Online Damage Report

The 27th April 2014 Tornado Outbreak

Parkwood Meadow Subdivision in Vilonia, AR, April 27, 2014
(Image Courtesy: Reuters/Carlo Allegri)

University of Florida's Wind Hazard Damage Assessment Team

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29 April 2014

EXECUTIVE SUMMARY

A significant outbreak of severe thunderstorms spawned eleven confirmed tornadoes that rapidly moved through Oklahoma, Kansas, Iowa, Arkansas and Louisiana on Sunday, 27 April 2014. One particularly damaging storm system produced a tornado on the ground almost continuously for 80 miles, causing catastrophic damage to the towns of Mayflower and Vilonia in Arkansas. Preliminary reports have rated this tornado at least an EF-3. Sixteen direct fatalities have been reported for 27 April, 2014 alone, 14 of which occurred in the towns of Mayflower and Vilonia. The other fatalities occurred in Quapaw, OK (1 fatalities) and White County, AR (1 fatality).

This report is the first of a two-part report on the damage caused by this tornado outbreak. The severe weather (as predicted) has continued yesterday and today (April 28th and 29th 2014), and so more building damage is likely to occur.

The damage to buildings followed similar patterns that have been observed by others and us in previous tornado outbreaks. In the worst hit areas, trees were toppled, stripped of leaves and branches had their bark removed. As usual, of constructed buildings, light-framed wood residential structures suffered by far the worst damage, perhaps due to their sheer numbers exposed to the tornado and also because such structures are not designed to be resilient to tornadic loads. Houses were shifted off their foundations in several towns, and in a few instances (Vilonia, AR), new slab-on-grade homes were swept clean. One under-construction school (85% completed) in Vilonia, AR, also collapsed.

Stronger buildings can be built quite economically today that would mitigate some structural damage and improve life safety protection in our homes. It is up to communities and their leaders to decide whether they wish to pursue such resilient and sustainable approaches to construction or whether to continue with the status quo. These solutions come at a price, yet to be determined and accepted. Engineers and scientists are working together to gain a better idea of the appropriate design loads, and to develop cost-effective technologies that can resist those loads. It is up to society, people at large to determine what costs are acceptable to reduce the risks and minimize economic losses from tornadoes.

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BACKGROUND

The Spring 2014 tornado season has started slowly, with just 36% of the median number of tornadoes (92) touching down from January 1 through April 19th. This is the lowest total number of tornadoes to start the year in over 60 years of record keeping by the Storm Prediction Center (SPC). There had also been no fatalities in the US from tornadoes as of April 26th, the longest fatality-free start of the tornado season in 99 years.

The National Weather Service computer models identified the impending instability conducive to a significant tornado outbreak in the 25 April 2014-7:30 am Convective Outlook for 27 April 2014 (Figure 1). The outlook product stated that the atmospheric conditions would be conducive to supercells capable of producing hail and strong tornadoes.

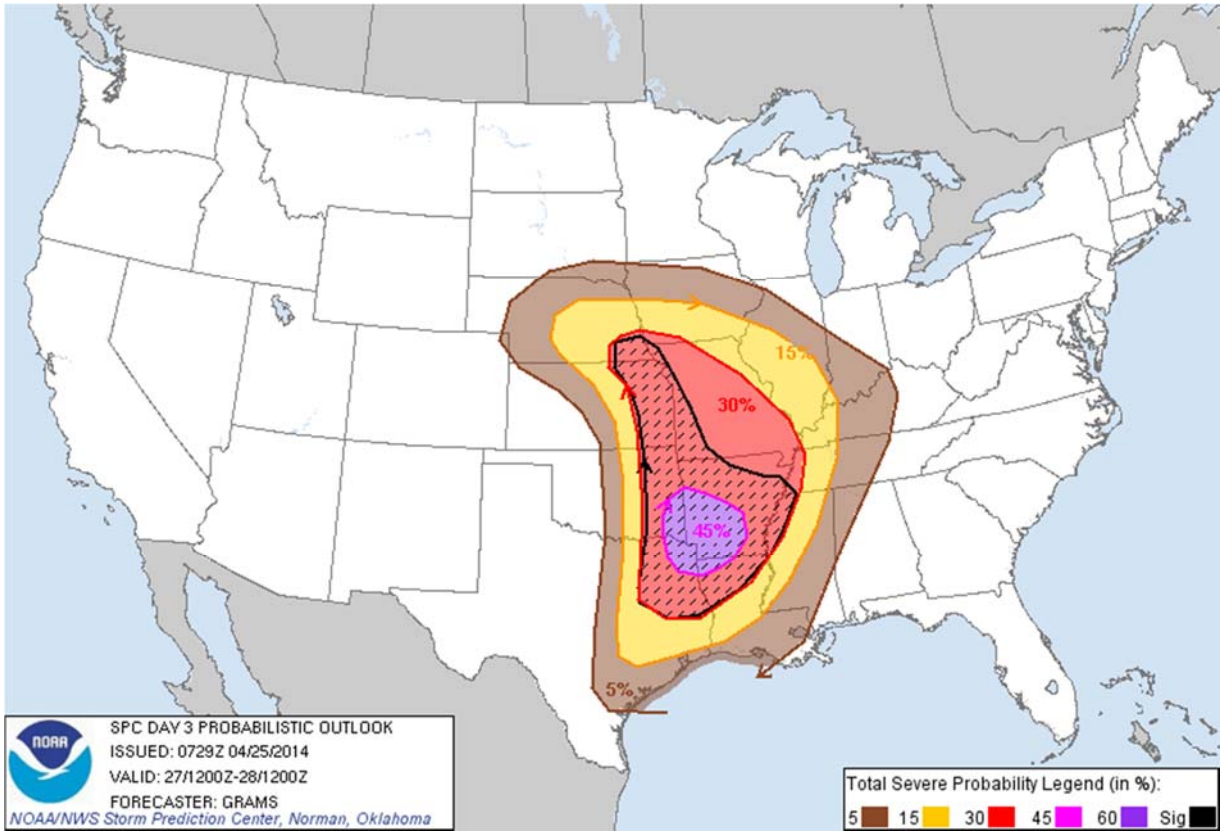

Figure 1. Day 3 Convective Outlook by SPC for April 27 showing likelihood of severe weather

TIMELINE

The timeline of events in the 27 April, 2014 outbreak is illustrated in the tweets below. Social media has become an important tool in documenting real-time weather reports.

SUMMARY OF IMPACTED TOWNS

SPC confirmed a total of 30 tornado reports on 27 April 2014, spread over seven states and 16 counties. These events caused at least 16 fatalities; 14 in Arkansas, 1 in Oklahoma and 1 in Iowa. Regrettably, the number of tornado-related fatalities increased yesterday to 25, as the tornado outbreak continued through 28 April, 2014. At this time, damage survey teams have not yet completed documenting the damage and providing EF-Scale estimates for most of the tornadoes. A map of the 27 April, 2014 tornado reports is provided in Figure 2.

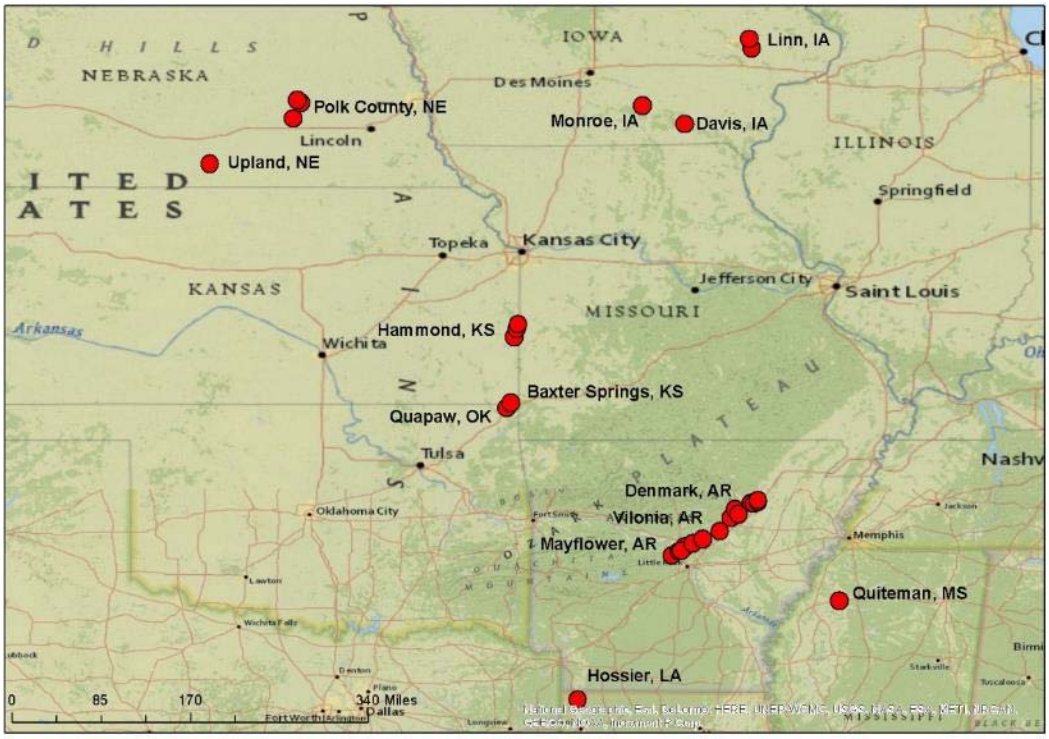

Figure 2. Map of tornado reports for 27 April, 2014

Preliminary reports indicate that the heaviest damage was sustained by the towns of Mayflower and Vilonia in Arkansas, Quapaw, OK and Baxter Springs, KS. The information that is known about the damage to these towns is summarized below in Table 1.

Table 1. Summary of major impacts from 27 April, 2014 tornadoes

Time	City	State	EF-Rating	Fatalities	Injuries	# of Buildings
6:32PM	Quapaw	OK	2	1[1]	6[1]	60[1]
6:35PM	Baxter Springs	KS	2	0[2]	25[2]	100[2]
8:25PM	Mayflower	AR	3	5[3]	> 100[3]	~3,000[4]
9:01PM	Vilonia	AR	3	10[3]		

[1] http://www.tulsaworld.com/news/state/tornado-hit-oklahoma-town-of-quapaw-without-warning/article_6600b47b-e60a-562b-9ff5-ab6daea30e22.html
[2] http://www.wsmv.com/story/25358045/tornado-leaves-path-of-damage-in-baxter-springs
[3] http://abclocal.go.com/wtvd/story?section=news/national_world&id=9520147
[4] http://www.arktimes.com/ArkansasBlog/archives/2014/04/29/entergy-3000-homes-damaged-in-tornado

OVERVIEW OF HEAVIEST TORNADO IMPACTS

Quapaw, OK

Quapaw, OK is a small Oklahoma town just SW of Baxter Springs, KS with a population of 906. An aerial view of the tornado track through the town is shown in Figure 3. The tornado destroyed 15

structures in the town, including five businesses and the volunteer fire department station. Approximately 45 other structures also sustained damage. One fatality was confirmed, due to a concrete wall falling onto a car, killing the driver. The National Weather Service has given a preliminary EF-2 rating to this tornado.

Figure 3. Aerial view of tornado path through Quapaw, OK.

Baxter Springs, KS

Baxter Springs, KS is a town with a population of about 4,100 in far East Kansas, about 12 miles WSW of Joplin, MO. It was founded in 1868 and grew rapidly in the early 1870 as well as the late 1920s. Over 95% of the homes in Baxter Springs were built before 2000. Eight tornadoes have been reported near Baxter Springs since 1950, shown in Figure 4, but no direct impacts had been recorded prior to April 27, 2014.

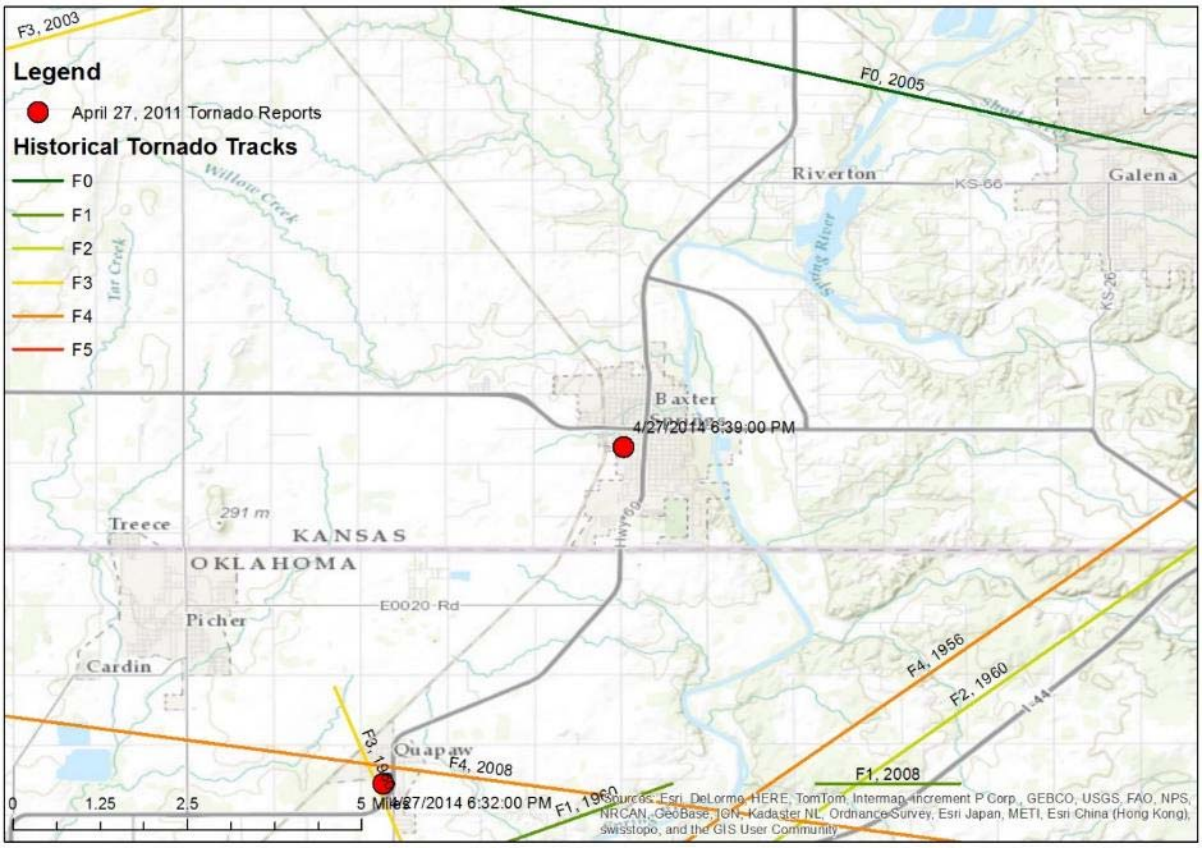

Figure 4. Historical tornado tracks near Baxter Springs, KS since 1950

The April 27, 2014 tornado struck the town at about 5:45pm on Sunday afternoon, a time when most of the town's residents would be in their homes. The tornado damaged nearly 100 homes and businesses and caused 25 confirmed injuries, but fortunately no fatalities. The path of the tornado through the town is visible in Figure 5. Damage to homes is shown in Figure 6 and Figure 7.

Figure 5. Aerial view of damage through Baxter Springs, KS (AP Photo/Orlin Wagner)

Figure 6. Degree of Damage 7 (113 mph - 153 mph). Possibly an EF2 rating. (AP Photo/Orlin Wagner)

Figure 7. Degree of Damage 6 (104 mph – 142 mph). Possibly an EF2 rating. (AP Photo/Orlin Wagner)

Long-Track Arkansas Tornado

At approximately 8:25pm EST, a tornado touched down in Pulaski County, AR, nearly 16 miles NW of Little Rock, AR. The tornado and its parent supercell tracked almost continuously for over 80 miles, with only a small gap in the center separating two distinct tornado tracks. The heaviest damage occurred to the towns of Mayflower and Vilonia near the start of the tornado, as shown in Figure 8.

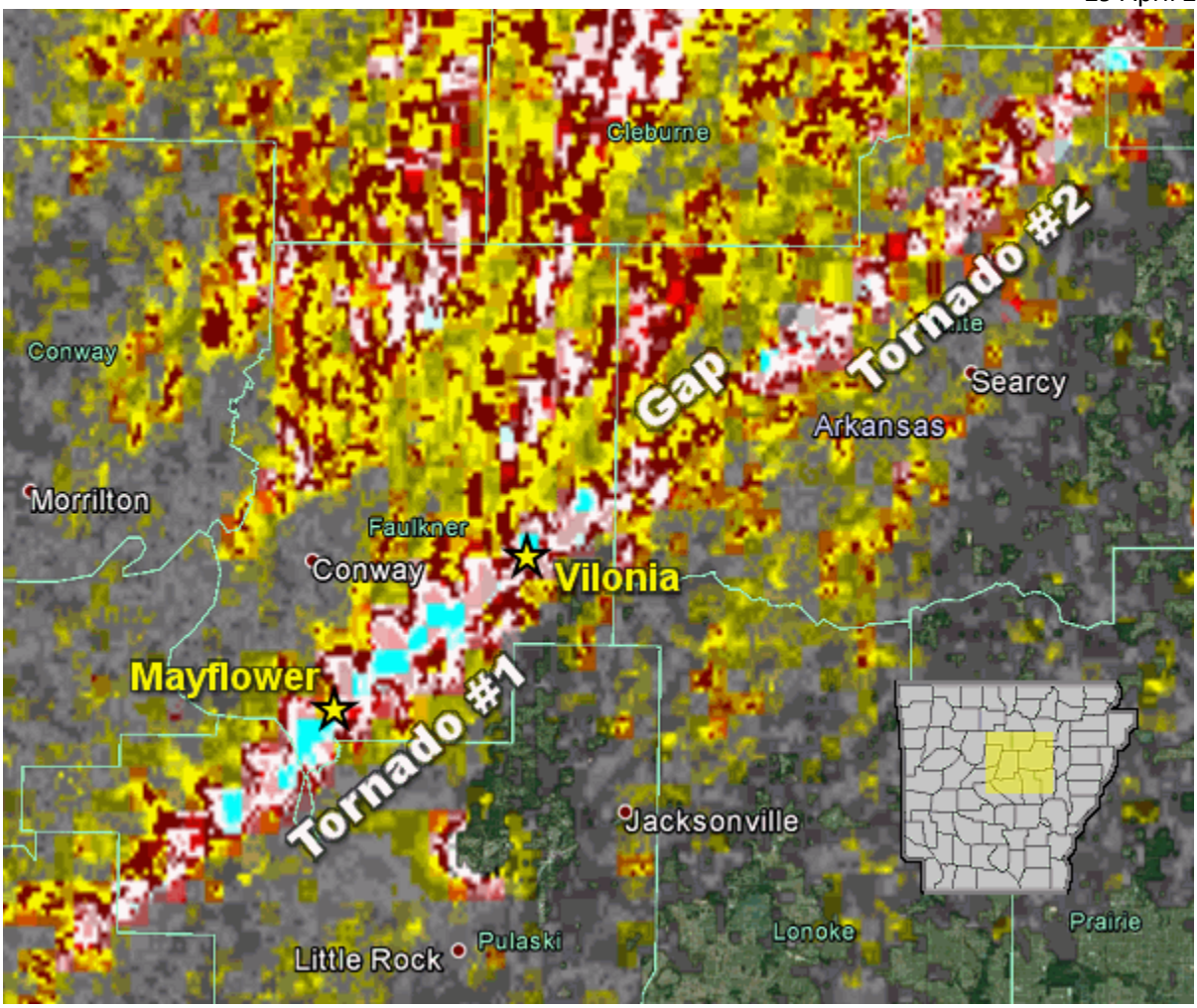

Figure 8. Long-track tornado in Central Arkansas on April 27, 2014 (Image Courtesy of NWS)

Mayflower, AR

Mayflower, AR is a suburb of Little Rock, AR located in Faulkner County with a population of about 1,600 residents. An EF-2 tornado tracked across its SE corner in 2011, and an F-0 tornado tracked directly across the town in 2000. Beyond tornadoes, an Exxon Mobile pipeline carrying heavy crude oil ruptured nearby in 2013, spilling over 5,000 barrels of oil into regions of the town and forcing the evacuation of twenty-two homes.

The April 27, 2014 tornado entered Mayflower around 8:30pm and caused three fatalities, two in the relatively new River Plantation subdivision. The River Plantation subdivision is located just east of the Arkansas River and contains approximately 100 luxury homes, all less than 15 years old. The area sustained heavy damage as shown in Figure 9 and Figure 10. As of the time of this report the number of damaged or destroyed homes here is not known. The exact location of the fatalities is also not yet known.

Figure 9. Severe damage in the River Plantation development east of Mayflower, AR

Figure 10. Roof destroyed from home in River Plantation development

From photographs of the damage and available realtor reports, it appears the homes in this area are generally masonry construction with wood rafters framing the roofs. The roofs appear to consist of wood sheathing and asphalt shingles. All of the homes appear to have enclosed garages. The available photographs indicate similar wood-frame construction that was observed in damaged homes in Moore, OK last year. The use of long wood rafters with steep sloped roofs is ill-suited to resist the high uplift wind forces. In those Moore, Ok homes, surveyed by the PI last year, the rafters were toe-nailed into the wall plates, which provided insufficient capacity to resist the loads. The wind uplift loads are exacerbated by the presence of roof overhangs. For example, the roof failure of a Mayflower, AR home shown in Figure 11 suggests a combination failure mechanism, initiated by high loads on the overhang, causing roof-to-wall connections to fail and then the remaining roof section to be swept away.

Figure 11. Before (bottom, from Google StreetView) and after (Courtesy of Twitter user @courtneyism) of a Mayflower, AR home in River Plantation.

Vilonia, AR

Vilonia, AR is a small town north of Little Rock, AR in Faulkner County with a population of 3,815. The town was formed in 1938 but has several new subdivisions around it. The town has had several tornadoes pass through or in close proximity in the past, including an EF2 tornado in 2011 that caused three fatalities when it struck a mobile home community southwest of the town. The 27 April, 2011 tornado struck a newly constructed Intermediate School SW of the town before traveling NE through the center of the town and through a new development NE of the town off Naylor Rd. The estimated tornado track is shown in Figure 12. Eight fatalities have been confirmed in the town so far, at least four in the new home development off of Naylor Rd.

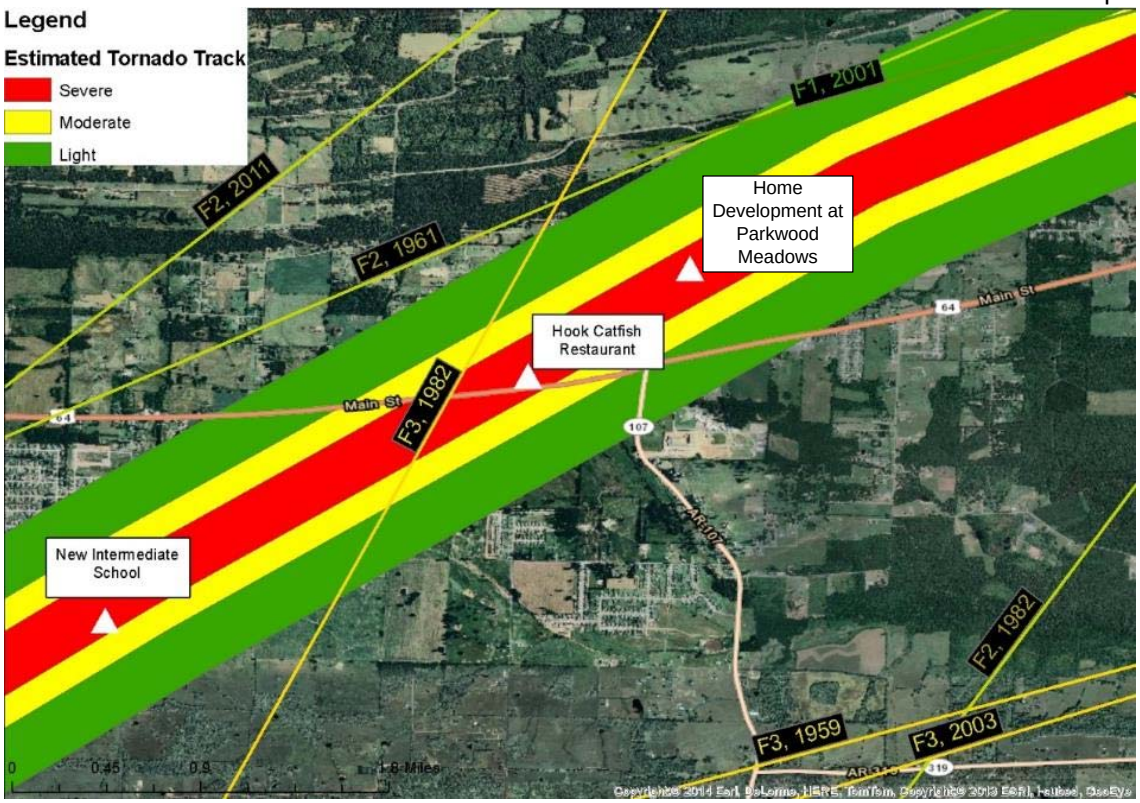

Figure 12. Estimated tornado track through Vilonia, AR with historical tracks overlayed. Points of significant damage highlighted by white triangles. Estimated track from ESRI Disaster Response Maps.

Damage to Intermediate School under Construction

A new Intermediate School just SW of downtown Vilonia, AR suffered a direct hit from the tornado. The $12 million school was under construction and 85% completed, set to open in Fall 2014. A construction photo from September 2013 shown in Figure 13 indicates the primary structure was a steel portal frame with masonry walls between the steel columns and steel purlins supporting the roof.

Figure 13. New Intermediate School in Vilonia, AR while under construction. Photo was taken September 29, 2013 by Linda Hicks.

The school sustained severe damage, with the majority of the cladding removed and destroyed and significant damage to the structural members as well, as shown in Figure 14 and Figure 15. Because of the complete destruction of a large portion of the building as shown in Figure 15, this damage could be rated as high as DOD 10 using the Elementary School Damage Indicator of the EF-Scale. This would put the estimated wind speeds between 152 mph and 203 mph with an expected value of 176 mph, which would be an EF-4. A more thorough ground-based investigation would be needed to confirm this.

Figure 14. Severe damage to new Intermediate School in Vilonia, AR set to be opened Fall 2014. Red arrow indicated location and direction of photo shown in Figure 15.

Figure 15. Collapse of structural members at the Intermediate School in Vilonia, AR.

Damage to Downtown Vilonia, AR

Damage to the downtown region of Vilonia included the complete destruction of the former Catfish Hook restaurant, which was reportedly reduced to only a slab. A number of homes and businesses along Main Street were also destroyed or heavily damaged, including a Valero gas station shown in Figure 16.

Figure 16. Before (top, looking North) and after (bottom, looking South) of downtown Vilonia, AR at the corner of S. Church St and Main St, looking NW.

Damage to Homes at Parkwood Meadows Subdivision

Realtor data from Zillow.com indicates the homes in the Parkwood Meadows subdivision were less than five years old. Some had just been finished prior to the tornado. From the available photographs, 44 of the 53 homes in the development were destroyed by the tornado, and nine fatalities have been confirmed. With an average home value of approximately $150,000, the damage to this development alone represents over $6,000,000 in economic losses. Figure 17 provides a before and after view of the subdivision. Many garage doors have collapsed outward in the homes north of Clover Ridge Dr, as shown in Figure 18. Loss of the roof is noted in homes south of Clover Ridge Dr, and total collapse can be seen along Aspen Ridge Dr.

The homes here were wood-frame construction with brick façades, and wood rafters framing hip roof. Detailed photos of the damage do not show anchor bolts were used for wall-to-foundation connections, and metal roof straps were not used to tie the rafters to the walls. The damage here would be described by DOD 9 (all walls collapsed) from FR12 of the EF-Scale, which has an expected wind speed of 170 mph. The tornado would likely be rated either an EF-3 or EF-4 here, depending upon the more detailed ground observations.

Figure 17. Comparison of Parkwood Meadows subdivision before and after the tornado. The yellow arrow indicates the East direction, while the red arrow indicates the estimated tornado centerline through the subdivision. (Photo Courtesy of Twitter user @Scott_Ar).

Figure 18. Looking North over the development after the tornado. Note the gradation of damage present with the garage doors collapsed outward along the north side of Clover Ridge Dr. (Photo Courtesy of USA Today)

Unconfirmed Failure of Storm Shelter Door and Fatality

In his news conference after surveying the damage to Mayflower and Vilonia, Arkansas Governor Mike Beebe mentioned that a woman had died when debris hit the door to her safe room, causing it to collapse. This account has been carried by several additional news outlets, including Reuters, but no further details have been obtained at this time. We were unable to confirm this occurrence or get further information on the whereabouts of this incident. Governor Beebe made reference to this story in his interview with Scott Pelley on the CBS News of 4/28/2014.

DISCUSSION

Our research and field surveys of previous tornadoes and hurricanes suggests that some tornado damage should be categorized as disproportionate collapse, where arguably, the resulting damage progresses to a state of collapse that is disproportionate to the original cause. Due to limited knowledge of actual wind speeds and pressures everywhere within the tornado, it is difficult to say with certainty that disproportionate structural collapse has occurred. However, in the case of the 44 collapsed homes in the Parkwood Meadows sub-division, undoubtedly some of that damage could have been prevented.

We contend that hurricane-resistant design techniques used within fully-engineered wood-framed structures can economically minimize the extensive damage that occurred. It requires some engineering, mainly of the connections, to match the capacity of those connections to the expected loads from the tornadoes. As engineers, we are now in a better position to establish a reasonable load range for tornado design and so, once this is available, the next step will be selecting appropriate connections. With better engineering, homes can be made more resilient, such that catastrophic failures and loss of life can be reduced.

The solutions begin with applying well-understood wind resistant techniques – roof-to-wall metal hurricane ties, robust wall-to-foundation anchors with large washers, structurally robust garage doors. Some techniques could include designing independent roof structures over open porches, so that its failure will not propagate the failure into the main roof structure. Time and again, engineering studies and contractor estimates have shown that single-family homes can be made more resistant to wind loads by adding less than 3 to 5% of the construction of the home. Putting that into perspective in terms of the Parkwood Meadows homes, an up-front investment of $3,000 (2% increase per house) could have made the difference between some houses that stood up and total destruction of those 44 homes. So for a total additional cost of roughly $160,000, the estimated $6,000,000 in losses from the Parkwood Meadows subdivision could have been substantially reduced.

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