4.2 Tornadoes

A tornado is a rapidly rotating vortex or funnel of air extending to the ground from a cumulonimbus cloud. When the lower tip of a vortex touches earth, the tornado becomes a force of destruction. The path width of a tornado is generally less than a half-mile, but the path length can vary from a few hundred yards to dozens of miles. A tornado moves at speeds from 30 to 125 mph, but can generate winds exceeding 300 mph.

Each year Oklahoma has more tornado events per square mile than any other state

4.2.1 Hazard Profile

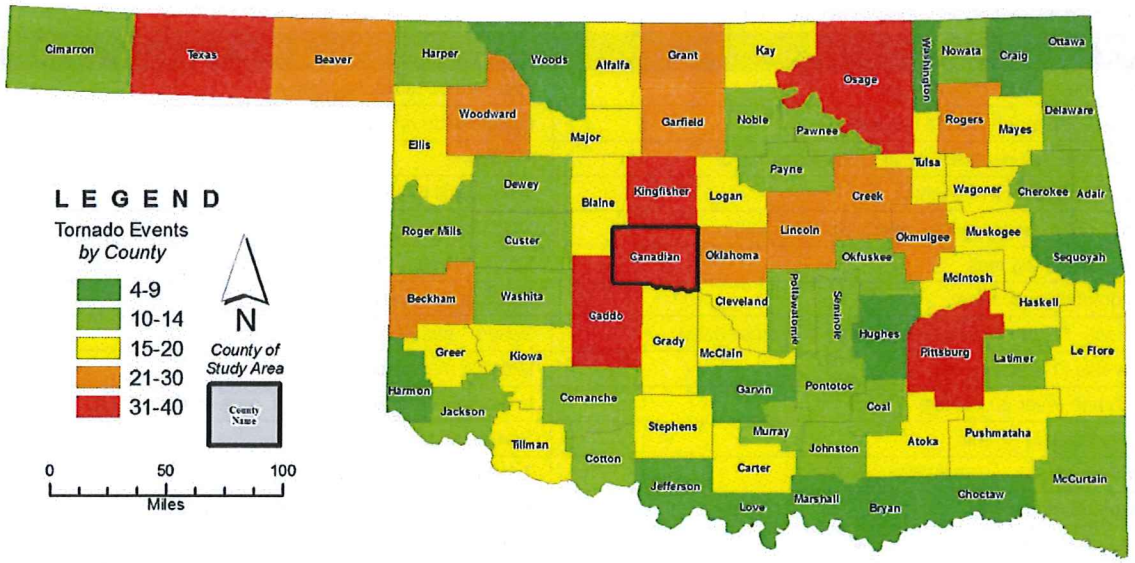
Severe thunderstorms produce about 1,000 tornadoes each year in the United States. FEMA reports that 106 federal disaster declarations over the past 20 years have included tornado damage.

The path width of a tornado averages about 200 yards and therefore can have a substantial impact on human life and property. Damage from an average tornado can include the destruction of roof surfaces, mobile homes being pushed off their foundations, and automobiles being blown off roadways. More severe tornadoes can lift 300-ton objects and toss homes more than 300 feet.

Location

Oklahoma, along with Texas, Arkansas, Missouri, and Kansas, is located in "Tornado Alley," the most tornado-prone area of the nation. The entire jurisdiction of Canadian County is considered to be vulnerable to the effects of a tornado event. See Figure 4-4 for the number of tornado events per county in Oklahoma.

Figure 4-4: Tornadoes in Oklahoma from 1989-2009



Source: National Climatic Data Center U.S. Storm Events Database

Flanagan & Associates, LLC

Measurement

Almost 70% of all tornadoes are measured EF0 and EF1 on the Enhanced Fujita Scale, causing light to moderate damage, with wind speeds between 40 and 112 miles per hour. EF4 and EF5 tornadoes are considerably less frequent, but cause the most devastating impact including loss of life and property. Sixty-seven percent of all tornado deaths were caused by EF4 and EF5 storms, which represent only 1% of all tornadoes. The Enhanced Fujita Scale was adopted in early 2007, although the layperson frequently refers to the earlier F-scale. The new scale is based on a broader set of degrees of damage to a wider variety of structures. A description of the Fujita Scale and comparison to the recently adopted Enhanced Fujita Scale (EF) are included in Table 4-10. The average tornado length (miles) and width (yards) is listed by EF classification in Table 4-11. Additional information on the Enhanced Fujita Scale is available at: http://www.spc.noaa.gov/efscale

Table 4–10: Fujita Scale and Enhanced Fujita Scale

Fujita Scale			EF Scale	
Category	**Wind Speed (mph)**	**Current Damage Indicators**	**Category**	**3 Second Gust (mph)**
F0	Gale (40-72)	***Light***: Damage to chimneys, tree branches, shallow-root trees, sign boards	EF0	65-85
F1	Moderate (73-112)	***Moderate***: Lower limit is beginning of hurricane wind speed--surfaces peeled off roofs, mobile homes pushed off foundations or overturned, cars pushed off roads	EF1	86-110
F2	Significant (113-157)	***Considerable***: Roofs torn off frame houses, mobile homes demolished, boxcars pushed over, large trees snapped or uprooted, light-object missiles generated	EF2	111-135
F3	Severe (158-206)	***Severe***: Roofs and some walls torn off well-constructed houses, trains overturned, most trees in forest uprooted, cars lifted off the ground and thrown	EF3	136-165
F4	Devastating (207-260)	***Devastating***: Well-constructed houses leveled, structures with weak foundations blown off some distance, cars thrown and large missiles generated	EF4	166-200
F5	Incredible (261-318)	***Incredible***: 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	EF5	Over 200

The F-scale and Enhanced F-scales are a set of wind estimates (not measurements) based on damage. The Enhanced Scale uses three-second gusts estimated at the point of damage based on a judgment of 8 levels of damage to the 28 indicators listed below. These estimates vary with height and exposure.

Structures Used as Damage Indicators in the Enhanced Fujita Scale	
Small barns, farm outbuildings	One- or two-family residences
Single-wide mobile home (MHSW)	Double-wide mobile home
Apartment, condo, townhouse (3 stories or less)	Motel
Masonry apartment or motel	Small retail building (fast food)
Small professional (doctor office, branch bank)	Strip mall
Large shopping mall	Large, isolated ("big box") retail building
Automobile showroom	Automotive service building
School - 1-story elementary (interior or exterior halls)	School - middle or senior high school
Low-rise (1-4 story) bldg.	Mid-rise (5-20 story) building
High-rise (over 20 stories)	Institutional building (hospital, govt. or university)
Metal building system	Service station canopy
Warehouse (tilt-up walls or heavy timber)	Transmission line tower
Free-standing tower	Free-standing pole (light, flag, luminary)
Tree - hardwood	Tree - softwood

Table 4–11: Mean Tornado Length and Width by EF class

Class	Length (mi)	Width (yds)
EF0	.87	31.06
EF1	2.92	69.99
EF2	6.65	137.69
EF3	13.98	288.28
EF4	27.09	503.83
EF5	33.93	607.5

Source: Benefit-Cost Analysis – Tornado Methodology

On February 1, 2007, the Fujita scale was decommissioned in favor of the more accurate Enhanced Fujita Scale, which replaces it. None of the tornadoes recorded on or before January 31, 2007 will be re-categorized. Therefore maintaining the Fujita scale will be necessary when referring to events prior to that date.

Extent/Severity

Canadian County may experience a tornado ranging from EF0 to EF5 on the Enhanced Fujita Scale shown in Table 4-10.

Canadian County considers a minor severity tornado to be less than an EF2 on the Enhanced Fujita Scale and a major severity to be an EF2 or higher.

Frequency

Between the years 1991-2010, NCDC reported an average of 62 tornado occurrences per year for the State of Oklahoma. During this averaging period, Oklahoma ranked 4th in the United States with the most tornado occurrences per year, just behind Florida, Kansas, and Texas.

Canadian County has been impacted by 34 reported tornado events in the last 15 years, according to the NCDC severe storms database, which equates to a frequency of 2.26 per year. The number of tornadoes by county from 1989-2009 is depicted in Figure 4-4.

Impact

The impact of this hazard occurs during times of severe storms. Storms that generate tornadoes also have the ability to cause lightning, hail, high winds, and flooding damage. This can result in the direct loss of homes, businesses, and lives and indirectly cause the loss of income, medical care, and the ability for the government to respond to the disaster.

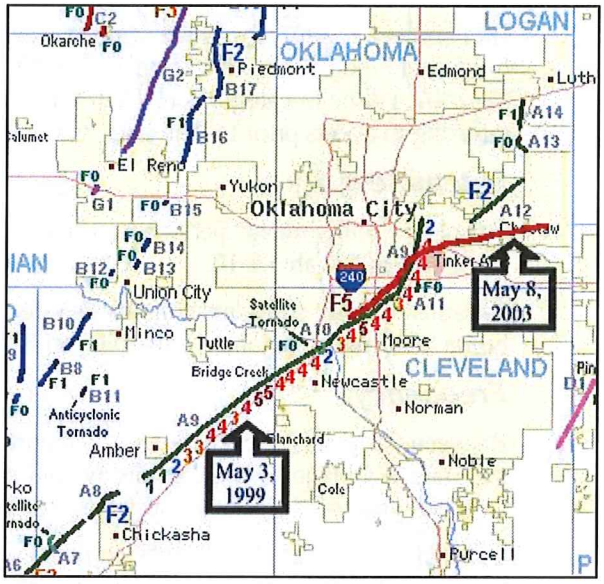
4.2.2 History/Previous Occurrences

Oklahoma has a long history of deadly and damaging tornadoes. Some of the deadliest tornado events in Central Oklahoma include:

- **April 25, 1893**- Thirty-eight people died in the 10 Mile Flats area near Norman in the worst recorded tornado disaster of the 19th century in Oklahoma.
- **November 19, 1930**- Twenty-three people died and 125 were injured when a tornado hit Bethany in Oklahoma County.
- **June 12, 1942**- Thirty-five people died in an Oklahoma City Tornado.
- **April 12, 1945**- 102 people were killed in a violent series of tornadoes. Sixty-nine died in Antlers, 13 in Muskogee, including many at the Oklahoma School for the Blind. Eight people died at Tinker Air Force Base, five in Roland, four near Hulbert, and three in Latimer County.

- **May 25, 1955**- This tornado killed 114 people, including 20 in Blackwell, and 80 in Udall, Kansas, where the town was leveled.
- **May 24, 1973**- Six injuries, 22 demolished homes, 18 demolished trailers, and 49 damaged buildings resulted from a tornado that moved through Union City. The tornado was a quarter-mile wide and stayed on the ground for 28 minutes. Damage was approximately $2 million. The Union City tornado was the first to leave a "velocity signature" on radar, which produced a breakthrough in severe storm forecasting. It was also the first tornado to be intercepted and photographed by storm chasers.
- **May 3, 1999**- A series of severe thunderstorms swept out of the southwest and produced many tornadoes that greatly intensified as they moved across the state. Figure 4-5 shows tornado touchdowns, paths, and direction. The visual representation makes it clear that this incident was indeed a huge outbreak.

Figure 4–5: 1999 and 2003 Tornado Paths



One of the tornadoes was an F5, which occurred southwest of Oklahoma City and was measured at 318 mph (the highest wind speed ever recorded for a tornado). The tornado stayed on the ground about four hours and left a path approximately 38 miles long. This storm was the first F5 tornado to affect metropolitan Oklahoma City. The path included 6.5 miles of continuous F4 damage as well as several areas of F5 destruction. Several homes were completely removed from their slabs.

The National Weather Service reported that 57 tornadoes were recorded in the state during the outbreak. The Oklahoma Hospital Association reported that 44 people were killed and 742 treated at 30 hospitals. Approximately 10,000 homes and businesses were affected by the storms, with total losses exceeding $1 billion. Oklahoma Emergency Management reported that in Oklahoma, 3,009 homes, 117 businesses, and 10 public buildings were destroyed, including 645 in Oklahoma City, six in Tulsa and 95% of the town of Mulhall. Sixteen Oklahoma counties were declared Federal Disaster Areas. Damage was estimated at over $1 billion.

- **May 8, 2003**- At about 5 pm, an F-4 tornado, 19-miles long, hit Moore, Midwest City, Del City, Stroud and Oklahoma City, many of the same areas damaged by the killer tornado of 1999. Local hospitals reported 145 injuries. Initial damage estimates included 432 homes destroyed and 2,457 damaged. About 20 businesses were destroyed. The Oklahoma City General Motors automobile plant sustained substantial damage and was knocked out of production. The Xerox plant and five schools were also damaged. The City of Moore reported three churches destroyed, and damage to a fire station and elementary school. The Lincoln National Bank in Oklahoma City was leveled. Oklahoma Gas and Electric reported that 4,000 customers in Oklahoma City, Moore, and Midwest City were without power. Damage was estimated at more than $100 million.

Oklahoma and Canadian County Tornadoes 1995-2009

In Oklahoma from 1995-2009, there were 62 fatalities and over 1,104 injuries from tornadoes. Table 4-12, shows tornado frequencies and associated damages for the State of Oklahoma and Canadian County, as reported by the National Climatic Data Center, between 1995 and 2009. A map displaying paths of historic tornadoes in Canadian County from 1950 through 2006 is shown in Figure 4-6. This map is based on best available data and will be updated as new data becomes available in future plan updates. The map also shows the path of the May 24, 2011 tornado, summarized below.

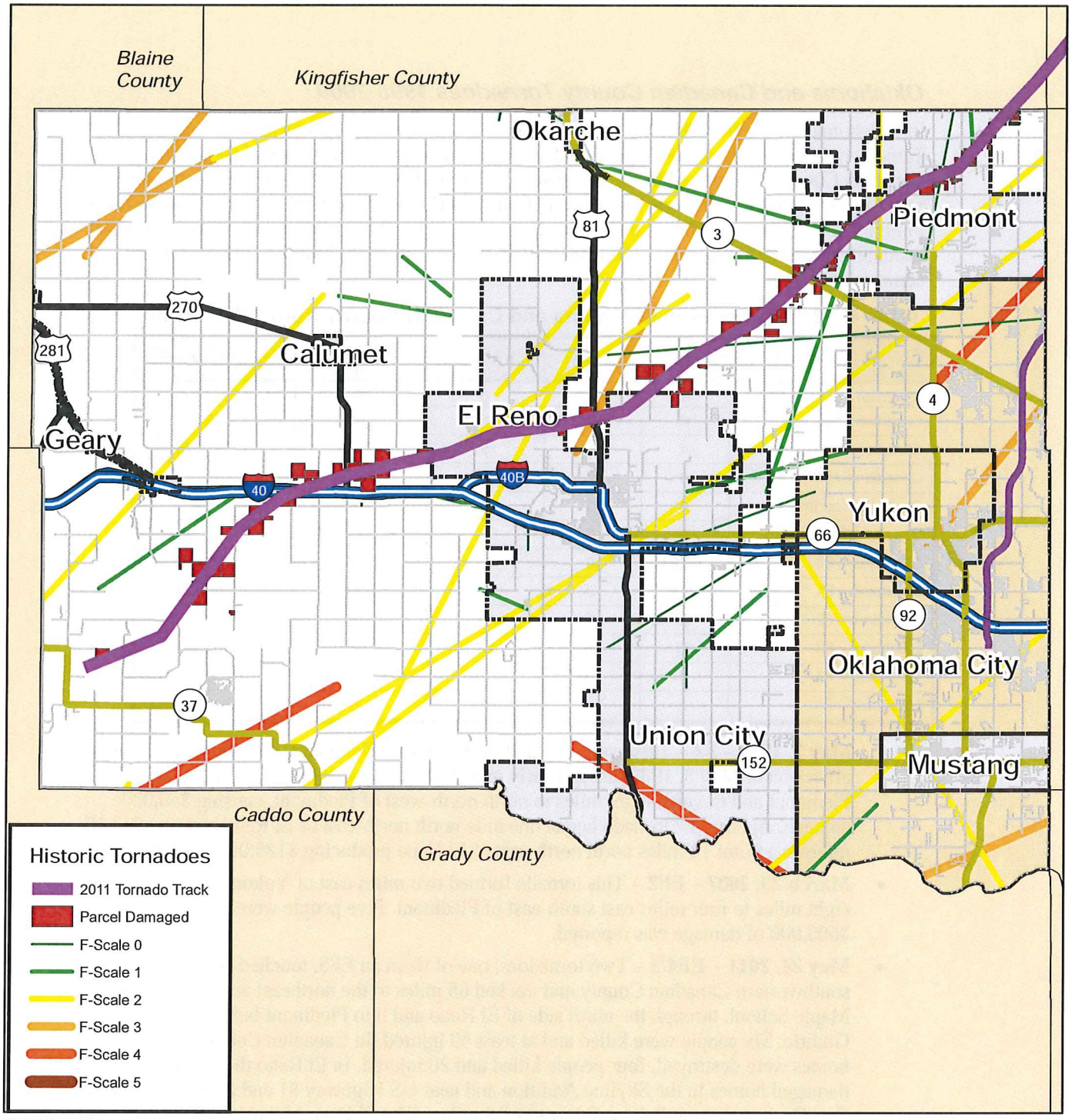
Table 4–12: Tornadoes in Oklahoma and Canadian County from 1995 - 2009

Location	Events	Deaths	Injuries	Damage Events	Property Damages
Canadian County – F0	15	0	0	5	$136,000
Canadian County – F1	15	0	0	14	$5,331,000
Canadian County – F2	4	0	5	4	$1,675,000
Canadian County – F3	0	0	0	0	0
Canadian County – F4	0	0	0	0	0
Canadian County – F5	0	0	0	0	0
Oklahoma – F0	589	0	14	136	$3,672,000
Oklahoma – F1	268	0	40	229	$50,104,000
Oklahoma – F2	93	5	88	81	$92,723,000
Oklahoma – F3	27	5	116	26	$403,211,000
Oklahoma – F4	7	29	514	7	$650,500,000
Oklahoma – F5	2	23	332	2	$540,000,000

- **May 3, 1999 – F2** – This event was part of the record Oklahoma tornado outbreak on the afternoon of May 3, 1999 through early morning of May 4. It began two miles west of Piedmont and traveled eight miles to north north-west of Piedmont, causing $50,000 damage. Another F2 tornado began one mile north north-east of El Reno and traveled 16 miles to a point 14 miles north north-east of El Reno producing $125,000 in damage.
- **March 29, 2007 – EF2** – This tornado formed two miles east of Yukon and traveled eight miles to four miles east south-east of Piedmont. Five people were injured and $500,000 of damage was reported.
- **May 24, 2011 – EF4/5** – Two tornadoes, one of them an EF5, touched down in southwestern Canadian County and tracked 65 miles to the northeast across I-40 near Maple School, through the north side of El Reno and into Piedmont before lifting near Guthrie. Six people were killed and at least 60 injured. In Canadian County, 35 to 40 homes were destroyed, four people killed and 20 injured. In El Reno the tornado damaged homes in the Skyline Addition and near US Highway 81 and Britton Rd., and at Fort Reno and along Britton Rd., east of the City. The El Reno MesoNet station recorded winds of 151 mph.

Probability/Future Events

Canadian County, like Oklahoma, is vulnerable to frequent thunderstorms and convective weather patterns, and therefore its vulnerability to tornadoes is a constant and widespread threat, especially during the spring months. Tornadoes can, and do appear in nearly all months of the year at all hours of the day, so it is important that even in "light activity" years, education and preparations continue to move forward.Canadian County, its Communities and Public School systems have a high probability of a future tornado event.



LEGEND

- Interstate
- US Highway
- State Highway
- Turnpike
- Streets
- Canadian County
- Not in Plan
- Statewide Counties

N W E S

0 3 6 Miles

CANADIAN COUNTY 1890 OK

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Figure 4-6

Canadian County

Historic Tornadoes 1950 - 2006

4.2.3 Vulnerability

This section summarizes information about Canadian County's vulnerability to tornadoes, including the impact on people, structures and buildings, critical facilities, and infrastructure. This information, as well as information provided by the County, Incorporated Communities and Public Schools, was used to determine the Vulnerability Criteria identified in Tables 4-2 and 4-3. Canadian County was determined to be at High risk to the tornado hazard. Appendices F and G, respectively, identify specific information for cities and towns and public schools.

The National Weather Service advises that tornadoes strike at random, and that all areas within Canadian County are vulnerable. All future development areas are also at risk from tornadoes.

Population

The people most at risk of fatality from a tornado are those living in mobile homes. Table 4-13 shows the numbers of tornado-related fatalities in the United States for each year from 1997 to 2010, and where the deaths occurred. It illustrates that those living in mobile homes are more vulnerable to the effects of a tornado than any other identifiable population. While the number of mobile homes is a small fraction of total residential dwellings, the number of deaths in mobile homes exceeds the number of deaths associated with inhabitants of permanent homes. In fact, over 45% of all tornado deaths during this period occurred in mobile homes.

Also significant is the number of tornado-related deaths in vehicles. People traveling in cars and trucks are at increased risk during a tornado event. Also at higher risk for these events are members of the hard-of-hearing/deaf community, people for whom English is not their primary language and those without access to broadcast media messages alerting them of approaching severe weather. While much progress has been made in expanding communication resources for these individuals, there are still a large number of residents facing these challenges unable to receive vital warnings in a timely manner.

Table 4–13: Tornado Fatalities in the United States

Year	Home	Mobile Home	Vehicle	Business	Outside Open	Other	Total for Year
1997	38	16	3	3	8	0	68
1998	46	64	16	1	3	0	130
1999	39	36	6	3	10	0	94
2000	7	28	4	0	2	0	41
2001	15	17	3	3	2	0	40
2002	15	32	4	1	3	0	55
2003	24	25	0	1	3	1	54
2004	21	11	2	2	0	0	36
2005	3	34	1	1	0	0	39
2006	31	27	7	2	0	0	67
2007	16	52	2	10	1	0	81
2008	42	56	14	10	3	0	125
2009	7	12	1	1	0	0	21
2010	11	20	7	1	6	0	45
2011*	204	118	35	85	8	96	546
Totals	519	548	105	124	49	97	1,442

Source: National Weather Service Storm Prediction Center
*** - 2011 information is as of 9/27/11**

Sheltering Options

Residents of Canadian County unable to seek adequate shelter, such as safe rooms, when tornadoes threaten are vulnerable to loss of life and injury as a result. Also vulnerable are those populations that have access to a safe room or shelter but choose to ignore the advance warning until it is too late. Schools using hallways as a safe sheltering option are potentially vulnerable to loss of life and/or injury during a tornado. As shown in past events, such as Enterprise, AL, school hallways can be turned into wind tunnels during tornadoes, scattering large debris from one end of the corridor to the other. Information regarding tornado safe rooms located in individual communities and school districts within Canadian County is included in Appendix F and G.

Structures/Buildings

Tornado damage is a factor of severity and location, both on a landscape scale – rural/urban areas – and on a structure-by-structure scale. An EF4/EF5 tornado in an urban area will create phenomenal damage, as experienced with the tornadoes that struck Greensburg, Kansas (EF5, 5/4/2007) and Picher, Oklahoma (EF4, 5/10/2008), but damage to structures will vary depending on how they are constructed. For example, mobile homes are more easily damaged than permanent structures, buildings with crawl spaces are more susceptible to lift, and foundation and roof construction can increase or decrease the structure's vulnerability.

With the percentage of older homes in Canadian County as a whole being high, (28.7% of homes in the County were built prior to 1969), the jurisdiction is vulnerable to tornado damage. See Table 1-5 for percentages of homes built prior to 1969, 1959 and 1939. More than half of the residential structures in Calumet and El Reno were built prior to 1969.

Structures utilizing more modern-looking building materials (reflective glass facades, open breezeways between wings, etc.) should be considered more vulnerable to damage from a tornado. Wind-driven debris (wood, metal, other larger items picked up by larger funnels) can cause catastrophic damage to buildings, as witnessed in the tornadoes that struck downtown Fort Worth in 2000 or Atlanta in May 2008.

All school facilities in Canadian County not constructed to meet or exceed FEMA safe room criteria are exposed to complete destruction as a result a tornado event. The most common damage to schools from high winds and tornadoes is to the roof systems. School roofs are vulnerable to being completely blown away or damaged to the point of collapsing. Exterior glazing is another structural vulnerability of school buildings. Metal wall paneling is at risk of being damaged or completely blown away. Non-load bearing exterior school walls often collapse. Some schools use portable classrooms as learning or office facilities. These types of structures are constructed similarly to mobile homes and are easily overturned or completely destroyed by high wind speeds. Students and faculty in portable classrooms must heed the same warning as occupants of trailer homes when tornados threaten the area: get out.

Critical Facilities

All critical facilities within Canadian County should be considered vulnerable to the effects of a tornado event. Structural integrity may be compromised if the building is in the direct path of the storm, in addition to secondary impacts, such as power disruption, water damage from accompanying rain, injury to workers/residents, etc. Table 1-6 lists critical facilities for Canadian County and Figure 1-8 shows their location.

Infrastructure

Water Treatment – Most significant effect during a tornado would be loss of electrical power.

Wastewater Treatment – The most significant threat to the operation of wastewater treatment facilities during a tornado would be power outages.

Utilities – Canadian County's primary electric service is provided by Oklahoma Gas and Electric Company (OG&E). Natural gas is primarily from Oklahoma Natural Gas Company (ONG).

Electricity – Tornadoes present huge challenges to electric service providers in meeting the needs of Canadian County, including: destruction of distribution and transmission poles, downed broken power lines, danger to workers derived from downed power lines, and fallen debris from trees or insufficient field and/or office staff to effectively handle the workload.

Gas: A tornado could cause breaks gas lines; fallen power lines or tree debris; inaccessibility to underground gas meters from debris; extreme temperatures; and insufficient field and/or office staff to effectively handle workload generated by the event.

Transportation Systems – Tornadoes could result in the interruption of normal operations at airports in the County and damage airport facilities and aircraft.

Emergency Services – Fire, Police and Medical Services are equally at risk to secondary effects of a tornado, such as downed power lines or debris blocking streets and highways. Debris in streets could lead to damage to emergency vehicles, potentially reducing the number of vehicles available for response. Medical Services (including treatment facilities) could be strained in responding to large numbers of injuries.

4.2.4 Tornado Scenario

A typical tornado path is reported to be approximately 600 feet in width, and 2.5 miles in length. The typical path in Oklahoma runs generally from southwest to northeast with the area of destruction being about 181 acres per event. Approximately 16 square miles of Oklahoma's 69,919 square miles are impacted by tornadoes each year. The annual chance of a tornado of any magnitude hitting any location is roughly 1 in 5,000. Bigger and more devastating tornadoes can and do occur, as evidenced by the 1999 Oklahoma City tornado, which stayed on the ground for 38 miles. However, these events are rare. The chance of an EF4 or EF5 striking an area is only about 1 in 417,000 per year.

Canadian County Tornado Scenarios

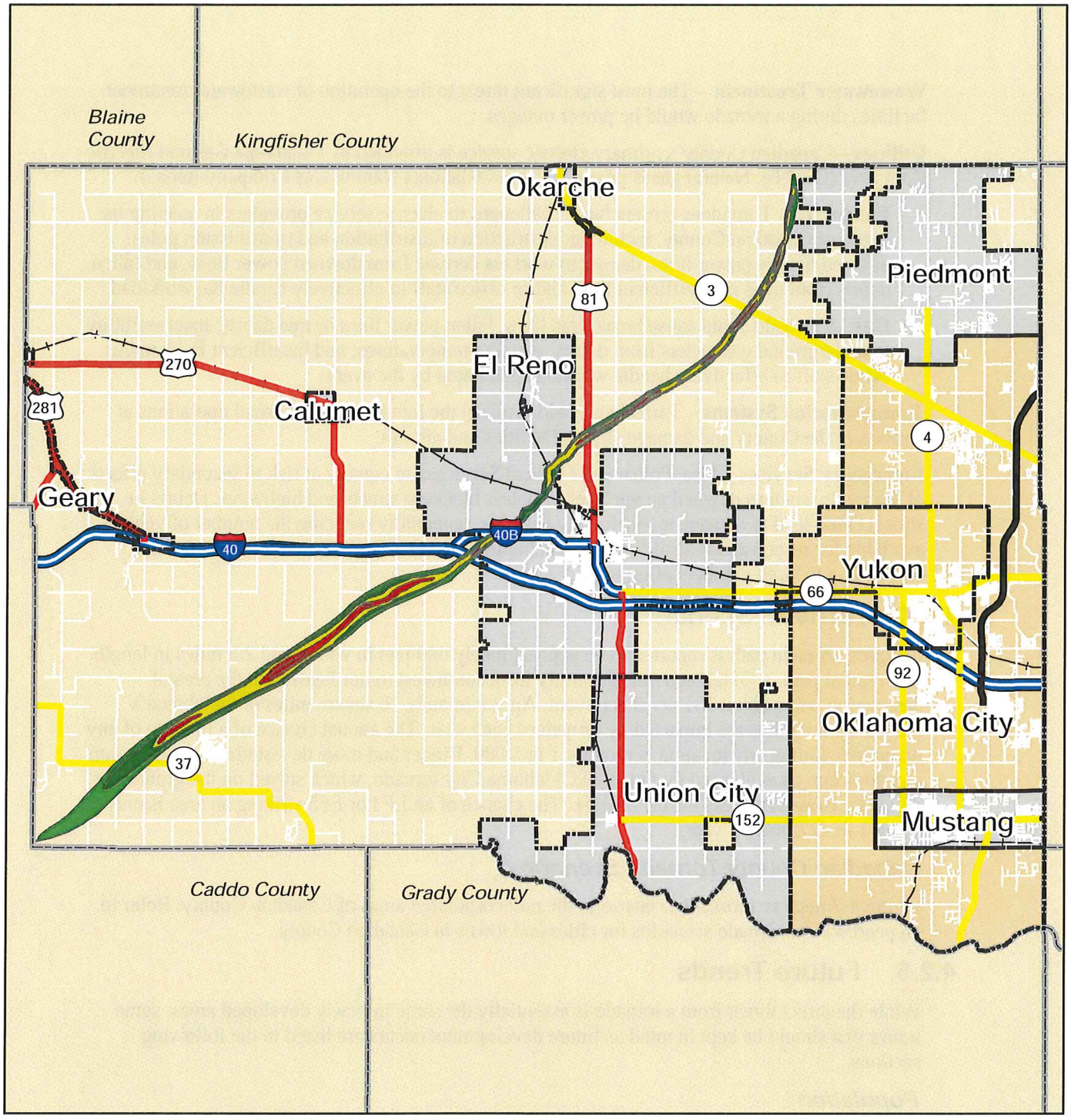
Figure 4-7 depicts a tornado scenario in the unincorporated areas of Canadian County. Refer to Appendix F for tornado scenarios for cities and towns in Canadian County.

4.2.5 Future Trends

While the direct threat from a tornado is essentially the same in newly developed areas, some issues that should be kept in mind as future development occurs are listed in the following sections.

Population

As the "baby-boomer" population begins to move into retirement, it can be anticipated that the number of people pursuing outdoor sports and/or social activities will increase. Attention should be given to the task of continuing to educate the community of the dangers associated with tornadoes. Also adding to this increase in out-of-doors activity could be the rising cost of fuel. With more families looking for activities closer to home, parks and other outdoor recreation areas may become more attractive. These facilities, and the persons frequenting them, should be considered especially vulnerable to the effects of tornado events.



LEGEND

- Interstate
- US Highway
- State Highway
- Turnpike
- Railroads
- Not in Plan
- City Limits

Tornado Scenario

- F-Scale 1
- F-Scale 2
- F-Scale 3
- F-Scale 4
- F-Scale 5

0 2.5 5 Miles

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Figure 4-7

Canadian County

Tornado Scenario

Technological advances in mobile entertainment could also factor into the increase of already escalating number of tornado related fatalities in automobiles. An ever-increasing market in the satellite radio industry is making it possible for more drivers to enjoy non-local network radio programming – thus adding to the "disconnectedness" of those driving during threatening weather conditions. Additionally, devices which interface personal MP3 devices with automobile radios are becoming more affordable, allowing drivers to listen to their own selection of music while traveling – again, decreasing the amount of localized and vital information that may be transmitted over the airwaves.

Structures/Buildings

As open areas are developed and existing structures renovated, actions to lessen the potential impacts of tornadoes should be considered. Safe Rooms constructed to meet or exceed the criteria of FEMA safe room specifications, and reinforced exterior materials (windows, doors, etc.) should become integral components of any new development anywhere in Canadian County

EF5 Tornado Damage in Piedmont, Oklahoma

Critical Facilities

As the threat from the effects of tornado events themselves cannot be eliminated, any critical facilities undergoing expansion, renovation or rebuilding should consider following updated techniques for such projects. The addition of safe rooms, reinforced exterior materials such as windows, doors, siding, etc. can do much to improve the safety of these facilities. Additionally, all efforts to guard against potential secondary effects should also be implemented. These secondary effects may include, but not be limited to, compromise of structural integrity, broken windows/doors from wind-strewn debris, water damage from accompanying rains, power interruptions/surges and communication interruption from lightning or wind damage.

Infrastructure

Ensuring local government facilities are well protected against the potential effects of tornado events is an on-going effort. Investigating and implementing new technology as it is made available will help ensure the continuity of operations at all levels of government—uninterrupted communications and protection of the ever-growing mountain of electronic data gathered in day-to-day operations should be considered priorities in any plans developed for future development. In addition, all critical county facilities should be equipped with backup generators.

4.2.6 Conclusion

Due to the nature of Canadian County's location and climate, severe thunderstorms and tornadoes will remain a threat to the County, its Communities and its Public School systems, as demonstrated by the EF5 tornado event of May 24, 2011. The vulnerability of Canadian County's jurisdictions is considered high. Efforts to educate the public and prepare for and fortify County facilities, Incorporated Communities and Public School Systems against tornado events should continue to be a priority. Improved building technologies, advances in public communication capabilities, and opportunities for collaboration among community agencies should remain prominent in the planning and response communities' activities

Data Limitations

There are many "intangibles" in tornado spotting. Low hanging "scud" clouds may be mistaken for a lowering funnel. Tornadoes are frequently reported more often near inhabited areas and major highways, due to the greater likelihood of witnesses being present when a tornado appears, whether any damage occurred or not. In addition, there is frequently disagreement on whether wind damage was caused by a tornado or just severe straight-line winds or a severe downdraft. Accurate reports of tornado numbers and damage may be skewed by these factors.

Update Changes

Identified significant changes made from previous Multi-Hazard Mitigation Plans from Canadian County, Calumet, El Reno, Mustang, Piedmont, and Union City are outlined in Appendix E. Changes are based on criteria outlined for Plan Updates in the Local Multi-Hazard Mitigation Planning Guidance document of July 1, 2008.

4.2.7 Sources

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