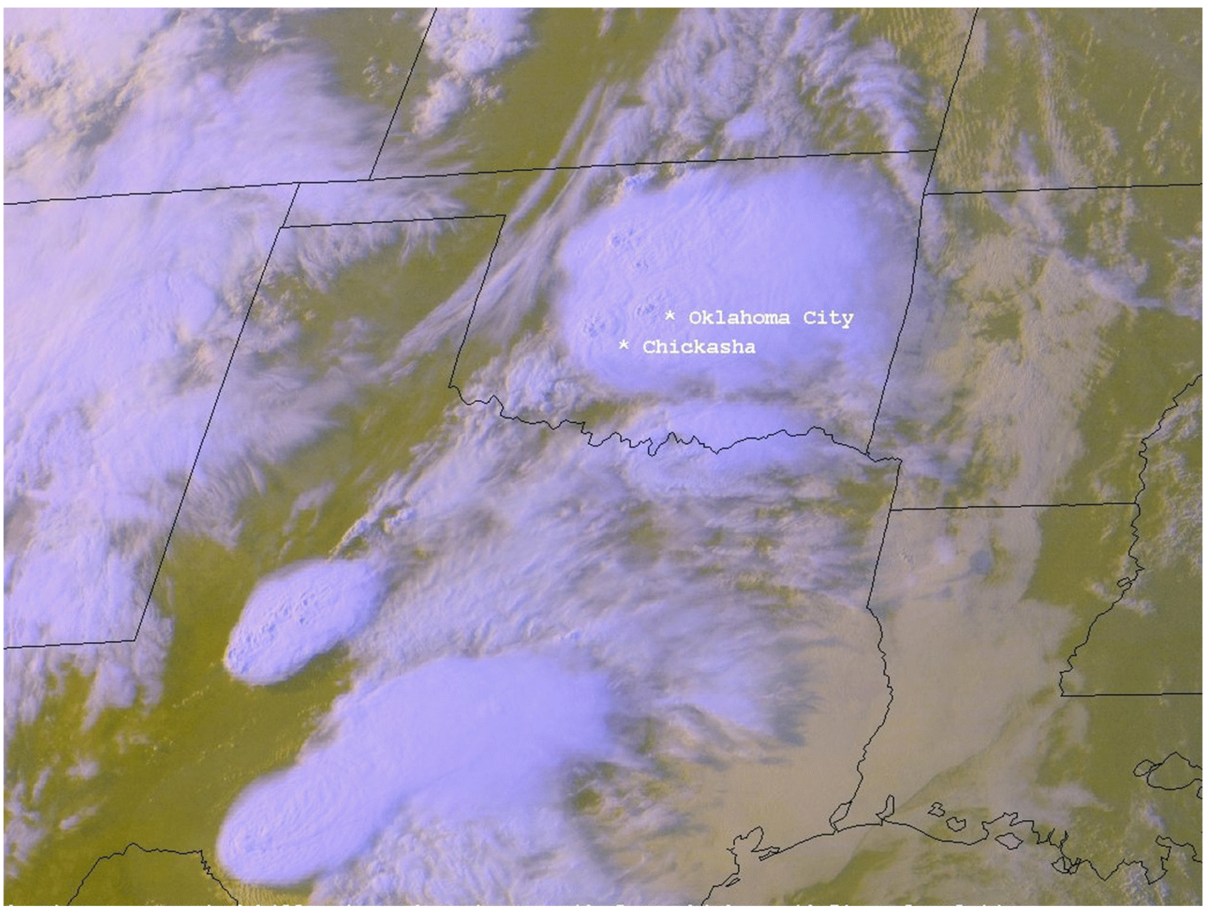
Service Assessment

Oklahoma/Southern Kansas Tornado Outbreak of May 3, 1999



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service
Silver Spring, Maryland

Cover: Supercell thunderstorms generated killer tornadoes in a swath from west-central Oklahoma through southern Kansas. Visible satellite imagery from Geostationary Operational Environmental Satellite-8, 6:45 p.m. Central Daylight Time (CDT), May 3, 1999. (Courtesy of the National Oceanic and Atmospheric Administration (NOAA)/National Environmental Satellite, Data and Information Service)

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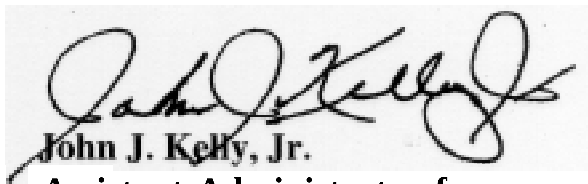
U.S. DEPARTMENT OF COMMERCE
William M. Daley, Secretary

National Oceanic and Atmospheric Administration
D. James Baker, Administrator
National Weather Service
John J. Kelly, Jr., Assistant Administrator

Preface

On May 3, 1999, one of the largest tornado outbreaks in history struck west-central Oklahoma and southern Kansas, killing 48 people, leaving thousands homeless and resulting in over $1 billion in property damage. Due to the magnitude of this event, the National Weather Service (NWS) conducted a Service Assessment to examine the effectiveness of NWS warnings and other services in minimizing loss of life and injuries.

Service Assessments are critical to the ongoing efforts of the NWS to improve the quality and timeliness of our warning services. Successful procedures are highlighted and shared with other offices; shortcomings are identified and resolved. This review process ensures that NWS forecast techniques, products and services will continue to evolve and improve.



John J. Kelly, Jr.
Assistant Administrator for Weather Services

August 1999

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Acronyms and Abbreviations

AFB	Air Force Base
AFOS	Automation of Field Operations and Services
APO	AWIPS Program Office
AWIPS	Advanced Weather Interactive Processing System
CAP	Civil Air Patrol
CAPE	Convective Available Potential Energy
CDT	Central Daylight Time
CRS	Console Replacement System
CWA	County Warning Area
EAS	Emergency Alert System
EMWIN	Emergency Managers Weather Information Network
EOC	Emergency Operations Center
FOS	Family of Services
HWO	Hazardous Weather Outlook (Product Identifier)
KICT	Wichita, Kansas, WSR-88D
KTLX	Twin Lakes, Oklahoma, WSR-88D (metropolitan Oklahoma City radar)
LDAD	Local Data Acquisition and Dissemination
LSR	Local Storm Report (Product Identifier)
MIC	Meteorologist in Charge
MSD	Meteorological Services Division (National Weather Service)
NAWAS	National Warning System
NCF	Network Control Facility
NEXRAD	Next Generation Radar
NIDS	NEXRAD Information Dissemination Service
NOAA	National Oceanic and Atmospheric Administration
NOW	Short Term Forecast (Product Identifier)
NSSL	National Severe Storms Laboratory
NWR	NOAA Weather Radio
NWS	National Weather Service
NWSFO	NEXRAD Weather Service Forecast Office
NWSO	NEXRAD Weather Service Office
NWWS	NOAA Weather Wire Service
OCS	Oklahoma Climatological Survey
OK-FIRST	Oklahoma's First-response Information Resource System using Telecommunications
ORDA	Open systems Radar Data Acquisition
ORPG	Open systems Radar Product Generator
OSF	Operational Support Facility (National Weather Service)
OSO	Office of Systems Operations (National Weather Service)

PC	Personal Computer
PNS	Public Information Statement
PUP	Principal User Processor
RUC II	Rapid Update Cycle version II
SAME	Specific Area Message Encoder
SEL	Severe Thunderstorm or Tornado Watch (Product Identifier)
SKYWARN	Term for Storm Spotter Network
SOO	Science and Operations Officer
SPC	Storm Prediction Center (National Weather Service)
SPS	Special Weather Statement (Product Identifier)
SRH	Southern Region Headquarters (National Weather Service)
SVR	Severe Thunderstorm Warning (Product Identifier)
SVS	Severe Weather Statement (Product Identifier)
SWO	Severe Weather Outlook (Product Identifier)
TOR	Tornado Warning (Product Identifier)
TPMS	Transition Power Maintenance System
WarnGen	Warning Generation (AWIPS software)
WCM	Warning Coordination Meteorologist
WDSS	Warning Decision Support System
WISEII	Warning and Interactive Statement Editor, version II
WSOM	Weather Service Operations Manual
WSR-88D	Weather Surveillance Radar-1988 Doppler (NEXRAD)
ZFP	Zone Forecast Product (Product Identifier)

Service Assessment Team

The Service Assessment Team was activated on May 4, 1999. Team members traveled to the Next Generation Radar (NEXRAD) Weather Service Forecast Office (NWSFO) Norman, Oklahoma, on May 5 and left on May 10. A team meeting and an overview of the event was held on May 5 with representatives from NWSFO Norman, Storm Prediction Center (SPC), Operational Support Facility (OSF) and National Severe Storms Laboratory (NSSL) in attendance. At that time it was learned that the emergency manager representative selected for the team was unable to participate. Four team members were designated to begin the Service Assessment in Oklahoma while the fifth was assigned to perform the Service Assessment in southern Kansas. To assist the team member in Kansas, the team leader and NWSFO Norman Meteorologist in Charge (MIC) coordinated with the OSF and selected an OSF individual to help with the Kansas Service Assessment. Before leaving Oklahoma, the team completed the first draft of the report. After completion of the field work, the team continued to gather information and collaborate on the findings before preparation of the final version of this Service Assessment.

The team was comprised of the following individuals:

Ken Mielke	Team Leader, MIC, NWSFO Great Falls, Montana
Craig Edwards	MIC, NWSFO Minneapolis, Minnesota
Mike Foster	Science and Operations Officer (SOO), NWSFO Fort Worth, Texas
Larry Vannozzi	Warning Coordination Meteorologist (WCM), NWSFO Lubbock, Texas
Curtis Carey	Southern Region Headquarters (SRH), Public Affairs Officer, Fort Worth, Texas

Other valuable contributors include:

Gayland Kitch	Director, Emergency Management and Communications, Moore, Oklahoma
Dan Carey	Safety and Emergency Management Director, Cleveland County, Oklahoma
Randall Duncan	Emergency Management Director, Sedgwick County, Kansas
John Ferree	OSF/Training Branch, Norman, Oklahoma (assisted the team with the southern Kansas Service Assessment and the writing of this report)

Dennis Walts NWS Headquarters, AWIPS Program Office (APO), Boulder, Colorado

William Lerner NWS Headquarters, Office of Meteorology, Silver Spring, Maryland

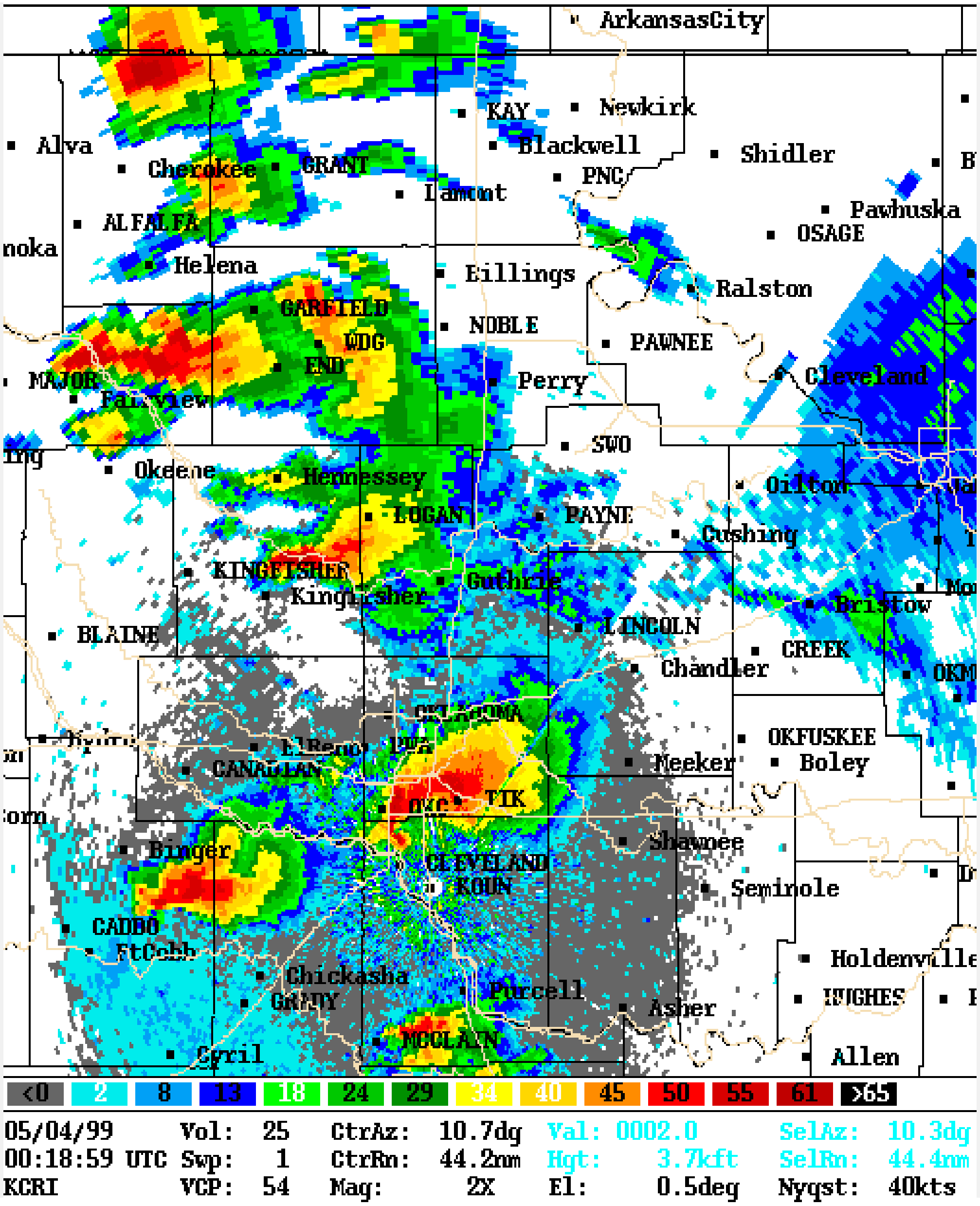
Linda Kremkau NWS Headquarters, Office of Meteorology, Silver Spring, Maryland

Robert Saffle NWS Headquarters, Office of Systems Development, Silver Spring, Maryland

Jerry Stephens NWS Headquarters, Office of Systems Operations (OSO), Silver Spring, Maryland

The Service Assessment Team also acknowledges the valuable information provided by the staffs at NWSFO Norman, Oklahoma; NEXRAD Weather Service Office (NWSO) Wichita, Kansas; and the SPC.

The tornado, which hit Moore/Oklahoma City, Oklahoma, is shown here near Amber, Oklahoma, at 6:30 p.m. CDT, May 3, 1999. (Photograph courtesy of the Oklahoma Climatological Survey)



Radar reflectivity image from the Twin Lakes, Oklahoma, WSR-88D radar at 7:18 p.m. CDT, May 3, 1999, shows several severe thunderstorms in west-central Oklahoma and southern Kansas. (Courtesy of NOAA/NSSL)

Event Overview

A large part of the central United States was hit by a significant outbreak of tornadoes and other severe weather on May 3 and 4, 1999. From the afternoon of May 3 through the evening of May 4, there was an outbreak of tornadoes from southwest Texas through southeast South Dakota. The most devastating part of this outbreak occurred during the late afternoon and evening of May 3 over Oklahoma and southern Kansas (Figure 1).

Between 6:23 p.m. and 7:50 p.m. CDT[1] on Monday evening, May 3, a long-track, violent tornado traveled from near Chickasha, Oklahoma, to just east of Oklahoma City, Oklahoma. Along its path this tornado produced areas of F5 (see Appendix A, Fujita Tornado Intensity Scale) damage to both rural sections of central Oklahoma as well as densely populated areas of Oklahoma City and its suburbs. In the wake of this single tornado, 38 people were left dead and several hundred injured. There were 4 additional fatalities outside the Oklahoma metropolitan area as a result of other tornadoes that afternoon and evening. Soon thereafter, between 8:30 p.m. and 9 p.m., another violent tornado, rated F4 intensity, plowed through Haysville in suburban Wichita, Kansas. This tornado was responsible for 6 deaths and 150 injuries. While these two tornadoes received the greatest attention, they were just two of a rare and significant outbreak of violent tornadoes. Over 70 tornadoes, many of them rated F3 or stronger, were spawned by a dozen supercell thunderstorms across Oklahoma and southern Kansas. In Oklahoma, 16 counties were declared disaster areas with $1 billion in damage; in Kansas, there was $145 million in damage and one county was declared a disaster area. What was unusual about this event was not just the number of tornadoes but the number of violent tornadoes. Event statistics are given in Appendix B.

The outbreak began around 4 p.m., May 3, when a thunderstorm developed near Lawton, Oklahoma. The storm became severe in a short time and became tornadic before 5 p.m. Moving northeastward, this storm later produced the F5 tornado that devastated parts of Bridge Creek, Oklahoma City, Moore, Del City and Midwest City. A second storm formed west of the Lawton storm and soon became tornadic. By early evening, these storms and several others were cutting a swath through central and north-central Oklahoma, with each storm producing one or more violent tornadoes. Additional storms formed over extreme northern Oklahoma. These storms soon crossed into southern Kansas and produced the tornadoes that struck Wichita.

Oklahoma City and its suburbs have been struck by numerous tornadoes over the years, most recently on June 13, 1998. Moore was hit by a tornado on October 4, 1998; the May 3, 1999, tornado crossed portions of Moore that were struck just 6 months earlier. The May 3 tornado was the first F5 tornado to strike Oklahoma City; F4 tornadoes have been reported in the city seven times before. With 38 fatalities, the May 3, 1999, tornado was the most deadly in

[1] All times listed in this Service Assessment are CDT.

Oklahoma City metropolitan area history; the previous most deadly tornado occurred on June 12, 1942, when 35 people were killed.

Wichita, Kansas, also has been struck by several tornadoes over the years. The most recent violent tornado to strike the city was on April 26, 1991, when the large tornado which devastated Andover, Kansas, killed 4 people in the southern part of the Wichita metropolitan area. The May 3, 1999, tornado, with 6 fatalities, was the most deadly for Wichita and Sedgwick County.

The Norman NWSFO issued the first severe thunderstorm warning (SVR) of the event at 4:15 p.m. and the first tornado warning at 4:47 p.m. for the storm near Lawton, Oklahoma. This storm moved northeastward and struck Oklahoma City about an hour later. By 5:52 p.m., the early stage of this eventual F5 tornado was 4 miles south of Verden, moving to the northwest side of Chickasha at 6:19 p.m. and south of Amber at 6:26 p.m (see Figure 1). The Norman NWSFO continued issuing effective warnings, short term forecasts (NOWs) and severe weather statements (SVSs). Also by this time, Oklahoma City media outlets were running continuous live coverage of the tornado with live helicopter and ground-level video. All warnings, forecasts and statements were disseminated over the NOAA Weather Wire Service (NWWS), the NOAA Weather Radio (NWR), the Family of Services (FOS), the Emergency Alert System (EAS), the National Warning System (NAWAS), and the local amateur radio network. The wide coverage of the event by the National Weather Service and media outlets, the long lead time of National Weather Service warnings, and the high state of tornado preparedness of Oklahoma residents are credited with saving many lives.

The Wichita NWSO provided an accurate warning on the development of a violent tornado that first struck the town of Haysville and moved due north into heavily populated areas of southern Wichita. The warning, based on a radar signature, received wide dissemination on NWWS, local television and radio, NWR, EAS and NAWAS. The warning prompted the activation of the siren system and initiated an all-channel cable override for Wichita. Residents followed severe weather safety plans and took cover in the lowest levels of houses or apartments, saving many lives.

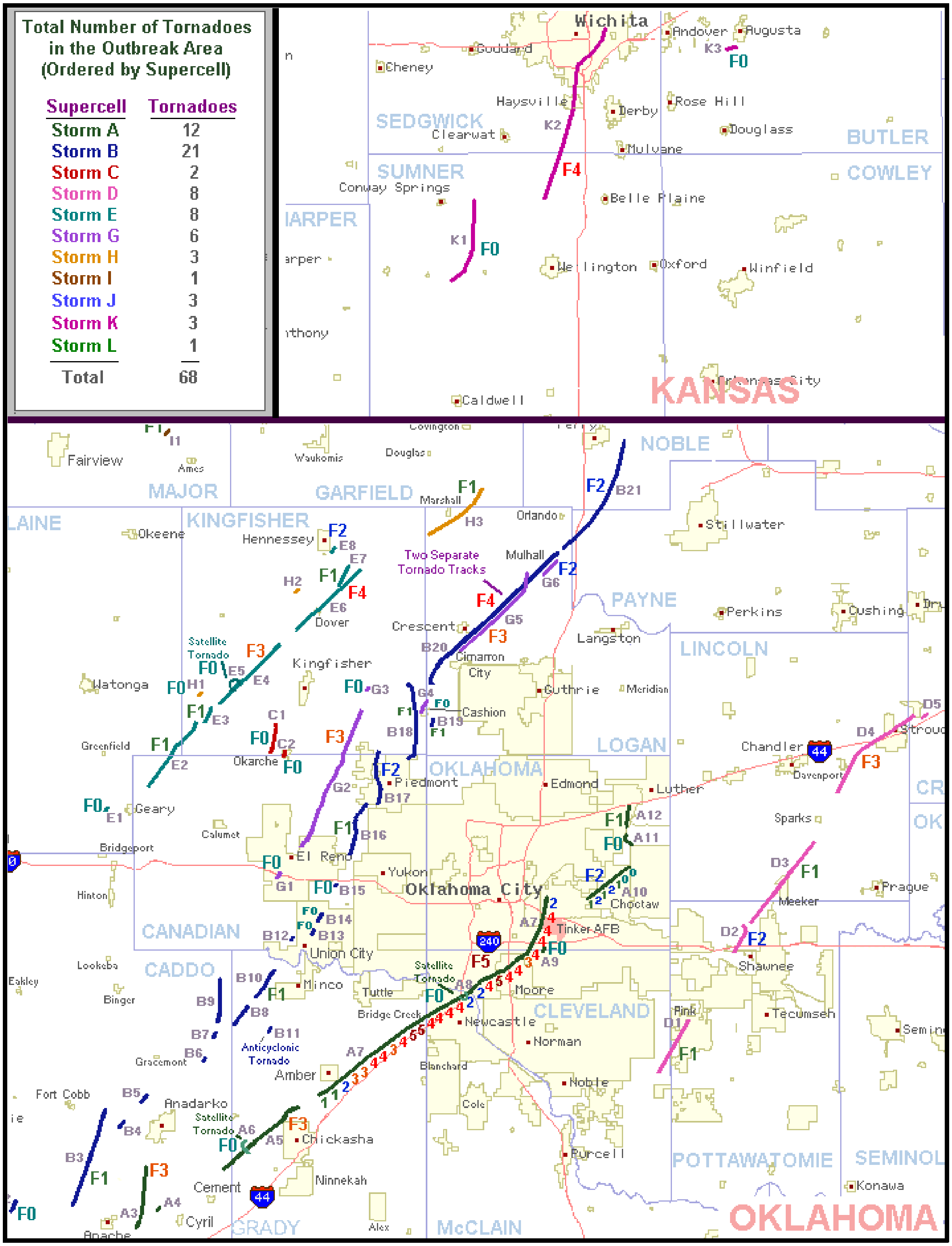


Figure 1. Approximate damage paths and highest Fujita scale ratings for tornadoes which occurred during the May 3, 1999, outbreak in west-central Oklahoma and southern Kansas. (Courtesy of Steve Kruckenberg and Douglas Speheger, NWSFO Norman, Oklahoma)

Aerial view of the Moore/Oklahoma City, Oklahoma, May 3, 1999, tornado path. The dark mud trail shows the path of the tornado in the middle foreground and center of the picture. Interstate Highway 44 is visible in the lower right through the center of the picture. (Photograph courtesy of John Jarboe, NWS Coordinator, Federal Aviation Administration Academy, Oklahoma City, Oklahoma)

Ground view of the Moore/Oklahoma City, Oklahoma, May 3, 1999, tornado path. View is looking northeast towards Oklahoma City from the Bridge Creek Community in Grady County, Oklahoma. Note swath of reddish brown earth extending to the horizon where the tornado pulled grass and other vegetation from the ground. (Photograph courtesy of William Lerner, NWS Headquarters)

Synoptic Overview

Many elements of a classical Great Plains severe weather outbreak were in place during the afternoon and evening of May 3, 1999. The synoptic-scale pattern was characterized by a large-scale middle and upper tropospheric trough over the western United States and a downstream ridge to the east (Figure 2). There was a strong upper-level jet stream on the west side of the trough with wind speeds greater than 130 knots over the west coast of the United States. Moving through the synoptic-scale trough were several smaller scale short waves, the most important of which was located along the New Mexico/Texas border by late afternoon. At the surface, a low pressure center was located along the Wyoming/Colorado border and a low pressure trough extended southward along the lee of the Rockies. In response to the approaching jet stream and short wave, several atmospheric adjustments took place over the Plains. The surface low and lee trough deepened throughout the afternoon. This caused surface winds ahead of the dryline to strengthen and a strong low-level, southerly jet stream developed from northwest Texas into Oklahoma. As a result of the strengthening surface trough and low-level jet, deep low-level moisture streamed northward into Oklahoma and Kansas. As surface heating proceeded through the afternoon, mixing of the shallow moisture over southwest Texas moved the dryline to near the western Oklahoma border. At the same time, the lapse rates in the mid-troposphere over Kansas and Oklahoma were steepening, owing to the effects of the approaching upper-level jet and short wave. These factors contributed to the development of the large atmospheric instability and vertical wind shear profiles favorable for the development of supercell thunderstorms.

With an atmosphere conducive to the development of supercell thunderstorms, the last element necessary was a triggering mechanism. By late afternoon, two bulges developed along the dryline; one located southwest of Wichita Falls, Texas, and a second near Woodward, Oklahoma. In addition, a pool of cooler, drier air over central Oklahoma resulted in a mesoscale boundary, oriented from southwest Oklahoma to south-central Oklahoma, separating the cooler air from the very warm, moist air which was streaming northward across western Oklahoma. The presence of the dryline bulges and the mesoscale boundary led to prolonged enhanced moisture convergence which resulted in explosive thunderstorm development over southwest Oklahoma by late afternoon and northwest Oklahoma to south-central Kansas by early evening.

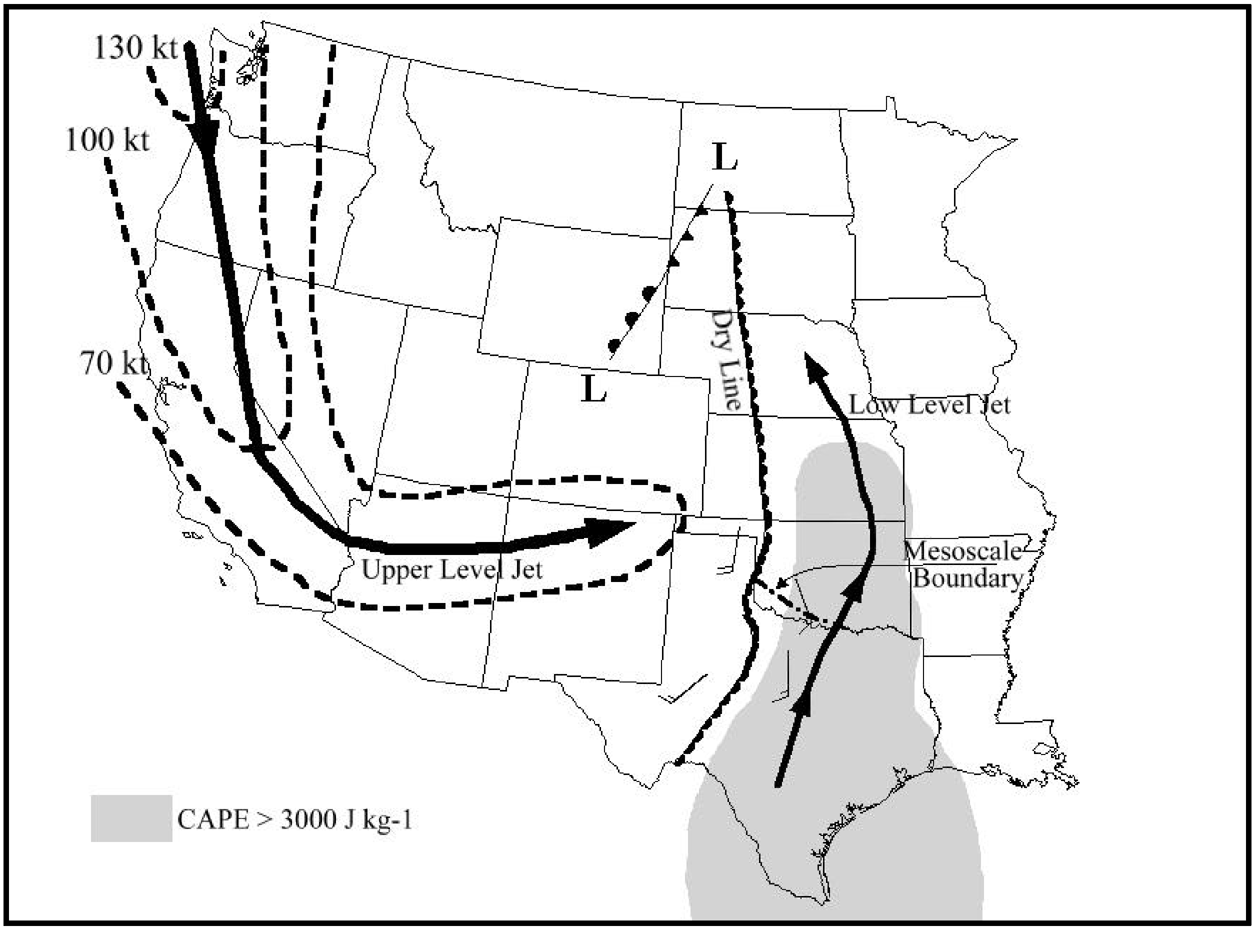


Figure 2. Significant features associated with the May 3, 1999, tornado outbreak. Depicted are the 4 p.m. CDT positions of the upper-level and low-level jets, the dryline, surface winds, and a mesoscale boundary in southwest Oklahoma. The shaded area is where the Convective Available Potential Energy (CAPE) exceeded 3000 Joules Kg^{-1}. (Courtesy of Mike Foster and Jason Jordan, NWSFO Ft. Worth, Texas)

Facts, Findings and Recommendations - Part 1
Oklahoma and Southern Kansas Outbreak Combined

National Centers for Environmental Prediction Guidance, Products and Services

FACT: The 11:15 a.m., May 3, 1999, SPC Day 1 Severe Weather Outlook (SWO) was upgraded to a moderate risk for severe thunderstorms in the Oklahoma/Kansas outbreak area based on 7 a.m. soundings, midday profiler observations and Rapid Update Cycle II (RUC II) forecasts of instability and shear.

FACT: The SPC began an Experimental Probabilistic Outlook in the spring of 1999. The forecast is made available on the SPC Forecast Products Web Page. The Experimental Probabilistic Outlook issued at 3 p.m. for Oklahoma and southern Kansas highlighted a significant chance for F2 or greater tornadoes.

Finding 1: From mid-morning to mid-afternoon on May 3, 1-hour, 250-meter interval vertical wind profiles from the profiler at Tucumcari, New Mexico, showed a descending and strengthening jet approaching Oklahoma. The jet was deeper, stronger and lower in the atmosphere than forecasts from numerical models and favored development of supercells. It was profiler data that led SPC forecasters to upgrade the SWO from moderate to high risk for severe weather in the outbreak area and caused F2 or stronger tornadoes to be highlighted in the Experimental Probabilistic Outlook (see FACT above). In the opinion of the Service Assessment Team, without profiler data, SPC forecasters would not have upgraded from moderate to high risk. Also, the state of readiness of NWS offices, emergency managers, and the media in the severe weather outbreak area would not have been as high. The profiler network is “experimental” and not funded by the NWS.

Recommendation 1: The NWS should make a decision on how to support the existing profiler network so that the current data suite becomes a reliable, operational data source.

FACT: Tornado Watch #195 for western and central Oklahoma, including Oklahoma City, was issued at 4:30 p.m., valid 4:45 p.m. to 10 p.m. The first severe thunderstorm warning was issued by NWSFO Norman at

4:15 p.m. Based on Weather Surveillance Radar-1988 Doppler (WSR-88D) radar signatures, the first tornado warning followed at 4:47 p.m.

FACT: Tornado Watch #200 for Kansas, including Wichita, was issued at 7:21 p.m., valid from 7:30 p.m. until 12 midnight. NWSO Wichita issued its first tornado warning at 7:38 p.m. (Sumner County), a severe thunderstorm warning for Sedgwick County at 7:49 p.m., and a tornado warning for Sedgwick County at 8:16 p.m.

Total destruction of a residential area in Moore, Oklahoma, as an F5 tornado ripped through this city during the evening of May 3, 1999. (Photograph courtesy of Curtis Carey, NOAA/NWS Public Affairs)

Oklahoma Outbreak Summary
NWSFO Norman, Oklahoma

Summary of Warning and Forecast Services

The potential for severe weather in Oklahoma was reflected in National Weather Service forecast products as much as 36 hours prior to the outbreak. The May 2 SPC Day 2 SWO (valid May 3) and the May 3 Day 1 SWO predicted a slight risk for severe weather. At 6:30 a.m. on May 3, NWSFO Norman issued a Thunderstorm Outlook, noting a slight risk of severe storms in western and central Oklahoma that afternoon and night. It mentioned the increasing low-level moisture, dryline and approaching upper-level low pressure trough would combine to cause a threat of hail, damaging winds and isolated tornadoes. It also cautioned emergency managers and spotter groups to be prepared for possible activation in the afternoon.

Forecasts later that day advertised an increasing possibility of severe storms. The 11 a.m. SPC Day 1 Outlook upgraded much of the eventual outbreak area to a moderate risk, as did the 12:30 p.m. Thunderstorm Outlook issued by NWSFO Norman. The increasing risk was further reflected when the 3:49 p.m. SPC Day 1 Outlook upgraded the risk once again—this time to a high risk.

The Norman NWSFO issued the first severe thunderstorm warning (SVR) of this event at 4:15 p.m. Soon after, the SPC issued Tornado Watch #195 for western and central Oklahoma, valid from 4:45 p.m. until 10 p.m. The first tornado warning was issued at 4:47 p.m. About 10 hours later, after the main part of this event concluded, NWSFO Norman had issued 70 tornado warnings and 46 severe thunderstorm warnings for 32 of the 56 counties within its county warning area (CWA) (see product chronology highlights in Appendix C).

The Norman Office of the National Weather Service was very successful in giving the public significant advance warning of the individual tornadoes. They achieved a remarkable 32-minute lead-time average for the first tornado warning issued in each of the Oklahoma City metropolitan area counties that was affected by the F5 tornado. Warnings for this Oklahoma City F5 tornado, which hit Grady, McClain, Cleveland and Oklahoma Counties, were issued with lead times of 65, 18, 31 and 13 minutes, respectively.

These excellent lead times were a function of several factors. These included very good severe weather knowledge and radar interpretation skills, modernized National Weather Service equipment (especially the WSR-88D and the Advanced Weather Interactive Processing System [AWIPS]), a well-trained and widespread spotter network and the long-lived nature of several of the tornadoes. Another factor, cited by the NWSFO staff, was the use of "sectorized" warning operations. The use of multiple AWIPS workstations, all with the same data and capabilities, permitted forecasters to divide warning responsibility by geographic area. This geographic division of responsibility improved efficiency and warning strategy during this widespread outbreak. The NSSL-developed Warning Decision Support System (WDSS) software also proved to be a useful tool during this event.

In addition to its excellent National Weather Service warnings, NWSFO Norman kept the public informed with numerous SVSs, NOWs and Local Storm Reports (LSRs). During the most active period of this event (4 p.m. until midnight), they issued 48 concise SVSs, 9 NOWs and 14 LSRs.

At 5:41 p.m., a NOW was issued alerting the Oklahoma City metropolitan area of severe thunderstorms and possible tornadoes. In part, this NOW read,

> **SEVERE THUNDERSTORMS...SOME PRODUCING TORNADOES...WILL MOVE NORTHEAST ACROSS PORTIONS OF SOUTHWEST AND CENTRAL OKLAHOMA THROUGH 6:30 PM.**

This NOW went on to state,

> **THE STORMS WILL BE MOVING TOWARD THE OKLAHOMA CITY METROPOLITAN AREA. IN ADDITION TO VERY LARGE HAIL AND DAMAGING WINDS...THESE STORMS MAY ALSO CONTINUE TO PRODUCE TORNADOES. IF YOU ARE IN THE PATH OF THE THUNDERSTORMS... EXERCISE YOUR TORNADO SAFETY PROCEDURES!**

To heighten awareness of the severity of the situation, the office alarmed several SVSs on NWR and issued an effective SVS at 6:57 p.m. that included the words **"TORNADO EMERGENCY"** in the headline. Following is a portion of that SVS:

> **...TORNADO EMERGENCY IN SOUTH OKLAHOMA CITY METRO AREA...**
>
> **AT 657 P.M .CDT...A LARGE TORNADO WAS MOVING ALONG INTERSTATE 44 WEST OF NEWCASTLE. ON ITS PRESENT PATH...THIS LARGE DAMAGING TORNADO WILL ENTER SOUTHWEST SECTIONS OF THE OKLAHOMA CITY METRO AREA BETWEEN 715 P.M. AND 730 P.M. PERSONS IN MOORE AND SOUTH OKLAHOMA CITY SHOULD TAKE IMMEDIATE TORNADO PRECAUTIONS!**
>
> **THIS IS AN EXTREMELY DANGEROUS AND LIFE THREATENING SITUATION.**

All NWS warnings, forecasts and statements were disseminated via the NWWS, NWR, FOS, EAS, NAWAS, the local amateur radio network, and the Emergency Managers Weather Information Network (EMWIN). NWS information was also disseminated by local television and radio stations, as well as through the Internet and OK-FIRST (Oklahoma's First-response Information Resource System using Telecommunications).

Two situations developed that could have impacted NWS warning services, but did not, thanks to a competent staff and pre-existing agreements. First, a number of warnings were not automatically sent through the Console Replacement System (CRS) to the NWR. Of the 72 warnings that were issued within NWR listening areas, 14 (19 percent) had to be done manually with only slight delays. The causes of most of the malfunctions were traced back to software issues with CRS/Airwave/Bubble (Airwave and Bubble are product formatting software which serve as an interface between AWIPS and CRS). Fixes for some of these problems were tested just days after the outbreak.

Second, telephone service, including cellular, was intermittent (at best) from around 6:30 p.m. until midnight—the duration of most of the outbreak. As the main tornadic storm approached NWSFO Norman, staff members used NAWAS to contact surrounding NWS offices to coordinate possible back-up support. Despite the lack of consistent phone service, numerous severe weather reports continued to flow into the NWSFO thanks to spotters, amateur radio operators and NAWAS.

Public Response

The fact that casualties were low (compared to the many thousands that were affected by the main Oklahoma City tornado) is, in large part, attributable to the effective response of the public to early National Weather Service severe weather warnings. To help enhance public response, the Norman NWSFO has conducted an aggressive preparedness campaign for years in Oklahoma. Within the 3 months prior to the outbreak, 32 spotter training classes were held. In the 5-month period leading up to the outbreak, the office hosted 9 tours, conducted 4 safety presentations, participated in 3 televised safety shows and presented 2 safety displays (information booths) within its CWA. The office also has been active in the state's annual severe weather awareness week.

Oklahoma City radio and television stations also played a crucial role that led to effective public response. They rapidly communicated National Weather Service warnings and gave hours of live coverage of spotter reports, aerial video and ground-level video of the tornadoes. Using the cable television override capability, the Moore City Emergency Manager broadcast NWS warnings (audio only) to the community. Many radio stations provided simulcasts of the live telecasts from the three primary television stations, as the main tornado approached the Oklahoma City metropolitan area. One television station urged people to get out of the path of this destructive tornado. This statement was cited as one of the reasons many people fled the path of the tornado, only to return to damaged or demolished property. It should be noted that fleeing a tornado is not recommended but was effective in this particular event due to lengthy National Weather Service warning lead times, as well as the tornado's intensity and longevity.

Post-Storm Feedback

Positive feedback after the outbreak was overwhelming. Local and national news coverage often mentioned the advance warning provided by the National Weather Service and live video coverage by Oklahoma City television stations. Interviews with a number of local radio stations indicated the NWR information was very helpful in their efforts to alert the public. After the event, NWSFO Norman issued a series of informative Public Information Statements (PNSs) on May 4 and 5. These statements provided considerable detail regarding tornado paths, preliminary intensities and comparisons to previous Oklahoma City tornadic events. In addition, NWSFO Norman, as well as the SPC and NSSL, posted photographs, preliminary tornado tracks, storm time lines and informative summaries on their Web pages which served as a source of information for the media and other users.

Emergency managers were pleased with the severe weather information supplied by various National Weather Service dissemination systems. Of special note was the Oklahoma Climatological Survey's (OCS) OK-FIRST, which emergency managers cited as a valuable tool during the outbreak. A large Oklahoma City business called the Norman NWSFO after the outbreak to express thanks for assistance in updating the company's safety plan prior to this event. Unlike the company's previous plan, the new plan instructed employees to seek shelter at that location rather than to drive away. Since the tornado passed close to this business, this change in the plan may have saved lives and prevented injuries.

The Norman NWSFO developed excellent working relationships with local emergency managers. The strong partnerships eased the communication process during the severe weather outbreak and also enabled NWS officials to gain access to the damaged areas to conduct surveys. Many of the severely damaged areas remained barricaded by the National Guard and/or local law enforcement until at least May 9, 1999.

Summary

This was a unique event. Despite the large number of tornadoes in the NWSFO Norman CWA and the tremendous devastation in residential areas, casualties were minimal for several reasons.

- One very large tornado caused most of the damage and casualties.
- National Weather Service tornado warnings were issued with long lead times.
- There were live, on-the-scene broadcasts of the tornado on the local Oklahoma City television stations well before it reached the densely populated metropolitan area.
- The main tornado struck in late afternoon and early evening after schools were out and most commuter traffic had reached its destination.

- Residents were well-versed in tornado safety precautions due to extensive training and outreach by the National Weather Service, local news media and emergency management agencies.

Had this tornado struck during the late nighttime hours, even with the long National Weather Service tornado warning lead times, the number of casualties could have been much higher.

In summary, the public was very well served by the National Weather Service in Norman prior to and during this significant event. Effective warnings and follow-up statements minimized loss of life and property.

An F5 tornado wrapped a large 4-wheel drive pickup around a utility pole, stripping off most of the truck's sheet metal. (Photograph courtesy of Curtis Carey, NOAA/NWS Public Affairs)

F5 damage to a home in Moore, Cleveland County, Oklahoma, May 3, 1999. Note most debris has been blown away. (Photograph copyright 1999. The Oklahoma Publishing Co.)

Wooden projectiles driven into the ground by the tornado on the west side of Oklahoma City, Oklahoma, May 3, 1999. Note different directions of impact. (Photograph courtesy of William Lerner, NWS Headquarters)

Facts, Findings and Recommendations - Part 2
Oklahoma Outbreak

Local Office Warning and Forecast Service

FACT: At 12:30 p.m., May 3, a Thunderstorm Outlook was issued by NWSFO Norman upgrading the western half of Oklahoma to a moderate risk of severe thunderstorms. It noted the likelihood for some supercell thunderstorms and isolated tornadoes. Emergency managers and spotter groups were encouraged to be ready for possible activation later that afternoon.

FACT: During the main part of this severe weather episode (4 p.m., May 3, until 2 a.m., May 4), NWSFO Norman issued 116 warnings (70 tornado warnings; 46 severe thunderstorm warnings). In the Oklahoma City metropolitan area, the average lead time for the *first* tornado, in each county warned, was 32 minutes. NWSFO Norman's average lead time for *all* tornado warnings issued during this event was 18 minutes.

FACT: At 6:57 p.m., NWSFO Norman issued a uniquely worded SVS (headlined **"TORNADO EMERGENCY IN SOUTH OKLAHOMA CITY METRO AREA"**) which heightened awareness of this serious situation. It urged people in Moore and south Oklahoma City to take immediate tornado precautions (25 minutes before the tornado entered those areas). This SVS was formatted with the Specific Area Message Encoder (SAME) information and was tone-alerted on NWR. The phrase was picked up by media outlets and credited with adding the emphasis that prompted numerous residents to action.

FACT: Two members of the OSF assisted with the operations of the Norman NWSFO Principal User Processor (PUP) during the event and provided helpful feedback/analysis to the operational forecasters.

Systems

Weather Surveillance Radar-1988 Doppler (WSR-88D)

FACT: Most radar-based tornado warning decisions at NWSFO Norman were made using the base reflectivity, storm relative velocity and Vertically Integrated Liquid products from the WSR-88D.

FACT: One communications equipment malfunction (resulting in the loss of one volume scan) occurred with the Twin Lakes WSR-88D (KTLX) radar during the tornado event. The OSF Hotline staff (in the same building) came to the NWSFO to reset the WSR-88D. The forecast office staff did not have to become involved in problem resolution. That level of service is not available at other NWS field offices.

FACT: This Service Assessment focuses on the Oklahoma City and Wichita area tornadoes. However, it is noteworthy that, within this severe thunderstorm and tornado outbreak area on May 3, NWSO Wichita and NWSFO Tulsa were able to provide effective warning services during this event through the use of nearby WSR-88Ds. This is a testimony to the effectiveness of the redundant WSR-88D coverage (mainly east of the Rockies) and the back-up procedures employed by these two offices.

Finding 2: The NWSFO Tulsa WSR-88D gearbox malfunctioned and dropped into the azimuth electrical harness on May 2 at 10 a.m. Depot maintenance was dispatched from OSF within 4 hours and brought the system up 24 hours later.

Recommendation 2: Once the gearbox problem is determined, the OSF should implement appropriate maintenance procedures and/or fixes at all WSR-88D sites.

Warning Decision Support System (WDSS)

FACT: The NSSL-developed WDSS provided useful information to the warning staff at NWSFO Norman during the outbreak. WDSS offers access to the full wide-band suite of reflectivity and velocity data, improved algorithm guidance, and dynamic tables which rank storms according to algorithm-derived severe weather threats.

Finding 3: WDSS severe storm cell tables and trend displays focused the forecasters' attention on those storms that could require warning. WDSS displays of full resolution velocity products were confidence builders for tornado warning decisions. WDSS also incorporates advanced versions of the NSSL mesocyclone detection and tornado detection algorithms. The NEXRAD Open systems Radar Product Generator (ORPG) is required to implement advanced algorithms and to provide high resolution products to AWIPS for these WDSS capabilities. The NEXRAD Open systems Radar Data Acquisition (ORDA) will provide improved base data (e.g., high resolution reflectivity, better anomalous propagation suppression).

Recommendation 3: The National Weather Service should give high priority to the ORPG and ORDA projects and to the incorporation of high resolution WSR-88D data in the AWIPS Build 5.X series.

NOAA Weather Radio (NWR) / Console Replacement System (CRS) Performance

FACT: The CRS automated voice was used by NWSFO Norman during the event. CRS proved to be beneficial overall, as many statements and warnings reached the public faster than would have been possible via manual recordings.

FACT: Despite the speed advantage provided by CRS, there were some adverse occurrences. In NWSFO Norman's NWR coverage areas, 14 warnings (19 percent of the warnings broadcast) required manual transmission through the CRS Emergency Override. Quick action by the NWS enabled these warnings to be broadcast with delays of less than 60 seconds.

FACT: Fourteen warnings were not automatically broadcast due to software problems. CRS's Airwave formatter did not accept warnings with three bullets of information (compared to the "typical" four-bullet format referenced in Operations Manual Letter 1-98). CRS did not accept warnings that contained the "&" symbol (signifying a severe weather report) if that symbol was positioned before the latitude/longitude coordinates in WarnGen-created warnings; this symbol caused Airwave to lock up. Two warnings were not automatically broadcast due to the "Active/Inactive" bug (products flagged as neither active nor inactive, thus are not broadcast). Also, a software problem occurred with Bubble's communication with CRS (the "escape-a" bug).

The first two problems listed above were fixed by field personnel within days of the outbreak. The third was fixed with a patch from CommPower (a work-a-round was available on the NWS CRS Home Page 2 days after the outbreak). The fourth problem remains unsolved as of this writing.

FACT: To heighten awareness, 24 of the 48 SVS products issued during this event were broadcast using the warning alert tone. Because most SVS products are not tone-alerted, these urgent SVSs required manual intervention. CRS's Airwave formatter, along with AWIPS's WarnGen software, do not have the capability to produce both non-tone-alerted and tone-alerted SVS products.

Finding 4: Various CRS formatters in field offices provide a useful service but do not satisfy the needs of all offices. In addition, there are operational problems associated with most of these formatters. There is a need for standardized CRS formatter software to provide an efficient, reliable interface between AWIPS and CRS. Earlier this year, NWS regional representatives provided OSO a set of field requirements for a universal CRS formatter.

Recommendation 4a: OSO should establish a schedule for the development and implementation of universal, AWIPS-based, and nationally supported formatters for CRS.

Recommendation 4b: In the interim, OSO should establish a national forum to collect and publicize improvements and fixes that have been made to the CRS formatters currently in use.

AWIPS Performance

FACT: AWIPS was critical to the success of this event. It would have been impossible to duplicate the number of successful warnings and lead times and to keep track of the large number of severe storms with a mixture of PUPs, PCs and Automation of Field Operations and Services (AFOS) systems.

Finding 5: All warnings at NWSFO Norman were generated with WarnGen (AWIPS Build 4.1.1); the staff invested substantial effort during the months prior to the event, customizing preformats for warnings and SVSs, which included the generation of detailed city boundary backgrounds.

Recommendation 5: NWS regions should ensure that all forecast offices customize warning preformats and generate city boundary backgrounds for their CWAs.

Finding 6: AWIPS pixel replication zoom distortion led forecasters to supplement WSR-88D velocity data with alternate display systems (e.g., WDSS). AWIPS Build 4.2 provides non-distorted magnification but requires more time to display the product. Substantial improvement in performance will not be possible with the existing AWIPS hardware.

Recommendation 6a: For the near term Build 5 time frame, the AWIPS Program Office (APO) should make modifications that result in more rapid display of non-distorted magnified products within the existing AWIPS framework.

Recommendation 6b: For the long term, the APO should evaluate what improvements in display time could be achieved for non-distorted magnification of WSR-88D products as AWIPS hardware and software evolve.

Finding 7: The Norman NWSFO accessed, via the Internet, data sets not available through AWIPS and helped forecasters focus on the convective initiation over southwest Oklahoma. These included:

< Advanced Regional Prediction System model output from the Center for the Analysis and Prediction of Storms at the University of Oklahoma,
< RUC II model output, and
< the Oklahoma mesoscale network.

Methods for ingesting data sets into AWIPS, via Local Data Acquisition and Dissemination (LDAD), have been implemented at a few forecast offices but are not widely known or documented.

Recommendation 7: The APO should provide to the Regions for distribution to field offices documentation and procedures for using LDAD to ingest data sets not available through AWIPS.

FACT: The Norman NWSFO SOO alerted the Network Control Facility (NCF) at 5 p.m. and requested enhanced monitoring. The NCF opened a remote terminal session into Norman and was ready for problem resolution. When one of the radar data streams stopped coming into the AWIPS, the SOO notified NCF personnel who promptly performed a modem reset. This was the only modem reset required during this event.

FACT: The AWIPS program that sends data to AFOS failed once and delayed one warning by 30 seconds. Because this process fails often at NWSFO

Norman, the SOO anticipated this and had a remote terminal window open and ready to run “startAFOS.”

Finding 8: AWIPS performed very well during this event. However, two interruptions of AWIPS processes (e.g., AWIPS to AFOS communication and WSR-88D to AWIPS communication) led to delays in product receipt and transmission. An additional delay was caused by having to contact the NCF. Also, a potential AWIPS point of failure, with respect to contacting the NCF, is possible when phone lines are unavailable, as was often the case at NWSFO Norman during this event.

Recommendation 8: The APO should develop a method to allow local restart of basic AWIPS processes, saving valuable time during severe weather events.

Internal and External Coordination

FACT: The Norman NWSFO’s strong partnership with the amateur radio community in central and western Oklahoma proved very valuable on May 3. Amateur radio information played a crucial role in the warning process and in subsequent follow-up information (SVSs and LSRs). Seventy-five severe event reports were received via the amateur radio network. The office’s amateur radios were of even greater importance that night since its phone service was often interrupted for several hours (6:30 p.m. until at least midnight).

FACT: Amateur radio repeaters helped keep the Norman NWSFO in contact with spotters and Emergency Operations Centers (EOCs) throughout the far reaching counties in its CWA. This was critical for these outlying communities because local TV coverage was focused on the Oklahoma City metropolitan area F5 tornado.

FACT: Post-storm visibility with the media was very positive. Local and national news coverage focused on the advance warning provided by the National Weather Service and the extensive live video coverage by the Oklahoma City TV stations. NWS Headquarters, SRH, NWSFO Norman, SPC, OSF and NSSL all participated in interviews following the event. There were over 200 media contacts following this event. Pro-active efforts by NOAA Public Affairs included:

- Press conference by NWSFO Norman, the SPC, OSF and NSSL on May 4, 1999.
- Press conference in Washington, DC, by NOAA Administrator D. James Baker and NWS Deputy Director John Jones.

- Several press releases and media advisories.
- A multitude of pro-active interviews with local reporters. Coverage included stories in several major newspapers and news magazines plus interviews and related coverage by the major television networks.

FACT: Soon after the live broadcast of the Presidential visit to the city on May 8, 1999, a TV newscaster from the Oklahoma City NBC affiliate, KFOR, thanked the National Weather Service for the advance warning.

FACT: The Moore Emergency Manager included a severe weather awareness insert in the city's water bills to residents during severe weather awareness week (held 2 months prior to the tornado). The insert gave specific instructions on what the residents should do in the event of a tornado. The Norman NWSFO gave technical assistance to the emergency manager on this project.

FACT: A large Oklahoma City area telecommunications company called NWSFO Norman after the tornado to express thanks for their assistance in updating the company's severe weather safety plan, completed prior to the tornado. The new plan instructed employees <u>not</u> to travel home during a tornado for safety reasons. This was a significant change from the previous plan, which allowed employees to go home. The new plan may have saved lives since the F5 tornado passed within 1 mile of the company.

Dissemination

FACT: Interviews with several Oklahoma City radio stations (KNOR, KOMA, KQCV, KTOK, KATT, KYIS, KCYI, KNTL and WWLS) indicated that NWR information was used often in their operations during the outbreak. One general manager said that he was "grateful" for the NWR service, while another station's official said that his station "lives and dies by" NWR.

FACT: CRS voice quality was not a major issue in this event, at least with the limited number of customers interviewed. During the event, some stations played the actual NWR automated voice on the air, although one radio station's general manager acknowledged that they did not air the actual broadcast due to CRS's "poor voice quality." In the weeks following the event, NWSFO Norman received some voice quality complaints from the public.

FACT: The Deputy Director of the Oklahoma Civil Emergency Management agency stated EMWIN provided prompt information to the emergency managers during this event. He further stated EMWIN is one of the most valuable emergency management tools to come along in many years.

FACT: Local emergency management officials cited the OK-FIRST system as a very helpful weather information tool. The OK-FIRST system includes Internet access to real-time WSR-88D radar data plus all NWS text products. This system was developed by the Oklahoma Climatological Survey. The Norman NWSFO staff and OSF Training Branch assisted the OCS in its extensive training of OK-FIRST users.

Finding 9: In addition to the NWS text products, such as warnings and follow-up statements, real-time radar data was available to some emergency managers via OK-FIRST. These radar data provided valuable information on storm structure, location and track of the storms. A basic set of WSR-88D products will soon be available (in Build 4.3) on the AWIPS Satellite Broadcast Network. However, these products cannot be made available outside the NWS until the NEXRAD Information Dissemination Service (NIDS) contract expires.

Recommendation 9: The APO should devise a method that can be implemented, once the NIDS vendor contract expires, whereby partners and customers can access a basic set of radar products in real-time.

Response

FACT: The ample National Weather Service warning lead times and live local TV coverage allowed many individuals to escape the path of this tornado (from their homes) via automobile.

FACT: A Grady County resident living in an area with primarily mobile homes credited advance National Weather Service warnings with saving many lives in his neighborhood. The early warning gave his family time to gather neighbors into his storm cellar. Thirty-five people crammed into the cellar. The winds from the F5 tornado pulled the cellar door open, but all survived. Their mobile homes were destroyed.

FACT: Citing advance National Weather Service warnings, a Grady County Deputy Sheriff was able to pre-position himself close to the projected path of the tornado to immediately deploy into the stricken area after it passed. As a result, he was on the scene of some of the worst destruction in his county and delivered emergency care to casualties.

FACT: An award ceremony at West Moore High School could have ended in disaster without the quick thinking of the school's assistant principal. The assistant school principal ushered the participants and guests into the interior hallways and bathrooms. The roof of the gym was ripped off by the tornado. There were no fatalities at the school.

FACT: Using National Weather Service warnings and radar information, as well as their own radars, TV stations in Oklahoma City are credited with helping save many lives. TV coverage of the Oklahoma City metro area F5 tornado is regarded as an extraordinary event. Two news helicopters flew adjacent to the tornado reporting the location and path to the public. One station simultaneously showed a text box on the screen with projected street names the tornado would hit and approximate time the tornado would reach a particular site.

Finding 10: Two deaths were attributed to individuals seeking shelter under highway overpasses during this event. There were also reports of people who were severely injured after seeking shelter under overpasses.

Recommendation 10: NOAA Public Affairs, with assistance from the Office of Meteorology, should update tornado safety brochures with statements which warn against seeking shelter under overpasses during a tornadic event.

Training

FACT: The Norman NWSFO staff completed a severe weather drill just prior to the May 3, 1999, outbreak. One part of the drill was a scenario which simulated a violent tornado approaching Oklahoma City. Each forecaster was required to write appropriate warnings and NOWs for such an event.

Management Procedures

FACT: The Norman NWSFO has encouraged and nurtured a productive partnership with the local agencies, the University of Oklahoma and the public to assist in weather-related scenarios. Early in the morning on May 4 following the tornado outbreak, there were enough qualified volunteers (including volunteers from all local NOAA components) to assemble nine storm survey teams. These quality surveys were posted on the NWSFO Norman Home Page soon after the event. This was very helpful to the Service Assessment Team. Although such a rapid and thorough survey cannot be expected at other offices in the country, it does point to the importance of being prepared for a quick response.

Devastating tornado damage in the small community of Haysville, south of Wichita, Kansas. (Photograph courtesy of John Ogren, NWSO Wichita, Kansas)

Southern Kansas Outbreak Summary
NWSO Wichita, Kansas

A destructive tornado moved through south-central Kansas on the evening of May 3, 1999 (see Figure 1). The hardest hit area extended from Haysville northward into the southern sections of Wichita. NWSO Wichita provided accurate information on the tornado as it developed in northern Sumner County and moved north into Sedgwick County. As the tornado tracked towards the southern sections of the city of Wichita, it veered to the northeast, sparing a strike on the center of the city.

Summary of Warning and Forecast Services

Early in the day, the operational staff was aware that there was potential for severe thunderstorms on Monday evening, May 3. The SPC included the area in a slight risk for severe thunderstorms in the 7 a.m. Day 1 SWO. Following the 11:15 a.m. Day 1 SWO, elevating the potential to a moderate risk, NWSO Wichita issued a Hazardous Weather Outlook (HWO) at 12:18 p.m. for the potential of severe thunderstorms and the possibility of isolated tornadoes. At 3:49 p.m., the SPC upgraded the Day 1 SWO to indicate the high risk for severe thunderstorms in central Oklahoma and central Kansas.

A NOW was issued at 4:12 p.m., announcing the expected development of thunderstorms between 5 p.m. and 7 p.m. stating,

> **"SOME OF THE THUNDERSTORMS WILL BE SEVERE...PRODUCING LARGE HAIL AND DAMAGING WINDS. ISOLATED TORNADOES ARE ALSO POSSIBLE."**

Another NOW was issued at 6:38 p.m. indicating,

> **"THUNDERSTORMS WILL DEVELOP RAPIDLY THIS EVENING.... NOW IS THE TIME TO REVIEW YOUR SEVERE WEATHER SAFETY PLANS."**

Thunderstorms developed rapidly over south-central Kansas between 6:45 p.m. and 7 p.m. The shift supervisor called to request SKYWARN activation around 7 p.m. At 7:17 p.m., NWSO Wichita issued a severe thunderstorm warning for Harper County, based on the potential for large hail, as indicated by the WSR-88D. The SPC issued Tornado Watch #200 at 7:21 p.m., valid from 7:30 p.m. to midnight.

At 7:19 p.m., the Wichita WSR-88D malfunctioned. The shift supervisor initiated immediate remedial actions by calling the OSF Hotline. Next, he attempted to correct the failure by working with the OSF from the Radar Data Acquisition site. In the intervening time, the other forecaster initiated a dial back-up to the Vance Air Force Base (AFB) radar to ingest imagery on the PUP. At 7:38 p.m., the Vance AFB WSR-88D indicated strong rotation in Sumner County, and a tornado warning was issued by NWSO Wichita valid until 8:15 p.m. for northern Sumner County.

Since NWSO Wichita was dialed into the Vance AFB WSR-88D via the PUP, radar imagery was not available on AWIPS. The full capability of WarnGen, the AWIPS-resident warning generation tool, cannot be realized without current radar imagery. Therefore, the staff used the back-up PC-resident software (Warning and Interactive Statement Editor, version II [WISEII]) to issue severe weather warnings. It should be noted that AWIPS Build 4.2, which will be installed at all NWS offices this summer, will have a continuous dial capability to nearby radars allowing forecasters to use the full capability of WarnGen if the primary WSR-88D should malfunction.

A severe thunderstorm warning was issued for Sedgwick County at 7:49 p.m. based on a spotter report of dime-size hail at 7:45 p.m. near Haysville. The storm later produced golfball-size hail in the city of Wichita. Based on radar data from the Vance AFB WSR-88D, which depicted a dramatic increase in the rotational velocities within the mesocyclone, NWSO Wichita issued a tornado warning for northern Sumner County and southeast Sedgwick County at 8:16 p.m., valid until 9:20 p.m. The warning was corrected 2 minutes later to indicate the warning was for northern Sumner and *eastern* Sedgwick County. The tornado warning was relayed from NWSO Wichita to the Sedgwick County EOC at 8:17 p.m. The 911 dispatcher activated the siren system and initiated an all-channel cable override for Wichita.

A tornado entered Sedgwick County moving north at 30 mph from Sumner County. Damage was rated at F1 as it crossed into Sedgwick County about 8:30 p.m. Around 8:35 p.m., the tornado struck the town of Haysville with F2 to F3 intensity. An isolated section in north Haysville suffered F4 damage.

An SVS issued at 8:33 p.m. read,

> **"TRAINED SPOTTERS AND RADAR INDICATED A TORNADO ON THE GROUND NEAR PECK ON THE SUMNER/SEDGWICK COUNTY LINE. THIS TORNADO WILL PASS THE KANSAS TURNPIKE JUST SOUTH OF HAYSVILLE AT ANY TIME."**

Another SVS issued at 8:46 p.m. asserted,

> **"AT 8:43 P.M. ...DOPPLER RADAR INDICATED A TORNADO ENTERING SOUTH WICHITA...FROM THE HAYSVILLE AREA. ...A TORNADO WAS REPORTED IN HAYSVILLE WITH STRUCTURAL DAMAGE AROUND 8:35 P.M. PERSONS IN WICHITA SHOULD TAKE SHELTER IMMEDIATELY."**

As the tornado turned to the northeast, it moved across the southern sections of the city of Wichita. The SVS issued at 8:52 p.m. noted,

“TRAINED WEATHER SPOTTERS REPORTED DAMAGE FROM A TORNADO AT MACARTHUR AND SENECA ROAD. THIS DANGEROUS STORM WILL CONTINUE TO MOVE NORTH AT 30 MPH THROUGH THE MIDDLE OF WICHITA.”

From the damage path and reports from spotters, the tornado lifted about 8:53 p.m. in eastern Sedgwick County. A chronology of the products issued by NWSO Wichita and the SPC is given in Appendix D.

Public Response

Warnings and statements, disseminated by the National Weather Service via the NWWS, FOS and NWR, were relayed by the local radio and television stations. Extensive coverage on local television and radio allowed for widespread awareness of the approaching tornado. On-site interviews were conducted in Haysville where the tornado did considerable damage. Those interviewed said the warnings were very good, stating that the siren lead time was 10 to 15 minutes. Residents followed severe weather safety plans and took cover in the lowest levels of the houses or apartments. Several had time to invite neighbors to their basements. No fatalities occurred in automobiles. There were no reports of travelers seeking shelter under overpasses.

Additional interviews with those affected by the storm indicated that radio station KFDI provided effective weather information of the approaching tornado. A telephone interview was conducted with a reporter from KFDI AM/FM radio in Wichita who commented that the products and services from the National Weather Service were timely. He believed that the report of the tornado in Sumner County at 7:40 p.m. elevated the awareness of the station and the listeners.

Post-Storm Feedback

The Sedgwick County Emergency Management team cited several National Weather Service products as being valuable in preparing the county emergency staff for this tornado event. These included the Day 1 and Day 2 SWOs from the SPC and the HWO issued at 12:18 p.m. by NWSO Wichita. The NOW issued by NWSO Wichita at 4:12 p.m., predicting the expected development of thunderstorms between 5 p.m. and 7 p.m. with the potential for isolated tornadoes, heightened awareness. Also, the tornado warning for Sumner County at 7:38 p.m. elevated public awareness of the tornado potential for the Wichita area, enhancing the effectiveness of the response to the 8:16 p.m. tornado warning for southeast Sedgwick County.

Just before the issuance of the tornado watch around 7:15 p.m., the Sedgwick County Communication Officer initiated spotter activation. The county EOC monitors the weather warnings and forecasts through EMWIN. Two other video monitors are used to view cable television delivery of radar imagery on Cable TV channels 51 and 52. The county EOC also has a Data Transmission Network and NWR with the SAME feature.

The Sedgwick County EOC has the lead responsibility for siren activation in Wichita. The county EOC is co-located with the 911 Dispatch. There is a direct line between NWSO Wichita and the communication center. Sirens were activated upon receipt of the tornado warning at 8:17 p.m. The county EOC staff was very complimentary of the relationship with the NWSO and the services provided during this event.

The WCM began the first field survey of damage in Sedgwick County Tuesday afternoon, May 4. An aerial assessment was made by the WCM during a fly-over of the damage path in a police helicopter. From the aerial survey, it was determined that portions of the damage track were category F4. A lead forecaster from Wichita conducted a ground survey of damage in Sumner County on Wednesday, May 5. A ground survey of the damage in Sedgwick County was conducted by the WCM and a member of the Service Assessment Team on Friday, May 7. By that time, the damaged area was contaminated by removal of debris and bulldozing efforts.

To reduce the influx of media inquiries, the WCM prepared a well-worded PNS Tuesday morning, May 4, listing pertinent details of the previous evening's event. This PNS was released at 9:30 a.m. and was deemed valuable in minimizing follow-up interviews from the media.

A follow-up press release was issued by the WCM at 4 p.m. as a PNS on Tuesday, May 4. In this release, the WCM announced the damage was assessed as category F4. The press release contained pertinent information on the damage path and the timetable of warnings and statements issued by NWSO Wichita. On May 6, NWSO Wichita posted a tornado track map on its Web page.

Interviews were conducted with the staffs of all three major TV network affiliations (KAKE-TV10 ABC, KWCH-TV12 CBS, KSNW-TV3 NBC) in Wichita. These television stations indicated that NWSO Wichita performed an excellent service with effective warnings and statements. All three TV stations broke into programming after the issuance of the 7:38 p.m. tornado warning for Sumner County. Continuous on-air television coverage began in the 8:16 to 8:22 p.m. time frame and continued for 1 ½ hours.

As was the case in the Oklahoma City area, effective warnings and follow-up statements by NWSO Wichita served the public very well during this event. It is noteworthy that these services were provided despite the malfunction of the Wichita WSR-88D, about 1 hour before the event. The NWSO Wichita staff is commended for their proficiency in using back-up procedures.

Facts, Findings and Recommendations - Part 3
Southern Kansas Outbreak

Local Office Warning and Forecast Service

FACT: NWSO Wichita issued two NOWs at 4:12 p.m. and 6:38 p.m., predicting the potential for severe thunderstorms and the possibility of isolated tornadoes.

FACT: The initial tornado warning for *southeast* Sedgwick County was issued at 8:16 p.m, with a lead time of 14 minutes. This warning was corrected 2 minutes later to include *eastern* Sedgwick County. SVSs issued at 8:33 p.m., 8:46 p.m. and 8:52 p.m. contained information on the tornado's location or damage, as reported by spotters in Sedgwick County.

Systems

FACT: The NWSO Wichita WSR-88D radar (KICT) failed at 7:19 p.m. The Wichita electronic technician replaced a trigger amplifier and two shorted backswing diodes in the modulator. The radar was brought back on-line at about 10:15 p.m. The failure does not appear to be associated with any specific action on the part of the radar operator (e.g., power source change, or Volume Coverage Pattern change). However, these components could weaken over time due to power transfers and surges. The OSF is in the process of installing Transition Power Maintenance Systems (TPMSs) at all WSR-88D sites, which will ease power transitions and surges. The NWSO Wichita WSR-88D TPMS installation is scheduled for the year 2000.

FACT: Two of the local television stations have their own local radars, in addition to the NIDS products, such as the composite radar imagery from Weather Services Incorporated. The other station had continuous NIDS access to the Vance AFB WSR-88D via a NIDS vendor. Most of the time, this station's meteorologist displays the Vance AFB radar data when storms are close to the KICT radar. All television stations said they were able to communicate the threat of the approaching tornado despite the outage of the Wichita WSR-88D.

Internal and External Coordination

FACT: NWSO Wichita has developed a strong working relationship with the SKYWARN program and has expanded it within the amateur radio community. This partnership resulted in the prompt and accurate communication of tornado and damage reports throughout the event.

Finding 11: When NWSO Wichita began receiving detailed locations of tornado damage (i.e., street addresses), personnel were not readily equipped to identify the location, since they did not have a local city map. The only map of Wichita was in the Yellow Pages of the phone directory.

Recommendation 11: NWS Regions should ensure that offices have up-to-date, detailed maps for the larger metropolitan areas in their CWA to track significant weather movement and damage reports.

Dissemination

FACT: The sirens were activated by the 911 dispatcher through the Sedgwick County EOC upon receipt of the NWS warning at 8:17 p.m. Lead time on the siren alert to residents in the tornado's path ranged from approximately 12 minutes (Haysville) to 20 minutes (south Wichita).

FACT: The 911 dispatchers disseminated the warning via the All-Channel Override of the Cable Television at 8:18 p.m. to warn television viewers who were not tuned to the local Wichita TV stations.

FACT: Wichita is home to Weather Data Incorporated which had several clients in both Oklahoma and Kansas affected by this event. Using WSR-88D data obtained via NIDS and other data sets, including National Weather Service warnings, the Weather Data Incorporated forecasters disseminated several warnings to their clients. Mike Smith, President of Weather Data Incorporated, cited this event as a good example where the "public-private partnership worked well."

Response

FACT: All those interviewed in the damaged areas commented that they had heard the National Weather Service warnings before the tornado struck. Citizens were clear on the information of the approaching tornado and followed recommended safety measures.

FACT: Employees of Norland Plastics in Haysville were warned via NWR. Eighty-five employees were directed by the supervisor to the designated shelter area in the basement. None were injured, although the building was heavily damaged.

FACT: Monthly community tornado drills proved beneficial. Thirteen clients of a residential facility for disabled adults moved to the bath tubs and covered themselves. None were injured, although their homes, built on concrete slabs, were almost destroyed.

FACT: Since the Wichita area Civil Air Patrol (CAP) does not have access to aircraft for aerial storm surveys, the WCM arranged for an aerial helicopter survey with the Wichita police. Note: A National Memorandum of Understanding between the CAP and the Office of the Federal Coordinator for Meteorological Services and Supporting Research for support of aerial storm surveys, already exists (August 1997) for those NWS offices with active CAP units in their area.

Finding 12: On May 4, the day after the event, a ground survey in Sedgwick and Sumner Counties could not be done due to more severe weather. An aerial survey was conducted in Sedgwick County on May 4, and a ground survey was completed in Sumner County on May 5. Weather Service Operations Manual (WSOM) Chapter J-02, section 4.3.3, reads in part: "[It] is the responsibility of the local Meteorologist in Charge or their designated representative to go to the site, survey the damage, and obtain overflight capabilities...."

Recommendation 12a: Regions should reemphasize the requirement contained in WSOM Chapter J-02, section 4.3.3, that NWS offices should conduct ground surveys as soon as practical after a severe weather event where there are fatalities, a large number of injuries or significant damage.

Recommendation 12b: NWS Regional Meteorological Services Divisions (MSDs) should establish procedures to perform prompt post-storm surveys at forecast offices needing assistance from nearby forecast offices or the regional headquarters.

Training

FACT: Proficiency in back-up procedures was critical to the smooth transition of the warning program once the radar failed. In late February and March, the NWSO Wichita staff completed proficiency checks on WarnGen, WISEII, transfer power, calling NCF and use of CRS.

Finding 13: The National Weather Service Wichita forecasters were skilled in using the back-up dial-in feature of the PUP to access radar imagery from the Vance AFB WSR-88D.

Recommendation 13: NWS Regional MSDs should ensure that office drills include proficiency checks in using the back-up dial-in feature of the PUP.

Supporting Activities

FACT: Sedgwick County Emergency Management, in cooperation with the local NWS office, conducted 21 separate spotter training/public safety programs from March 1 to April 8 for over 1,000 participants. The NWSO Wichita WCM conducted two of the sessions and had earlier trained the Sedgwick County Deputy Director to provide the other training seminars.

FACT: Within 24 hours of the event, two separate press releases were issued as PNSs at 9:30 a.m. and 4 p.m, May 4, by the NWSO Wichita WCM. These press releases were valuable in reducing the need for media interviews and communicated the information on the tornado's intensity and the timeliness of NWS products.

Practices to Emulate

The Service Assessment Team identified practices at NWSFO Norman and NWSO Wichita that were particularly effective and which other field office managers may wish to emulate. Those practices having widespread applicability were also identified as Recommendations earlier in this Service Assessment.

Sectorization of Warning Operations:	During the height of the tornado outbreak, NWSFO Norman divided warning responsibility by geographical area, using multiple AWIPS workstations. This geographical division of responsibility improved efficiency and warning strategy and is recommended during a widespread outbreak of severe weather.
AWIPS Map Customization:	NWSFO Norman created AWIPS map background boundaries for the major metropolitan areas within its CWA. As a result, forecasters were able to generate warnings faster and provide more detail in their warning products. (See Recommendation 5)
Tone-alerted SVSs:	Typically, SVSs are not tone-alerted. However, during this widespread tornado outbreak, NWSFO Norman forecasters tone-alerted 24 of 48 SVSs which helped maintain a high level of public awareness.
Familiarization with Back-up Procedures:	Demonstrated proficiency in using WSR-88D dial back-up procedures was included in NWSO Wichita's spring drill. This proved valuable, as their primary radar malfunctioned just prior to this event. (See Recommendation 13)

Appendix A

Fujita Tornado Intensity Scale[2]

The Fujita Tornado Intensity Scale is a scale of wind damage intensity which wind *speeds* are inferred from an analysis of wind *damage*.

<u>Category</u>	**<u>Definition and Effect</u>**
F0	**<u>Gale tornado (40-72 mph): Light damage</u>.** Some damage to chimneys; break branches off trees; push over shallow-rooted trees; damage sign boards.
F1	**<u>Moderate tornado (73-112 mph): Moderate damage</u>.** 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	**<u>Significant tornado (113-157 mph): Considerable damage</u>.** Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light-object missiles generated.
F3	**<u>Severe tornado (158-206 mph): Severe damage</u>.** Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off ground and thrown.
F4	**<u>Devastating tornado (207-260 mph): Devastating damage</u>.** Well-constructed houses leveled; structure with weak foundation blown off some distance; cars thrown and large missiles generated.
F5	**<u>Incredible tornado (261-318 mph): Incredible damage</u>.** 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; steel-reinforced structures badly damaged; incredible phenomena will occur.

[2] From *J. Atmos. Sci*., August, 1981, p. 1517-1519

Appendix B

Event Statistics#

May 3-4, 1999
4 p.m.-3 a.m.

`	NWSFO Norman CWA	NWSO Wichita CWA
# Tornadoes	57 *	3
# Tornado Warnings	70	7
Avg Lead Time for All Tornado Warnings	18 min	11 min
# Severe Thunderstorm Warnings	46	4
Fatalities	42	6
Injuries	795	150
Homes Destroyed	3,315	1,114
Homes Damaged	4,722	2,272
Schools Destroyed	2	2
Businesses Destroyed	164	72
Businesses Damaged	90	38
Damage Cost	$1 billion	$145 million

 # Most of the data in this table was provided by the May 14 *Daily Oklahoman*; Sedgwick County, Kansas, Emergency Management; American Red Cross; and the Oklahoma Department of Civil Emergency Management.

*** 65 tornadoes in all of Oklahoma during this event period.**

Appendix C

Oklahoma/Southern Kansas Tornado Outbreak of May 3, 1999

NWSFO Norman Chronological Product Highlights

Valid Time (CDT)	Product Issued or Severe Report	Area/Counties Affected	Remarks
1204 5/2/99	SWODY2	Most of Oklahoma	Slight risk of severe storms
0055 5/3/99	SWODY1	Most of Oklahoma	Slight risk of severe storms late this afternoon and tonight
0430	ZFP	NWSFO Norman CWA	Severe storms possible later today and/or tonight for most zones
0630	SPS	NWSFO Norman CWA	Slight risk of severe storms this afternoon and tonight; isolated tornadoes possible
1115	SWODY1	Most of Oklahoma	Part of the Slight risk area upgraded to Moderate risk
1230	SPS	NWSFO Norman CWA	Moderate risk of severe storms later this afternoon through tonight
1549	SWODY1	Western/Central Oklahoma	Part of the Moderate risk area upgraded to High risk
1523	SWOMCD	Western/Central Oklahoma	Increasing threat of supercells near the dryline late afternoon and evening
1600	ZFP	NWSFO Norman CWA	“Some thunderstorms may be severe” mentioned in most zones for tonight
1615-1700	SVR	Comanche Co.	First warning of the event issued

1620	HAIL	Lawton (in Comanche Co.)	First severe occurrence (1-inch diameter hail) of this event
1645	SEL5	Western/Central Oklahoma	Tornado Watch #195 issued; "tornadoes, hail to 3 inches, and wind gusts to 80 mph possible"
1647-1730	TOR	Comanche, Grady, and Caddo Counties	First tornado warning of the event issued
1651	**TORNADO**	7 miles east-northeast of Medicine Park (Comanche Co.)	Spotters report first tornado of this event (near I-44)
1713	SOFTBALL-SIZED HAIL	5 miles north of Altus (Jackson Co.)	Spotters report the first occurrence of very large hail of this event
1741	NOW	Oklahoma City Metro Area	Potential for tornadoes to move into the area that evening
1752	**TORNADO**	Grady Co.	First tornado in Grady County (4 miles south of Verden)
1830	NOW	NWSFO Norman CWA	Ongoing tornadic storms detailed for some counties; rest of area informed that "threat for tornadoes will continue to be high through the evening"
1840-1930	TOR	Cleveland and McClain Co.	First tornado warning that was issued for these counties
1858	**TORNADO**	McClain Co.	First tornado in McClain County (along Interstate 44 west of Newcastle)
1857	SVS	Oklahoma City Metro Area	Headlined, "...Tornado Emergency in South Oklahoma City Metro Area..." Predicts large damaging tornado will enter southwest metro area between 7:15-7:30 p.m. "Persons in Moore and south Oklahoma City should take immediate tornado precautions!"
1859	SEL8	Central Oklahoma	Tornado Watch #198 replaced #195; "particularly dangerous situation with destructive tornadoes possible"

1911	**TORNADO**	Cleveland Co.	First tornado in Cleveland County (crossed South Canadian River near SW 149th Street)
1917-2000	TOR	Oklahoma Co.	First tornado warning that was issued for this county
1925	**TORNADO**	City of Moore	Tornado moved through Moore
1930	**TORNADO**	Oklahoma Co.	First tornado in Oklahoma County (entered southern part of county east of Interstate 35)
1931	SVS	Oklahoma City Metro Area	Headlined, "...Large Damaging Tornado Moving Through Oklahoma City Metro..." Also states, "Persons in southeast Oklahoma City and Midwest City are in danger!"
1934	**TORNADO**	Oklahoma Co.	Tornado near Tinker Air Force Base

NOTE: This table reflects only the highlights of the Oklahoma chronology. It lists some of the key statements, watches, warnings and severe reports but does *not* attempt to recreate all of the products that were issued and all the reports received during this extended tornado outbreak.

Appendix D

Oklahoma/Southern Kansas Tornado Outbreak of May 3, 1999

NWSO Wichita Chronological Product Log

Valid Time (CDT)	Product Type	Area/Counties Affected	Remarks
1204 5/2/99	SWODY2	Eastern Kansas	Slight risk of severe storms
0055 5/3/99	SWODY1	Eastern 2/3 Kansas	Slight risk of severe storms
1115	SWODY1	Southern Kansas	Upgraded to moderate risk
1218-0000	SPS	NWSO Wichita CWA	Highlighted threat of hail, damaging winds, and isolated tornadoes
1549	SWODY1	Southern Kansas	Upgraded to high risk
1612-1900	NOW	Sumner and Sedgwick Counties	Forecast rapid storm development between 1700-1900
1836-2100	NOW	Sumner, Sedgwick and Harper Counties	Forecast rapid storm development between 1900-2100
1917-2000	SVR	Harper Co.	18SW Anthony radar indicated hail up to 1 inch and winds over 55 mph
1921	SEL0	Central Kansas	Tornado Watch #200 1930-midnight
1938-2015	TOR	N Sumner Co.	Radar indicated strong rotation 2E of Mayfield
1944	SVS	N Sumner Co.	**Tornado** 1N of Mayfield
1949-2050	SVR	Sedgwick Co.	Hail near Haysville

2002	SVS	N Sumner Co.	**Tornado** 3NW of Wellington
2004	SVS	Sedgwick Co.	Hail in downtown Wichita
2016-2120	TOR	SE Sedgwick and N Sumner Counties	**Tornado** 4NW Wellington, strong rotation 2NE Wichita. Reissue for N Sumner 1 min after previous TOR expired
2016-2120	TOR	E Sedgwick and N Sumner Counties	Corrected warning to include all of east Sedgwick County
2023-2230	NOW	NWSO Wichita CWA	Forecast of continued development of severe storms with large hail, damaging winds, and isolated tornadoes possible
2029	SVS	Sedgwick Co.	Strong rotation near Kechi quarter sized hail near Andale
2033	SVS	E Sedgwick and N Sumner Counties	**Tornado** near Peck, possible tornado 7NW Wellington
2046	SVS	E Sedgwick Co.	**Tornado** entering S Wichita 1st mention of Wichita being in path
2047-2150	SVR	W Sedgwick Co.	Warning re-issuance—radar indicated severe storm near Anness
2052	SVS	E Sedgwick Co.	**Tornado** moving through middle of Wichita
2059-2200	TOR	W Butler Co.	Radar indicated strong rotation near Andover
2107	SVS	W Sedgwick Co.	Radar indicated severe storm near Anness
2111	SVS	W Butler Co.	Radar indicated tornado near Rosehill
2116	SVS	E Sedgwick and N Sumner Counties	Allow warning to expire at 2120
2121	SVS	W Butler Co.	**Tornado** 1SW Augusta
2129-2215	SVR	Sumner Co.	Nickel sized hail near Perth

2130-2300	NOW	NWSO Wichita CWA	Severe storms to continue developing near and E of Anthony/Wichita/Marion
2132	SVS	W Sedgwick Co.	Warning canceled
2137-2225	TOR	Butler Co.	Radar indicated strong rotation 10NE and 8SW El Dorado
2145	SVS	Butler Co.	**Tornado** NE of El Dorado
2151	SVS	Sumner Co.	Radar indicated severe near Dalton and Oxford
2201	SVS	Butler Co.	Wall cloud N of El Dorado Lake
2209	SVS	Sumner Co.	Warning canceled
2211	SVS	Butler Co.	Warning canceled
2227	SPS	NWSO Wichita CWA	HWO indicating continued potential for storms overnight