TORNADO OUTBREAK *of* 2011

IN ALABAMA, GEORGIA, MISSISSIPPI, TENNESSEE, AND MISSOURI

7 Observations on Critical Facility Performance: Healthcare, First Responder, and Emergency Operations Centers

The MAT observed a total of 41 critical facilities in the path of tornado tracks or track periphery areas across five States.

A general discussion of critical facilities pertinent to both chapters is presented in the introduction to Chapter 6. This chapter presents information on healthcare facilities, first responder (police and fire) facilities, and EOCs.

All of the 41 observed critical facilities were located where the basic (design) wind speed prescribed in IBC 2009 is 90 mph. Table 6-1 lists the type and total number of critical facilities observed by the MAT. The locations of the Tuscaloosa and Joplin critical facilities described in this report are shown on Figure 7-1 (April 25–28, 2011 tornado event) and Figure 7-2 (May 22, 2011 tornado event); the facilities described in this chapter are highlighted.

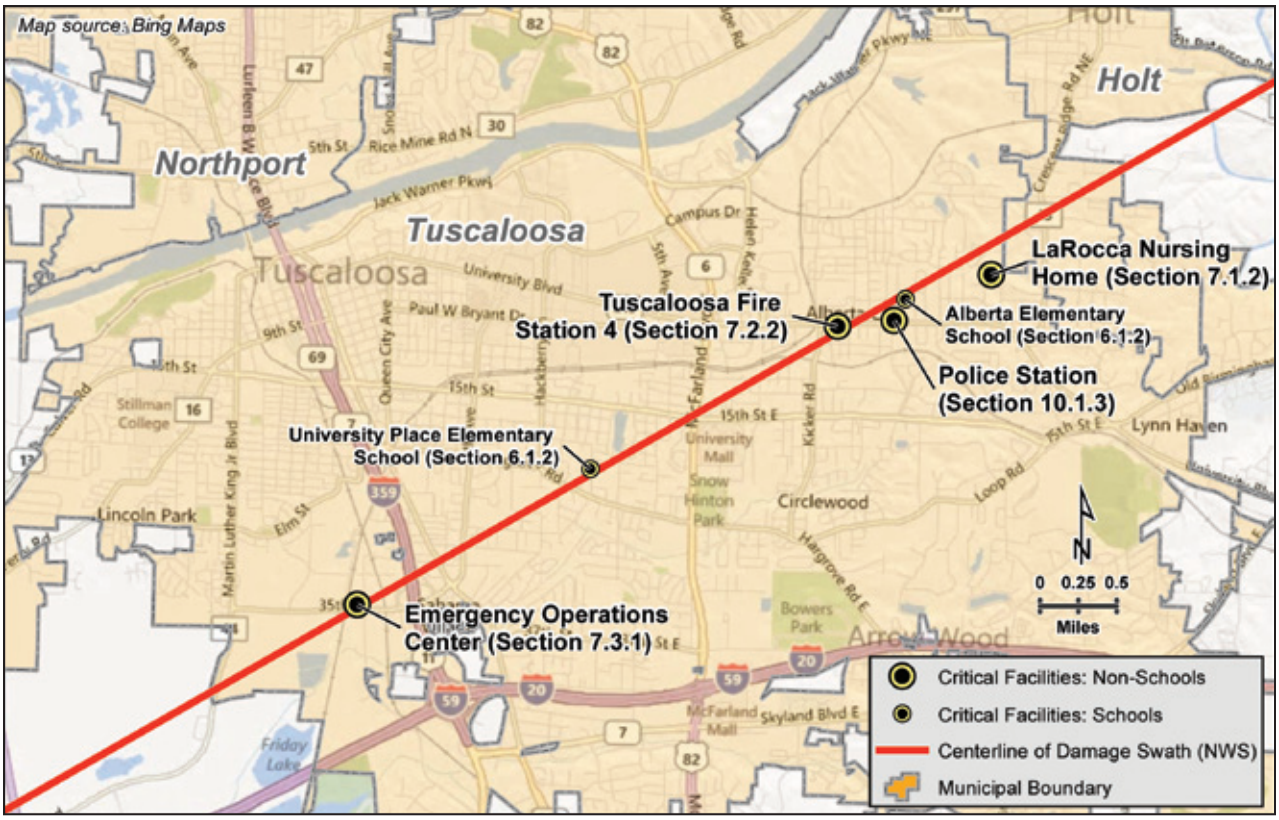

Figure 7-1: Location of Tuscaloosa, AL, critical facilities described in Chapters 6 and 7. The EOC (southwestern end of tornado damage swath shown, red line) is approximately 4.7 miles from the LaRocca Nursing Home (northeastern end of tornado damage swath shown).

SOURCE FOR TORNADO TRACK: HTTP://WWW.SRH.NOAA.GOV/SRH/SSD/MAPPING

In addition to the 41 critical facilities that were in tornado tracks or track periphery areas, the MAT visited some additional facilities that were outside of the tracks or track periphery. Some of these additional critical facilities were not struck by high winds, and thus were not damaged. However, some of these additional critical facilities were damaged by thunderstorm winds.

Sections 7.1.1 and 7.3.2 describe two facilities that were not struck by

The National Institutes of Standards and Technology (NIST) established a research team to study of the impacts of the disaster in Joplin, MO.

The objectives of the NIST technical study include:

- Determine the characteristics of the wind hazard from the tornado
- Determine the pattern, location and cause of injuries and fatalities, and how these numbers were affected by emergency communications and the public response to those communications
- Determine the performance of residential, commercial and critical (police stations, firehouses, hospitals, etc.) buildings
- Determine the performance of lifelines (natural gas, electrical distribution, water, communications, etc.) as they relate to maintaining building operation
- Make recommendations, if warranted, for improvements to building codes, standards and practices based on the findings of the study

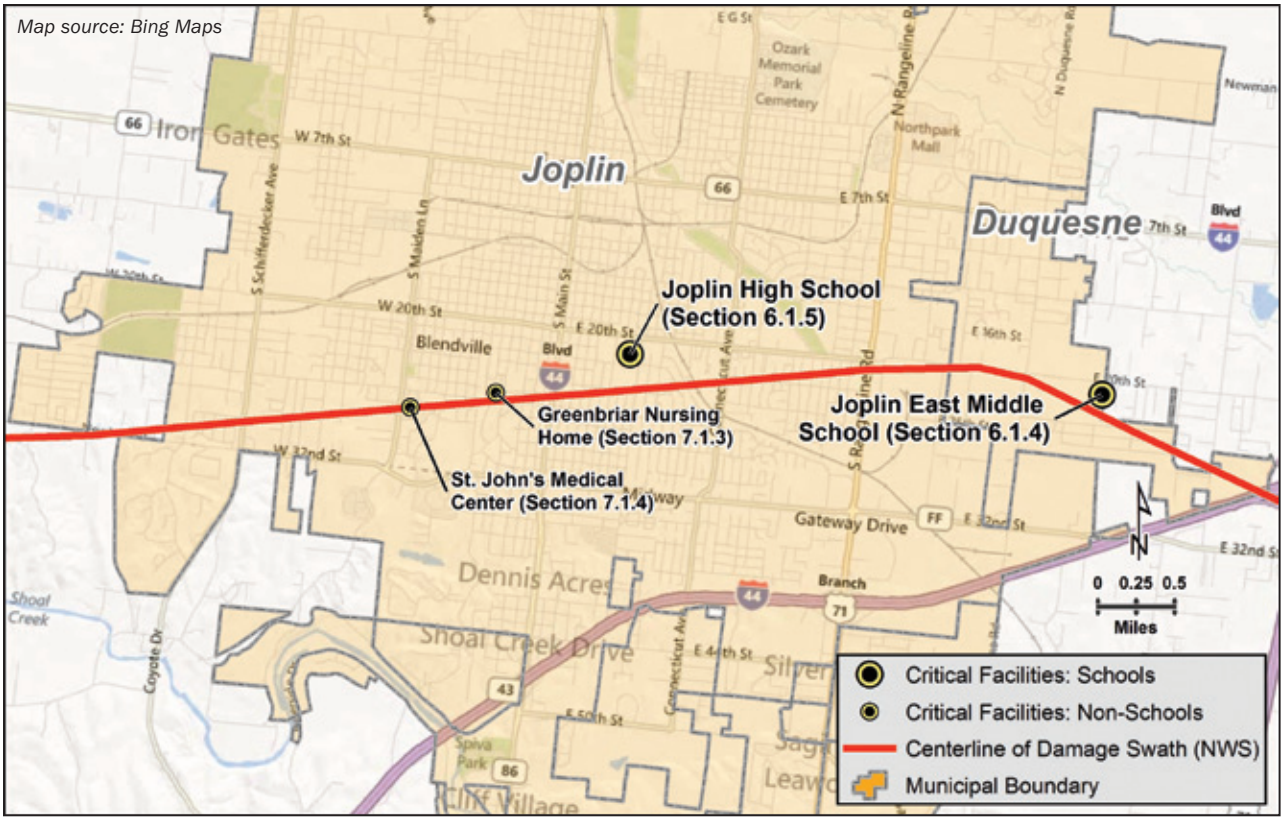

Figure 7-2: Location of Joplin, MO, critical facilities described in Chapters 6 and 7. The St. John's Medical Center (western end of tornado damage swath, red line) is approximately 4.5 miles from the East Joplin Middle School (eastern end of tornado damage swath).

SOURCE FOR TORNADO TRACK: HTTP://WWW.CRH.NOAA.GOV/SGF/?N=EVENT_2011MAY22_SUMMARY

tornadoes. Section 7.1.1 describes a healthcare facility located just outside of a tornado periphery area; although not struck by the tornado, the facility response to the near miss provided an opportunity to learn some operational issues. Section 7.3.2 describes an EOC that was not in the tornado path. It is included because it has design enhancements intended to allow the facility to remain operational even if struck by a violent tornado. Except for the critical facilities discussed in Sections 7.1.1 and 7.3.2, none of the observed critical facilities outside of the tornado tracks or track periphery areas are discussed in this report.

7.1 Hospitals and Health Care Facilities

Health care facilities are at the front line of community protection, especially during and after a natural disaster event. Their capacity to continue to provide services to existing patients, and to respond to the needs of victims following a disaster, depends not only on protecting the integrity of the structure and the building envelope, but on the facilities' ability to carry out their intended functions with little or no interruption. Continued and uninterrupted operation of health care facilities, regardless of the nature of the disaster, is one of the most important elements of a community's continuity of operations (COOP) and disaster recovery program.

7.1.1 Birmingham Nursing and Rehabilitation Center (Birmingham, AL)

Location of Facility near Tornado Path: The Birmingham Nursing and Rehabilitation Center was not damaged. Figure 7-3 shows a view of the nursing home after the tornado. Figure 7-4 shows an aerial view of the tornado track. This facility was a few hundred yards from the periphery of a tornado that NWS rated as an EF2 at the center of circulation.

Lessons Learned: Although the facility was not damaged, this event provided useful lessons. The MAT was advised by facility personnel that the facility has periodic training for various hazards, and in certain events, the facility is required to evacuate all occupants. The staff can evacuate all the residents in less than 10 minutes.

As the tornado approached the facility, the staff believed there was a natural gas leak in the building due to an intense gas smell in the air. The smell was thought to be coming from their facility. However, the gas smell was actually from lines in nearby neighborhoods that had been broken by the tornado. The gas was driven into surrounding areas ahead of the storm. Being unaware of the approaching tornado, and believing that they were in imminent danger due to a gas leak in the facility, the occupants were moved in a matter of minutes to an outdoor courtyard (Figure 7-3).

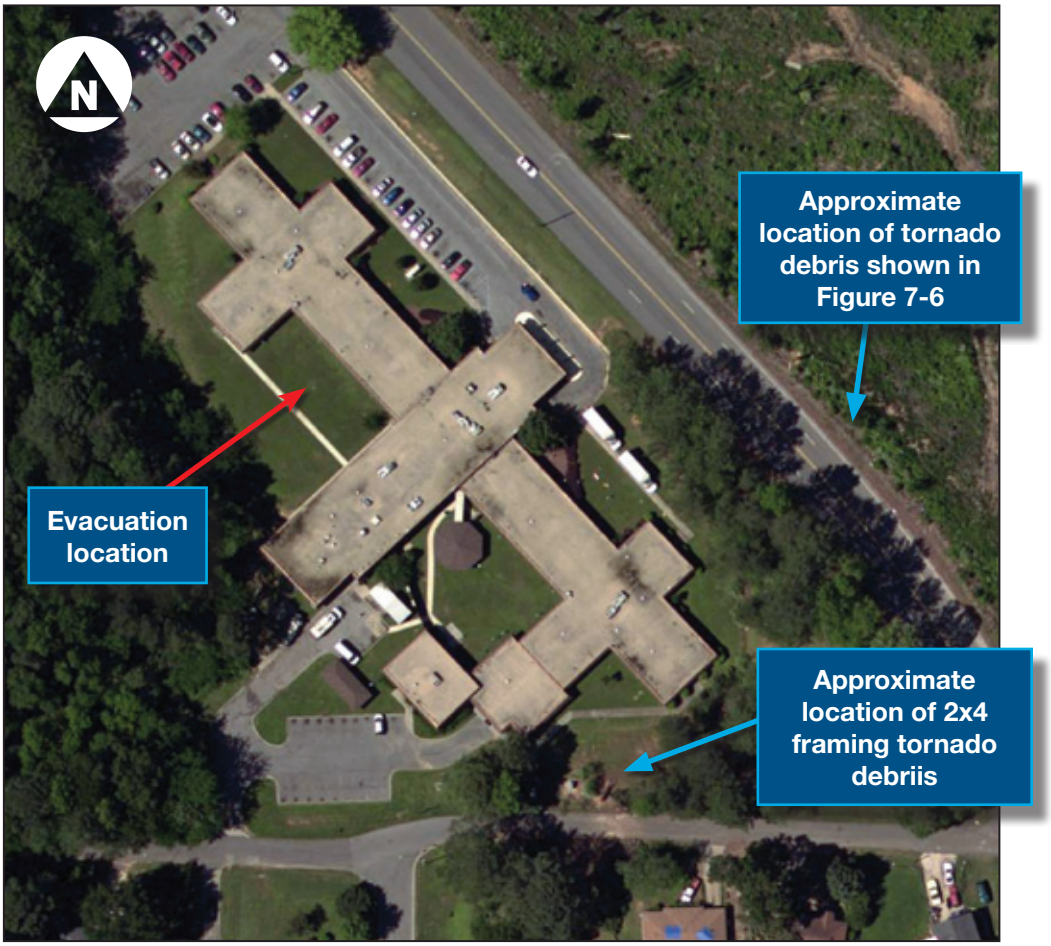

Figure 7-3: Aerial view of the nursing home. The red arrow shows the courtyard where residents were evacuated to. The blue arrows show impact locations of wind-borne debris (Birmingham, AL).
SOURCE: © GOOGLE EARTH

Soon after the facility was evacuated, the facility director realized that a tornado was nearby and on an apparent intercept path with the nursing home (Figure 7-4). The occupants were moved back into the facility corridors, which were designated as the tornado refuge areas for the facility (Figure 7-5).

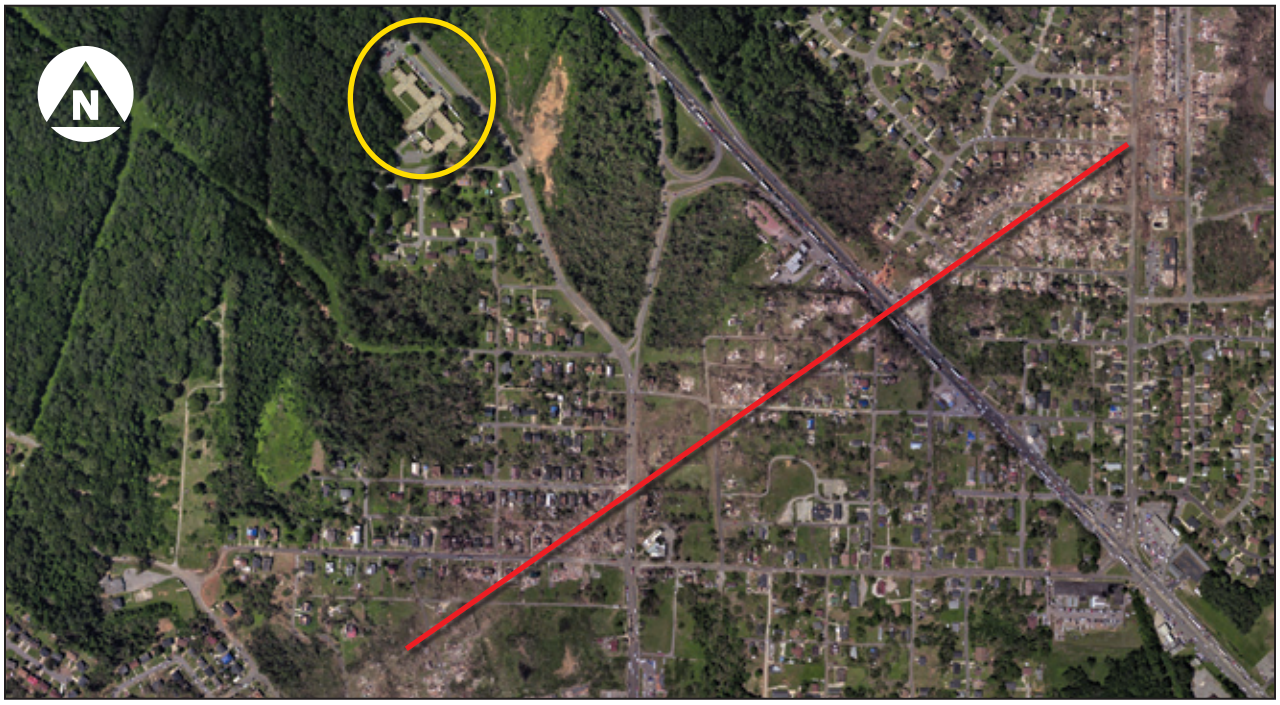

Figure 7-4: Aerial view of the nursing home (yellow circle) in relation to the approximate centerline of the tornado damage swath, shown by the red line[1] (Birmingham, AL)

SOURCE: ALL AERIAL PHOTOGRAPHS ARE FROM NOAA IMAGERY (HTTP://NGS.WOC.NOAA.GOV/STORMS) UNLESS OTHERWISE NOTED

EF contours were not developed by NWS for sites in Birmingham, Tuscaloosa, and Fultondale, AL, and Smithville, MS, described in Chapter 7.

Figure 7-5: View of interior corridors that serve as the residents' tornado refuge area (Birmingham, AL)

1 The red line in this and all similar figures is intended to represent the center of the damage swath. The track location is approximated by the MAT based on post-event aerial photographs. The actual centerline of circulation is offset from the centerline of the damage.

Although the facility did not experience tornado damage, wind-borne debris landed near the nursing home as shown in Figures 7-3 and 7-6.

Figure 7-6:
This portion of a roof from a nearby house was found across the street from the nursing home. The roof portion is approximately 10 feet x 20 feet. The damage potential for a missile of this size is very high (Birmingham, AL).

The nursing home had an emergency generator that was located outdoors (Figure 7-7). Although it was not damaged during this event, the generator was susceptible to tree fall and wind-borne debris damage.

Figure 7-7:
The emergency generator (red arrow) is located near many trees that could easily have damaged the generator and taken it out of service (Birmingham, AL)

7.1.2 LaRocca Nursing Home (Tuscaloosa, AL)

Location of Facility in Tornado Path: The location of LaRocca Nursing Home is shown in Figure 7-1. Figure 7-8 shows an aerial view of the tornado track in the vicinity of the nursing home. The NWS rated the center of the tornado circulation in the vicinity of the nursing home as an EF4. There were 68 occupants (including residents and staff) in the facility when the tornado struck. No injuries occurred at this facility (DeMonia 2011).

Facility Description: This older skilled nursing facility had capacity for 75 residents. A portion of the northern wing had two floors. The remainder of the facility was one story. The steep-slope roofs had asphalt shingles over 1x6 plank decking supported by rafters. The exterior bearing walls were wood studs with 1x6 plank boards, wood fiberboard sheathing, and brick veneer. The facility did not have a storm shelter or safe room.

General Wind Damage: Portions of the roof structure were blown off of four areas (Figures 7-9 to 7-12). Some brick veneer was blown off (Figure 7-10), several windows were broken (Figures 7-11 and 7-13), tree-fall caused roof structure and wall damage (Figure 7-14), and some exterior walls collapsed (Figure 7-15).

The facility had two emergency generators, one on the north side of the facility and the other on the southwest. Both generators were outdoors. Had the wall collapsed outward rather than inward, the generator shown in Figure 7-15 may have been taken out of service.

Figure 7-8: Aerial view of the track in the vicinity of the nursing home (yellow circle). The center of the damage swath is approximated by the red line. Inflow damaged the nursing home and buildings within the blue box (Tuscaloosa, AL).

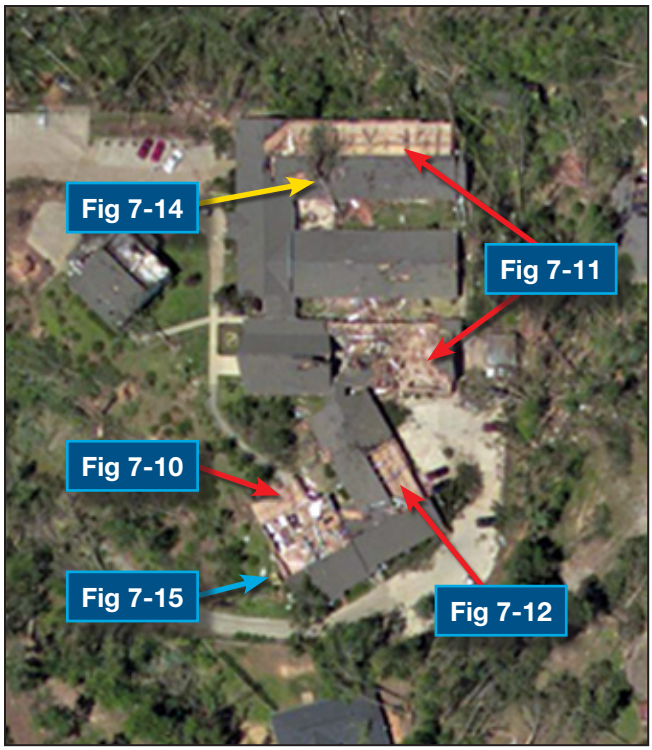

Figure 7-9:
Close-up of the nursing home shown in Figure 7-8. Red arrows indicate where the roof structure was blown off (Figures 7-10 to 7-12). The yellow arrow indicates a tree on the roof (Figure 7-14). The blue arrow indicates the generator shown in Figure 7-15 (Tuscaloosa, AL).

Figure 7-10:
Roof structure and brick veneer were blown off the nursing home (Tuscaloosa, AL)

Figure 7-11: Roof structure blown off over resident rooms. The inset is a view from within one of the rooms. The window was broken. (Tuscaloosa, AL).

Figure 7-12:
Interior damage as a result of roof structure blow-off (Tuscaloosa, AL)

Figure 7-13:
View of the two-story wing. Most of the windows along this façade were broken (Tuscaloosa, AL).

Figure 7-14:
Tree-fall damage. Note the boarded-up broken windows. The inset shows a close-up of the tree-fall damage (Tuscaloosa, AL).

Figure 7-15: Generator at the southwest side of the facility (red arrow). Note the roof structure blow-off and wall collapse (Tuscaloosa, AL).

MAT EF Rating: Using DI 5 (Apartments, Condominiums, and Townhouses; Three Stories or Less), the MAT selected DOD 4 ("uplift or collapse of roof structure leaving most walls standing") for this facility.[2] Considering the age of the facility and observed damage, the MAT assessed the wind speed as between the expected and lower-bound wind speeds for DOD 4. Hence, the MAT derived the tornado rating as EF2 (111–135 mph) based on damage to this building. Therefore, the estimated wind speed experienced by the building was above the current basic wind speed of 90 mph.

The NWS rated the center of the tornado circulation in the vicinity of the nursing home as EF4, which is above the MAT EF2 rating of this building. As shown in Figure 7-8, the nursing home is away from the center of circulation. Accordingly, wind speed decay would result in a lower speed at the nursing home.

Some of the wind damage at this nursing home was due to wind-borne debris. The MAT judged other building damage to be due to wind speeds substantially above the design wind speed, as well as inadequate wind resistance, which is reflective of the codes, standards, and design practices in the era when this nursing home was constructed.

Functional Loss: Prior to the late afternoon tornado strike, the residents were moved into corridors that were designated for use during tornadoes (DeMonia 2011). There were no injuries during the tornado.

It was not possible to evacuate the residents immediately after the tornado had passed because both of the roads from the facility to the street were blocked by several fallen trees. Residents were moved to portions of the building that were not badly damaged. It was the following morning before one of the roads was cleared and the residents and staff evacuated.

2 There is no DI for nursing homes. The type of construction listed for DI 5 is applicable to this nursing home.

7.1.3 Greenbriar Nursing Home (Joplin, MO)

Location of Facility in Tornado Path: The location of the Greenbriar Nursing Home is shown in Figure 7-2). Figure 7-16 shows an aerial view of the track in the vicinity of the nursing home. Figure 7-17 shows the nursing home before and after the tornado. The NWS EF contour ratings in the vicinity of the nursing home are shown on Figure 7-16. According to a representative of the nursing home, there were approximately 89 residents and 20 staff in the facility at the time the tornado struck.

Facility Description: This skilled nursing facility was built in 1965. It had a maximum occupancy of 120 residents. The 30,311-square-foot building had one core area and four wings. Figure 7-17 shows the nursing home before and after the tornado. The building was constructed with unreinforced CMU with brick veneer walls supporting wood roof trusses.

The facility did not have a storm shelter or safe room. Residents and staff used the central hallway as a tornado refuge area.

General Wind Damage: Almost the entire building was destroyed (Figures 7-17 to 7-19). According to witnesses, the tornado blew open the exterior doors and imploded the windows, leading to roof blow-off and wall collapse.

Figure 7-16: Aerial view of the track in the vicinity of the nursing home (yellow circle). The center of the damage swath is approximated by the red line (Joplin, MO).

Figure 7-17:
Close-up of Figure 7-16 showing the damaged nursing home. The inset shows the nursing home before the tornado struck (Joplin, MO).
INSET SOURCE: © GOOGLE EARTH

Figure 7-18:
Aerial view of the nursing home (red oval) after the tornado (Joplin, MO)

Figure 7-19:
Only one wall remained standing at the nursing home (Joplin, MO)

MAT EF Rating: Using DI 9 (Small Professional Building),[3] the MAT selected DOD 9 ("total destruction of entire building") for this facility. Considering the building age and observed damage, the MAT assessed the wind speed as between the expected and lower-bound wind speeds for DOD 9. Hence, the MAT derived the tornado rating as EF3 (136–165 mph) based on damage to this building. Therefore, the estimated wind speed experienced by the building was substantially above the current basic wind speed of 90 mph.

As shown in Figure 7-16, NWS derived the rating as EF5 at the nursing home, which is above the MAT EF3 rating of this building. The actual wind speed of the tornado at this site may have been higher than an EF3. However, since the expected wind speed for total destruction of a DI 9 facility is 157 mph, a determination of a higher wind speed could not be made with a facility of this type of construction. To assess whether higher winds may have occurred, a stronger facility (such as the hospital discussed in Section 7.1.4) would need to be evaluated.

The MAT judged wind damage at this nursing home to be due to it being subjected to wind speeds that were substantially above the design wind speed.

Functional Loss: According to a representative, the nursing home had a maximum occupancy of 120 residents; at the time the tornado struck, there were approximately 89 residents and 20 staff. There were 16 fatalities. Ten residents and one staff member died immediately, and five additional residents later died of their injuries. One quadriplegic victim died outside of the building when struck by wind-borne debris. Following the tornado, residents were evacuated to other facilities in the area. The nursing home will be completely rebuilt.

3 There is no DI for nursing homes. The type of construction listed for DI 9 is applicable to this nursing home. However, DI 9 is for buildings less than 5,000 square feet. Therefore, using DI 9 for this size of nursing home may underestimate the wind speed.

7.1.4 St. John's Medical Center (Joplin, MO)

Location of Facility in Tornado Path: The location of the St. John's Medical Center is shown in Figure 7-2. Figure 7-20 shows an aerial view of the tornado track in the vicinity of the hospital. The NWS EF contour ratings in the vicinity of the hospital are shown on Figure 7-20. According to a representative of the hospital, it was occupied by staff and approximately 180 patients when the tornado struck. Five patients lost their lives and a number of patients and staff were injured.

Facility Description: The St. John's Medical Center was constructed in 1968, with a second East Tower added in 1985 (Figure 7-21). The hospital had 367 beds and its emergency care department was level II trauma certified. The original tower had a concrete frame with cast-in-place concrete floors and a built-up roof. The East Tower addition had a steel frame with cast-in-place concrete floors, a single-ply membrane roof system, an aggregate ballasted roof system on the three-story portion of the addition, and precast concrete wall panels. The towers were joined by a steel superstructure with elevator shafts. The emergency room was located along the northwest corner of the hospital in the original tower; most of the surgery rooms and the intensive care unit (ICU) were in the East Tower addition. The one-story building that housed an emergency generator and switchgear had a steel deck, steel roof joists, and EIFS over unreinforced CMU exterior walls.

The hospital had an electronic medical records system with the data stored in the medical office building/outpatient center, which was connected to the hospital via a tunnel. The data were routinely backed up to an offsite location outside of the area impacted by the tornado.

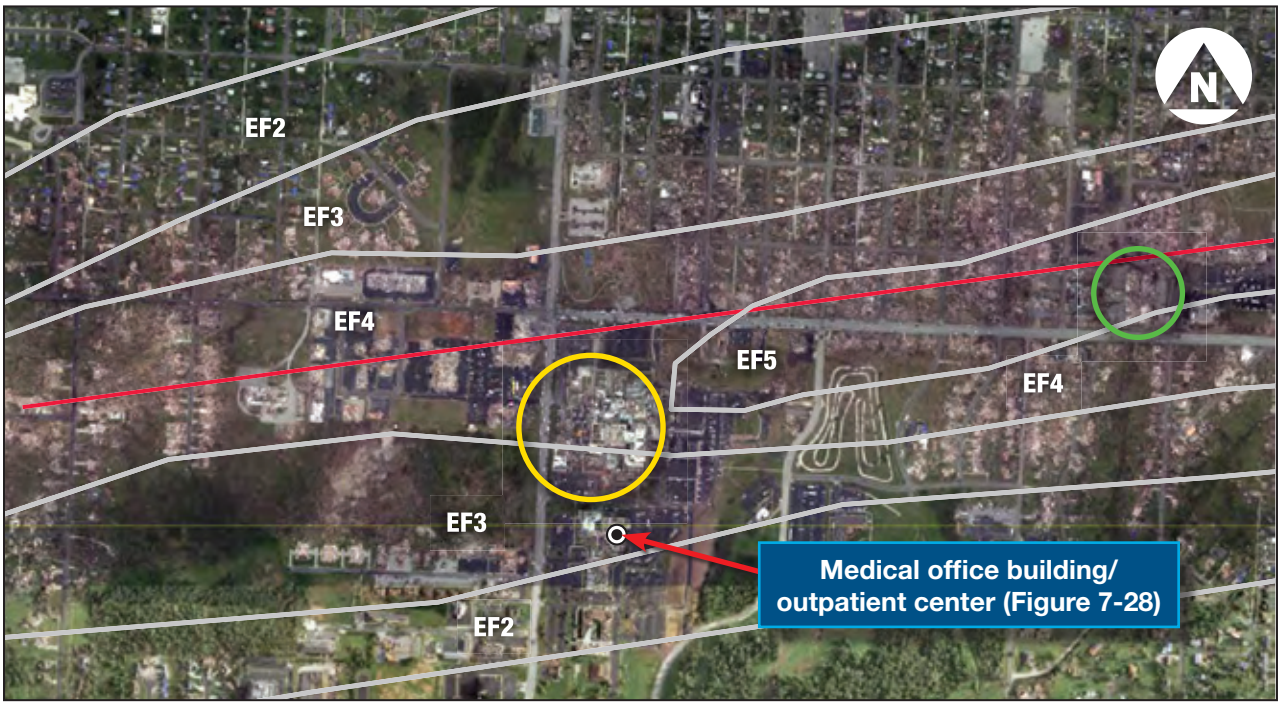

Figure 7-20: Aerial view of the track in the vicinity of the St. John's Medical Center (yellow circle). The blue arrow indicates the medical office building/outpatient center (shown in Figure 7-28). The center of the damage swath is approximated by the red line. The location of Greenbriar Nursing Home (Section 7.1.3) is indicated by the green circle (Joplin, MO).

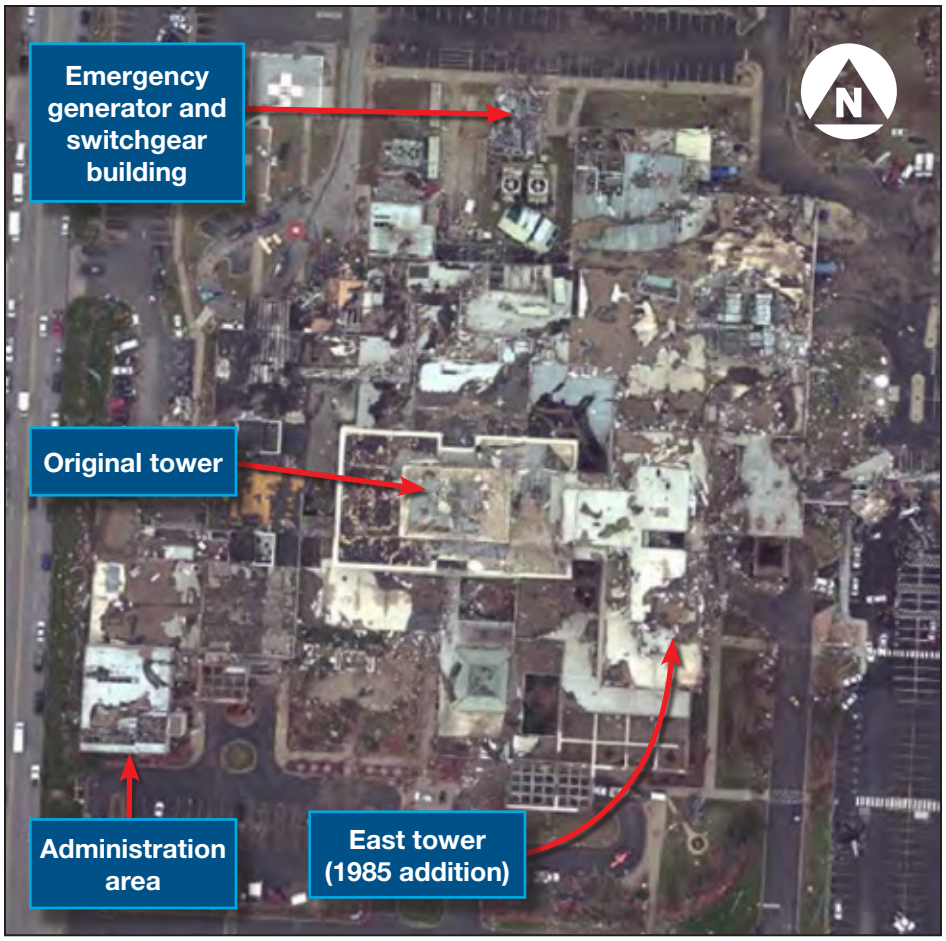

Figure 7-21:
Close-up of Figure 7-20 showing St. John's Medical Center (Joplin, MO)

The hospital did not have a tornado safe room or storm shelter. The hospital's tornado procedure entailed moving patients into corridors, except in the ICU, where patients and hospital personnel were to remain in the unit and seek protection to the extent possible. Evacuation sleds were available to help move patients down stairwells and corridors during an emergency in the event elevators were not working.

General Wind Damage: Most of the exterior windows were broken, which resulted in injuries to patients and staff as well as extensive interior damage (Figure 7-22). See also Figure 5 in Tornado Recovery Advisory No. 5, *Critical Facilities Located in Tornado-Prone Regions: Recommendations for Facility Owners* (FEMA 2011c) in Appendix F.

There was extensive blow-off of roof membranes on both towers and lower-level roofs, and some roof decking blow-off on the lower-level roofs (Figure 7-21), blow-off of roof aggregate (Figure 7-23), collapse of brick veneer walls at the original tower (Figure 7-24 inset), collapse of metal wall panels at the East Tower addition (Figure 7-24), and collapse of a precast concrete wall panel at the loading dock (Figure 7-25). A hospital representative told the MAT that engineers working on behalf of the hospital determined that the structural steel frame of the East Tower addition had been twisted by the tornado.

Figure 7-22:
View of the glazing damage at patient rooms (Joplin, MO)

Figure 7-23:
This parking lot was littered with 1½-inch nominal diameter aggregate from the ballasted roof membrane. (Joplin, MO).

Figure 7-24:
Collapse of a portion of the exterior metal composite foam wall panels at the East Tower addition (red arrows). The inset shows collapsed brick veneer at the Original Tower. Most of the glazing shown in this photograph was broken (Joplin, MO).

Figure 7-25:
View of a missing precast concrete wall panel (red box) at the loading dock (Joplin, MO)

Several of the lower-level areas, including an equipment room and an administrative area, had metal roof decking blown off (Figures 7-26 and 7-27). Some exterior walls also collapsed (Figure 7-27).

Figure 7-26:
Metal decking blow-off and glazing damage in the administrative area (Joplin, MO)

Figure 7-27:
Exterior wall collapse (EIFS over unreinforced CMU) at an equipment room (Joplin, MO)

The water main and natural gas lines had been labeled at some point prior to the tornado and were closed soon after the event, thereby avoiding flooding, fire, and explosion.

The hospital had two emergency generators, one within the original tower and the other within the building shown in Figure 7-21. The generator/switchgear building collapsed, which resulted in total loss of electrical power throughout the hospital. This building is shown in Figures 12 and 13 of Tornado Recovery Advisory No. 6, *Critical Facilities Located in Tornado-Prone Regions: Recommendations for Architects and Engineers* (FEMA 2011b) in Appendix F. The generator in the original tower did not function because the switchgear was severely damaged by the building collapse.

The medical office building/outpatient center, which housed the medical records server, experienced significant glazing damage, EIFS puncture by wind-borne debris, EIFS blow-off, and roof membrane and roof decking blow-off (Figures 7-21 and 7-28). The on-site medical records server did not survive, but the data were remotely backed up.

MAT EF Rating: Using DI 20 (Institutional Building), the MAT selected DOD 10 ("collapse of some top story exterior walls") for the hospital. Using the expected wind speed for DOD 10, the MAT derived the tornado rating as EF3 (136–165 mph) based on damage to this building. Hence, the estimated wind speed experienced by the building was substantially above the current basic wind speed of 90 mph.

Using DI 17 (Low-Rise Building, 1–4 Stories), the MAT selected DOD 6 ("significant damage to exterior walls and some interior walls") for the medical office building/outpatient center. Considering the building age and observed damage, the MAT assessed the wind speed as between the expected and lower-bound speeds for DOD 6. Hence, the MAT derived the tornado rating as EF 3 (136–165

Figure 7-28:
Metal decking blow-off and glazing and EIFS damage (red arrows) at the medical office building/outpatient center. Inset shows a close-up of the damage (Joplin, MO).

mph) based on damage to this building. Therefore the estimated wind speed experienced by this building was substantially above the current basic wind speed of 90 mph.

As shown in Figure 7-20, the NWS derived the rating as EF3 at the medical office building/outpatient center, which correlates with the MAT EF3 rating for this building. The NWS derived the rating as EF5 at one portion of the hospital and EF4 at other portions, which are different from the MAT EF3 rating for this building.

The MAT judged wind damage at this hospital to be due to wind-borne debris and its subjection to wind speeds substantially above the design wind speed.

Functional Loss: According to a representative, the hospital was occupied by staff and approximately 180 patients when the tornado struck. Five patients lost their lives during evacuation efforts and a number of patients and staff were injured as well.

With loss of all electrical power and other significant damage to the building, it was necessary to evacuate the hospital. The emergency lighting in the stairways and corridors was powered by the emergency generator. With loss of the generators, and in the absence of battery-powered exit lighting as a secondary back-up, patients were evacuated down dark stairways and through dark corridors. The hospital was evacuated in about 1½ hours. Patients were either moved to an initial emergency triage area that was set up near the heliport or to another hospital in town.

Within a week, a temporary 60-bed hospital was established across the parking lot from the existing hospital. On January 3, 2012, construction of a new 825,000-square-foot hospital began to replace the former St. John's Medical Center at a new location in Joplin. The new hospital is scheduled to be completed by 2015, with an estimated construction cost of $345 million. Demolition of the existing hospital is expected to take 5 months, and hospital officials plan to donate the land to the City. Hospital personnel expressed the importance of having electronic patient records, which eased the process of evacuating patients to other hospitals and enabled the quick transition to the temporary 60-bed hospital.

7.2 First Responder Facilities (Police and Fire)

Police and fire rescue facilities are critical to disaster response because an interruption in their operation as a result of building or equipment failure may prevent rescue operations, evacuation, assistance delivery, or general maintenance of law and order, which can have serious consequences for the community.

7.2.1 Fultondale Municipal Complex (Fultondale, AL)

Location of Facility in Tornado Path: Figure 7-29 shows an aerial view of the tornado track in the vicinity of the Fultondale Municipal Complex. The NWS rated the center of the tornado circulation in the vicinity of this complex as an EF2.

The Fultondale municipal complex has four major buildings (Figure 7-30): 1) Fire Department, 2) Library/"Shelter," 3) Building and Inspections Department, and 4) City Hall (which houses the police station, jail, and natural gas utility offices). According to a representative of the complex, citizens seeking refuge from the tornado were in the library when the tornado struck. The jail was also occupied during the event. The Municipal Complex was damaged in several locations.

- The Fire Department lost the entire roof structure over the apparatus bay.
- The Library/"Shelter" had damage to the siding and mansard. The entrance to the "Shelter," referred to hereafter as a tornado refuge area, is shown by the yellow arrow in Figure 7-30.
- The roof structure of the Buildings and Inspections Department was lifted off and came to rest upside down in the area indicated by the blue oval at Figure 7-30.
- The City Hall and Police Station had roof damage to the porte-cochere (red box in Figure 7-30), and the emergency generator was taken out of service by a fallen tree (red arrow).

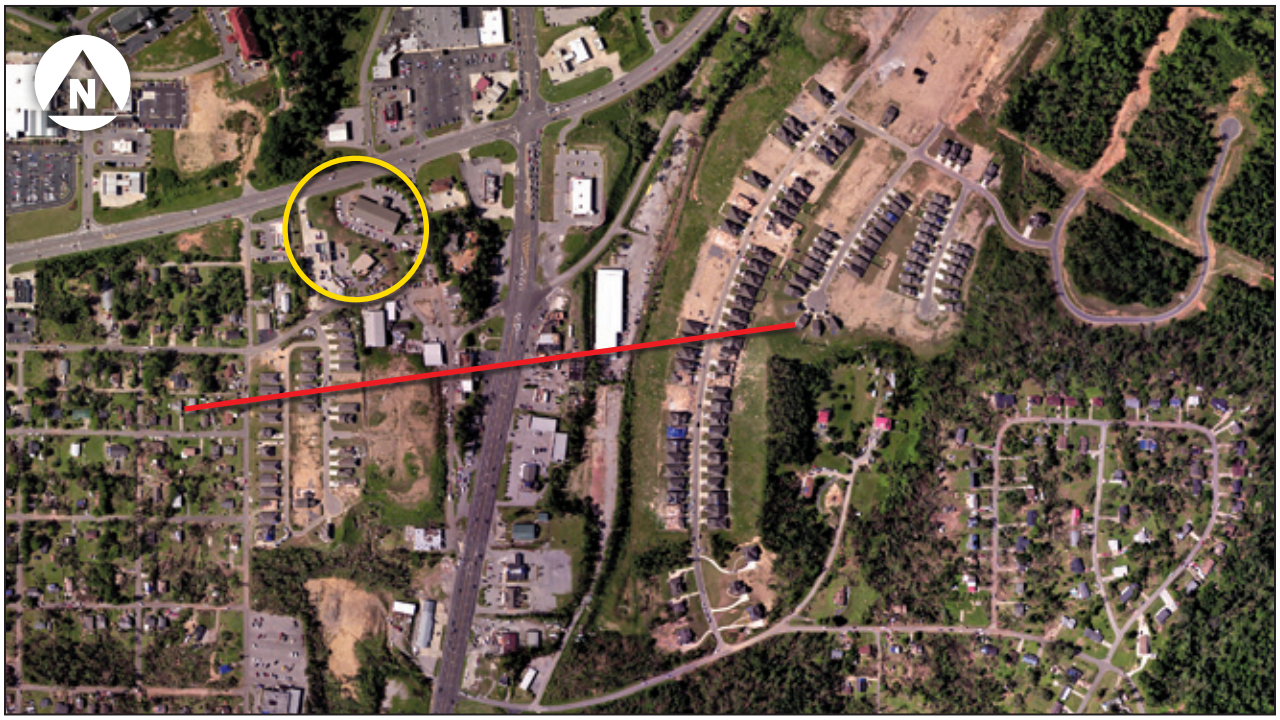

Figure 7-29: Aerial view of tornado track in the vicinity of Fultondale Municipal Complex in Alabama (yellow circle). The center of the damage swath is approximated by the red line (Fultondale, AL).
SOURCE: © GOOGLE EARTH

Figure 7-30: Tornado winds damaged an emergency generator (red arrow) and a roof (red box), and lifted a roof (final location shown by blue box). Yellow arrow shows the "shelter" entrance (Fultondale, AL).
SOURCE: © GOOGLE EARTH

7.2.1.1 Fire Department

Facility Description: The fire department is a PEMB that was built around 1995. The walls have brick veneer cladding over the frame.

General Wind Damage: The apparatus bay doors collapsed, most of the metal roof covering blew off, and some of the metal fascia blew off (Figures 7-31 and 7-32).

MAT EF Rating: Using DI 21 (Metal Building Systems),[4] the MAT selected DOD 3 ("metal roof or wall panels pulled from the building") for this facility. Using the expected wind speed for DOD 3, the MAT derived the tornado rating as EF1 (86–109 mph) based on damage to this building. Hence, the estimated wind speed experienced by the building was not substantially above the current basic wind speed of 90 mph.

The MAT judged the wind damage at this fire station to be due to inadequate wind resistance.

Functional Loss: According to a representative of the complex, two pieces of apparatus that received minor damage were freed from the damaged building and were in service in less than 2 hours. Several more hours were required to free the balance of the equipment. Although damaged, the building remained useable after debris removal. The building will need substantial work to bring it back into full service.

Figure 7-31:
The apparatus bay doors of the fire department collapsed (Fultondale, AL)

4 There is no DI for fire stations. DI 21 was deemed appropriate for this facility.

Figure 7-32:
The metal roof panels blew off the apparatus bay of the fire department. The panels unlatched from the clips, shown at another angle in the inset (Fultondale, AL).

7.2.1.2 Library and "Shelter"

Facility Description: The library was built in the early to mid-1970s. The Fultondale Community "Shelter" is located in the daylight basement of the library. The tornado refuge area was well publicized and was used by up to 150 people during the day of the storms. The refuge area has glass doors and a window wall system (Figure 7-33) that do not possess the wind pressure and wind-borne debris resistance specified in FEMA 361(2008a) or ICC 500 (2008). Therefore, the glazing presents a potential hazard to the occupants. Because of the glazing vulnerability, this area is considered a tornado refuge area rather than a storm shelter or safe room (refer to Section 9.1 for additional information).

General Wind Damage: The library had minimal damage to the metal panel fascia at the entrance vestibule (Figure 7-33). There was also some brick veneer damage on the side of the building that faced the fire station. This damage was minor and easily repaired.

Figure 7-33:
The library is on top of the community tornado refuge area. The note in the window (red circle) directed people to the "shelter" below (Fultondale, AL).

MAT EF Rating: Using DI 17 (Low-Rise Building, 1–4 Stories), the MAT selected DOD 1 ("threshold of visible damage") for this facility. Using the expected wind speed for DOD 1, the MAT derived the tornado rating as EF0 (65–85 mph) based on damage to this building. Hence, the estimated wind speed experienced by the building was below the current basic wind speed of 90 mph.

The MAT judged the wind damage at this building to be due to inadequate wind resistance, which is reflective of the codes, standards, and design practices in the era when this facility was built.

Functional Loss: The building did not experience a loss of function.

7.2.1.3 Building and Inspections Department

Facility Description: The Buildings and Inspections Department building was constructed in the late 1970s to house a medical response vehicle. The building has CMU bearing walls and a wood truss roof system.

General Wind Damage: The roof structure lifted off the walls and flipped over in one complete piece into the side yard (Figures 7-30 and 7-34). The top course of the CMU wall was made from cap blocks and not a bond beam (Figure 7-35). The trusses were attached to a wooden plate that was nailed into the cap blocks. The cap blocks had no positive anchorage to the main wall. The wall also appeared to be unreinforced masonry and was damaged.

Figure 7-34: The roof structure of the Buildings and Inspections Department building blew off in one complete section (red arrow). The yellow oval area is shown in Figure 7-35 (Fultondale, AL).

Figure 7-35: Note the inadequate anchorage from the truss nailer (red arrow) that was nailed to the wall top cap block (blue arrow). The inset shows a close-up. Also note the lack of anchorage between the top cap block and the main wall (Fultondale, AL).

MAT EF Rating: Using DI 9 (Small Professional Building), the MAT selected DOD 7 ("uplift or collapse of entire roof structure") for this facility. Considering the building age and observed damage, the MAT assessed the wind speed as the lower-bound wind speed for DOD 7. Hence, the MAT derived the tornado rating as EF1 (86–110 mph) based on damage to this building. Therefore, the estimated wind speed experienced by the building was not substantially above the current basic wind speed of 90 mph.

The MAT judged the wind damage at this building to be due to inadequate wind resistance, which is reflective of the codes, standards, and design practices in the era when this building was constructed.

Functional Loss: According to a representative of the complex, the building was determined to be a total loss. After the tornado, the department temporarily relocated to the basement of the library.

7.2.1.4 City Hall

Facility Description: The City Hall was built in 1985. It is a single-story, light-framed building with a truss roof.

General Wind Damage: The City Hall lost its metal roof covering over the porte-cochere (Figure 7-36). The emergency generator was taken out of service by a fallen tree. The tree caused the generator to shift, which broke the natural gas fuel line (Figure 7-37).

A properly protected generator should not be taken out of service by a fallen tree. FEMA Recovery Advisory No.6, *Critical Facilities Located in Tornado-Prone Regions: Recommendations for Architects and Engineers* (Appendix F), provides recommendations for architects and engineers including enhancements to generators to avoid interrupted operations.

MAT EF Rating: Using DI 17 (Low-Rise Building, 1–4 Stories), the MAT selected DOD 2 ("loss of roof covering (<20%)") for this facility. Considering the building age and observed damage, the MAT assessed the wind speed to be between the expected and lower-bound wind speeds for DOD 2. Hence, the MAT derived the tornado rating as EF0 (65–85 mph) based on damage to this building. Therefore, the estimated wind speed experienced by the building was below the current basic wind speed of 90 mph.

The MAT judged the small amount of wind damage at this building to be due to inadequate wind resistance, which is reflective of the codes, standards, and design practices in the era when this facility was built. The damage to the generator was due to a tree that was too close to the generator.

Functional Loss: According to a representative of the complex, the loss of City power and damage to their emergency generator resulted in no lighting (other than flashlights) or ventilation in the jail area. Once the natural gas line to the generator was repaired, the building operated on emergency power. Municipal power was restored approximately 3 days after the tornado. The building damage was minor and easily repaired.

Figure 7-36: The front of the City Hall showing damage to the metal roof covering over the entrance (Fultondale, AL)

Figure 7-37:
Back of the City Hall. The red arrow points to the generator that was disabled by a fallen tree (Fultondale, AL).

7.2.1.5 Summary of the MAT EF Ratings for the Fultondale Municipal Complex

For two of the Fultondale Municipal Complex buildings, the MAT derived an EF0 rating. An EF1 rating was derived for the other two buildings.

As can be seen in Figure 7-30, the four buildings are near one another; hence, they likely experienced similar wind speeds. The buildings may have experienced different wind loads due to differences in angle of attack, shielding, or exposure. However, the different EF ratings may be due to uncertainties in the accuracy of the wind speeds associated with the different DIs and DODs. The NWS rated the center of the tornado circulation in the vicinity of the complex as an EF2, which is above the MAT EF0 and EF1 ratings of the complex. As shown in Figure 7-29, the complex is on the left periphery of the center of circulation. Accordingly, the wind speed at the complex should be less than the wind speed at the center of circulation.[5]

7.2.2 Tuscaloosa Fire Station 4 (Tuscaloosa, AL)

Location of Facility in Tornado Path: The location of Tuscaloosa Fire Station 4 is shown in Figure 7-1). Figure 7-38 shows an aerial view of the tornado track in the vicinity of the fire station. The NWS rated the center of the tornado circulation in the vicinity of the fire station as an EF4. According to a representative of the fire department, four fire station personnel were in the building when the tornado struck—none were injured.

Facility Description: This fire station, which opened in 1952, had a modified bitumen roof membrane system over a cast-in-place concrete deck. Some of the exterior walls were brick (which appeared to be bearing walls). Other exterior walls were stucco over wire lath over furring over what appeared to be cast-in-place concrete. The apparatus bay had two sectional doors at the front and back of the bay.

The facility did not have a storm shelter or safe room.

5 The wind speed is higher on the right side of the center of circulation than it is on the left side.

Figure 7-38: Aerial view of the track in the vicinity of the fire station (yellow circle). The center of the damage swath is approximated by the red line (Tuscaloosa, AL).

General Wind Damage: The MAT also observed nearby apartment buildings when they visited this fire station because the fire station's specific construction type is not covered in the EF rating system. Therefore, damage to two nearby apartment buildings was used to determine EF ratings (as discussed later).

Apartment Buildings: The two nearby apartment houses were heavily damaged (Figure 7-39). The apartment house shown by the left yellow arrow lost its entire wood roof structure, and a portion of the unreinforced CMU wall collapsed. The wood-frame apartment house shown by the right yellow arrow lost the roof structure, and several of the exterior and interior walls on the second floor collapsed.

Fire Station: At the fire station, all four apparatus bay doors were blown away, all of the exterior windows were broken, the roof membrane was punctured in a few areas, some of the cap sheet was blown away, and some rooftop equipment was blown away.

Figure 7-40 is a view of the fire station and the adjacent apartment building. The inset shows were a section of stucco and lath was broken away by wind-borne debris. The marks on the wall indicate the amount of debris that impacted this area. Figure 7-41 is a view of the fire station living quarters. All of the windows were broken. Fire station personnel took refuge in the rest room shown in Figure 7-42. Figure 7-43 shows the wood-framed apartment building behind the fire station.

Figure 7-39: The fire station is within the red circle. The apparatus bay is indicated by the blue arrow, and the living quarters are indicated by the green arrow. The yellow arrows indicate the nearby heavily damaged apartment buildings (Tuscaloosa, AL).

PHOTOGRAPH COURTESY OF TUSCALOOSA COUNTY SHERIFF'S OFFICE

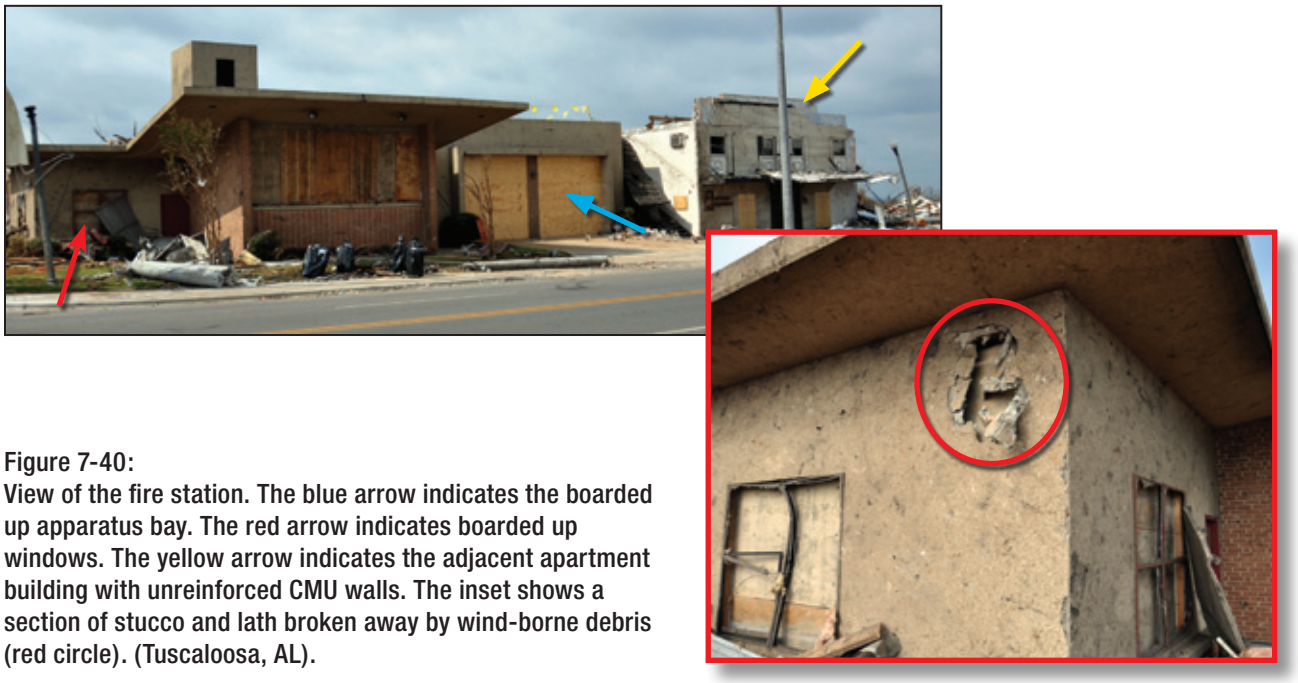

Figure 7-40:
View of the fire station. The blue arrow indicates the boarded up apparatus bay. The red arrow indicates boarded up windows. The yellow arrow indicates the adjacent apartment building with unreinforced CMU walls. The inset shows a section of stucco and lath broken away by wind-borne debris (red circle). (Tuscaloosa, AL).

Figure 7-41:
View of the living quarters of the fire station from outside; inset shows the interior. Note the amount and size of wind-borne debris adjacent to the walls (Tuscaloosa, AL).

Figure 7-42:
View of a restroom toward the center of the fire station where occupants took refuge. Note the mattress that was taken into the room for additional protection (Tuscaloosa, AL).

Figure 7-43: View of the wood-frame apartment building behind the fire station. The inset shows the far end of the building. The walls were brick veneer over wood fiberboard over wood studs (Tuscaloosa, AL).

MAT EF Rating: Because of this fire station's unusual type of construction, none of the DIs were judged appropriate for it. Therefore, two nearby apartment buildings were used instead, and they were rated as follows:

Masonry apartment building: Using DI 7 (Masonry Apartments or Motel), the MAT selected DOD 5 ("collapse of top story walls") for this facility. Considering the building age and observed damage, the MAT assessed the wind speed to be between the expected and lower-bound wind speeds for DOD 5. Therefore, the MAT derived the tornado rating as EF2 (111–135 mph) based on damage to this building.

Wood-frame apartment building: Using DI 5 (Apartments, Condominiums, and Townhouses; Three Stories or Less), the MAT selected DOD 5 for this facility. Considering the building age and observed damage, the MAT assessed the wind speed to be between the expected and lower-bound wind speeds for DOD 5. Therefore, the MAT derived the tornado rating as EF3 (138–167 mph) based on damage to this building.

As can be seen in Figure 7-38, the wood-frame apartment building with the EF3 rating was closer to the center of the tornado circulation than the masonry apartment building with the EF2 rating, so the difference in the ratings may be due to wind speed decay. However, the difference may also be due to uncertainties in the accuracy of the wind speeds associated with the DODs.

Based on the apartment building EF ratings, the fire station either experienced EF2 or EF3 winds. Hence, the estimated wind speed at the fire station was either above or substantially above the current basic wind speed of 90 mph.

The NWS rated the center of the tornado circulation in the vicinity of the fire station as EF4, which is above the MAT EF2 or EF3 ratings of the fire station. As shown in Figure 7-38, the fire station is to the left of the center of circulation. Accordingly, the wind speed at the fire station should be less than the wind speed at the center of circulation.

The damaged glazing was due to wind-borne debris. The damage to the apparatus bay doors was due to either wind-borne debris, or more likely, wind pressures that were substantially above the pressures the doors were designed for. The MAT judged the good performance of the structural system to be due to the use of concrete.

Functional Loss: According to a representative of the fire department, one fire engine and one personal vehicle were in the apparatus bay when the tornado struck. The engine was damaged to an extent that it was not usable for emergency response. Fire station personnel therefore provided assistance to the community on foot. The personal vehicle was totaled.

For about the first week after the tornado, the damaged fire station was used to provide services. Then for about two weeks, personnel from this station operated out of Fire Station 6. After that time period, a temporary station was set up about two blocks from Fire Station 4. The temporary station consisted of a mobile office and a canvas apparatus bay.

A new facility will be built for Fire Station 4 at another location. Plans for the damaged fire station have yet to be determined at the time of this report.

7.2.3 Webster's Chapel Volunteer Fire Department (Wellington, AL)

Location of Facility in Tornado Path: An aerial view of the Webster's Chapel Volunteer Fire Department prior to the tornado is shown in Figure 7-44. The NWS EF contour ratings in the vicinity of the fire station are shown on Figure 7-44**.** According to a representative of the fire department, the fire station was occupied shortly before the tornado struck, but the occupants left the station before the tornado struck and sought refuge in a church across the street, which was outside of the tornado track and not damaged.

Facility Description: The Webster's Chapel Volunteer Fire Department was originally designed as a school several decades ago. When the facility was converted to a fire station, there was only one apparatus bay. A new apparatus bay was added circa 2007 (Figure 7-45). The original building was wood-frame construction with brick veneer walls. The multipurpose room had an aggregate surface built-up roof system over a cementitious wood-fiber deck. The older apparatus bay had a wood roof structure and unreinforced CMU walls. The new apparatus bay is a PEMB with metal roof and wall panels.

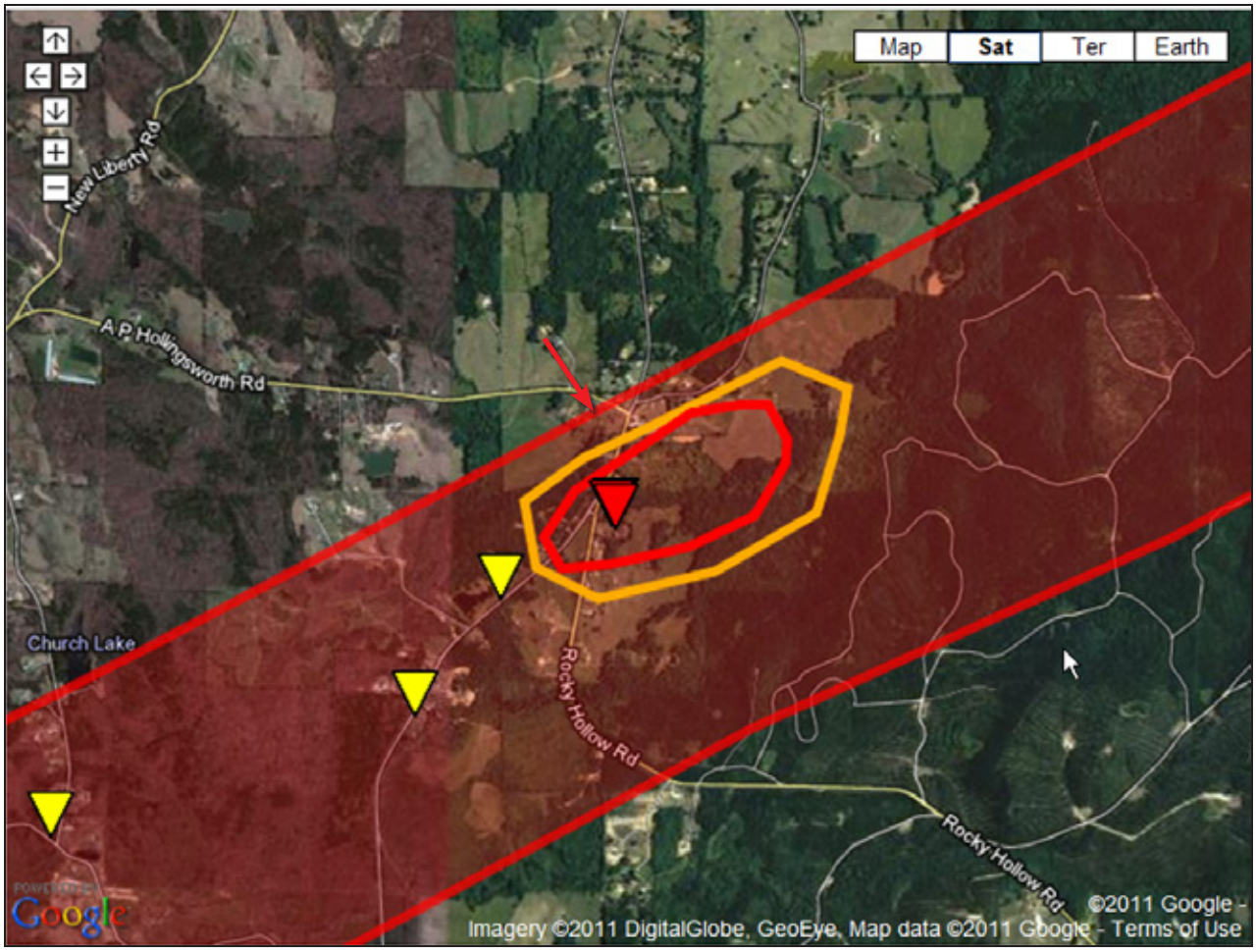

Figure 7-44: View of the Webster's Chapel Volunteer Fire Department (red arrow) in relation to the tornado.[6] The red triangle indicates the location of two houses where NWS rated the tornado as EF4. The yellow triangles indicate the locations of houses where NWS rated the tornado as EF2 (Wellington, AL).

SOURCE: © GOOGLE EARTH
SOURCE OF TORNADO TRACK: NOAA (HTTP://NGS.WOC.NOAA.GOV/STORMS)

The facility did not have a storm shelter or safe room.

General Wind Damage: The tornado struck the corner of the building where the multipurpose room and old apparatus bay were located. At the old apparatus bay, the rolling doors blew in on the equipment, the roof structure blew off, and part of the back wall collapsed (Figure 7-46). The roof membrane was blown off the multipurpose room, a few windows were broken, and portions of the roof structure and exterior wall were blown away on the backside of the building (Figure 7-47). The new apparatus bay had some wind-borne debris damage (inset at Figure 7-45), but this portion of the building did not experience high winds.

6 NOAA did not take post-tornado aerial photographs of this tornado. Therefore, a pre-storm image was used for this figure.

Figure 7-45:
View of the Webster's Chapel Volunteer Fire Department after the tornado. The new apparatus bay is indicated by the red arrow. The older apparatus bay is indicated by the yellow arrow. The inset shows wind-borne debris damage at the back side of the new apparatus bay. The green arrows indicate plywood debris that penetrated the metal wall panel sidelaps (Wellington, AL).

Figure 7-46:
View of the old apparatus bay of the Webster's Chapel Volunteer Fire Department. The multipurpose room is indicated by the red arrow (Wellington, AL).

Figure 7-47:
View of the back of the building. The old apparatus bay is shown by the yellow arrow and the new bay by the red arrow. Roof structure and wall damage occurred within the red box. The debris in the foreground is from the multipurpose room roof and the old apparatus bay (Wellington, AL).

MAT EF Rating: Only the old apparatus bay portion of the facility was rated. Using DI 14 (Automobile Service Building),[7] the MAT selected DOD 6 ("uplift or collapse of roof structure") for this facility. Considering the facility age and observed damage, the MAT assessed the wind speed as near the lower-bound wind speed for DOD 6. Hence, the MAT derived the tornado rating as EF1 (86–110 mph) based on damage to this building. Therefore, the estimated wind speed experienced by the building was not substantially above the current basic wind speed of 90 mph.

As shown in Figure 7-44, the NWS derived the rating as EF1 in the vicinity of the fire station, which correlates to the MAT EFI rating.

The MAT judged the wind damage at this fire station to be due to inadequate wind resistance, which is reflective of the codes, standards, and design practices in the era when this building was constructed.

Functional Loss: According to a representative of the fire department, all three pieces of equipment in the old apparatus bay were significantly damaged and were therefore not available for response and recovery operations.

7.2.4 Smithville Police Department (Smithville, MS)

Location of Facility in Tornado Path: Figure 7-48 shows an aerial view of the tornado track in the vicinity of the Smithville Police Department. Figure 7-49 shows the building prior to the tornado. The NWS rated the center of the tornado circulation in the vicinity of the police department as an EF5. According to a representative of the police department, there were seven people in the building at the time the tornado struck, five of whom were injured by the tornado damage. None of the injuries was life threatening.

Facility Description: The Smithville Police Department was constructed in 1962. It was previously the town's health department building. The building was constructed of unreinforced CMU with brick veneer. The building had brick veneer over 4-inch-wide CMU walls. Truss wire was noted with 8 inches-on-center shear reinforcement.

The facility did not have a storm shelter or safe room.

General Wind Damage: During the storm, the roof of the police department was blown off, and large portions of the walls on the north, east, and south sides of the building collapsed (Figure 7-50). Figure 7-51 shows a photograph taken directly after the tornado. To the left side of the figure, a portion of the building's walls can be observed. Figure 7-52 shows the damage to the police station looking south from the back (north) side of the building. The collapse of the east wall, which is also depicted in Figure 7-53, can be noted in Figure 7-49.

7 There is no DI for fire stations. The type of construction listed for DI 14 is applicable to this fire station.

Figure 7-48: Aerial view of the tornado track in the vicinity of the Smithville Police Department (yellow circle). The center of the damage swath is approximated by the red line (Smithville, MS).

Figure 7-49:
Smithville Police Department prior to the tornado (Smithville, MS)
SOURCE: © GOOGLE EARTH

Figure 7-50:
Smithville Police Department (close-up of Figure 7-48). The red arrow indicates the room where refuge was taken during the tornado (Smithville, MS).

Figure 7-51:
Smithville Police Department. Note the collapsed communications tower (red arrow) (Smithville, MS).

PHOTOGRAPH COURTESY OF TIM BURKITT, FEMA

Figure 7-52:
The red arrow indicates the office where two children and an adult took refuge under the desk (Smithville, MS)
PHOTOGRAPH COURTESY OF DARWIN HATHCOCK, CHIEF OF POLICE

Figure 7-53:
View of the collapsed east wall (red arrow) and restroom (blue arrow) of the Smithville Police Department. Note that some of the restroom walls collapsed (Smithville, MS).
PHOTOGRAPH COURTESY OF DARWIN HATHCOCK, CHIEF OF POLICE

MAT EF Rating: Using DI 9 (Small Professional Building),[8] the MAT selected DOD 8 ("collapse of exterior walls; closely spaced interior walls remain standing") for this facility. Considering the building age and observed damage, the MAT assessed the wind speed to be between the expected and lower-bound wind speeds for DOD 8. Hence, the MAT derived the tornado rating as EF2 (111–135 mph) based on damage to this building.[9] Therefore, the estimated wind speed experienced by the building was above the current basic wind speed of 90 mph.

The NWS rated the center of the tornado circulation in the vicinity of the Smithville Police Department as an EF5, which is different from the MAT EF2 rating of this building. As shown in Figure 7-48, the police department was on the right side of the center of the damage swath, and hence the right side of the center of circulation, where the wind speed is the highest. It is likely that there was wind speed decay between the center of circulation and the police station. The MAT judged the wind damage at this police station to be due to wind speeds that were above the design wind speed and inadequate wind resistance, which is reflective of the codes, standards, and design practices in the era when this police station was constructed.

Functional Loss: According to a representative of the police department, there were seven people in the building at the time the tornado struck—four employees and three civilians, including one adult and two children—who came to the police station to seek refuge. One occupant injured his arm and shoulder when winds tore a door from his grasp, while another sustained injuries from debris.

Communications for emergency response after the tornado were hampered by the collapse of the communications tower at the police department. The department had a hand-held walkie-talkie, but communication with the Smithville Fire Department, Monroe County Sheriff's Department, the 911 call center, and the Amory Police Department was not possible because of tornado damage at these other sites. The patrol car radios did not work because they had gotten wet. The cell phone circuits were also jammed. The Smithville Police Department was unable to let other emergency personnel know how bad the damage was and what their immediate needs were.

The police officers had no working or accessible equipment. The patrol cars were destroyed. Without equipment, the officers used pieces of wood as pry bars to try to rescue people trapped in cars and rubble. Doors from houses were used as backboards to transport the injured.

The facility did not have an emergency generator on site, but did have access to generators that could have been set up if needed.

As a result of the tornado, the Smithville Police Department lost complete functionality at its original location and has been relocated to the town hall, where it shares the space with the mayor's office. The town has plans to rebuild a facility that will house the police, fire, water, and town hall services in one building.

8 There is no DI for police stations. The type of construction listed for DI 9 is applicable to this facility.

9 It should be noted that the walls of the police station that were still standing immediately following the tornado were demolished several days later, before the MAT and other assessment teams arrived. The demolition caused another damage assessment team to derive an EF4 rating for this facility using DI 9, DOD 9 ("total destruction of entire building"), and the upper-bound wind speed. As evidenced by the damage photographs provided to the MAT, the selection of DOD 9 and an EF4 rating was not reflective of conditions immediately after the tornado.

7.3 Emergency Operations Centers

EOCs function as the physical location at which the coordination of information and resources to support incident management (on-scene operations) activities normally takes place.[10] The command and response personnel must remain on duty, in full readiness for action both during and in the aftermath of a disaster. In addition to personnel and resources, EOCs house the information and communications systems that provide feedback to the emergency managers to help them make decisions about efficient and effective deployment of resources. They also relay information to local residents, storm shelters, media, and other first responders, while providing continuity of government and COOP. The loss of an EOC can severely affect the overall response and recovery in the area. For these reasons, the performance of these facilities in tornadoes is of utmost importance.

7.3.1 Tuscaloosa EOC (Tuscaloosa, AL)

Location of Facility in Tornado Path: The Tuscaloosa EOC was housed in the Curry Building city complex. Figure 7-54 shows an aerial view of the tornado track in the vicinity of the Curry Building city complex. The NWS rated the center of the tornado circulation in the vicinity of the Curry Building as an EF4**.** According to a representative of the city, there were approximately 15 people in the EOC at the time the tornado struck, none of whom was injured.

The EOC was located on the ground floor of the southeast corner (red circle in Figures 7-54 and 7-55). Figure 7-56 is a view of the EOC before and after the tornado.

Facility Description: The Tuscaloosa County EMA was housed in the Curry Building city complex, which was constructed in 1967 as a textile manufacturing plant and later used as an automotive parts manufacturing facility. The Curry Building city complex also housed the Environmental Services Department and general storage.

Most of the southern end of the complex (which housed the EOC) was a two-story steel-framed building with a built-up roof over steel decking. The exterior walls were unreinforced CMU with brick veneer. The first floor had a daylight basement. Most of the second floor had a high bay (equivalent to two stories).

Most of the remainder of the building (in the yellow rectangle in the Figure 7-54 inset), was a one-story steel-framed building with a built-up roof over steel decking. Some of the exterior walls were unreinforced CMU with brick veneer, while others were metal panels. There were several loading dock doors on the north and west sides of the building.

The Curry Building did not have a tornado safe room or storm shelter. However, there was a tornado refuge area within the EOC and another tornado refuge area shown by the blue circle at the Figure 7-54 inset and at Figure 7-55.

General Wind Damage: Most of the area shown in the yellow rectangle in the Figure 7-54 inset collapsed (Figures 7-57 and 7-58).

10 Definition for EOC from the National Response Framework (http://www.fema.gov/emergency/nrf/glossary.htm#E)

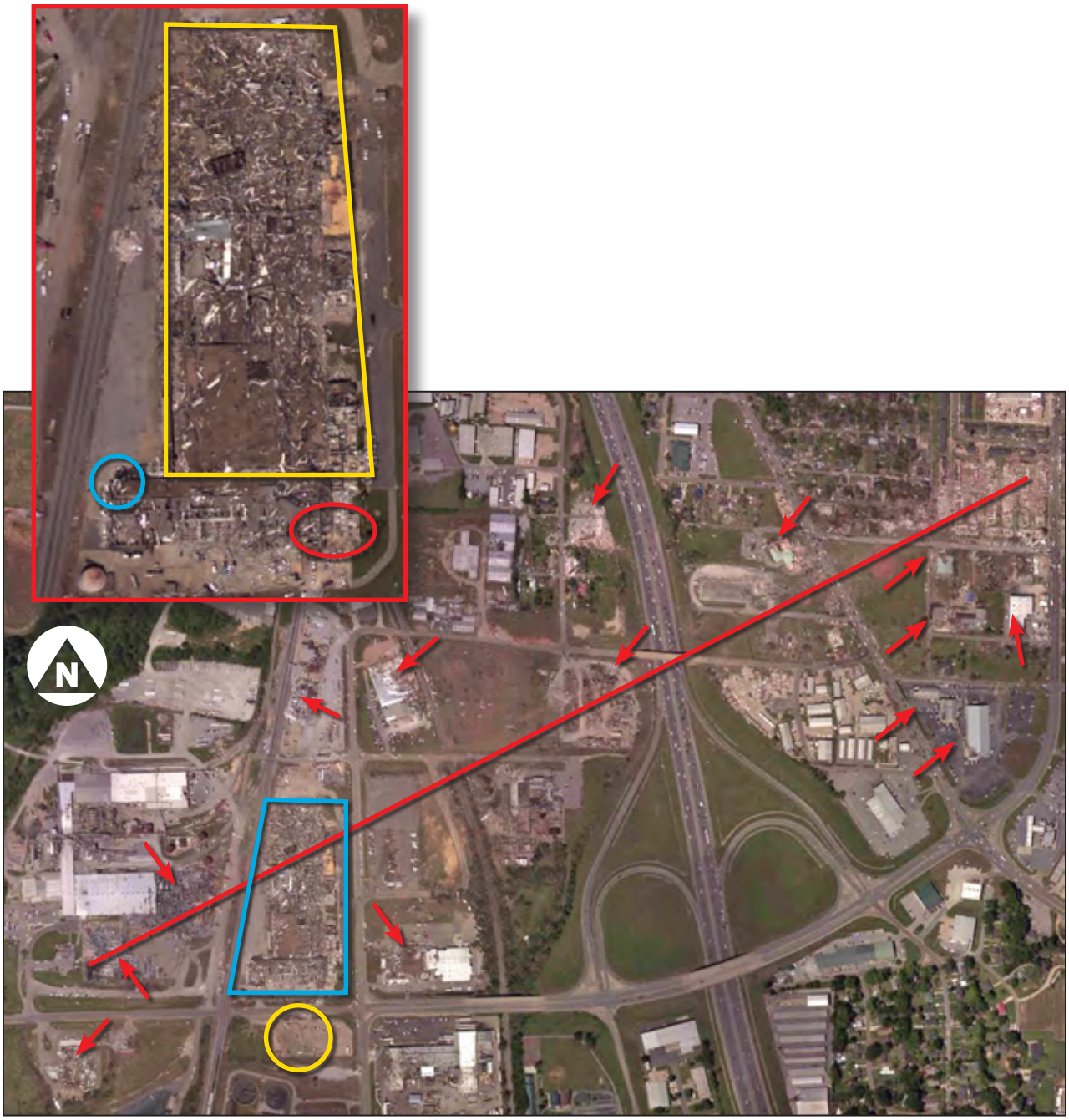

Figure 7-54: Aerial view of the track in the vicinity of the Curry Building city complex (blue rectangle). The center of the damage swath is approximated by the red line. The yellow circle indicates the EOC's collapsed communications tower. The red arrows indicate damaged buildings. In the inset, the red oval shows the EOC and the blue circle shows a tornado refuge area. Most of the area in the yellow rectangle collapsed (Tuscaloosa, AL).

Figure 7-55: Oblique view of Figure 7-54 showing the Curry Building. The green circle indicates the EOC's emergency generator. The red circle shows the ground floor of the southeast corner, the location of the EOC. The blue circle shows the tornado refuge area.

PHOTOGRAPH COURTESY OF TUSCALOOSA COUNTY SHERIFF'S OFFICE

Figure 7-56:
View of the southeastern end of the Curry Building before the tornado struck. The EOC is located on the ground floor of the red box. The floor above the EOC collapsed (green line). The building to the left of the EOC (blue X) collapsed. The inset shows post-storm conditions (Tuscaloosa, AL).

SOURCE: © GOOGLE EARTH

Figure 7-57:
View of a portion of the collapsed one-story area (Tuscaloosa, AL)

Figure 7-58:
View of a portion of a collapsed loading dock area (Tuscaloosa, AL)

There was a tornado refuge area in a portion of the first floor in the southwest corner of the building (red oval, Figure 7-59). This area was marked with a sign reading "emergency shelter" that had a tornado graphic. The exterior walls in this area were concrete and had adequate strength to resist tornado wind forces. However, the rolling door, personnel door with glass vision panel, and the wall louver lacked sufficient wind pressure and wind-borne debris impact resistance for the area to be considered a safe room or storm shelter. The floor above this refuge area collapsed, indicated by the blue oval, and the roof decking blew off adjacent to this area as indicated by the red arrow. Further along the building, a portion of the roof structure and exterior wall collapsed as indicated by the blue arrow.

Most of the steel decking and some joists were blown off of the southern portion of the building (Figure 7-60) and much of the brick veneer/CMU wall collapsed. The metal door shown at the inset was buckled inward by CMU debris.

Figure 7-61 is a close-up of the Figure 7-56 inset, showing the EOC area.

MAT EF Rating: Using DI 23 (Warehouse Building), the MAT selected DOD 7 ("total destruction of a large section of building or entire building") for the portion the facility that housed the EOC (i.e., the southern portion of the complex). Considering the building age, the MAT assessed the wind speed to be between the expected and lower-bound wind speeds for DOD 7. Hence, the MAT derived the tornado rating as EF3 (136–165 mph) based on damage to this portion of the building. Therefore, the estimated wind speed experienced by the building was substantially above the current basic wind speed of 90 mph.

The NWS rated the center of the tornado circulation in the vicinity of the Curry Building city complex an EF4, which is different from the MAT EF3 rating of the EOC portion of this building. As shown in Figure 7-54, the EOC was on the right side of the center of the damage swath and hence, the right side of the center of circulation, where the wind speed is the highest. It is likely that there was wind speed decay between the center of circulation and the EOC.

The MAT judged the poor wind performance of the Curry Building city complex to be due to wind speeds that were substantially above the design wind speed and inadequate wind resistance, which is reflective of the codes, standards, and design practices in the era when this building was constructed. The good performance of the structural system at the EOC and refuge area was judged to be due to the use of concrete.

Functional Loss: According to a representative of the city, there were approximately 15 people in the EOC at the time the tornado struck, including a worker and two family members who were in the Environmental Services Department prior to taking refuge in the EOC. Although the area housing the EOC did not comply with FEMA 361 (2008a) or ICC 500 (2008) criteria for safe rooms and storm shelters, the exterior concrete walls and concrete slab of the second floor provided a level of occupant protection during this event and none of the occupants were injured.

The emergency generator did not come on when normal power was lost because the lines connecting it to the EOC were severed during the storm. The EOC was flooded because the fire sprinkler system was damaged during the tornado. The EOC also lost communications because a large nearby communications tower collapsed (Figure 7-54 and Section 8.3.1.1).

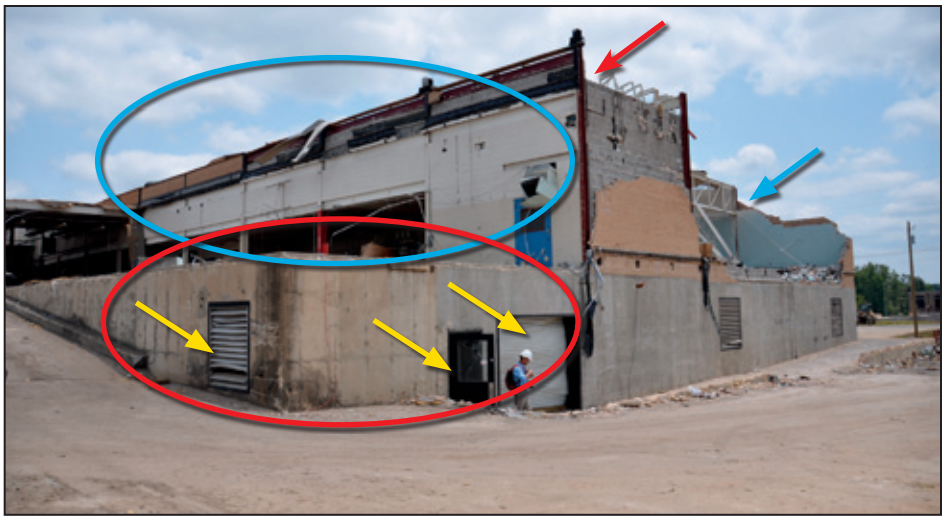

Figure 7-59:
View of the refuge area (red oval). Note the rolling door, personnel door, and louver wall openings (yellow arrows). The floor above the refuge area (blue oval) collapsed and the roof decking in the adjacent area (red arrow) blew off. A portion of the roof structure and exterior wall collapsed (blue arrow) (Tuscaloosa, AL).

Figure 7-60: Part of the southern portion of the building. The inset shows a metal door that buckled inward (Tuscaloosa, AL).

Figure 7-61:
The door with the red arrow leads to the EOC area. The inset shows the area above the EOC that collapsed (Tuscaloosa, AL).

The EOC lost complete functionality as a result of the tornado. The EOC had no functionality for approximately an hour after the tornado, at which point they set up at the Tuscaloosa Police Department for several hours. Following this, the EMA was relocated to the UA EOC until approximately May 3, at which point it was moved to a temporary location at the Alabama Fire College. A new permanent location will be required.

The Environmental Services Department is planning to build a new building and a recycling plan on the site of the collapsed Curry Building city complex. The Department temporarily moved into modular buildings across the street after the tornado. Destruction of the Department's facility hampered pickup of recyclables and trash in the first days after the tornado.

7.3.2 Cullman County EOC (Cullman, AL)

This facility was not struck by the Cullman tornado on April 27, 2011. Although the facility was not damaged, it is presented in this chapter because of special enhancements that were incorporated into its design in order to avoid facility disruption if struck by a tornado.

In 2008, the Cullman County EMA moved into its new facility in the basement of the newly constructed Cullman County Water Department Building.[11] The EMA portion of the facility was designed as a safe room in accordance with FEMA 361 (2000) to resist the wind pressures and wind-borne debris associated with EF5 tornadoes (Figure 7-62): wind speeds of 250 mph (3-second gust) and debris impact from a 15-pound 2x4 board missile traveling horizontally at 100 mph.

The design criteria were selected by the County and the architect to ensure that EMA staff would be safe and that operations would be maintained if the facility were impacted by a tornado.

The EMA portion of the facility occupies approximately 6,250 square feet and includes a reception area, an operations room that is approximately 1,000 square feet (Figure 7-63), bath rooms, two conference rooms, six offices, storage facilities, a communications closet, and a large multi-purpose room. All these areas are located within the reinforced concrete basement of the building. Two stairwells and one elevator provide access to the below-grade portions of the facility. The stairwells are also constructed of reinforced concrete and spiral downward from the above-grade entrance to the operations room. The emergency generator, air handler, and heating system for the facility are located within a special room in the above-ground portion of the facility. The walls and roof of the room protecting the generator were constructed from reinforced concrete to also meet the FEMA 361 (2000) criteria.

Figure 7-62:
An exterior view of the Cullman County government building housing the Water Department (above grade) and the County EMA facility (below grade) (Cullman, AL)

11 The facility was designed by Harris & Associates Architects and Planners, Birmingham, AL.

Figure 7-63:
Interior view of the emergency operations room of the Cullman County EMA facility (Cullman, AL)

FEMA 361 (2000) design elements and criteria implemented by the owner and architect include:

- A design wind speed of 250 mph and wind-borne debris impact protection for the EOC portion of the facility and also for the generator room.
- Wind-borne debris protection of the openings in the generator and mechanical room area to resist a 15-pound 2x4 missile traveling horizontally at 100 mph. This was created with concrete baffle walls. Use of concrete wall baffles allowed the use of traditional louvers between the baffles.
- Protection of fuel storage. This was achieved by placing the large tank for the generator below ground (including all piping connecting the tank to the generator).
- Protection of building systems (for example, the heating and air handling systems) by locating the equipment within the same protected space as the generator. Note: the cooling systems for the facility were not in the protected space. Since the EOC is located below grade, it was determined that protecting the cooling system was not critical and that the facility could function for a short period of time if this system were not available.
- Location of all communications systems, switches, and computer servers for both the EMA and the Water Department within the lower level.
- Provision of food and water storage within the lower level.
- Provision of a large multipurpose conference room within the lower-level area that holds over 100 operational personnel for use by the EMA or others responding to an event.

- High ceilings and multiple layers of lighting. These elements give the facility a light and open feel in spite of the fact that it is totally underground with no natural lighting. The underground facility maintains a more constant temperature with less difficulty and cost than an above-ground facility.

- Provision of space for additional staff when needed for emergency response. During times of full activation, such as was experienced on April 27, 2011, the two full-time Cullman County EMA staff members were joined by more than 20 people. Representatives from the local emergency response community rotated through on 12-hour shifts to assist the EMA personnel. This included both paid and volunteer response agencies. Staff can also be supplemented as needed by administrative personnel from other county departments such as the Revenue Commission, etc. The multipurpose space adjacent to the EOC on the lower level provides protected space for the county staff plus any additional emergency responders who may be at the facility during an event.

According to the architect, the portions of the facility designed to the FEMA 361 (2008a) criteria were constructed for approximately $200 per square foot for a total cost of roughly $1,250,000. By contrast the upper floor of the facility (used for other Cullman County offices) was constructed at a cost of approximately $120 per square foot. If constructed to the building code in effect at the time, the EMA portion of the facility would have cost approximately 50 percent less. Implementing the FEMA 361 criteria for the selected portions of the facility ended up accounting for approximately 65 percent of the total building cost. By choosing to spend an additional 25 percent on the facility, the owner and architect were able to achieve both personal protection for the 25 County staff and also provide continuity of operations during events. Additionally, based on FEMA 361 criteria regarding the number of occupants, the multipurpose room can provide protection for the facility staff as well as up to 300 additional persons (if needed).

The construction of this facility shows how a community, with no Federal funding assistance, was able to implement the best-available guidance on tornado-resistant construction to design and construct a building that provides life-safety protection for the EMA staff , and also provides for continuity of operations if struck by a tornado.

7.4 Summary of Conclusions and Recommendations

Table 7–1 provides a summary of the conclusions and recommendations for Chapters 6 and 7, and provides section references for supporting observations. Additional commentary on the conclusions and recommendations is presented in Chapters 10 and 11.

Table 7-1: Summary of Conclusions and Recommendations for Critical Facility Performance

Observation(s)	Conclusion	Recommendation
Schools which sustained damage and did not have a FEMA 361-compliant safe room or ICC 500-compliant storm shelter: • Alberta Elementary School (Section 6.1.1) • University Place Elementary School (Section 6.1.2) • Ringgold High School and Ringgold Middle School (Section 6.1.3) • Joplin East Middle School (Section 6.1.4) • Joplin High School (Section 6.1.5) 911 call stations, EOCs, or fire, rescue, ambulance, and police stations that sustained damage and did not have a FEMA 361-compliant safe room or ICC 500- compliant storm shelter: • Fultondale Municipal Complex (Section 7.2.1) • Tuscaloosa Fire Station 4 (Section 7.2.2) • Webster's Chapel Volunteer Fire Department (Section 7.2.3) • Smithville Police Department (Section 7.2.4) • Tuscaloosa EOC (Section 7.3.1)	**Conclusion #4** **IBC-compliant facilities can be susceptible to building damage.**	**Recommendation #10** **Propose IBC code change.** Submit IBC code change proposal to require a FEMA 361-compliant safe room or ICC 500-compliant storm shelter in all areas where shelter design wind speeds are 250 mph or greater for all new kindergarten through 12th grade schools. **Recommendation #11** **Propose IBC code change** Submit IBC code change proposal to require a FEMA 361-compliant safe room or ICC 500-compliant storm shelter in all areas where shelter design wind speeds are 250 mph or greater for all 911 call stations, emergency operation centers, and fire, rescue, ambulance, and police stations.
Older facilities with significant wind-resistance vulnerabilities: • Ringgold High School and Ringgold Middle School (Section 6.1.3) • Joplin High School (Section 6.1.5) • Webster's Chapel Volunteer Fire Department (Section 7.2.3) • Smithville Police Department (Section 7.3.4)	**Conclusion #16** **Older facilities were susceptible to damage from weak tornadoes.** Older facilities were subject to considerable building damage and disruption of facility operations when struck by even weak tornadoes	**Recommendation #25** **Perform a vulnerability assessment.**
Facilities lacking of adequate signage, for example: • Joplin East Middle School (Section 6.1.4) • Fultondale Municipal Complex's Library (Section 7.2.1) • Tuscaloosa EOC (Section 7.3.1)	**Conclusion #17** **There was a lack of adequate signage directing occupants to refuge areas.** (See also Conclusions #8 and #28)	**Recommendation #26** **Identify best available refuge areas.**

Table 7-1: Summary of Conclusions and Recommendations for Critical Facility Performance (concluded)

Observation(s)	Conclusion	Recommendation
Critical facilities in path of tornado track with lack of FEMA 361-compliant safe room or ICC 500-compliant shelter: • Alberta Elementary School (Section 6.1.1) • University Place Elementary School (Section 6.1.2) • Ringgold High School and Ringgold Middle School (Section 6.1.3) • Joplin East Middle School (Section 6.1.4) • Joplin High School (Section 6.1.5) • LaRocca Nursing Home (Section 7.1.2) • Greenbriar Nursing Home (Section 7.1.3) • St. John's Medical Center (Section 7.1.4) • Fultondale Municipal Complex (Section 7.2.1) • Tuscaloosa Fire Station 4 (Section 7.2.2) • Webster's Chapel Volunteer Fire Department (Section 7.2.3) • Smithville Police Department (Section 7.2.4) • Tuscaloosa EOC (Section 7.3.1)	**Conclusion #5 and #18** **(#5) Many of the critical facilities observed lacked safe rooms and/or storm shelters.** **(#18) There was a lack of safe rooms and storm shelters in critical facilities.**	**Recommendation #27 Include safe rooms in design of new facilities.**
Critical facilities with glazing damage, for example: • Alberta Elementary School (Section 6.1.1) • Ringgold High School and Ringgold Middle School (Section 6.1.3) • Joplin High School (Section 6.1.5) • LaRocca Nursing Home (Section 7.1.2) • St. John's Medical Center (Section 7.1.4) • Tuscaloosa Fire Station 4 (Section 7.2.2)	**Conclusions #15 Glazing is susceptible to damage.**	**Recommendation #28 Enhance building design to better withstand tornadoes.**
Critical facilities that did not remain operational following a tornado: • Alberta Elementary School (Section 6.1.1) • University Place Elementary School (Section 6.1.2) • Ringgold High School and Ringgold Middle School (Section 6.1.3) • Joplin East Middle School (Section 6.1.4) • Joplin High School (Section 6.1.5) • LaRocca Nursing Home (Section 7.1.2) • Greenbriar Nursing Home (Section 7.1.3) • St. John's Medical Center (Section 7.1.4) • Fultondale Municipal Complex (Section 7.2.1) • Tuscaloosa Fire Station 4 (Section 7.2.2) • Webster's Chapel Volunteer Fire Department (Section 7.2.3) • Smithville Police Department (Section 7.2.4) • Tuscaloosa EOC (Section 7.3.1)	**Conclusion #4 IBC-compliant facilities can be susceptible to building damage.**	**Recommendation #29 Strengthen facilities to remain operational.**