U.S. DEPARTMENT OF COMMERCE
Office of Inspector General

National Oceanic and Atmospheric Administration

Rogers, Minnesota: Complex Weather Conditions, Radar Limitations Delayed NWS Warning of Deadly Tornado

Audit Report No. DEN-18354-7-0001/March 2007

Office of Audits, Denver Regional Office

UNITED STATES DEPARTMENT OF COMMERCE
The Inspector General
Washington, D.C. 20230

MAR 29 2007

MEMORANDUM FOR: David L. Johnson
Assistant Administrator for Weather Services

FROM: Johnnie E. Frazier

SUBJECT: *Rogers, Minnesota: Complex Weather System, Radar Limitations Delayed NWS Warning of Deadly Tornado*
Audit Report No. DEN-18354-7-0001

Attached is the final report on our examination of NWS' actions, policies, and technological capabilities for forewarning the public of a deadly tornado that struck the town of Rogers, Minnesota, on September 16, 2006. OIG initiated this examination in response to a request from Senator Mark Dayton (D-Minnesota), in which he asked us to determine whether NWS forecasting technology is state-of-the-art, its severe weather notification procedures are adequate, and agency personnel acted properly on the evening of the deadly tornado.

We found that NWS, and particularly the staff at the Chanhassen WFO, generally complied with agency policy and procedures for handling severe weather situations and utilizes the best technology available for observation and forecasting. However, we did note several factors that might have adversely impacted NWS' ability to issue a warning prior to the tornado hitting Rogers. A summary of our findings and recommendations appears on page i. Detailed recommendations for NWS appear on pages 10 and 15.

On March 1, 2007, NOAA responded to our draft audit report, dated February 6, 2007. In general, NOAA agreed with our findings and recommendations. NOAA's response is summarized in the appropriate sections of this report and is included in its entirety as Appendix 1.

In accordance with DAO 213-5, please provide us with the audit action plan for our review and concurrence, addressing all of the report recommendations, within 60 days of this memorandum. If you would like to discuss the contents of the final report, please give me a call on (202) 482-5910.

We appreciate the cooperation and courtesies we received from NWS personnel at the agency's headquarters, national weather center, regional offices, and WFOs during our audit.

Attachment

cc: Mack Cato, NOAA Audit Liaison

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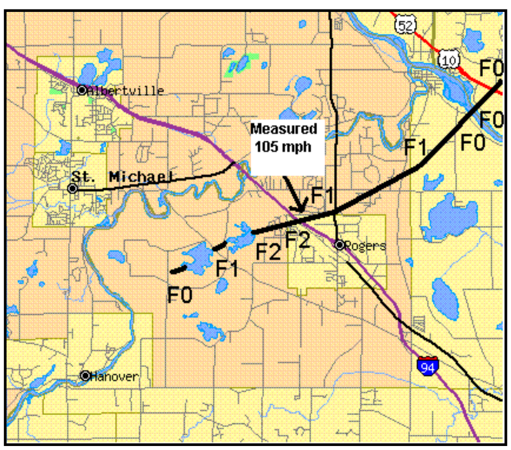
SUMMARY

On September 16, 2006, a few minutes before 10:00 p.m. local time, a tornado struck the city of Rogers, Minnesota, killing a 10-year-old girl, injuring six others, and damaging dozens of structures. Although the area was under both a tornado watch and severe thunderstorm warning at the time, the National Weather Service (NWS) did not issue a tornado warning before the tornado hit. NWS' Chanhassen, Minnesota, weather forecast office (WFO) is responsible for issuing tornado and severe thunderstorm warnings for Hennepin County, which includes the city of Rogers.

During the 12 minutes the tornado was on the ground, the Chanhassen office received no reports of tornado sightings from public safety officials or trained weather spotters.[1] But the WFO's damage assessment performed the following day determined that a tornado rated F2 on the Fujita Scale[2] had indeed hit the city. The assessment also determined that the tornado initially touched down about 3.5 miles west of Rogers, moved northeast through the northern part of the city, and dissipated in a neighboring county. The tornado left a path of damage 8 miles long.

Based on the NWS damage assessment, the tornado's winds were estimated to be less than 73 miles per hour when it touched down, but it quickly gained strength. Wind speeds had reached an estimated 113-157 mph when it hit Rogers. The storm's intensity diminished as it moved into adjacent Anoka County.



Source: National Weather Service

In response to a request from Senator Mark Dayton (D-Minnesota), we examined NWS' actions in connection with the Rogers tornado as well as agency policies and technological capabilities for forewarning the public. Our purpose was to assess whether NWS policies and procedures are adequate and were followed before and during the Rogers tornado, whether the Chanhassen WFO has state-of-the-art severe forecasting and observations technology, and if that equipment was operating properly on September 16, 2006.

In responding to the Senator's inquiry, we found that the Chanhassen WFO, NWS Central Region, and Storm Prediction Center for the most part followed agency policies for handling severe weather events and have equipment in place that is considered to be the best available technology for reading weather conditions. But at the same

[1] An individual trained by the National Weather Service to report on local observed weather conditions.

[2] F2 tornadoes cause **considerable damage**—roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground. Fujita Scale wind estimates are as follows: F0 (<73 mph); F1 (73-112 mph); F2 (113-157 mph); F3 (158-206 mph); F4 (207-260 mph); F5 (261-318 mph).

time, we noted several factors that may have adversely impacted Chanhassen's handling of the situation and warrant close management attention:

- ≈ ***Chanhassen WFO did not follow policy to the letter.*** NWS policy requires that severe thunderstorm warnings issued for areas concurrently under a tornado watch must state that tornadoes are also possible.[3] *The severe thunderstorm warning issued at 9:43 p.m.—9 minutes before the tornado touched down—did not contain such a statement.*
- ≈ ***Dividing staff to monitor conditions left Rogers with reduced coverage.*** Shortly before the tornado hit, Chanhassen assigned warning responsibility for a region southwest of Minneapolis/St. Paul to two forecasters on duty at the time, because this area appeared most likely to spawn tornadoes. One other forecaster was assigned warning responsibility for an area north of the Twin Cities, which included Rogers. Three minutes later, the WFO issued a severe thunderstorm warning for Hennepin and a neighboring county, and 9 minutes after that, the tornado touched down near Rogers. The theory behind dividing staff—to allow forecasters to focus on more limited areas during the volatile weather conditions—is normally a best practice. But the events in Rogers underscore the unpredictability of severe weather: in this case, a rapidly developing event that may have warranted coverage by two forecasters.
- ≈ ***Notice from Storm Prediction Center suggested improving conditions.*** At 9:54—as the tornado was on the ground in the vicinity of Rogers—the NWS Storm Prediction Center in Norman, Oklahoma, issued a notice stating that the risk for tornadoes was diminishing across northern and central Minnesota, including Hennepin County. While this notification did not state that the possibility for tornadoes had ended, it appeared to send a message that conflicted with actual conditions. Its intention was to notify forecasters of the beginning of an hours-long period of atmospheric evolution during which tornadoes would normally become less likely.
- ≈ ***Weather spotter's report was misinterpreted but did not impact performance.*** At 10:13 p.m., a weather spotter en-route through Rogers from Albertville, Minnesota, called the Chanhassen WFO to report encountering hail in Albertville at 9:55 p.m. and seeing storm damage in Rogers. The Chanhassen technician who took the call did not ascertain the spotter's point of departure and erroneously assumed she was traveling in the opposite direction—from Rogers to Albertville. After calculating the driving distance between the two cities, the technician logged the time of the Rogers observation at 9:45—10 minutes before the tornado actually struck the city. This erroneous time, entered as the official time of the damage observation in NWS' storm reporting system, made it appear as though NWS knew about the tornado 13 minutes before the forecaster reported observing tornado conditions on radar and 19 minutes before issuing a tornado warning. This misinterpretation and subsequent logging of the report was a major factor in the controversy surrounding NWS' role in connection with the deadly Rogers tornado.

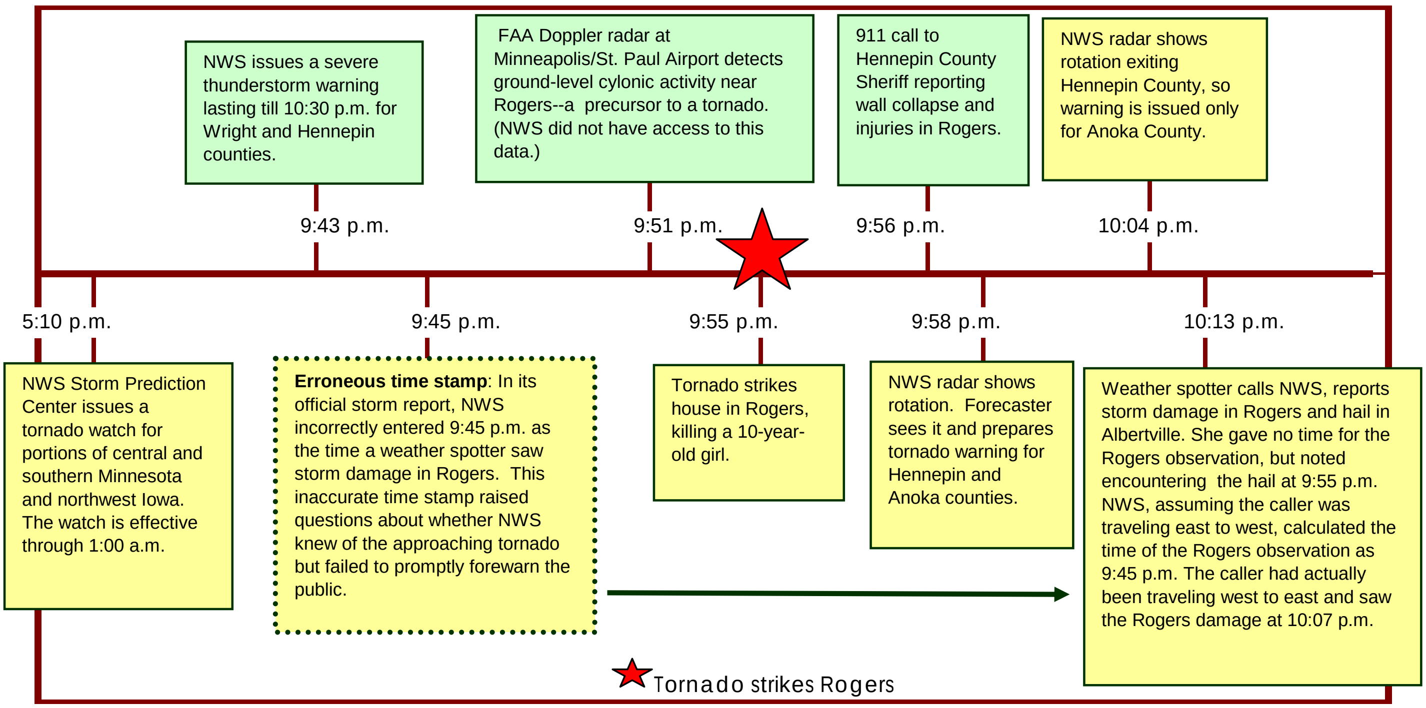
[3] See NWS Instruction 10-511 at http://www.weather.gov/directives/sym/pd01005011curr.pdf.

≈ ***Access to FAA radar data could have aided decision making.*** NWS relies on the Next Generation Radar system (NEXRAD)[4] to monitor atmospheric conditions at 122 weather forecast offices. The Departments of Defense and Transportation also operate more than 30 NEXRAD systems. Many WFOs have access to these radars' data, although there is no DOD or DOT NEXRAD system nearby the Chanhassen WFO. While considered the best available technology for reading weather conditions, NEXRAD has some limitations—for example, in reading precipitation, it has limited ability to distinguish between rain, hail, sleet, birds, snow and other airborne materials. Additionally, some weather conditions can cause the radar beam to bend up or down, creating false images on the screen. There is no evidence to suggest, however that any of these conditions played a part in the events surrounding the Rogers tornado. NWS advised us that technology known as dual polarization is currently under development. With planned implementation from late 2007 through 2012, dual polarization should greatly enhance NEXRAD's ability to distinguish between various types of radar reflections.

To augment its radar capabilities in some locations, NWS also uses the Federal Aviation Administration's Terminal Doppler Weather Radar (TDWR), which is designed for use at major airports. TDWR has several technical differences from NEXRAD, including lower peak power and a shorter maximum Doppler range. TDWR scans low levels of the atmosphere at 1 minute intervals to provide important weather data for approaching and departing aircraft. Though TDWR is available in the Minneapolis/St. Paul area, the Chanhassen office is not connected to it. Subsequent analysis of TDWR data after the Rogers tornado found that the radar showed indicators of a possible tornado on or near the ground about 3 minutes sooner than NEXRAD, primarily because NEXRAD was scanning a higher elevation at the time of the TDWR scan. TDWR information, in combination with NEXRAD data, might have accelerated the warning decision process. We were told that NWS is not connected to all TDWR sites due to funding priorities.

[4] NEXRAD radar is often referred to as WSR-88D, which stands for Weather Surveillance Radar 1988 Doppler, in reference to the radar's 1988 design date.

Tornado Time Line, Rogers, Minnesota
September 16, 2006



To enhance its forecasting abilities, we recommend that the director of NWS take the necessary actions to ensure the agency:

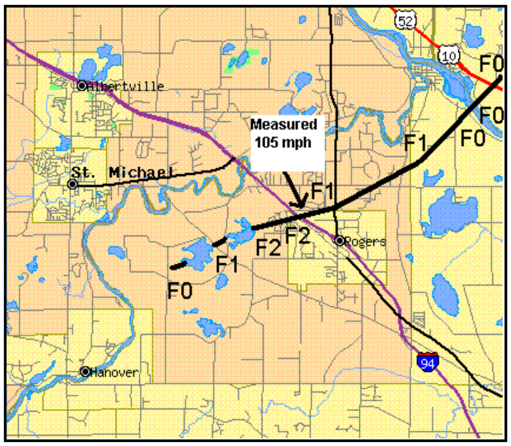
1. Reinforces through ongoing forecaster training, NWS requirements for preparing weather products such as watches and warnings so that weather field offices provide the public with all required information.
2. Researches methods to automate the inclusion of required information in weather products to ensure they are issued in accordance with NWS policies.
3. Explores ways to improve coordination between the Storm Prediction Center and the weather field offices so that communiqués clearly distinguish between current and anticipated future weather conditions.
4. Assesses alternative staffing models and practices that will permit WFOs to assign at least two forecasters to monitor individual areas of severe weather when conditions necessitate dividing warning responsibilities.
5. Develops a standard protocol for field office staff to follow when collecting spotter observations to ensure they ascertain accurate time frames, precise locations and direction, and all other pertinent details.
6. Assesses the feasibility of connecting Chanhassen and other weather field offices to FAA's Doppler radar systems, where available, and deploying all available technology upgrades.

NOAA's Response

In general, NOAA agreed with the OIG's findings and concurred with our six recommendations. The bureau also suggested minor technical changes to the report which have been incorporated in the final version.

INTRODUCTION

On September 16, 2006, a few minutes before 10:00 p.m. local time, a tornado measuring F2 on the Fujita Scale struck the city of Rogers, Minnesota, about 25 miles northwest of downtown Minneapolis, killing a 10-year-old girl, injuring six others, and damaging dozens of structures. Although the area was under both a tornado watch and severe thunderstorm warning at the time, the National Weather Service (NWS) did not issue a tornado warning prior to the tornado hitting Rogers. The NWS weather forecast office in Chanhassen, Minnesota, is responsible for issuing tornado and severe thunderstorm warnings for Hennepin County, Minnesota, which includes the city of Rogers.



Source: National Weather Service

Tornado's path:
The tornado touched down with estimated wind speed of less than 73 miles per hour, or category F0 on the Fujita Scale, based on an NWS damage assessment. It quickly gained strength, hitting Rogers with estimated wind speeds of 113-157 mph (F2), then lost intensity as it moved into adjacent Anoka County.

F2 tornadoes cause **considerable damage**--roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.

Fujita Scale wind estimates:

F0 <73 mph	F1 73-112 mph
F2 113-157 mph	F3 158-206 mph
F4 207-260 mph	F5 261-318 mph

Hennepin County emergency notification procedures require activation of the county's emergency alert system, including outdoor warning sirens, when the Weather Service issues a tornado warning. Because the Chanhassen office did not issue a warning prior to the tornado hitting Rogers, the emergency alert system and outdoor sirens were not activated, nor were warnings broadcast on television or radio. However, the area had been under a tornado watch from 5:10 p.m., and at 9:43 p.m., after NWS issued a severe thunderstorm warning, local television stations began scrolling "crawlers"[1] announcing the warning.

During the time the tornado was on the ground, the Chanhassen NWS office received no reports of tornado sightings from public safety officials or trained weather spotters. But a damage assessment performed the following day by a meteorologist from the Chanhassen office determined that a tornado reaching a maximum strength of F2 on the Fujita Scale had indeed hit the city. The assessment also determined that the tornado initially touched down about 3.5 miles west of Rogers, moved northeast through the northern part of the city, and dissipated in a neighboring county. The tornado was on the ground for about 12 minutes and left a path of damage 8 miles long.

[1] Crawlers are lines of text that scroll across the bottom portion of a television screen during a broadcast.

OIG Time Line of Events

To better understand how the events of September 16 unfolded and why NWS did not issue a tornado warning prior to the tornado hitting Rogers, we developed a detailed time line[2] of NWS actions in response to evolving weather conditions affecting Hennepin County, as follows:

5:10 p.m.	**The NWS Storm Prediction Center issued a tornado watch**, effective until 1:00 a.m. the following morning, for northwest Iowa and central and southern Minnesota, including Hennepin County. The watch contained the statement, "This is a particularly dangerous situation." According to officials at the Storm Prediction Center, the "particularly dangerous situation" designation is added to a tornado watch when conditions are likely to produce two or more strong tornadoes in the watch area.
9:38 p.m.	**The Chanhassen WFO issued a special weather statement** for Hennepin and Wright counties. (Wright County borders Hennepin County to the west.) The statement said that NWS Doppler radar was tracking a line of strong thunderstorms west of Rogers, moving to the east at 55 miles per hour. The special weather statement noted that winds of 50 miles per hour and hail a half-inch in diameter could be expected from these storms.
Approximately 9:40 p.m.	**The Chanhassen WFO divided responsibility** for monitoring two distinct areas of severe weather that had developed over the hours: one to the southwest of the Minneapolis/St. Paul area, and one to the northwest. According to NWS personnel, atmospheric conditions in the southern area showed greater potential for developing tornadoes. Consequently, two forecasters were assigned warning responsibility for the southwest area and one for the northwest, which covered Rogers. This division of responsibility (called "sectorizing") is a recommended best practice that is incorporated into NWS forecaster training and is designed to focus the decision maker's attention on a smaller set of data.
9:43 p.m.	**The Chanhassen WFO issued a severe thunderstorm warning** for Hennepin and Wright counties, effective until 10:30 p.m. The warning requested activation of the emergency alert systems in the affected counties, but Hennepin County emergency procedures do not provide for activation of warning sirens for a "severe thunderstorm warning." Text of the warning message stated that NWS Doppler radar indicated a severe thunderstorm capable of producing large hail and damaging winds near Buffalo, Minnesota, about 15 miles west of Rogers, and moving east at 40 miles per hour. NWS policy states that local weather forecast offices should issue severe thunderstorm warnings when there is reliable data of wind gusts of 58 miles per hour or greater and/or hail of at least three-quarter inch in diameter.

[2] Times are Central Daylight.

9:52 p.m.	**A tornado touched down** about 3.5 miles west of downtown Rogers. As mentioned above, there were no real-time reports of a tornado sighting from public safety officials or trained weather spotters. The time and location of initial touchdown are based on NWS' subsequent damage assessment and analysis of data recorded by the weather radar located at the Chanhassen weather forecast office.
9:54 p.m.	**The NWS Storm Prediction Center issued a "mesoscale discussion[3]"** concerning the existing tornado watch. While this product did not cancel the tornado watch, it did state that the tornado potential appeared to be diminishing across northern and central Minnesota. It also stated that the risks for strong winds and large hail were expected to diminish "within the next few hours." Also at 9:54 p.m., the weather radar at Chanhassen was indicating a strong rotation near the ground in the Rogers area. Several experts who subsequently examined the data agree that this is the signature of the tornado that struck Rogers. The forecaster assigned to monitor this area on the evening of September 16 does not recall whether he noticed the rotation signature on the radar display at that time. In an after-action summary of the event, the forecaster wrote that none of the storms up to that point in the evening had shown any of the classic radar signatures of tornado-producing thunderstorms and that he may have been awaiting additional data from subsequent radar scans before concluding a tornado had developed.
9:55 p.m. (estimated)	**The tornado strikes** a home, killing a young girl. The time of the incident is based on Chanhassen weather radar data relative to the location of the home and the timing of a 911 call by an older sibling to Hennepin County emergency services. The first 911 call from Rogers was logged at 9:56:20, reporting a collapsed wall and injuries at the home in which the girl died. After this, Hennepin County emergency services received numerous calls reporting damage and injuries in Rogers. County records show 911 operators received more than 40 calls in the 50-minute period from 9:56 p.m. to 10:46 p.m.
9:58 p.m.	**The NWS forecaster monitoring conditions in the Rogers area observed a strong radar rotation** signature in northern Hennepin County. He briefly consulted with another forecaster who concurred that a tornado warning should be issued. The forecaster began preparing the warning message to include Hennepin and Anoka counties. (Anoka County borders Hennepin County to the east.) According to the forecaster, just as he was about to issue the tornado warning, weather radar indicated the storm was exiting Hennepin County. The forecaster chose to revise the warning message to include only Anoka County because he saw no sense in issuing a warning for Hennepin County after the storm had passed.

[3] A **mesoscale discussion** is an NWS product issued to meteorologists that describes what is currently happening, what is expected in the next few hours, the meteorological reasoning, and when and where a watch will be issued.

10:04 p.m.	**NWS issued a tornado warning,** effective until 10:30 p.m., for Anoka County. After issuing the warning over the NWS system, the forecaster called three television stations serving the Minneapolis/St. Paul area to advise them of the tornado warning. It is the policy of the Chanhassen office to directly contact local television stations when tornado warnings are issued for the Minneapolis/St. Paul area. A Hennepin County Sheriff Department officer who lives in Anoka County told us he recalls hearing warning sirens from his home around 10:00 p.m. on the night of September 16.
10:13 p.m.	**A trained weather spotter called the NWS Chanhassen office** to report that she had observed debris on the road and a traffic sign wrapped around a pole while driving through Rogers. The NWS technician who took the call asked whether the spotter had anything else to report. The spotter replied that she had encountered hail hitting her car in Albertville at 9:55 p.m. Albertville is about a 10-minute drive northwest of Rogers. Since the spotter reported the observation in Rogers before Albertville, the NWS technician assumed the spotter had been traveling from Rogers to Albertville. Based on the assumed direction of travel and distance between the cities, the technician noted the time that damage was observed in Rogers as 9:45 p.m. The 9:45 p.m. time stamp was assigned to the local storm report entered into NWS' data system. The time stamp in the local storm report made it appear that NWS was aware of possible tornado damage in Rogers approximately 10 minutes before the young girl was killed, yet took no action to issue a tornado warning that might have saved her life. In reality, the spotter had traveled from Albertville to Rogers and had actually observed the damage in Rogers at 10:07 p.m. OIG auditors interviewed both the weather spotter and the NWS technician who received the call and they agreed on the actual sequence of events.

NWS Conducted an Internal Post-Assessment of Rogers Tornado

The NWS Central Region formed an assessment team to evaluate its performance in relation to the Rogers tornado. The five-member team consisted of volunteers from across NWS: the meteorologist-in-charge of the Tulsa, Oklahoma, weather forecast office led the group[4], which included meteorologists from WFOs in Mount Holly, New Jersey, Rapid City, South Dakota, and Central Region headquarters in Kansas City, Missouri, as well as a service assessment program manager from an NWS program office in Silver Spring, Maryland. The team was formed on September 19, 2006, and was on-site in Minnesota to begin its assessment the following day. It evaluated all aspects of the Chanhassen office's products and services relative to the tornado that struck Rogers and assessed the overall satisfaction of local emergency management officials and broadcast media with NWS' performance on the night of the tornado.

The NWS team's report, released to the public on November 2, 2006,[5] contained three findings:

[4] As Oklahoma is in the NWS Southern Region, the assessment team leader was not in the chain of command of the Central Region.
[5] To view the report, visit http://www.crh.noaa.gov/crh/pdf/RogersAssessment.pdf.

- "Under ideal circumstances" the Chanhassen office could have issued a tornado warning as early as 9:52 p.m. based on weather radar volume scans at 9:50 p.m., which indicated potential wind rotations at approximately 5,600 feet above ground level.[6] The assessment team believed, however, that the radar scan at 9:54 was more conclusive and that a tornado warning could have been issued at 9:56 p.m.—a minute after the tornado struck the home in which the young girl was killed.

- Although staffing at the Chanhassen office was adequate on the evening of September 16, 2006, the need to divide warning responsibility into sectors resulted in a less than ideal staffing situation.

- The severe thunderstorm warning issued at 9:43 p.m. contained a technical deficiency: it did not note that a severe thunderstorm can produce a tornado. NWS policy requires this notation when a severe thunderstorm warning is issued for an area that is also under a tornado watch.

<u>OIG observations are consistent with the NWS Assessment.</u>

The findings of our independent analysis are consistent with those of the NWS assessment team and with other information contained in its report. We believe the assessment team conducted a comprehensive analysis of the events that occurred on the night of the Rogers tornado.

[6] Detailed post-event analysis of NEXRAD data by the assessment team found evidence of tornado formation in the storm west of Rogers in a 9:50 p.m. radar display. However, time to perform such a detailed analysis would not have been available to the staff at the Chanhassen office as they were monitoring ongoing severe weather situations.

OBJECTIVES, SCOPE, AND METHODOLOGY

Senator Mark Dayton (D-Minnesota) asked the Department of Commerce Office of Inspector General to perform an independent examination of the National Weather Service's actions in connection with the tornado that struck Rogers, Minnesota, on September 16, 2006. In response, we assessed how NWS handled the event, as well as its policies and technology for tracking severe weather and forewarning the public. Our objectives were to determine whether (1) NWS policies and procedures are adequate and were followed before and during the Rogers tornado, (2) whether the Chanhassen WFO has state-of-the-art severe weather forecasting and observations technology, and (3) if that equipment was operating properly on September 16, 2006.

We conducted fieldwork from September through December 2006. In Minnesota, we visited the Chanhassen WFO, and emergency management officials in Hennepin County and the city of Rogers. In Oklahoma, we visited the WFO in Tulsa and the Radar Operations Center, National Severe Storms Laboratory (NSSL), Cooperative Institute for Mesoscale Meteorological Studies, Storm Prediction Center, and Warning Decision Training Branch, all located in Norman. We also visited the WFO in Sterling, Virginia, and NWS headquarters in Silver Spring, Maryland.

We interviewed 44 individuals including weather experts, radar experts, scientists, technicians, and local government officials. We did not review general and application controls over information technology systems, as they were not relevant to our analysis, but did conduct other substantive tests and procedures to assess staff qualifications as well as the reliability of internal controls and computer-processed data.

We examined radar data, severe weather event logs, spotter reports, and tornado damage in Rogers. We analyzed equipment maintenance records, performance measures and statistics, staff training, and severe weather simulations. We evaluated forecasting technologies being explored and developed for future use, and NWS coordination with the Federal Aviation Administration (FAA) to share radar data.

We reviewed the Chanhassen WFO's compliance with (1) pertinent laws and regulations, (2) its own internal *Policies and Procedures Manual*, (3) NWS national directives, and (4) Hennepin County Severe Weather Procedures.

We conducted our audit in accordance with generally accepted government auditing standards and under the authority of the Inspector General Act of 1978, as amended, and Department Organization Order 10-13, dated May 22, 1980, as amended.

FINDINGS AND RECOMMENDATIONS

I. NWS Generally Followed Policies and Procedures for Handling Severe Weather Events

On the evening of September 16, NWS issued four products in response to evolving weather conditions that would ultimately spawn the tornado that hit Rogers: a tornado watch at 5:10 p.m., a special weather statement at 9:38 p.m., a severe thunderstorm warning at 9:43 p.m., and a tornado warning at 10:04 p.m. These actions were in keeping with NWS policy, with one exception—the thunderstorm warning omitted a required piece of information, as noted below.

NWS Severe Weather Notification Requirements:

- Tornado watches are issued[7] to alert communities within the watch area about organized thunderstorms forecast to produce two or more tornadoes or any tornado that could produce F2 or greater damage. Tornado watches cover large areas—a minimum of 8,000 square miles—and are issued for periods of 2 hours or more. NWS policy allows the message to include the statement, "This is a particularly dangerous situation," when there is a likelihood of multiple strong tornadoes (damage F2 or F3) or at least one violent tornado (F4 or F5). The watch issued at 5:10 p.m. contained this statement.
- Severe thunderstorm warnings are issued to give advance notice to the public of the potential for damaging wind gusts and large hail accompanying a storm, in response to radar or satellite data and/or reliable spotter reports indicating wind gusts 58 mph or greater and/or hail at least three-quarter inch in diameter. If the area is also under a tornado watch, the severe thunderstorm warning must state that tornadoes are also possible.[8] *The warning issued at 9:43 p.m. did not contain such a statement.*
- Tornado warnings are issued to provide advance warning of actual tornadoes when radar or satellite data indicate tornado activity or when a weather spotter reports seeing the funnel cloud.[9] The Chanhassen forecaster issued the tornado warning at 10:04 p.m. for Anoka County after observing radar data that showed tornado activity moving from the adjacent Hennepin County (which includes Rogers) into Anoka.
- Special weather statements are issued[10] to provide the public with information concerning ongoing or imminent weather hazards that do not meet the criteria for issuing a severe weather warning.

NWS measures forecast office performance in issuing tornado and severe thunderstorm warnings by three statistical factors: probability of detection, false alarm rate, and lead time. Probability of detection is computed by dividing the number of events for which warnings were issued by total events for which warnings should have been issued. Probability of detection scores are expressed as decimals and range from 0, the worst, to 1, the best. False alarm rate is determined by dividing

[7] See National Weather Service Instruction 10-512 at http://www.weather.gov/directives/sym/pd01005012curr.pdf.
[8] See NWS Instruction 10-511 at http://www.weather.gov/directives/sym/pd01005011curr.pdf.
[9] Ibid.
[10] http://www.weather.gov/directives/sym/pd01005017curr.pdf.

the number of unverified warnings[11] by the total number of warnings issued. False alarm rates range from 1 to 0. The probability of detection and false alarm rate are often combined to create a composite measure known as the critical success index. Lead time refers to the difference between the time when a warning is issued for a specific county, and the time the event covered by the warning is first reported in that county. A WFO that issued warnings for every event that warranted a warning and had no false alarms during the measurement period would have a critical success index of 1.

We examined the Chanhassen WFO's performance scores against those of other WFOs in the central region and across the nation for the 10-year period 1996 through 2005. The Chanhassen WFO's critical success index for severe thunderstorm warnings exceeded regional and/or national averages in 7 of the 10 years. We also found the WFO's annual tornado warning critical success index exceeded regional and/or national averages in 7 of the 10 years. We concluded that the Chanhassen WFO's historical performance in issuing severe thunderstorm and tornado warnings has been good or above average.

September is traditionally a month of little tornadic activity in Minnesota. But the unannounced F-2 tornado that hit Rogers severely damaged scores of homes, such as the one above, and left one child dead.

Source: NWS

[11] An event is verified when conditions covered by the warning are observed by credible sources, such as trained weather spotters or public safety officials, and reported to the WFO, or through other means such as an after-event damage assessment by NWS staff. For example, a tornado warning would be verified if trained spotters called the WFO to report a tornado on the ground within the warning area. However, if a tornado were to touch down in a warning area, but not be observed by a trained or credible source and not cause measurable damage, NWS would consider this a false alarm because the event was not verified.

Aside from omitting the tornado advisory in the severe thunderstorm warning, NWS implemented these time-tested policies and procedures as required, but the community of Rogers still was not warned in advance of the impending tornado. The reasons why are complex, and largely a reflection of the unusual weather dynamics and circumstances under which the tornado developed rather than a failure on the part of NWS. Still, we noted some policy and procedural weaknesses that may have impacted the WFO's performance and likely contributed to confusion about the events of September 16.

A. Staffing Arrangements, Communications Protocols May Have Diminished Effectiveness of Warning Procedures

Dividing staff to monitor conditions left Rogers with reduced coverage. As noted in the time line (pages 2-4), at about 9:40 p.m., Chanhassen forecasters divided warning responsibilities as two distinct areas of severe weather emerged. Two forecasters were assigned to a region southwest of Minneapolis/St. Paul, which appeared more likely to spawn tornadoes. Another forecaster was assigned warning responsibility for the area northwest of the Twin Cities, which included Rogers. Shortly thereafter, the WFO issued its severe thunderstorm warning for Hennepin and Wright counties, and 9 minutes after that, the tornado touched down near Rogers. The theory behind this division of responsibility is a good one—to allow forecasters to focus on more limited areas during the most volatile weather conditions—and is taught as a best practice in NWS training. The forecast from the Storm Prediction Center also supported the Chanhassen WFO's assessment that the area southwest of the Twin Cities had the higher potential for tornado formation. But the events in Rogers underscore the unpredictability of severe weather, and a rapidly developing event that may have warranted a second forecaster's assistance did not have it. The NWS assessment team noted in its report that having an additional forecaster available to monitor the area north of the Twin Cities would have been the ideal staffing situation.

Interim notice from NWS Storm Prediction Center suggested improving conditions. The time line also notes that the Storm Prediction Center in Norman, Oklahoma, issued a "mesoscale discussion" at 9:54 p.m.—as the tornado was on the ground in the vicinity of Rogers—stating that the risk for tornadoes was diminishing across northern and central Minnesota, including Hennepin County. Mesoscale discussions are not broadcast to the general public, but rather are targeted to professional meteorologists and contain technical information on weather conditions that are expected to develop over longer time periods than would be covered by a warning. While the 9:54 p.m. mesoscale discussion did not state that the possibility for tornadoes had ended, it appeared to send a message that conflicted with actual conditions. Its intention was simply to notify forecasters of the beginning of an hours-long period of atmospheric evolution during which tornadoes would become less likely. The notification stated that additional weather watches were not anticipated in the covered area. The Chanhassen forecaster assigned to the Hennepin County area told us that he and the other forecasters may have briefly scanned the Storm Center's notification when it was issued, but they were "not depending only on SPC." However, by asserting that the potential for tornadoes was diminishing, the center's notification may have negatively impacted the decision-making process.

B. Misinterpretation of Weather Spotter's Report Suggested NWS Failed to Act

The final event in our time line details a 10:13 p.m. call to Chanhassen from a weather spotter en route through Rogers from Albertville, in which she reported encountering hail in Albertville at 9:55 p.m. and seeing storm damage in Rogers. The Chanhassen technician who took the call did not ascertain the spotter's point of departure or destination, and erroneously assumed she was traveling in the opposite direction—from Rogers to Albertville. After calculating the driving distance between the two cities, the technician logged the time of the Rogers observation at 9:45 p.m.—10 minutes *before* the tornado struck the city. And this was entered as the official time of the damage assessment in NWS' storm reporting system.

We interviewed the spotter and technician, determining the actual sequence of events. The spotter actually observed the damage in Rogers at 10:07 p.m., several minutes after the tornado had passed. We also learned that NWS has no formal nationwide policy or procedures for technicians who collect and report spotter observations to ensure they ascertain accurate time frames and solicit all pertinent details. However, officials told us that certain WFOs, especially those in areas with frequent severe weather, have local procedures and training programs. Chanhassen staff told us that the storm reporting system requires them to assign times to events. These are often estimates based on the best information available, but the system does not allow NWS to note the time as being an estimate.

RECOMMENDATIONS:

To enhance its forecasting abilities, we recommend that the director of NWS take the necessary actions to ensure the agency:

1. Reinforces through ongoing forecaster training, NWS requirements for preparing weather products such as watches and warnings so that weather field offices provide the public with all required information.
2. Researches methods to automate the inclusion of required information in weather products to ensure they are issued in accordance with NWS policies.
3. Explores ways to improve coordination between the Storm Prediction Center and the weather field offices so that communiqués clearly distinguish between current and anticipated weather conditions.
4. Assesses alternative staffing models and practices that will permit WFOs to assign at least two forecasters to monitor individual areas of severe weather when conditions necessitate dividing warning responsibilities.
5. Develops a standard protocol for field office staff to follow when collecting spotter observations to ensure they ascertain accurate time frames, precise locations and direction, and all other pertinent details.

NOAA's Response

NOAA responded to OIG's draft audit report on March 1, 2007. In general, NOAA agreed with OIG's findings and concurred with the five draft report recommendations. NOAA disagreed with OIG's presentation of the impact of SPC's notification that conditions were improving on the Chanhassen forecasters' decision-making. However, NOAA did not disagree with our finding and recommendation that NWS explore ways to improve communication between SPC and WFOs. NOAA also suggested minor technical changes to selected language in the report. NOAA's response is included in its entirety as Appendix 1.

OIG Comments

We acknowledge NOAA's commitment to address our findings and recommendations. We made minor alterations to selected language that had appeared in our draft audit report in accordance with NOAA's suggestions.

II. Radar Was Working Properly, but Inherent Limitations Constrain Forecasting Capabilities

Radar is perhaps the most critical tool forecasters have for accurately predicting and identifying tornados and other sudden, threatening weather events. Radar gives forecasters real-time information about atmospheric conditions occurring over very large areas of land by measuring wind velocity toward and away from the radar instrument along with concurrent data about precipitation.

We determined that Chanhassen's radar equipment was operating properly on the night of September 16, a finding confirmed by the NWS assessment team and the University of Oklahoma's Cooperative Institute for Mesoscale Meteorological Studies (CIMMS).[12] It also appears, based on our discussions with weather radar experts, that this equipment is state-of-the-art. But current radar technology is limited in the type and quality of information it provides, and these limitations may have hampered Chanhassen forecasters' ability to predict the impending tornado and forewarn the residents of Rogers.

A. "Volume" Scanning Pattern, Certain Weather Conditions Create Vulnerabilities in Next Generation Weather Radar (NEXRAD)

The National Weather Service relies on NEXRAD at 122 weather forecast offices to monitor atmospheric conditions. The Departments of Defense and Transportation also operate more than 30 NEXRAD systems. Many WFOs have access to these radars' data, although there is no DOD or DOT NEXRAD system nearby the Chanhassen WFO. The system was designed in 1988[13] and has since undergone significant upgrades and enhancements. NEXRAD scans "slices" of the atmosphere to get a better picture of all weather activity from near the ground to the highest point of scanning. This allows forecasters to see atmospheric conditions at various intervals. The fastest scan rate, VCP-12 (Volume Coverage Pattern 12) slices the atmosphere into 14 sections over a period of 4.1 minutes.

As noted above, weather radar provides forecasters with information on wind velocity and precipitation, displayed on a screen in two-dimensional multicolored graphics. But in reading precipitation, NEXRAD has limited ability to distinguish between rain, hail, sleet, ground clutter, birds, snow, and other airborne materials. NWS advised us that technology known as dual polarization is currently under development. With planned implementation from late 2007 through 2012, dual polarization should greatly enhance NEXRAD's ability to distinguish between various types of radar reflections. Additionally, some weather conditions can cause the radar beam to bend up or down, creating false images on the screen.[14] There is no evidence to suggest any of these conditions played a part in the events surrounding the Rogers tornado.

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[12] CIMMS researchers were asked by NWS' Radar Operations Center to analyze and comment on radar data from both the NEXRAD and the FAA's Terminal Doppler Weather Radar (TDWR).
[13] NEXRAD radar is often referred to as WSR-88D, which stands for Weather Surveillance Radar 1988 Doppler, in reference to the radar's 1988 design date.
[14] For a comprehensive description of radar and some of the challenges facing weather forecasters, visit http://www.srh.noaa.gov/jetstream/remote/radarfaq.htm.

While NEXRAD is considered one of the best systems in the world, its usefulness as a forecasting tool is dependent upon interpretation of the NEXRAD data by trained forecasters. The capriciousness and complexity of atmospheric conditions, such as those at work in Rogers on September 16, can further complicate a forecaster's task of issuing severe weather warnings. In summarizing the conditions of that evening, the NWS assessment team noted that the location of the storm that produced the tornado was within a line of storms and thus made it more difficult to detect tornado precursors. "Key radar features typically associated with a rotating thunderstorm were difficult to discern because the storm was embedded within the line of thunderstorms. As a result, the Rogers storm did not exhibit classic supercell characteristics."[15]

As noted in the time line, the tornado was estimated to have touched down at 9:52 p.m., but NEXRAD's first clear indication of a possible tornado on the ground near Rogers came at 9:54 p.m. This apparent lag in the data is explained by how NEXRAD completes its volume coverage pattern. The Chanhassen NEXRAD was operating in the fastest (VCP-12) mode on September 16, scanning the atmosphere in 14 elevation slices, ranging from 0.5 to 19.5 degrees above the horizon, over a period of 4.1 minutes. NEXRAD begins its volume coverage pattern at the lowest elevation angle, 0.5 degrees, and makes a pair of 360-degree sweeps before the radar antenna elevates to its next angle and makes another pair of 360-degree sweeps. NEXRAD continues this progression, with two sweeps at each of the 3 lowest elevations, and single sweeps at the remaining 11 elevations. Thus, in VCP-12 mode, NEXRAD makes a total of 17 360-degree rotations, sampling the atmosphere at 14 elevation angles during the 4.1 minute volume scan. After completing the highest elevation, the radar antenna resets to the lowest elevation and the process begins again. While the total volume scan takes 4.1 minutes, NWS forecasters can display data from each progressive radar sweep in near real time. When NEXRAD data is archived, a time stamp is assigned based on the time the volume scan began. All elevation slices in a given volume scan receive the same time designation. The two NEXRAD volume scans closest to the tornado's touchdown on September 16 began at 9:50 p.m. and 9:54 p.m. When NEXRAD was at its lowest elevation for the beginning of the 9:50 p.m. volume scan, the tornado had not yet touched down and there was no rotation near the ground for the radar to display. When the tornado touched down at 9:52 p.m., NEXRAD was in the middle of its 9:50 p.m. volume scan and thus was not scanning at its lowest elevation angle, nearest the ground.[16] After the radar reset to its lowest angle and began the 9:54 p.m. volume scan, evidence of rotation appears at the lowest elevation, which is consistent with a tornado on the ground.

B. Access to FAA Radar Might Have Enhanced Local Forecasters' Tornado Detection Capabilities

The Federal Aviation Administration's Terminal Doppler Weather Radar (TDWR), designed for use at major airports, scans low levels of the atmosphere more frequently than NEXRAD to detect dangerous weather conditions that could affect aircraft operations. TDWR can be

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[15] U.S. Department of Commerce, National Oceanic and Atmospheric Administration, NWS Central Region Headquarters. November 2006. *Tornado in Rogers, Minnesota September 16, 2006.*

[16] As noted in the NWS assessment team report, the 2.4-degree elevation sweep in the 9:50 p.m. volume scan indicates rotation in the storm west of Rogers. Given the time required to complete lower level scans before reaching 2.4 degrees, this sweep would have taken place at about 9:52 p.m., which is coincident with touchdown of the tornado.

configured to scan near the ground, which is FAA's main concern at an airport, every 60 seconds. The radar is located in 45 major metropolitan areas, including Minneapolis. NWS is connected to TDWR at 10 locations to support its warning and forecast operations, but not in Minneapolis. Connections at additional sites including Minneapolis are planned for the future, but current funding priorities have delayed the connections thus far. So, while the Doppler radar at Minneapolis-St. Paul International Airport was operational on the night of September 16, 2006, staff at the Chanhassen WFO did not have access to its readings. NWS and CIMMS reviewed TDWR data after the fact and found that in the case of the Rogers tornado, the radar had detected ground-level cyclonic activity—the precursor to a tornado touching the ground—about 3 minutes sooner than NEXRAD did. This is likely the result of differences in timing between when the FAA Doppler and NEXRAD scanned at their lowest elevations. TDWR data, used in combination with the NEXRAD data, could have offered additional evidence of the tornado activity near Rogers and might have accelerated the warning decision process.

CONCLUSION

FAA's Doppler radar aside, we found that the Chanhassen WFO has at its disposal state-of-the-art forecasting equipment, and this equipment was fully functional the night of September 16. Inherent limitations in radar technology and lack of visual confirmation of a tornado constrained forecasters' ability to detect the tornado and forewarn Rogers' residents. But having access to FAA's radar could have mitigated some of these limitations and enhanced Chanhassen's efforts to issue timely warnings.

Radar technology is constantly evolving, with newer hardware and software providing enhancements and capabilities significantly better than prior versions. Many of the limitations with current systems are being addressed by the National Severe Storms Laboratory—NOAA's focal point for weather radar research. In addition to dual polarization, mentioned previously, NSSL scientists described the following advances on the horizon that should vastly improve current weather radar operations:

- Three-Dimensional Displays will provide enhanced graphical views of weather patterns that may prove useful to understanding the development of circulations at mid and lower atmospheric levels. Implementation is projected for November 2007.

- Super resolution will double the resolution of radar displays and greatly enhance the clarity of radar images**.** Projected implementation is April 2008.

- Phased Array Radar (PAR) is a very promising technology that has been proven effective for military applications, and has the potential to revolutionize weather forecasting. Unlike other radar systems, this technology has no moving parts and is all electronic. PAR can scan atmospheric conditions significantly faster than NEXRAD's 4.1 minutes, and in cases of targeted storms, return data in less than a minute. The National Severe Storm Laboratory is establishing a partnership among several government, private sector, and educational institutions to research the feasibility of deploying PAR for nonmilitary applications.

RECOMMENDATION:

To maximize forecasting accuracy, we recommend that NWS assess the feasibility of connecting Chanhassen and other weather offices to FAA's Doppler radar systems, where available, and deploying all available technology upgrades.

NOAA's Response

NOAA responded to OIG's draft audit report on March 1, 2007. NOAA agreed with OIG's recommendation to assess the feasibility of expanding connections to FAA radars and deploying NEXRAD upgrades. In response to our statement that NEXRAD has limited ability to distinguish between certain types of precipitation and other objects, NOAA pointed out that technology known as dual polarization is currently under development and, when implemented, should reduce or eliminate this issue. NOAA also suggested minor technical changes to selected language in the report. NOAA's response is included in its entirety as Appendix 1.

OIG Comments

We acknowledge NOAA's commitment to address our finding and recommendation. We added text to the report section dealing with weather radar limitations to acknowledge development of dual polarization. We made minor alterations to selected language that had appeared in our draft audit report in accordance with NOAA's suggestions.

Appendix A. NOAA Response

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
CHIEF ADMINISTRATIVE OFFICER

MAR -1 2007

MEMORANDUM FOR: John M. Seeba
Assistant Inspector General for Auditing

FROM: William F. Broglie
Chief Administrative Officer

SUBJECT: *Rogers, Minnesota: Complex Weather System, Radar Limitations Delayed NWS Warning of Deadly Tornado*
Draft Audit Report No. DEN-18354-7-0001/Feb. 2007

Attached is the National Oceanic and Atmospheric Administration's (NOAA) response to the Office of Inspector General's draft report on its review of the National Weather Service's actions, policies, and technological capabilities for forewarning the public of a tornado that struck Rogers, Minnesota on September 16, 2006. The response was prepared in accordance with Department Administrative Order 213-3, *Inspector General Auditing*. We appreciate the opportunity to respond to your draft report.

Attachment

NOAA Response to the Draft OIG Report Entitled
"Rogers, Minnesota: Complex Weather System, Radar Limitations Delayed NWS Warning of Deadly Tornado"
(Draft Audit Report No. DEN-18354-7-0001/February 2007)

General Comments

The National Oceanic and Atmospheric Administration (NOAA) appreciates the opportunity to review the Office of Inspector General (OIG) report. The Rogers event will be the subject of a National Weather Service (NWS) Operations Committee video teleconference (VTC) on March 7, 2007. Participants in this VTC will include directors of all NWS regions, the National Centers for Environmental Prediction (NCEP), and the Storm Prediction Center (SPC), or their representatives. Results of the NWS service assessment and the OIG report will be discussed in detail and courses of action contained in responses below will be emphasized. It should be noted that NWS has already taken significant steps relative to all six OIG recommendations, which have improved its overall performance for the severe storm watch and warning program.

Page 9, 3rd paragraph, last sentence:
NOAA does not agree with this statement, "…by asserting that the potential for tornadoes was diminishing, the center's notification may have negatively impacted the decision-making process." We recommend the statement be removed from the report. NWS forecasters understand the purpose of the Mesoscale Discussion product; however, in this case, the chronology of events would have precluded any potential influence on the warning forecaster. The Mesoscale Discussion issued by SPC at 9:54 PM CST on September 16, 2006 reached the Chanhassen Weather Forecast Office (WFO) at least ten minutes after a severe thunderstorm warning had been issued for Hennepin County and nearly concurrent with the tornado's impact on Rogers.

Recommended Changes for Factual/Technical Information

Summary, page i, 3rd paragraph:
References to tornado winds speeds should be estimates. For example, the first sentence should read, "The tornado's winds were estimated to be less than 73 miles per hour…" Also, a statement should be made that wind speed estimates are from the NWS damage survey using the Fujita Scale.

Summary, page i, 5th paragraph:
The Storm Prediction Center is a vital part of the tornado outlook, watch, and warning process and should be included in the finding that NWS offices, "…for the most part followed agency policies for handling severe weather events…"

Summary, page ii, last paragraph, continuing to page iii and page 11, 3rd paragraph:
Besides the WSR-88D (or NEXRAD) radars at the 122 WFOs, many WFOs also have access to WSR-88Ds owned by the Department of Defense (DOD) and Department of Transportation (DOT), making a total of 155 WSR-88D radars used by the 122 WFOs. In the case of the Chanhassen WFO; however, there are no nearby DOD or DOT NEXRAD systems.

Page 11, 4th paragraph, 4th sentence:
Limitations of weather radars are well-known to forecasters who use the radars. It is not likely limitations regarding distinguishing rain from hail, for example, or beam bending had a significant impact on operations during the Rogers event. For this reason, the statement "…its usefulness as a forecasting tool is affected by the capriciousness and complexity of atmospheric conditions, such as those at work in Rogers on September 16" is not relevant and should be removed.

Page iii, 1st paragraph and page 11, 4th paragraph, 2nd sentence:
It would be more accurate to say "…NEXRAD currently has limited capability to discriminate among rain, hail, sleet, …" instead of "…NEXRAD cannot discriminate between rail, hail, sleet, …" Related to this limitation in discriminating "targets," a very significant upgrade to the WSR-88D radars, known as dual polarization, is under development and testing. Current plans for "dual pol" include establishing a production and deployment contract by the end of fiscal year 2007, with national deployment complete by the end of fiscal year 2012. OIG staff who interviewed radar experts in Norman, Oklahoma should have details on dual pol, which is a very important improvement for the future.

Page 7, last paragraph, 1st sentence:
This sentence should read, "NWS tornado warning performance is primarily measured in terms of probability of detection, false alarm rate, and lead time." Critical success index, as mentioned in this paragraph, is a derivative of probability of detection and false alarm rate. Probability of detection is the percent of tornado events for which tornado warnings were issued in advance.

Page 10, 2nd paragraph, 3rd sentence:
This sentence should read, "While there is no formal national policy or set of procedures for those who collect spotter reports, WFOs, especially those who deal more frequently with severe weather outbreaks, do have local procedures and informal training programs." It would be more accurate, recognizing the existence of local training efforts, to insert the words "formal" and "national," in this sentence, as stated above.

Editorial Comments

Summary, page iv and page 10:
Recommendations 4 and 5 are not stated the same on these two pages and should be corrected. In response to these recommendations, NOAA referenced page iv of the summary.

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NOAA Response to OIG Recommendations

Recommendation 1: We recommend that the director of NWS take the necessary actions to ensure the agency: Reinforces through ongoing forecaster training, NWS requirements for preparing weather products such as watches and warnings so that weather field offices provide the public with all required information.

NOAA Response: We concur. At least once a year, each forecaster at every WFO reviews all elements of the WFO's severe storm warning operation. NWS Instruction (NWSI) 10-1801, effective December 23, 2004, explicitly states, "Station management in each NWS field office is responsible for ensuring the readiness of office systems and staff through operational readiness checks and seasonal internal drills." In addition, NWSI 20-101, effective July 29, 2002, states, "The MIC (Meteorologist in Charge) will ensure all WFO staff with forecast and warning responsibilities complete at least two appropriate WES (Weather Event Simulator) simulations prior to the start of each significant weather season." These exercises include actual preparation of warning products which typically are reviewed by the WFO Science and Operations Officer (SOO) or delegated expert.

Target Implementation Date: Efforts in operational readiness at each WFO are ongoing; however, the requirements mentioned above will be reemphasized to all regional directors or their delegates at the March 7, 2007 Operations Committee VTC.

Recommendation 2: We recommend that the director of NWS take the necessary actions to ensure the agency: Researches methods to automate the inclusion of required information in weather products to ensure they are issued in accordance with NWS policies.

NOAA Response: We concur. Automatic inclusion of the tornado watch statement specified in the report is a feature in a software upgrade being distributed to all WFOs. Software Build 7.2 for the Advanced Weather Information Processing System (AWIPS) contains a feature for the Warning Generation (WarnGen) program, which automatically includes in severe thunderstorm warnings the required statement regarding the existence of a tornado watch and the possibility of tornadoes whenever a tornado watch is in effect for a warned county.

Target Implementation Date: All WFOs will receive and install AWIPS software upgrade 7.2 by early May 2007.

Recommendation 3: We recommend that the director of NWS take the necessary actions to ensure the agency: Explores ways to improve coordination between the Storm Prediction Center (SPC) and the weather forecast offices (WFOs) so that communiqués clearly distinguish between current and anticipated future weather conditions.

NOAA Response: We concur with the recommendation to continue working to improve collaboration between WFOs and national centers, including SPC. We also concur with the recommendation to improve the differentiation between current and anticipated weather conditions in SPC's Mesoscale Discussions.

Since the NWS modernization of the mid to late 1990s and with the implementation of the watch-by-county concept in 2005, collaboration between SPC and WFOs has increased and improved significantly. While forecasters at WFOs and SPC are sensitive to the workload and demands associated with watch and warning operations, they collaborate by telephone on the issuance, cancellation, and status of severe thunderstorm and tornado watches. Collaboration among WFOs and with national centers is a major point of emphasis at all levels of NWS management to operations staff.

As described in NWSI 10-517, Mesoscale Discussions are "…normally issued at least every 2 to 3 hours for each convective watch that is in effect and focus on mesoscale and storm scale features affecting the severe weather within the watch area." The discussion issued by SPC at 9:54 PM CST on September 16, 2006 did not contain a statement regarding the tornado watch in effect. Its statement that severe weather risks would diminish "within the next few hours" was validated; however, by the fact that no tornadoes occurred after the Rogers tornado dissipated. Leading off each Mesoscale Discussion with a short statement regarding watches in effect for the area of concern is a "best practice" that would help distinguish between current and anticipated conditions.

Target Implementation Date: Emphasis on the importance of collaboration between SPC and WFOs will be made at the March 7, 2007 Operations Committee VTC. SPC has already implemented a local policy to include an explicit statement in Mesoscale Discussions regarding the existence of ongoing watches.

Recommendation 4: We recommend that the director of NWS take the necessary actions to ensure the agency: Assesses alternative staffing models and practices that will permit WFOs to assign at least two forecasters to monitor individual areas of severe weather when conditions necessitate dividing warning responsibilities.

NOAA Response: We concur with the need to assess and evaluate severe storm operations, including management of the "sectorizing" concept, on an event-by-event basis. In fact, performing assessments of severe storm warning operations from the WFO level to the national level is outlined in NWSI 10-1606. The concept of sectorizing was first recognized and recommended as a best practice in the service assessment of the May 3, 1999, tornado outbreak in Oklahoma and Kansas. Since that time, it has become a standard practice used by most WFOs in widespread outbreaks; however, there have been no recommendations regarding specific numbers of forecasters or other staff. Rather, field managers, warning event coordinators, and lead forecasters take into account many factors in assigning tasks during warning operations such as experience, training, overall workload, currency with the ongoing event, fatigue, etc.

Both the NWS service assessment and the OIG review of the Rogers event recognize the sectorized operation at the Chanhassen WFO could have been better managed. The NWS assessment also recommended better use of another best practice referred to as "load-sharing," whereby some routine operations can be delegated among neighboring WFOs. Both of these operations concepts will be reviewed and emphasized in appropriate forums prior to the 2007 severe storm season.

Target Implementation Date: The Central Region Director reviewed the sectorized operations and load-sharing practices with his field managers at regional meetings in December 2006 and February 2007. The concepts will be covered for all regions at the March 7, 2007 Operations Committee VTC. In addition, in accordance with Recommendation 1a of the NWS service assessment of the Rogers event, the Warning Decision Training Branch has produced a training module on sectorized operations, which will be available to all NWS staff in March 2007.

Recommendation 5: We recommend that the director of NWS take the necessary actions to ensure the agency: Develops a standard protocol for field office staff to follow when collecting spotter observations to ensure they ascertain accurate time frames, precise locations and direction, and all other pertinent details.

NOAA Response: We concur with the need to improve report taking and documentation at NWS field offices; however, we are aware that attempts at many offices to develop standardized checklists and questionnaires for spotter reports have produced mixed results. Within the Advanced Warning Operations Course (AWOC), which has been already taken by most NWS forecasters, an excellent module on data quality addresses spotter reports and other ground truth information. A related module aimed specifically at asking the right questions to get the most accurate and timely information from spotter reports could be a valuable guide for the wide range of NWS staff, emergency managers, amateur radio operators, etc. who receive spotter reports and contribute them to the warning decision making process. The NWS Office of Climate, Water, and Weather Services (OCWWS) will investigate the utility of such a training module in lieu of developing standardized report questionnaires or documentation forms.

Target Implementation Date: OCWWS will provide a recommendation by June 1, 2007 including a target completion date for the recommended course of action.

Recommendation 6: We recommend that the director of NWS take the necessary actions to ensure the agency: Assesses the feasibility of connecting Chanhassen and other weather forecast offices to FAA's Doppler radar systems, where available, and deploying all available technology upgrades.

NOAA Response: We concur. In fact, NWS has determined continuing the process of connecting the FAA's Terminal Doppler Weather Radars (TDWR) to the appropriate, usually the nearest, WFO is among its highest priorities. Ten of 45 TDWRs have already been connected to neighboring WFOs for evaluation in real time use. Integration of TDWR data in nearby WFOs is expected to improve severe thunderstorm and tornado warnings by providing complementary data to that from the WSR-88D Doppler radar network. As in the Rogers event, TDWRs often provide an alternate viewing perspective which can aid storm analysis. They provide frequent updates of lower-altitude storm data and can be extremely valuable in providing backup data if the local WSR-88D is temporarily out of service.

Target Implementation Date: NWS plans to continue connecting and integrating data from all TDWR radars. Ten such connections are already complete. The remaining 35 systems will be connected in the fourth quarter of fiscal year 2008.