massive destruction, fatalities, and injuries from spotters in and near Arkadelphia influenced the forecasters' warning decisions for the remainder of the severe weather episode. Forecasters issued tornadoes warnings based on similar radar signatures throughout the afternoon. Forecasters continued to rely on spotter reports for ground truth verification that warning decisions based on radar data were correct.

Fact 4: NWSFO Little Rock used WSR-88D data as the primary tool for examining and interpreting atmospheric conditions and issuing warnings based on the information provided by the radar. Although reflectivity data only occasionally showed supercell indications, velocity data combined with innovative PUP color schemes did an excellent job of detecting storm-scale rotations.

GUIDANCE

Fact 5: Although all of the numerical models were in good agreement, the Nested Grid Model (NGM) output provided the best information to the Little Rock forecasters regarding potential for severe weather a day in advance as well as the day of the outbreak. The NGM and guidance products from SPC enabled the forecasters to include

severe thunderstorms in their forecasts for March 1 in the Friday afternoon, February 28, and Saturday, March 1, zone forecasts.

Fact 6: The SPC found the ETA model most valuable in developing their products. The SPC provided outstanding guidance in their convective weather outlook, severe weather outlook, and mesoscale discussion products. The outlooks from Friday, February 28, and Saturday, March 1, both provided advanced information regarding the potential for severe weather to NWS and private forecasters. The outlooks discussed the probability of stronger tornadoes over the area where the bulk of the subsequent fatalities, injuries, and property damage occurred. A mesoscale discussion was issued at 8 a.m., Saturday, March 1, indicated that atmospheric shear and instability were ripe for severe thunderstorms to develop in the next few hours. The SPC issued a tornado watch at 11:34 a.m., 2 ½ hours prior to the first severe weather occurrence.

WARNINGS/PREDICTIONS (includes watches, statements, forecasts, etc.)

Fact 7: The potential of severe weather occurrence in Arkansas was advertised well in advance. The SPC had forecast the risk of severe weather the day before with the early morning release of the Convective Outlook and Severe Weather Outlook for Day 2 on Friday, February 28.

Fact 8: The SPC issued Tornado watch No. 75 for western and central Arkansas at 11:34 a.m., more than 2 ½ hours prior to the first occurrence of severe weather in Arkansas. Gary Jones of the Federal Emergency Management Agency (FEMA) Region VI Headquarters stated that the watches issued by the SPC enabled FEMA to place many assets on standby in preparation for the potential catastrophic tornadoes that affected the area. FEMA immediately opened lines of communication with the state Emergency Operations Center, enabling FEMA to deploy an advanced team to the stricken area within hours of the event.

Fact 9: Prior to the development of the severe thunderstorms, NWSFO Little Rock issued Special Weather Statements and a summary alerting the public to the potential of severe weather. The Special Weather Statements, issued at 10 a.m. and 12:05 p.m., and the 11:25 a.m. Arkansas Area Weather Summary, indicated that severe

thunderstorms would produce large hail, damaging wind, and isolated tornadoes. These statements also urged people to stay informed of developing weather and to stay tuned to media for the issuance of watches, warnings, and other statements.

Fact 10: NWSFO Little Rock issued a county redefining statement (a companion statement to the SPC Tornado Watch No. 75) at approximately 11:40 a.m.

Fact 11: NWSFO Little Rock issued 57 county warnings for severe thunderstorms and tornadoes, 34 of which were tornado warnings. Average lead time for all warnings was 18 minutes. Lead times for tornado warnings ranged from 6 to 20 minutes for all five Arkansas counties in which the 25 deaths and nearly all of the injuries occurred. However, lead times for tornado warnings for the communities within these counties where all the deaths and the majority of the injuries occurred was 9 to 28 minutes. This includes the warning issued by NWSFO Memphis for Greene County.

SERVICE COORDINATION

Internal

Fact 12: The potential for severe weather later that day and the resultant staffing needs were discussed by NWSFO Little Rock staff during the morning. This enabled them to arrange for extra people to be on duty to handle the WSR-88D PUP and other duties throughout the expected time of the event.

Fact 13: Several phone conversations between SPC and Little Rock were held to discuss the potential for severe weather development and the formation of tornadoes. This contributed to the preparations for additional staffing made by the NWSFO in advance of the tornado outbreak. Other coordination calls were held to discuss the issuance of the two tornado watches that affected Arkansas that day.

Fact 14: NWSFOs Little Rock and Memphis discussed the severe weather threat as the storms were moving from the Little Rock CWA toward the Memphis CWA portion of northeastern Arkansas. This helped the NWSFO Memphis staff make decisions, regarding type and timing of warnings they issued.

External

Fact 15: A long-term relationship between the NWS and local media weathercasters, which included frequent informal contacts, led to a very good working relationship between the media, in general, and the NWS. This strengthened and enhanced the warning process. Because of the trust established by this close working relationship, the media broadcast NWS information very quickly and stressed the messages' importance to their listeners and viewers.

Fact 16: Little Rock forecasters discussed the severe weather threat with the Arkansas WeatherNet, Inc. Group and asked that the spotter (Ham radio) network be activated upon issuance of the watch 3 to 4 hours before severe weather started occurring in NWSFO Little Rock's CWA. Arkansas WeatherNet personnel came into the office to operate the Ham radio equipment and to maintain a flow of information to and from the NWS office.

Fact 17: Little Rock staff made phone calls and used the National Warning System to inform the emergency operations personnel and the Adams Field Airport personnel in Pulaski County, regarding the expected tornado path through the county. These direct contacts resulted in tornado sirens being activated immediately and ultimately saved many lives.

DISSEMINATION

Finding A: Cable viewers watching "out of region" stations were more likely to not see or hear warnings since local cable providers either do not use or have override for non-local channels.

Recommendation A: Cable providers should have and use the cable override feature to ensure that all of their viewers are made aware of impending danger.

Finding B: In at least one instance, the sirens were sounded when the warning was received. The siren was sounded again when the tornado was spotted. However, this may have been confusing to some residents because during tornado drills the second siren blast indicates an "all clear" signal.

Recommendation B: The NWS WCMs should work with emergency managers, regarding the methods used to alert the public and make recommendations that will help avoid confusion during emergencies.

Finding C: The EAS system reportedly worked quite well in a number of locations, primarily in Little Rock and areas north. Several radio stations south of Little Rock reported that the EAS system did not work. Media outlets affected by the EAS problems had other means of receiving NWSFO Little Rock's warnings, thus no direct connection can be found between EAS problems and any loss of life or injuries.

Recommendation C: Little Rock transmitters, frequencies, and procedures should be inspected to ensure the EAS signals are being transmitted properly. Little Rock staff should work with broadcasters to ensure that their receivers are properly tuned and programmed to receive NWS warning products.

Finding D: Although not a factor in this event, several users noted problems with their NWWS downlinks earlier in the morning prior to the severe weather outbreak. There is no alarm on the system to alert the customer that the system has failed, thus if it fails, no data will be received until discovered by an employee. When these failures occur, customers must contact the NWWS contractor and ask to have their downlink unit reconfigured in order to have service restored. Reportedly, this happens several times each week, and one customer stated that it was nearly a daily occurrence. This instability problem could have had disastrous consequences had the downlinks failed during the event. To compound the problem, most of the customers normally have smaller and less-experienced weekend staffs.

Recommendation D: NWS should work with the NWWS contractor to address the stability issue.

Fact 18: The strongest link in the warning process was between the NWS and various other public agencies (e.g., emergency managers, Arkansas Crime Information Center, which distributes information to 650 Law Enforcement and Fire department workstations across the state), and the media (e.g., TV, radio). The weakest link of the warning process was between local warning components (e.g., sirens, TV messages, radio messages) and the public (receipt of or reaction to warnings).

Fact 19: In general, it was shown that many people felt that sirens were an effective tool in the warning system. Many people in areas without sirens felt that having sirens would have improved the warning system in terms of getting the information to more local residents.

Fact 20: Radio and TV station representatives stated that they found the NWS warnings timely, helpful, and effective. The media obtain their information from a variety of sources, and many rely on more than one source. NWWS was the most widely used among TV and larger radio stations. Smaller market radio stations rely on a wider variety of sources, including EAS, NOAA Weather Radio (NWR), The Weather Channel, Data Transmission Network, AP Wire Services, and local TV stations' broadcasts.

RESPONSE

Finding E: The long lead time of warnings created problems with some people's perception of the threat. The lack of immediate visual confirmation were misinterpreted by many people, and they did not respond immediately to the warnings. Examples: In a College Station church, a woman in choir practice heard the sirens, went to the door, and looked out. It was still bright outside so the choir continued to practice. About 15 minutes later her son informed them that debris was falling outside, and it was very dark and windy. They all took shelter in the back of the church. There were several reports of people hearing the warnings and driving to a relative's home, arriving just seconds before the tornado.

Recommendation E: With improved warning capability and the resultant increase in warning lead time, the NWS must undertake a study to determine the most effective method of conveying threat information to the public to ensure an effective and timely response.

Finding F: SPC's forecast of possible severe weather the day before assisted the emergency management community in contingency planning although not all media outlets made effective use of the information.

Recommendation F: WCMs should take the necessary steps to apprise the office's partners in the warning process of the utility of the outlook products.

Fact 21: Mobile homes continue to be a very hazardous place to remain during severe weather events. Of the 25 Arkansas deaths, 14 (56 percent) were in mobile homes. Four people (16 percent) were killed in single dwelling houses, while 3 persons (12 percent) were killed in non-residential buildings. Two fatalities (8 percent) occurred in vehicles, and 2 (8 percent) occurred outdoors.

Fact 22: The day of the week (Saturday) and time of day (early afternoon) can make people more vulnerable to receiving warnings through radio or TV due to varied activities.

PREPAREDNESS

Fact 23: Little Rock maintains a very pro-active outreach program. A Severe Weather Awareness Week is held annually with state and county government organizations being active participants. The Governor has issued public proclamations, regarding Severe Weather Awareness Week, for the past 24 years in coordination with the NWS. Little Rock has been very active in storm spotter recruiting and training. The four counties where the deaths and injuries occurred have had 1 to 2 spotter training sessions within one year of this major event.

SYSTEM/INFRASTRUCTURE

Finding G: NWSFO Little Rock has developed two velocity color schemes which were very effective and enabled forecasters to quickly pick out the strongest velocity couplets. The "normal" and "gray" color scales use bright colors to highlight the approximate velocity criteria for tornadic mesocyclones and minimal mesocyclones, respectively.

Recommendation G: NWS Regions and the OSF should encourage Weather Forecast Offices to develop alternate color schemes that will make identification of important features easier to identify for most staff members than the preset color schemes.

Finding H: Transmission of warnings on NWR was a laborious task. The Little Rock NWR operator broadcast 31 warnings, requiring 39 separate transmissions from 12 noon to 5 p.m. Multiple transmissions were necessary because several warnings needed to be broadcast on two or more transmitters. Although the NWR

operator was experienced, it took 2 to 3 minutes to complete each transmission (it typically takes 2 ½ minutes per recording). During a period from 2:04 p.m. to 3:54 p.m., a total of 16 warnings were issued, requiring 23 individual transmissions. The NWR operator remained in the NWR room throughout this time with a perpetual backlog of three warnings awaiting transmission.

Recommendation H: Work in progress to streamline some of the NWR Specific Area Message Encoding functions should be accelerated. The Console Replacement System deployment strategy should be reevaluated to ensure that severe weather-prone areas (hurricane, tornado, etc.) are among the earliest systems deployed.

Appendix A

Fujita Tornado Intensity Scale

Category	Definition-Effective
(F0)	**Gale tornado (40-72 mph): Light damage.** Some damage to chimneys; break branches off trees; push over shallow-rooted trees; damage sign boards.
(F1)	**Moderate tornado (73-112 mph): Moderate damage.** The lower limit is the beginning of hurricane wind speed; peel surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads.
(F2)	**Significant tornado (113-157 mph): Considerable damage.** Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light-object missiles generated.
(F3)	**Severe tornado (158-206 mph): Severe damage.** Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off ground and thrown.
(F4)	**Devastating tornado (207-260 mph): Devastating damage.** Well-constructed houses leveled; structure with weak foundation blown off some distance; cars thrown and large missiles generated.
(F5)	**Incredible tornado (261-318 mph): Incredible damage.** Strong frame houses lifted off foundations and carried considerable distance to disintegrate; automobile sized missiles fly through the air in excess of 100 yards; trees debarked; incredible phenomena will occur.