Online Damage Summary of

June 16-18, 2014 Tornado Outbreak

(Source: Darin Epperly, @darinepperly via Twitter)

University of Florida Wind Hazard Damage Assessment Team

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Executive Summary

After a slow start to the 2014 tornado season, activity has been high in the month of June with tornadoes reported on every day except one as of June 20, 2014. The tornado outbreak from June 16-18 has led to a total of 89 preliminary tornado reports, although at the time of this report local National Weather Service offices were still working to confirm individual tornadoes. In the afternoon hours of June 16th, 2014 two tornadoes, forming within minutes of each other, touched down near the small village town of Pilger, NE. The first tornado started about 6 miles southwest of the town and after travelling about 4 miles northeast towards Pilger, a second formed and they travelled together for 12 miles. The northern tornado tracked through the Southern region of the town while the other bypassed the town. The tornado in Pilger, NE destroyed dozens of homes and resulted in substantial damage to the local middle school, post office, farmer's co-op, fire department building, Lutheran church, and storefronts in the downtown area, in addition to significant damage to residential structures. The tornadoes also caused two fatalities and approximately 20 injuries. The National Weather Service classified both tornadoes as EF-4 with damage paths stretching 19.3 and 11.6 miles.

In addition to the EF-4 tornadoes in Nebraska, a number of other tornadoes in this outbreak caused significant damage in South Dakota, Wisconsin and even Ontario, Canada. Two fatalities have been reported in this tornado outbreak, and a large number of homes and other structures have also sustained significant damage.

While damage was observed in several communities, a number of communities also narrowly avoided the impacts of strong tornadoes. The probability of a tornado strike is low, but communities can still work to strengthen their infrastructure and disaster response so that they are ready for what seems to be the inevitable strike. For many small towns, the decisions made now may impact whether they are still in existence after a future tornado strikes.

This work is part of the research at the University of Florida to document tornado outbreaks as they occur. The study is done in parallel to our research seeking to understand and quantify the strength of tornado loads and their interaction with vulnerable wood-framed structures. It is our thesis that engineering solutions are urgently needed and they will be found, to improve the tornado-resistance of houses. Stronger buildings can be built quite economically today that would mitigate structural damage and provide better life safety protection – it is up to communities and their leaders to decide whether they wish to pursue such resilient and sustainable approaches or whether to continue with the status quo. These solutions come at a price, yet to be determined, once engineers and scientists gain a better idea of the loads, and society determines what costs are acceptable to reduce the risks and minimize economic losses from tornadoes.

This report was prepared from online sources by University of Florida civil engineering students in Prof. David O. Prevatt's Research Group. It is part of their learning in forensic engineering and post-disaster damage investigation. Students were tasked to gather information from online sources and collate information on the tornado (from the National Weather Service, storm chaser Twitter feeds), injuries and fatalities (from media reports) and on structures (from the US Census Bureau and building code websites).

Please visit our website, http://windhazard.davidoprevatt.com, for additional information, and to download previous damage reports, survey results and for research on the interaction of tornadoes and residential infrastructure. A link to previous tornado damage surveys are also available on Dr. Prevatt's webpage, www.davidoprevatt.com, including the 2011 Tuscaloosa Tornado Damage Survey Report. A list of helpful references is included at the end of this report.

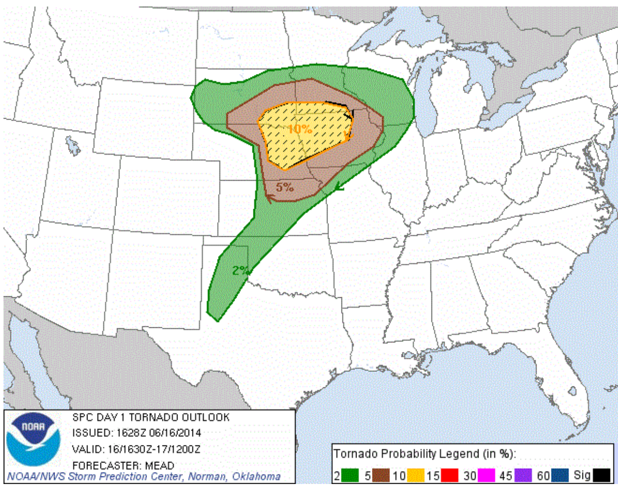
Your questions and comments on any aspects of our work are most welcome. Please direct your enquiries to NSF Graduate Research Fellow and PhD Graduate Student, Mr. David B. Roueche, who can be reached at david.roueche@ufl.edu.

About the Wind Hazard Damage Assessment Team

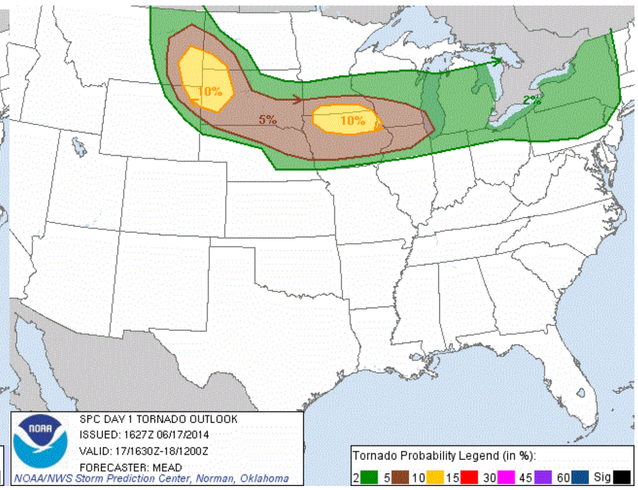
The Wind Hazard Damage Assessment Team was created through support from the NSF Award #1150975. Its mission is to train university students interested in building construction, engineering and architecture in the forensic engineering and techniques for post-hazard damage surveys and data collection. The team has surveyed damage after several Florida tornadoes and continuously monitors the prevalence of tornadoes worldwide. Ultimately the Team hopes to inspire upcoming engineers and building professionals in hopes to change the paradigm of widespread catastrophic damage to houses in tornadoes. Mr. Jeandona (JD) Doreste, is a civil engineering undergraduate student at UF and Webmaster of the Wind Hazard Damage Assessment Team site. JD is actively recruiting other UF students to join the team, and he can be reached at jdoreste1@ufl.edu.

PREDICTIONS

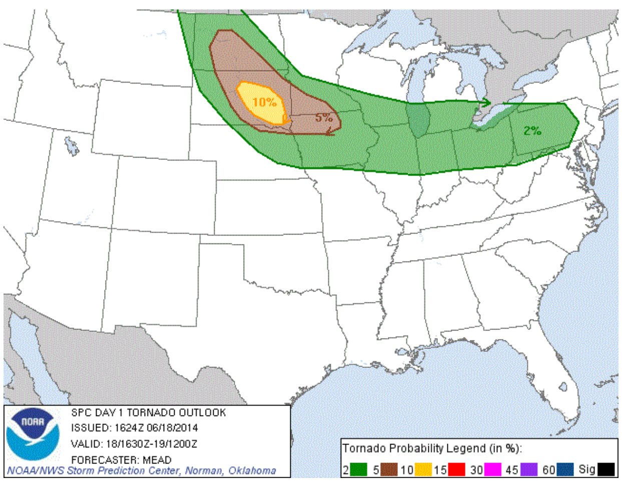
Initial expectations for tornado risk on June 16-18, 2014 were moderately significant. The Storm Prediction Center tornado outlook for June 16th showed a 10% probability of tornado genesis in Northeast Nebraska, Southeast South Dakota, Southwest Minnesota, and Northwest Iowa, for June 17th a 10% probability in Central South Dakota, and for June 18th a 10% probability in Northwest South Dakota, Northern Iowa and southern Montana.



(a) 06/16/2014 as Issued by NWS at 12:28PM EDT



(b) 06/17/2014 as Issued by NWS at 12:27PM EDT

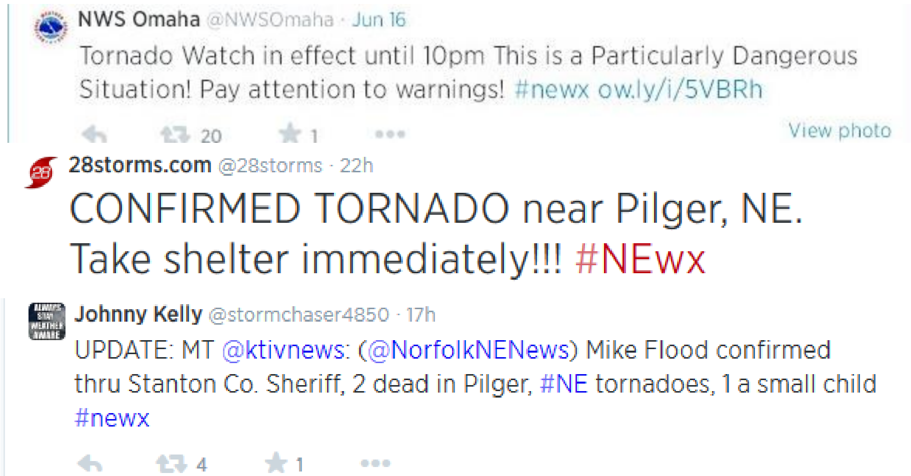


(c) 06/18/2014 as Issued by NWS at 12:24PM EDT

Figure 1: Tornado Probability for June 16-18, 2014 as Issued by NWS SPC on same day (Source: http://www.spc.noaa.gov/products/outlook/archive/2014/day1otlk_20140616_1630.html, http://www.spc.noaa.gov/products/outlook/archive/2014/day1otlk_20140617_1630.html, http://www.spc.noaa.gov/products/outlook/archive/2014/day1otlk_20140618_1630.html)

TWEETS

Stormchasers and NWS tweets suggested moderate to high expectations for tornado formation for the 16th of June and provided updates on status of the storm. Twitter continues to prove to be a reliable medium for relaying extreme weather notifications.



CONFIRMED TORNADO REPORTS

The Storm Prediction Center (SPC) has confirmed 89 tornado reports (shown in Figure 2), although local NWS offices are still working to confirm individual tornadoes, since many of the tornado reports may be from the same tornado. The NWS survey teams confirmed that four tornadoes occurred in NE Nebraska on the June 16th, 2014. Tornadoes have also been confirmed in Wisconsin, South Dakota, Michigan, Iowa and even the province of Ontario, Canada. A summary of the preliminary impacts of significant, confirmed tornadoes is given in Table 1. Information in this table was compiled from preliminary NWS surveys, as well as various local news releases which are hyperlinked in the table.

At this time there have been two confirmed fatalities from the outbreak, both from the Pilger, NE tornado. One fatality occurred in a mobile home in the town of Pilger, and the other fatality occurred in a vehicle just outside Pilger. At least 200 structures have been reported damaged or destroyed, the majority of them residential.

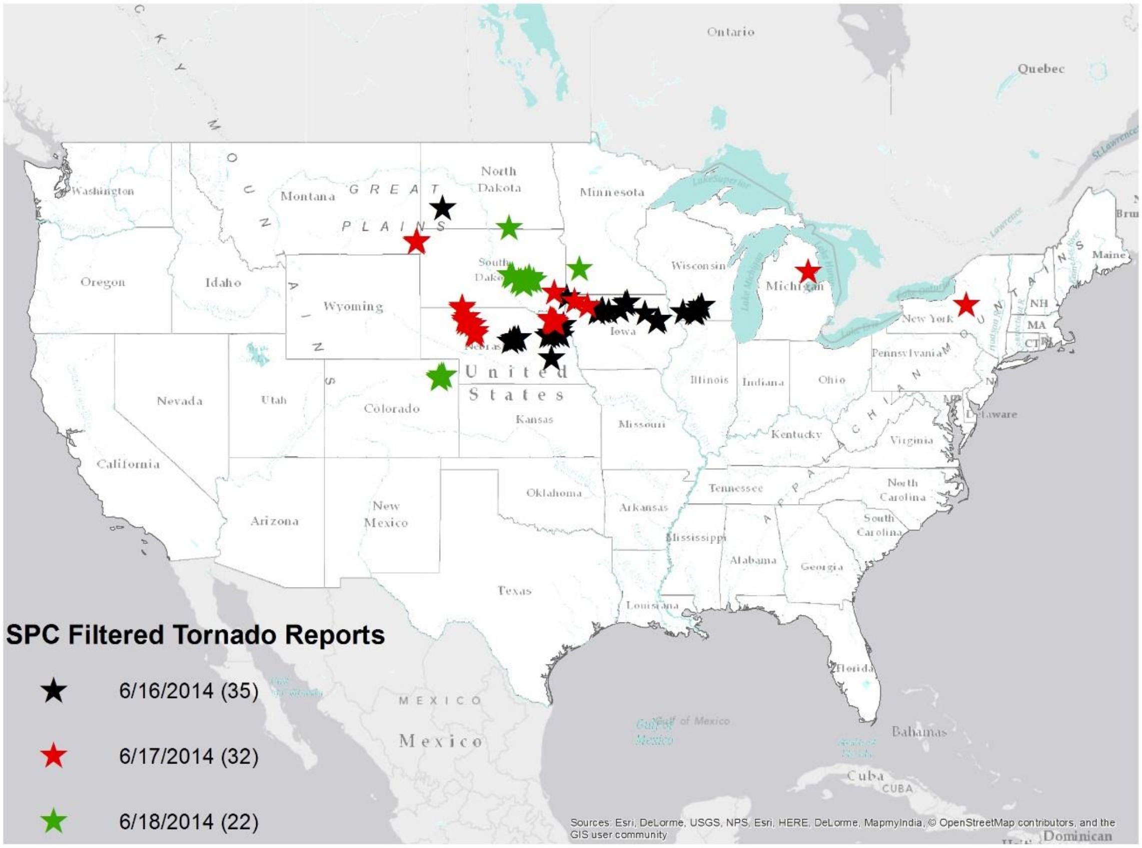


Figure 2: Filtered tornado reports from SPC by day (total number given in parentheses).

Table 1: Summary of Tornadoes Causing Significant Damage in the June 16-18, 2014 Outbreak

City	County / Township	State / Province	Population	EF Rating	Path Length (miles)	Fatalities	Injuries	Buildings Damaged
Stanton	Stanton	NE	1,577	EF-3	12.09	0	0	7
Pilger	Stanton	NE	352	EF-4	19.3	2	31	65
Eastern Pilger				EF-4	11.6			
Wakefield	Dixon	NE	1451	EF-4	12.76	0	0	28
Wessington Springs	Jerauld	SD	956	EF-2	2	0	1	53
Angus	Essa	Ontario (Canada)	8,603	EF-2		0	3	85
Platteville	Grant	WI	11,384	EF-2	4	0	5	12
Verona	Dane	WI	11,775	EF-3	1	0	0	30

HOUSING DEMOGRAPHICS IN IMPACTED TOWNS

The majority of the towns directly impacted by this tornado were relatively small, with populations ranging from 350 to nearly 12,000. Like the majority of the US, most of the homes in these towns are aging, with typically less than 10% built after 2000, as shown in Figure 3. An exception is Verona, WI, where nearly 35% of the homes were built after 2000.

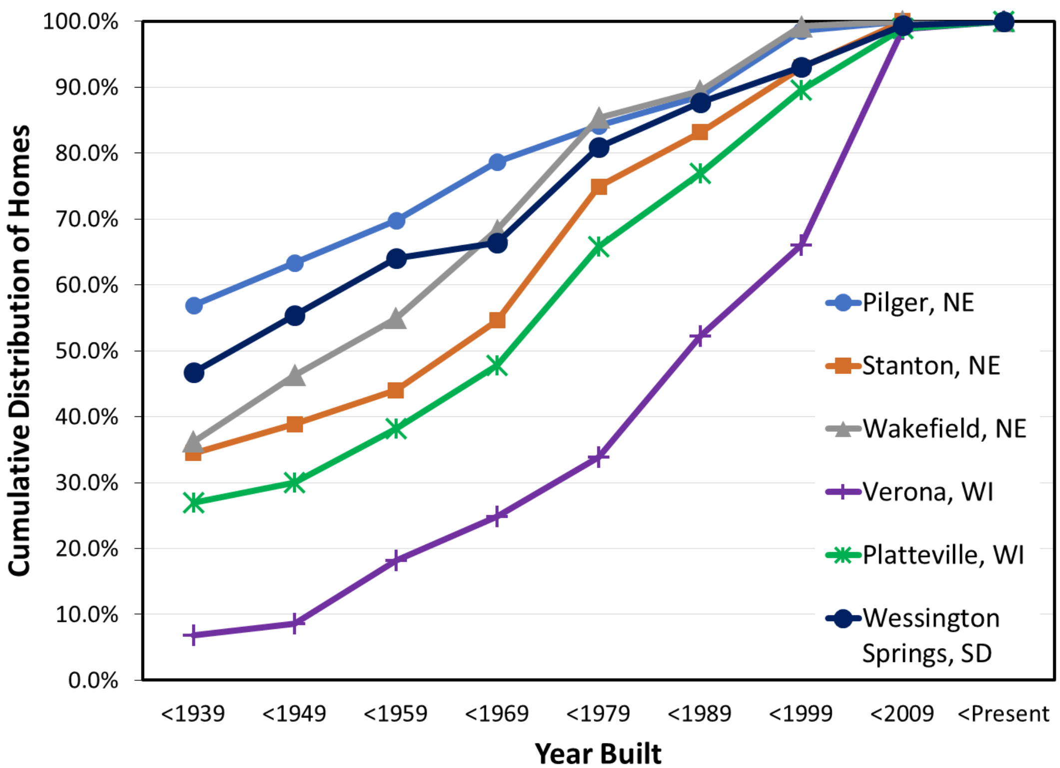


Figure 3: Distribution of the housing age in the towns impacted by June 16-18 tornadoes (American Housing Survey, 2010)

SELECTED DAMAGE REPORTS

Stanton, NE Tornado

At 3:42PM EST on June 16, 2014, a tornado touched down about 7 miles southwest of Stanton and traveled northeast for over 12 miles. The tornado passed just west of Stanton, NE, narrowly missing a direct impact, but did cause significant damage to approximately seven homes outside the town. Severe damage was observed to several farm homes about 5 miles north of the town of Stanton from the same tornado, leading to the EF-4 rating that was assigned. Images from the NWS survey of EF-4 and EF-3 damage are provided in Figure 4. Both homes were two-story with basements, and were constructed before 1920 with unreinforced masonry (Zillow, 2014).

Figure 4: EF-4 damage (left) and EF-3 damage (right) 5 miles north of Stanton, NE (Source: NWS Toolkit, Omaha Office)

Wakefield, NE Tornado

At 3:40PM EST on June 16, 2014, a tornado touched down approximately 10 miles south of Wakefield and move NNE for over 16 miles, passing about 2 miles to the east of the town itself. Over two dozen homes were heavily damaged or destroyed by the tornado, which was given a preliminary rating of EF-4 following the NWS survey. Construction here was similar to that in Stanton, primarily consisting of unreinforced masonry walls with wood frame roofs. The wood sill plates in Figure 5 (left), indicate at least a portion of one home was wood-frame.

Figure 5: EF-4 damage 4 miles SSE of Wakefield, NE to two homes built in the early 1900's. (Source: NWS Toolkit, Omaha Office)

Angus, Ontario (Canada) Tornado

On the evening of June 17, 2014, a tornado touched down in Angus, Ontario in Canada, damaging approximately 85 structures. Dr. Greg Kopp, from the University of Western Ontario, quickly mobilized a team to assess the damage. Preliminary findings were reported through Twitter, while a comprehensive report will be released shortly. We encourage interested readers to find Dr. Kopp (@gregoryalankopp) on Twitter for further updates.

The damaged structures were built in 2010, and were primarily 2-story wood-frame structures with garages and hip roofs with asphalt shingles. An aerial view of the damage path is shown in Figure 6. The tornado moved roughly West-to-East through the neighborhood, fortunately without causing any fatalities. The survey team noted about ten homes with failure of the entire roofs, many of which were linked to garage door failures. Garage doors are a known weakness that, when they fail, propagate failure to the rest of the structure, particularly the roof, due to the resulting increase in internal pressures.

Figure 6: Aerial view of damage to Angus, Ontario from EF-2 tornado. North is approximately indicated by the red arrow. (Photo Courtesy of Ian McInroy)

Figure 7: Tweets from Dr. Gregory Kopp of UWO during damage assessment of the EF-2 tornado in Angus, Ontario in Canada.

Platteville, WI Tornado

At 3:45PM UTC on June 17, 2014 a tornado touched down in a corn field about half a mile outside of Platteville, WI and traveled though the city for 3.82 miles. Significant roof damage was observed to several homes, several commercial and educational buildings suffered moderate damaged, including the University of Wisconsin – Platteville campus. The damage along the path was given a maximum rating of an EF-2. There were no fatalities and 5 injuries. The tornado caused damage to several commons, as well as Southwest Hall, the Engineering Hall, and the Greenhouse and Pioneer Stadium (Figure 8, left). The damage primarily consisted of broken windows, uplift of roof cover and downed trees.

Figure 8: EF-2 damage from to farmhouse (left), light tower knocked down at Pioneer Stadium on UW-Platteville campus (right) in Platteville, WI (Source: NWS Toolkit, Omaha Office, Green Bay Press Gazette)

Verona, WI Tornado

The June 17th, 2014 EF-3 tornado, as confirmed by the National Weather Service, destroyed or severely damaged dozens of homes in Verona, WI, and heavily damaged the County View Elementary School. Portions of the exterior wall, constructed with unreinforced masonry and brick façade, collapsed inward. Portions of the roof, constructed with bar joists and metal roof deck, also collapsed, although it is unclear whether the wall or roof collapsed first. Relatively new homes nearby (built post-2009) also suffered significant damage (Figure 9, right), with 19 deemed uninhabitable. The damaged homes were wood-frame construction with wood trusses.

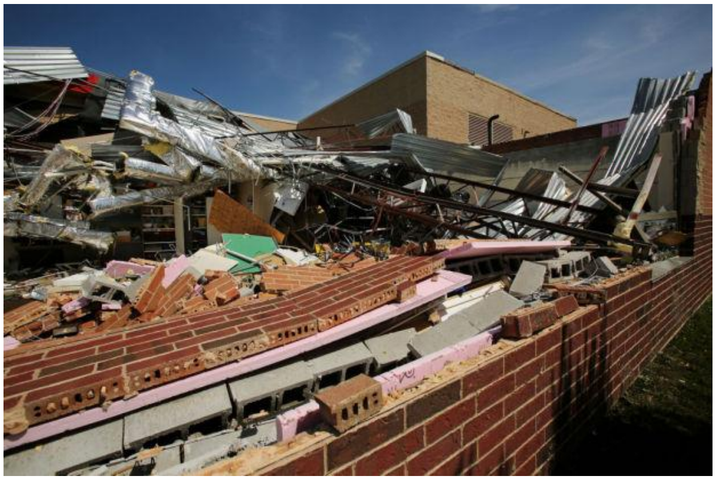


Figure 9: Collapse of classroom wall at County View Elementary school (left) and wall and roof failure at a nearby home (right) (Source: Wisconsin State Journal).

Wessington Springs, SD Tornado

A tornado was reported in Wessington Springs, SD around 10:30 PM EST on June 18, 2014. The path of the tornado took it through the SE corner of the town, destroying 23 homes, damaging 20 others, and damaging 10 businesses (Argus Leader, 2014). Fortunately only two injuries and no fatalities were reported, possibly a by-product of the 20 minutes of lead time the town had before the tornado struck. Over half of the homes in Wessington Springs were built before 1950, as it primarily grew in the early 1900's when a railroad was constructed through the town. An aerial view of the damage is provided in Figure 10.

Figure 10: Aerial view of the EF-2 damage in Wessington Springs, SD from a tornado on June 18, 2014. The red arrow indicates North in this view. The red oval gives the location of Wessington Springs High School, which narrowly avoided a direct hit. (Source: Argus Leader.com)

SUMMARY OF OBSERVED DAMAGE IN PILGER, NE

The most significant damage in this outbreak occurred in Pilger, NE, a small town of about 350 residents in NE Nebraska. Two different violent tornadoes passed by Pilger at nearly the same time, providing dramatic pictures such as that shown in Figure 10. The meteorological rarity of such an event - two strong tornadoes from the same parent supercell - is remarkable. Unfortunately, the tornadoes caused two fatalities and over 20 injuries. Reports indicate that the entire business district downtown was damaged, with some buildings completely destroyed (Local10). The preliminary NWS track of the Pilger tornado in relation to the other Nebraska tornadoes is provided in Figure 11. Individual assessments by the NWS survey team are provided in Figure 12, along with the location of key structures that were damaged in the town. An aerial view of the damage to the business sector in downtown Pilger is provided in Figure 13, while before and after views of key structures are shown in Figure 14.

Figure 10: Twin tornadoes near Pilger, NE. One passed directly through the town while the other passed just east of it. (Source: Kelly Rebecca via Facebook)

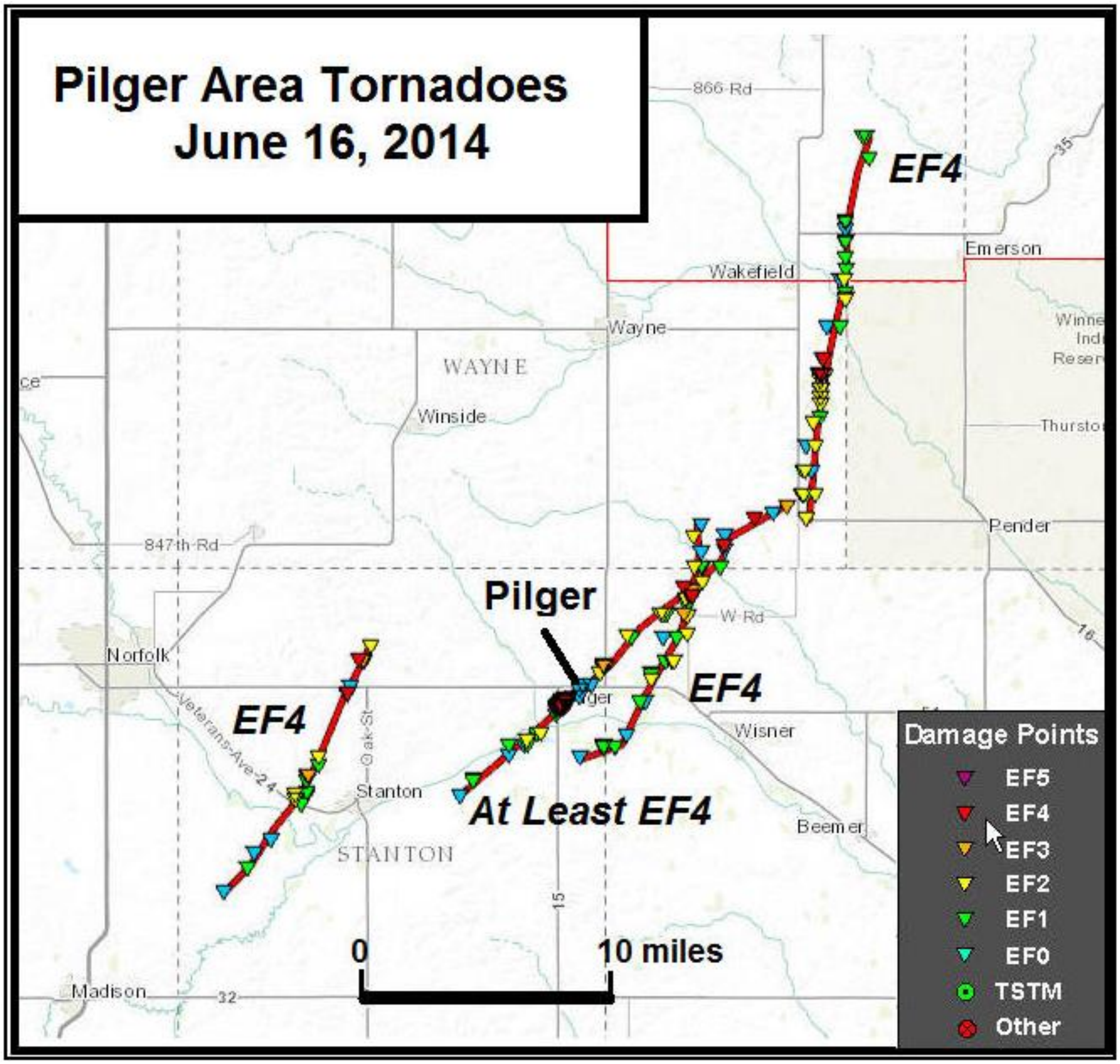


Figure 11: Results of NWS damage survey following tornadoes in NE Nebraska

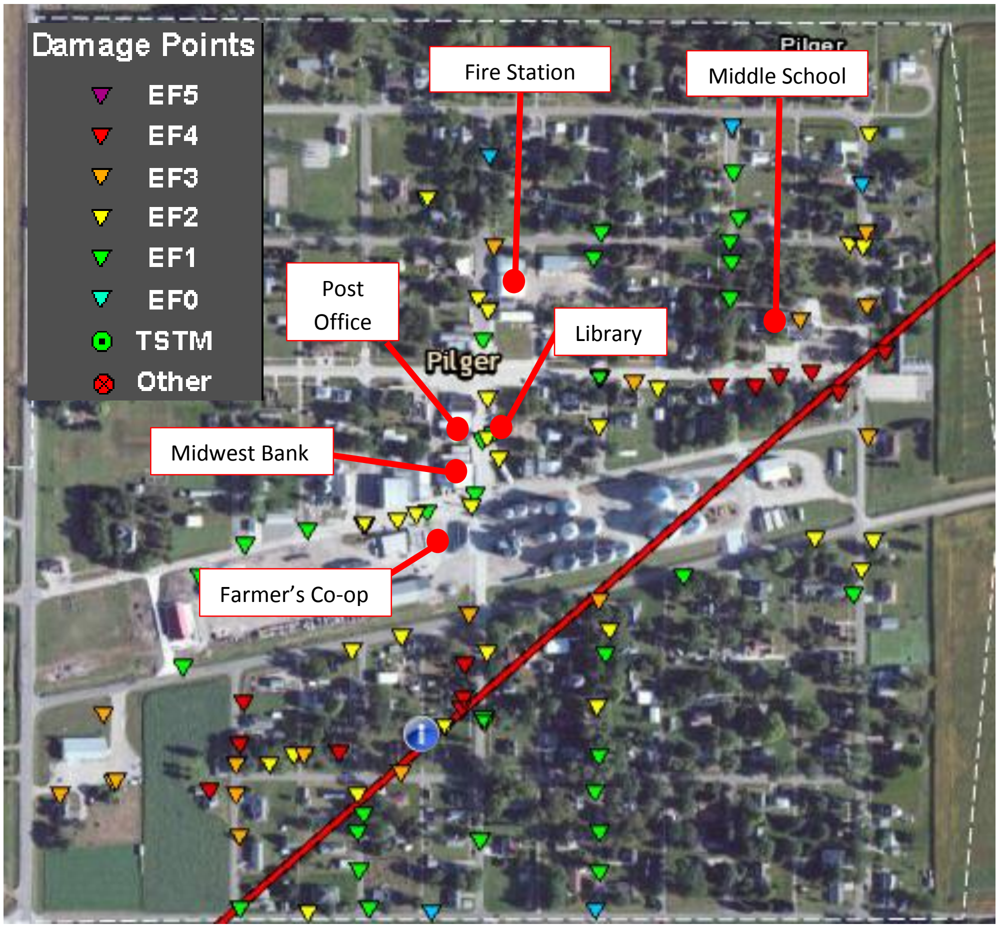


Figure 12: Preliminary results of NWS damage survey in Pilger, NE. The red line represents the estimated center of the EF-4 tornado as it passed through the town. Callouts provide the locations of key structures in the town damaged during the tornado.

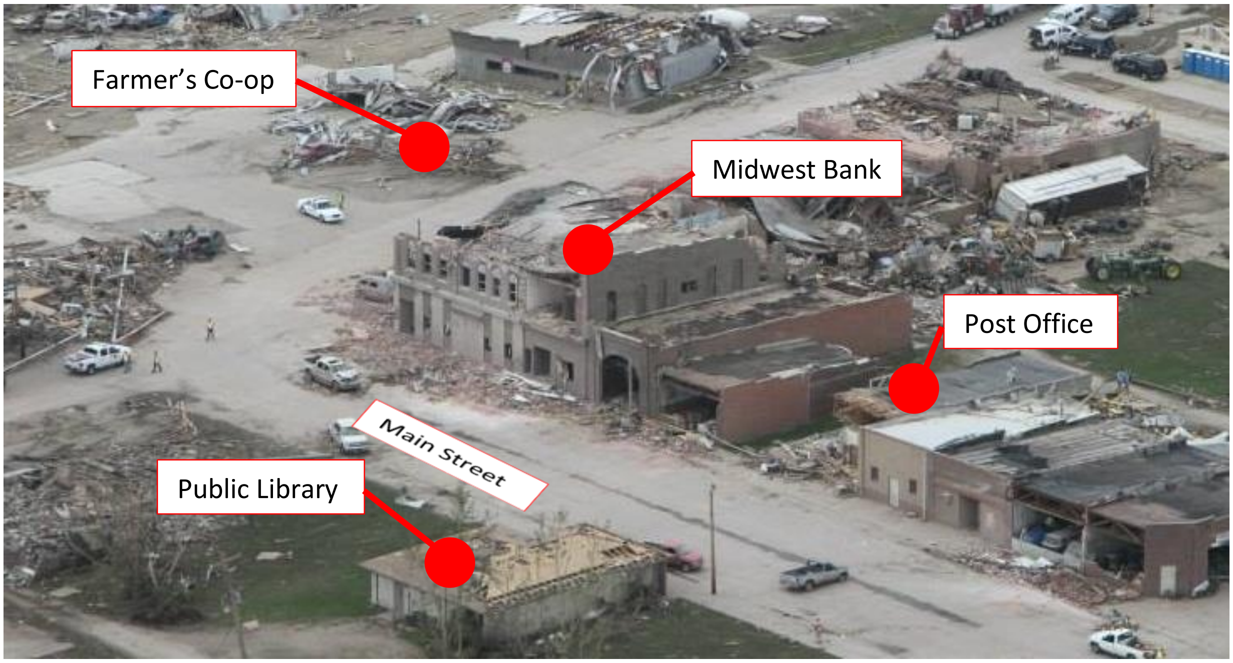
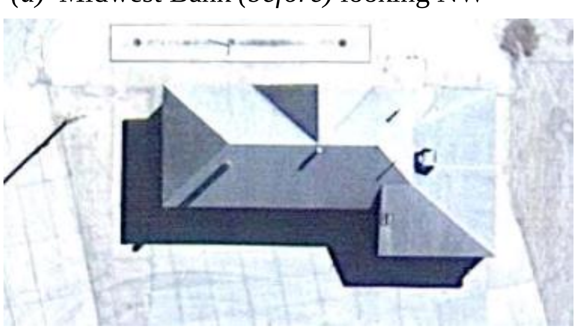


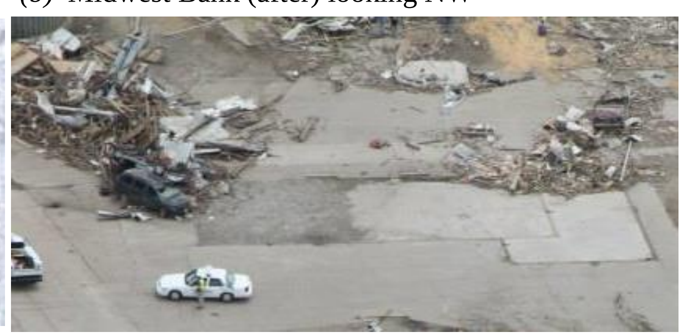
Figure 13: Damage to Pilger Public Library, Midwest Bank, post office, and empty lot where Farmers co-op used to be. View is looking southwest. (Source: NEMA)

(a) Midwest Bank *(before)* looking NW

(b) Midwest Bank (after) looking NW



(c) Farmers Co-op *(before)*



(d) Farmers Co-op *(after)*

(e) Pilger Middle School *(before)* looking N *(f)* Pilger Middle School *(after)* looking N
Figure 14: Before and after photos of damage to significant structures
(Source: Google Earth and Google Earth StreetView, KETV, NEMA)

As shown in the figures above, significant damage was sustained in the business sector. One failure mechanism that seemed to occur regularly was the total collapse of one or multiple walls, even without the failure of the roof. For example, in the Midwest Bank building, a room wall on the east side collapsed on the second story, while the entire length of the wall on the south side collapsed in both stories as shown in Figure 15. The bank was established in the year 1900 according to sources (BestBranch.com). Exterior walls appear to consist of a brick wall only, while wood rafters form the roof and floor joists between the first and second floors. A lateral load path does not appear to exist between perpendicular exterior walls, or between the exterior walls and the roof. In the age in which this structure was built, gravity was often relied upon and little positive reinforcement was included. This undoubtedly contributed to the collapse of multiple exterior walls in this bank. Interestingly, this same failure mechanism can be noted in several buildings along Main Street, mostly on the east face. This is an indication that significant suction pressures from the wind flow in the tornado developed on these walls, causing them to fail outward.

Figure 15: Total collapse of exterior wall along south side of Midwest Bank. Note the clean failure edge, suggesting little if any positive attachment existed between the south wall and the perpendicular east-west walls, or between the roof and the walls.

The Pilger Middle School sustained heavy damage, but the main structure appears to have remained mostly intact. The majority of the damage seems to be to the windows and opening, possibly due to the large debris cloud likely associated with the tornado from the earlier damage it caused in the town. Large piles of debris can be seen along the south face of the school. An aerial view of the damage is provided in Figure 16, where it can also be seen that significant damage was sustained in the second story of the east wing of the building, including possibly the collapse of exterior walls. Most of the roof covering was also removed throughout the building, although it is unknown what the roof covering originally consisted of.

Figure 16: Aerial view of Severe Damage to Pilger Middle School (Source: NEMA)

Damage to the Farmer's Co-op was also extensive, and perhaps the most significant to Pilger's economy, since it was the town's largest employer (NPPD, 2014). In fact, three of Pilger's top employers, Farmer's Co-op, Village of Pilger (which lost its roof during the tornado), and the Pilger Middle School, all sustained heavy damage. The workforce employed by these three employers accounted for approximately 25% of the town's total labor force. Damage to the Farmer's Co-op included the destruction of all of its storage silos, the partial or total collapse of all of its buildings, including a steel-frame warehouse building, and the loss of equipment. An aerial view of the damage can be seen in Figure 17.

Figure 17: Looking east at damage to Farmer's Co-op in Pilger, NE after EF-4 tornado (Source: NEMA)

CONCLUSIONS

The June 16-18, 2014 tornado outbreak resulted in over 85 tornado reports in six different states in the US, and an additional tornado report in the province of Ontario, CA. The majority of the impacts were borne by small rural communities, including the heaviest damage in Pilger, NE. While the damage in these towns was severe and sadly included loss of life, several towns also were fortunate to narrowly miss direct impacts from strong tornadoes. The towns of Stanton, Wisner and Wakefield in Nebraska all had large, EF-4 tornadoes pass within a few miles of them, but avoided direct strikes, limiting the damage to rural homes on the outskirts of the towns.

Every year during the tornado season, many towns in tornado-prone regions roll the dice, hoping to avoid what seems to be the inevitable strike. But despite the low probability of a tornado striking any specific town, when the tornado does strike, the results are so often deadly and catastrophic, particularly to residential construction. Should this always be the case? Despite having an incomplete knowledge of the tornado load model itself, engineers have known for more than 40 years where the weak points in the buildings lie. Further, we also know that strengthening these links in the vertical and lateral load paths would result in substantially reduced damage at a fraction of the economic losses that occur.

It is clear from our studies that towns and cities throughout Tornado Alley are not yet considering whether their current preparation is sufficient in light of the potential consequences from a tornado strike. Stronger buildings can produce more resilient communities, as they suffer less damage, and are associated with fewer fatalities and fewer post-event psychological problems. This enables communities to recover more quickly with less costs, as more of its infrastructure remains intact after tornadoes. It is not easy, as many towns have an aged building stock that is difficult and possibly expensive to retrofit. But at the very least, communities can begin to build stronger buildings from this point on, so that future loss of life can be avoided and losses mitigated.

Acknowledgements

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About the PI

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Peer-Reviewed Publications

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