TORNADO OUTBREAK of 2011

IN ALABAMA, GEORGIA, MISSISSIPPI, TENNESSEE, AND MISSOURI

6 Observations on Critical Facility Performance: Schools

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

Critical facilities include schools, healthcare facilities, police and fire stations, and emergency operations centers (EOCs). Critical facilities are vitally important to communities that have been struck by tornadoes. Functional schools are needed to provide educational continuity and they are often used to provide space for recovery operations. Functional hospitals and other healthcare facilities are needed to treat injuries and provide routine on-going care to the community. Functional police and fire stations and EOCs are needed to manage their normal mission, along with response and recovery operations after an event.

The tornadoes in April and May of 2011 significantly affected many critical facilities, totally destroying some of them and severely interrupting the operations of several others. Some of the observed facilities were damaged by winds that were below current design wind speeds. Most of the critical facilities observed did not perform any better than commercial buildings and several performed poorly. The damage to these buildings resulted in occupant deaths and injuries, and put many other occupants at risk of injury. Building damage also placed additional burdens on response and recovery personnel as they endeavored to provide assistance to their communities after the event.

Chapters 6 and 7 describe the performance of some of these critical facilities. The facilities that are discussed in Chapters 6 and 7 were selected to document lessons learned, both good and bad. Some these facilities are representative of various issues, such as common tornado vulnerabilities of older buildings. Other facilities are discussed because of their unique attributes.

In addition to describing facility performance, Chapters 6 and 7 also report on operational issues associated with tornado watches and warnings issued by the NWS. Because of different strategies that may be implemented for schools versus healthcare, police and fire stations, and EOCs, schools are addressed in this chapter and the other facilities are addressed in Chapter 7. See Section 6.2 for discussion of operational issues in the respective chapters.

General Discussion on Critical Facilities

Critical facilities are Category III and IV buildings as defined in the 2009 IBC (Section 1604, *General Design Requirements*, Table 1604.5) and ASCE 7-05 (Section 1.5, *Classification of Buildings and Other Structures*, Table 1-1). Category III and IV buildings include, but are not limited to, hospitals and other medical facilities, fire and police stations, primary communications facilities, EOCs, schools, shelters, and power stations and other facilities required in an emergency. FEMA considers critical facilities as those buildings that are essential for the delivery of vital services or protection of a community (FEMA 2007a).

The 2009 edition of the IBC has only two special wind-related provisions pertaining to Category III and IV buildings:

- *Importance Factor:* The Importance Factor for these buildings is 1.15, rather than the 1.0 factor that is used for most other types of buildings. Using the 1.15 Importance Factor effectively increases the wind design loads by 15 percent.

- *Wind-borne debris loads:* For buildings located within wind-borne debris regions (as defined in ASCE 7-05) of hurricane-prone regions, exterior glazing is required to be impact resistant. For Category III and IV buildings located where the basic wind speed is 130 mph or greater, the glazing is required to resist a larger momentum missile load than the glazing on other types of buildings.

  This provision is not applicable to the facilities observed by the MAT, because none of the facilities were located in a hurricane-prone region.

Critical Facilities Observed by the MAT

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 6-1 (April 25–28 tornado event) and Figure 6-2 (May 22, Joplin, MO, tornado event); the schools described in this chapter are highlighted.

Table 6-1: Number of Critical Facilities Observed by the MAT

Facility Type	Alabama	Georgia	Mississippi	Tennessee	Joplin, Missouri	Total Number of Facilities Observed by MAT	Total Number of Facilities Described in MAT Report
Schools (Section 6.1)	9	2	1	2	6	20	6
Hospitals/ healthcare (Section 7.1)	3	0	0	0	2	5	4
Police, Fire (Section 7.2)	10	0	2	0	3	15	4
EOCs (Section 7.3)	2*	0	0	0	0	2	2
Total	**23**	**2**	**3**	**2**	**11**	**42**	**16**

* The Cullman County EOC, AL, was visited but was not in the tornado track (see Section 7.3.2).

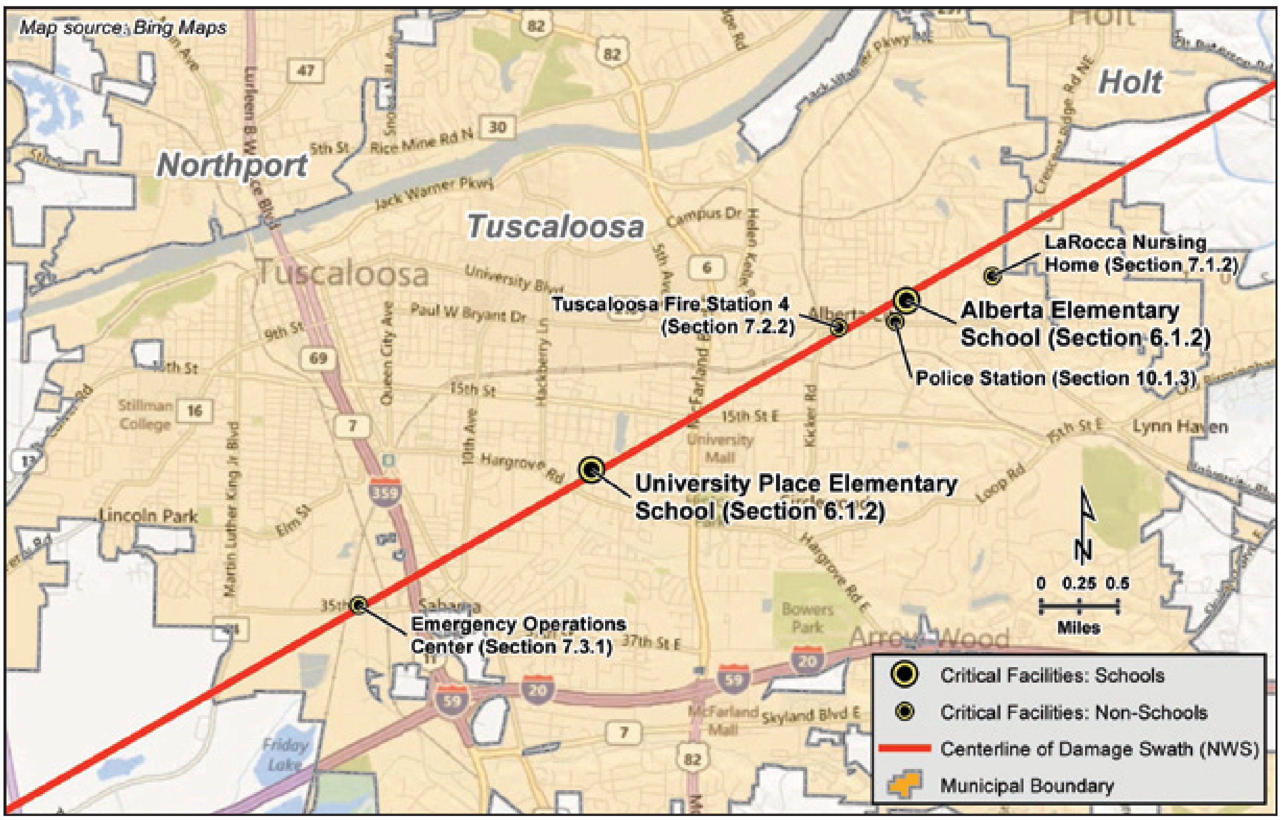


Figure 6-1: Location of Tuscaloosa, AL, critical facilities described in Chapters 6 and 7. The EOC (southwestern end of tornado track shown, red line) is approximately 4.7 miles from the LaRocca Nursing Home (northeastern end of tornado track shown).

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

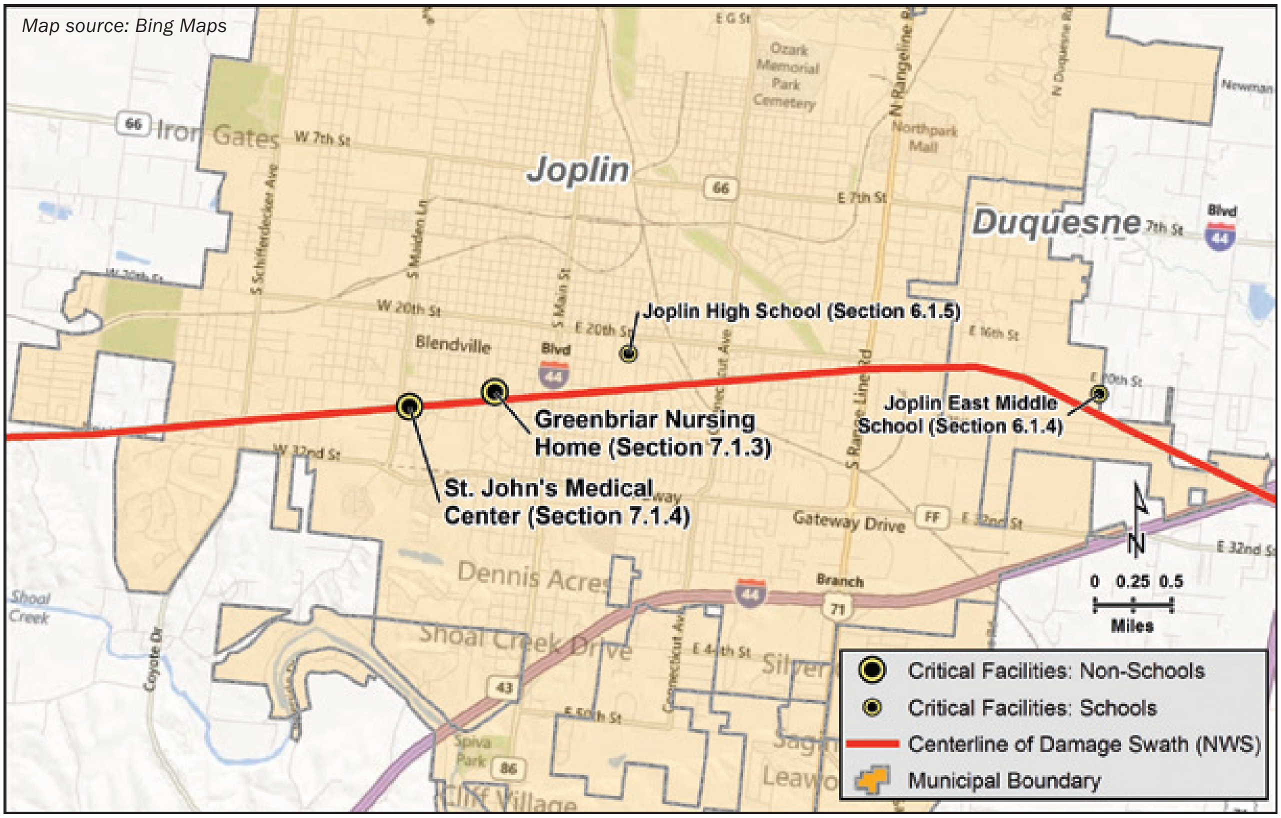


Figure 6-2: Location of Joplin, MO, critical facilities described in Chapters 6 and 7. It is approximately 4.5 miles from the St. John's Medical Center (western end of tornado track) to the East Joplin Middle School (eastern end of tornado track).

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

In addition to the 41 critical facilities that were in tornado tracks or track periphery, 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. None of the observed schools located outside of tracks or track periphery are discussed in this report.

6.1 Building Performance

In addition to their traditional role as educational facilities, schools can play an important role in providing space for recovery after a tornado. Thus, their loss of use can affect a community's ability to rapidly respond to the needs of disaster victims, as well as hamper resumption of school activities.

6.1.1 Alberta Elementary School (Tuscaloosa, AL)

Location of Facility in Tornado Path: The location of the Alberta Elementary School is shown in Figure 6-1. Figure 6-3 shows an aerial view of the tornado track in the vicinity of the school. The NWS rated the center of the tornado circulation in the vicinity of the school as an EF4. According to

Figure 6-3: Aerial view of tornado track in vicinity of Alberta Elementary School (yellow circle). The center of the damage swath is approximated by the red line[1] (Tuscaloosa, AL).

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

a representative of the school district, the school was not occupied when the tornado struck because the NWS warnings were issued well in advanced of the tornado.

Facility Description: The Alberta Elementary School opened in 2002. The one-story school had three classroom wings and a central core area. The central core area included the cafeteria, kitchen, media center, multipurpose room, music room, and offices. The wings and core area had 4:12 sloped roofs composed of asphalt shingles over plywood decking over wood roof trusses. The exterior walls were load bearing. At the wings and portions of the core, the exterior walls were brick veneer over steel studs. Other portions of the exterior core walls were brick veneer over reinforced CMU.

According to the contract drawings, the building was designed in accordance with the 1994 SBC. However, the wind loads were based on the 1995 edition of ASCE 7 using a basic wind speed of 90 mph, Importance Factor of 1.15, and Exposure B.[2]

The school had severe weather tornado refuge areas identified on floor plans that were posted in corridors. The refuge areas for the two surviving wings were located in the central core area (shown by the red arrow in Figure 6-4).[3]

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.

2 The basic wind speed, Importance Factor, and Exposure for this facility are the same in both the 1995 and 2005 editions of ASCE 7.

3 Presumably the tornado refuge area in the wing of the school that was destroyed was also located in the central core area where all the buildings converged, but the MAT was unable to confirm this.

General Wind Damage: One classroom wing and most of the central core collapsed (Figures 6-4 to 6-6, 6-9, and 6-10). The tornado refuge areas for the two surviving wings were destroyed (Figure 6-5). Figure 6-5 shows a portion of the collapsed central core area and the two wings that survived. The MAT judged the limited damage at the surviving wings to be due to shielding provided by the third wing and core area, rather than increased strength of these two wings.

Figure 6-4:
Area shown in yellow circle of Figure 6-3. The classroom wings are indicated by "W" and the core area by "C." The general location of the tornado refuge areas for the two surviving wings is shown by the red arrow. Yellow arrows indicate remnants of corridors between the core and wings. The blue arrows indicate restroom remnants. The yellow box indicates kitchen remnants (Tuscaloosa, AL).

Figure 6-5:
View of the central core area. Tornado refuge areas for the two surviving wings were in the collapsed area (red circle). The yellow arrows indicate the two surviving wings (Tuscaloosa, AL).

Several of the interior walls in the core area were reinforced CMU. Most of these walls collapsed. At the wall shown in Figure 6-6, the rebar was spaced at 4 feet on center. The rebar that was in the collapsed portion had only about 2 inches of embedment into the grouted CMU that is still in place and does not significantly strengthen the joint between the base of the wall and the floor or provide resistance to toppling. Similar splice laps were noted at exterior walls.

Figure 6-6:
Interior reinforced CMU wall in the central core area where rebar had deficient splice lap. Inset shows a close-up of the deficient splice lap (Tuscaloosa, AL).

Figure 6-7 shows one of the surviving classroom wings. All of the exterior windows and the glass vision panels in the exit doors were broken (there were eight windows along each of the long walls). This wing also lost a substantial amount of underlayment and asphalt shingles. The wing to the left of the area shown in the photograph lost a significant amount of deck sheathing at the far (south) end and several trusses were missing. Figure 6-8 shows the corridor in the surviving wing shown in Figure 6-7. A portion of the corridor wall partially collapsed.

Figure 6-7:
Center classroom wing remains standing while the wing to the right (red arrow) collapsed (Tuscaloosa, AL)

Figure 6-8:
Partially collapsed corridor wall (red arrow) (Tuscaloosa, AL)

Figure 6-9 shows the view looking down the corridor of the classroom wing that collapsed. The remnant shown by the red arrow is a restroom in the core area. The remnant shown by the blue arrow is the corridor between the collapsed wing and core. Figure 6-10 shows the reinforced CMU restroom remnant in the collapsed wing. The entire restroom area was open to the sky and there was a substantial amount of debris within the rooms. Although corridors and restrooms are sometimes the best available refuge areas, injury or death may occur in corridors and restrooms that are not specifically designed as safe rooms or storm shelters as shown in Figures 6-8 through 6-10 and as discussed in Chapter 9.

Figure 6-9: Looking down the corridor of the collapsed classroom wing; red arrow indicates a bathroom in the core remnant and yellow arrow indicates a corridor that remained standing (Tuscaloosa, AL)

Figure 6-10: The reinforced CMU walls around the restroom were left standing, but the rooms were littered with debris (as shown in the inset). The wall with the brick veneer (red arrow) was an exterior wall (Tuscaloosa, AL).

MAT EF Rating: Using DI 15 (Elementary School), the MAT selected DOD 10 ("total destruction of a large section of building or entire building") for the school. Using the expected wind speed for DOD 10, the MAT derived the tornado rating as EF4 (166–200 mph) based on damage to this building. Hence, the estimated wind speed experienced by the building was substantially above the basic wind speed of 90 mph the building was designed for. As shown in Figure 6-3, this building is near the center of the damage swath. The MAT EF4 rating for this building correlates with the NWS rating of EF4 for the center of the tornado circulation.

The MAT judged the wind damage at this school to be due to its subjection to wind speeds substantially above the design wind speed.

Functional Loss: The building will need to be reconstructed before school can resume at this location. According to the school district's Web site, the students were temporarily housed at another school for the 2011–2012 school year. The goal is to have the new Alberta facility ready for occupancy in the fall of 2012.

6.1.2 University Place Elementary School (Tuscaloosa, AL)

Location of Facility in Tornado Path: The location of the University Place Elementary School is shown in Figure 6-1. Figure 6-11 shows a view of the school after the tornado. Figure 6-12 shows an aerial view of the tornado track in the vicinity of the school. The NWS rated the center of the tornado circulation in the vicinity of the school as an EF4. According to a representative of the school district, the school was not occupied when the tornado struck because the NWS warnings were issued well in advanced of the tornado.

Figure 6-11: University Place Elementary School after the tornado. The red arrow shows the collapsed second story of one of the classroom wings. Several broken windows were boarded up at the time of the MAT visit (blue arrow) (Tuscaloosa, AL).

Facility Description: The University Place Elementary School opened in 1997. A gymnasium was added in 2008. The original building had two two-story classroom wings, a two-story media center and office area, cafeteria, kitchen, and multipurpose room, as shown in Figure 6-13. All areas had 3:12 sloped metal roof panels attached to steel roof deck supported by steel roof joists. The exterior walls are brick veneer over CMU bearing walls. The bearing walls of the classroom wings are unreinforced. The bearing walls of the media center and multipurpose wing are reinforced. The joists were welded to a plate that had two headed studs embedded into a single bond beam with two #4 horizontal steel reinforcing bars. The second floor assembly was precast, pre-stressed hollow-core slabs with a concrete topping. The slabs rest on the CMU; there is no tie between the slabs and CMU. According to the contract drawings, the building was designed in accordance with the 1991 SBC, using a basic wind speed of 70 mph (fastest-mile).[4] For this building, the wind loads derived from the 1991 SBC for the roof structure are similar to those derived from the 2005 edition of ASCE 7.

4 A 70 mph fastest-mile equates to about a 90 mph 3-second peak gust.

Figure 6-12: Aerial view of the tornado track in the vicinity of the University Place Elementary School (yellow circle). The center of the damage swath is approximated by the red line (Tuscaloosa, AL).

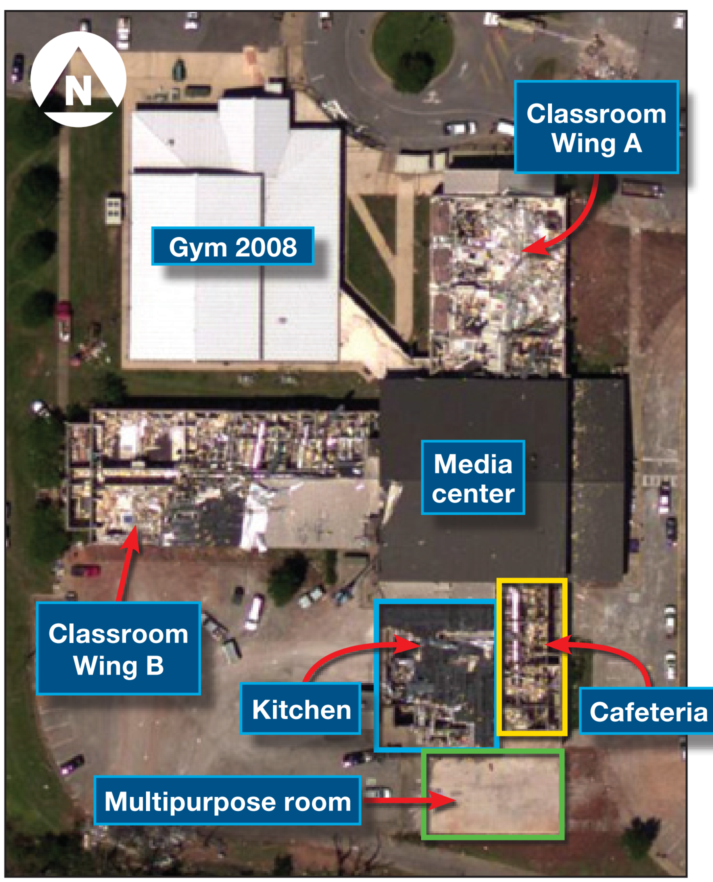


Figure 6-13: Close-up of Figure 6-12 showing classroom wings A and B and multipurpose wing (cafeteria, kitchen, and multipurpose room)[5] (Tuscaloosa, AL)

5 The multipurpose room debris was removed before the MAT visited this site.

The gymnasium is a pre-engineered metal building. Some of the walls are brick veneer over CMU, while other walls are metal panels. According to the contract drawings, the building was designed in accordance with the 2003 IBC, using a basic wind speed of 90 mph, Importance Factor of 1.15, and Exposure C.

The school did not have a tornado safe room or storm shelter. The first floor corridors in the two classroom wings were the designated refuge areas. The corridors ran down the center of each wing. Each wing had a pair of standard exit doors with glass vision panels at the end of the corridor.

General Wind Damage: Several exterior windows were broken (Figure 6-11). Most of the exterior and interior walls of the second floor of classroom wing A collapsed (Figures 6-11, 6-13, and 6-14). About 75 percent of the roof decking of classroom wing B blew off (Figures 6-13 and 6-14) and about 25 percent of the roof joists also blew off of this wing. Some of the second floor exterior wall of classroom wing B also collapsed (Figure 6-15 and 6-16).

The multipurpose wing was also heavily damaged. At the cafeteria, all of the roof decking and several of the roof joists were blown off (Figure 6-17). At the kitchen, much of the roof decking and some roof joists were blown off (Figure 6-18). Some brick veneer and exterior CMU also collapsed. The multipurpose room was destroyed (Figure 6-18). There were two girders at the multipurpose

Figure 6-14: View looking south showing damage of the classroom wings (red arrows) and multipurpose wing (blue oval). The yellow arrow indicates damaged walkway canopy (Tuscaloosa, AL).
PHOTOGRAPH COURTESY OF TUSCALOOSA COUNTY SHERIFF'S OFFICE

Figure 6-15: View looking north showing wall and roof structure damage to classroom wing B (red arrow) and damage to the multipurpose wing (blue oval) (Tuscaloosa, AL)
PHOTOGRAPH COURTESY OF TUSCALOOSA COUNTY SHERIFF'S OFFICE

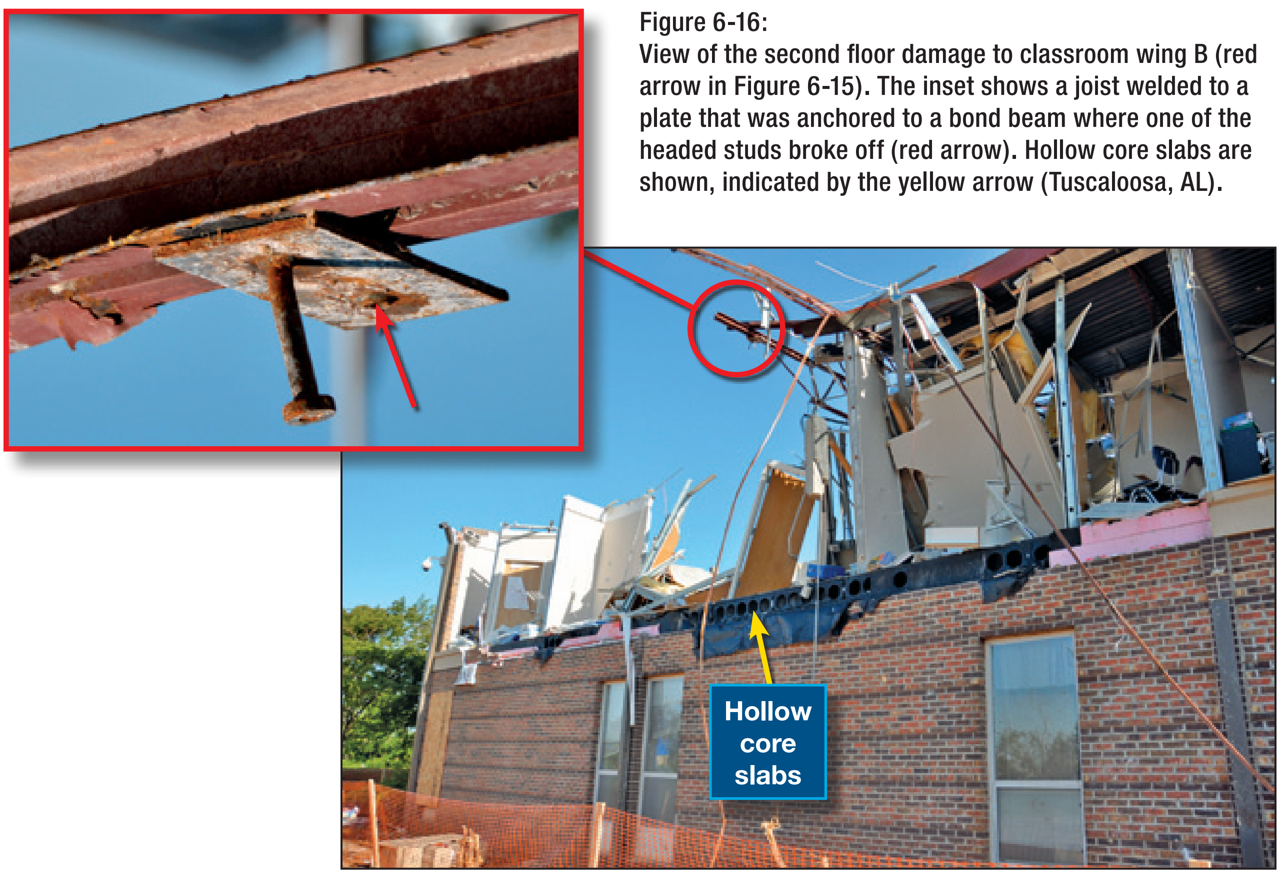


Figure 6-16:
View of the second floor damage to classroom wing B (red arrow in Figure 6-15). The inset shows a joist welded to a plate that was anchored to a bond beam where one of the headed studs broke off (red arrow). Hollow core slabs are shown, indicated by the yellow arrow (Tuscaloosa, AL).

Figure 6-17:
View inside the cafeteria (Tuscaloosa, AL)

Figure 6-18:
View toward the cafeteria (yellow arrow) and kitchen (red arrow) from within the multipurpose room. The inset shows a multipurpose room girder supported by a concrete column that is still in place (Tuscaloosa, AL).

room. The girders were supported by concrete columns (Figure 6-18 inset). One remained in place (Figure 6-18) and one blew away or collapsed (Figure 6-19).

The contract drawings indicate that the two multipurpose room girders were to be attached to the concrete columns with two ¾-inch diameter anchor bolts. At the failed girder shown in Figure 6-19, the girder bearing plate consisted of two plates that were welded together. There were two holes that were large enough to accommodate ¾-inch bolts in the bottom plate (Figure 6-19 top left inset). However, there was only one slotted hole in the top plate (Figure 6-19 bottom inset). Because of inadequate hole alignment, it was not possible for the girder plates to be anchored by ¾-inch bolts. Both ends of the girder were similar. Apparently the girder simply rested on top of the concrete column. The contract drawings also show a C-shaped plate that was to be anchored to the concrete column with headed studs. The bottom chord of the girder was to slip between the top and bottom of the C. The girder was not to be attached to the C. The C-shaped plate was not installed at the girder chord shown in the Figure 6-18 inset.

Figure 6-19:
Multipurpose room girder. Lack of alignment of the bolt holes in the top and bottom plates (see insets) prevented installation of the anchor bolts (Tuscaloosa, AL).

Several joist connections were observed. Figure 6-20 shows where a joist was welded to the girder shown by the yellow ovals on the left photograph of Figure 6-20. The right photograph of Figure 6-20 shows where a joist was welded to a bearing plate that was anchored to a bond beam. All of the observed welds were of poor quality.

Figure 6-20: The yellow ovals on the left photograph show weld remnants where a joist was attached to the girder. The red ovals on the right photograph show weld remnants where a joist was attached to a bearing plate at a bond beam (Tuscaloosa, AL).

Several deck welds were observed. Weld quality was variable, even within a few feet along a given joist. The weld in the left photograph of Figure 6-21 was quite strong—the decking tore. In the right photograph of Figure 6-21, however, the weld burnt through the joist flange and therefore this weld provided little attachment. Weld quality variability was also observed by MATs after the 1999 tornado outbreak (FEMA 342) and several hurricanes.[6]

Figure 6-22 shows what remains of the exterior end wall of the multipurpose room. A reinforced CMU bearing wall was present where the rebar extends through the slab. In this area, the rebar extends 5½ to 7 inches out of the slab; hence, it had deficient splice overlap with the rebar in the CMU. The contract drawings specified a 1-foot 10-inch-overlap for vertical splices.

The gymnasium (Figure 6-14) experienced only slight damage. There was some gutter damage, and most of the canopy walkway roof blew away (Figure 6-14). The MAT judged the damage to be due to the location of the gymnasium with respect to the tornado track, rather than building strength.

6 FEMA P-424, Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds, recommends a screw attachment be specified, rather than puddle welds, because screws are more reliable and much less susceptible to workmanship problems (2010a).

Figure 6-21: Red arrow shows a strong weld attaching a piece of decking to the joist (the dark area shown by the yellow arrow is a shadow). The photo on the right shows a weak deck attachment where the weld burnt through the joist (Tuscaloosa, AL).

Figure 6-22: Rebar extending out of the slab at the multipurpose room end wall (Tuscaloosa, AL)

MAT EF Rating: Using DI 16 (Junior or Senior High School),[7] the MAT selected DOD 10 ("most interior walls of top floor collapsed") for the school. Considering the observed workmanship issues, the MAT assessed the wind speed as between the expected and lower-bound wind speeds for DOD 10. 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 basic wind speed of 90 mph the building was designed for.

As shown in Figure 6-12, this building is near the center of the damage swath. The NWS rated the center of the tornado circulation in the vicinity of the school as an EF4, which is above the MAT EF3 rating of the school. Because the school is on the left side of the center of the circulation, the wind speed at the school should be less than the wind speed at the center of circulation.[8]

The MAT judged the wind damage at this school to be due to its subjection to wind speeds substantially above the design wind speed. Poor workmanship issues also contributed to the building damage.

Functional Loss: The school will need to be reconstructed before school can resume at this location. According to the school district's Web site, the students are temporarily housed at a former elementary school for the 2011–2012 school year.

6.1.3 Ringgold High School and Ringgold Middle School (Ringgold, GA)

Location of Facilities in Tornado Path: The Ringgold Middle and High Schools are near one another (Figure 6-23). Both schools were damaged during the April 2011 tornado outbreak. The NWS EF contour ratings (see Section 1.1.3 for additional information) in the vicinity of the schools are shown on Figure 6-23. The area was under tornado watches for most of the day the tornado struck. According to a representative of the school district, students and staff were dismissed early due to the weather forecast. The schools were not occupied when the tornado struck.

> The NWS developed EF rating contours for the Ringgold and Joplin tornadoes. EF contours were not developed by NWS for the Tuscaloosa tornado.

6.1.3.1 Ringgold High School

Facility Description: The high school was constructed in 1973. Eleven classrooms were added in 1977 and nine were added in 1985. A second (auxiliary) gymnasium, administrative offices, and an art center were added in 2008. Figure 6-24 is a view of the high school prior to the tornado.

7 Because this school has two stories, the Junior or Senior High School DI was judged to be more appropriate than the elementary school DI.

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

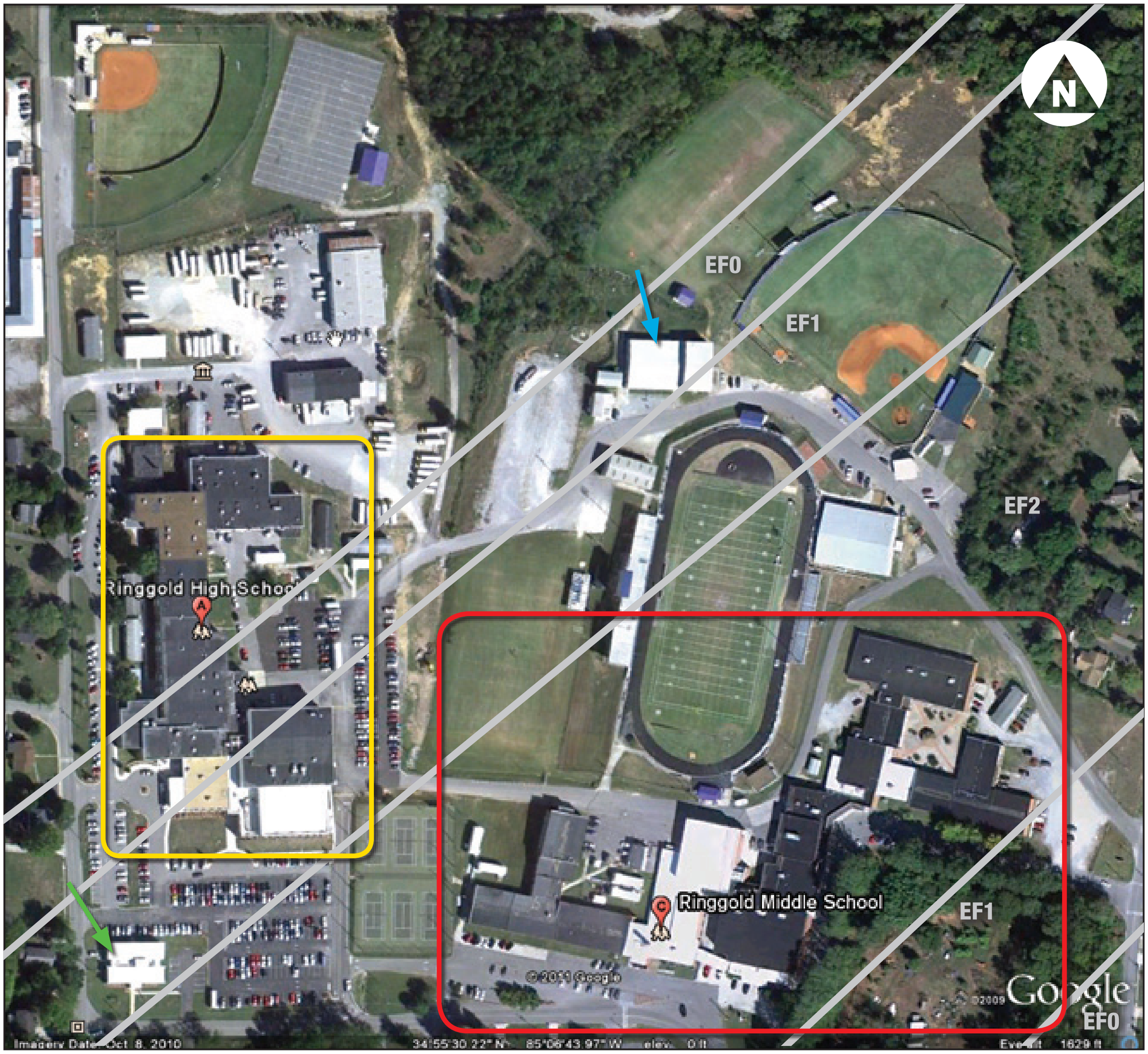
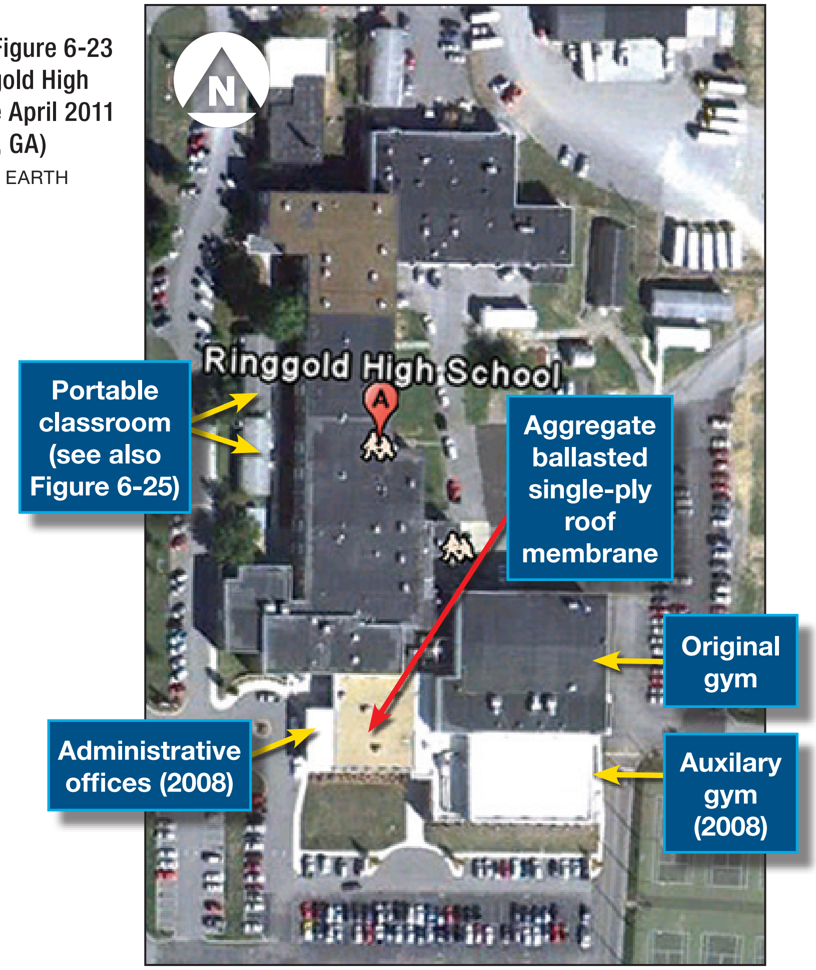


Figure 6-23:[9] View of the Ringgold High School (yellow box) and Ringgold Middle School (red box) prior to the April 2011 tornado. The art center and cheerleading/wrestling facility are shown by the green and blue arrows. NWS EF contour ratings are also shown (Ringgold, GA).

SOURCE: © GOOGLE EARTH

9 NOAA did not take post-tornado aerial photographs of this location, so a pre-storm image is used here for reference.

Figure 6-24:
Close-up view of Figure 6-23 showing the Ringgold High School prior to the April 2011 tornado (Ringgold, GA)
SOURCE: © GOOGLE EARTH



One of the classroom wings has two stories and another has one story. Most of the roof assemblies were fully adhered single-ply roof membrane systems over steel roof decks supported by steel roof trusses; there were also some aggregate ballasted single-ply membranes. The exterior walls of the school are primarily brick veneer over CMU, but some portions are exterior insulation and finishing systems (EIFS) over metal studs over CMU. There were four portable classrooms on the campus. Two classrooms on the west side of the high school were not damaged (Figure 6-25). Although they were not damaged, the MAT observed them to gather data on their condition and potential for becoming sources of wind-borne debris, and to assist in determining the EF rating. The portable classrooms were supported by stacked CMU and anchored down using an embedded anchor and galvanized metal strapping typical of manufactured homes. The MAT noted some of these anchors were in poor condition, some were loose, and one was completely corroded through (Figure 6-25 inset). Due to the condition of the foundation and anchorage straps, it is assumed that wind speeds around the portable classrooms were minimal since no shifting on the foundations appeared to have occurred.

The other two portable classrooms were double-wide units. They were also located on the west side of the high school. One classroom moved off its foundation and had extensive roof and wind-borne debris damage. The other classroom also had extensive roof and wind-borne debris damage. Both of these classrooms were demolished prior to the MAT site visit.

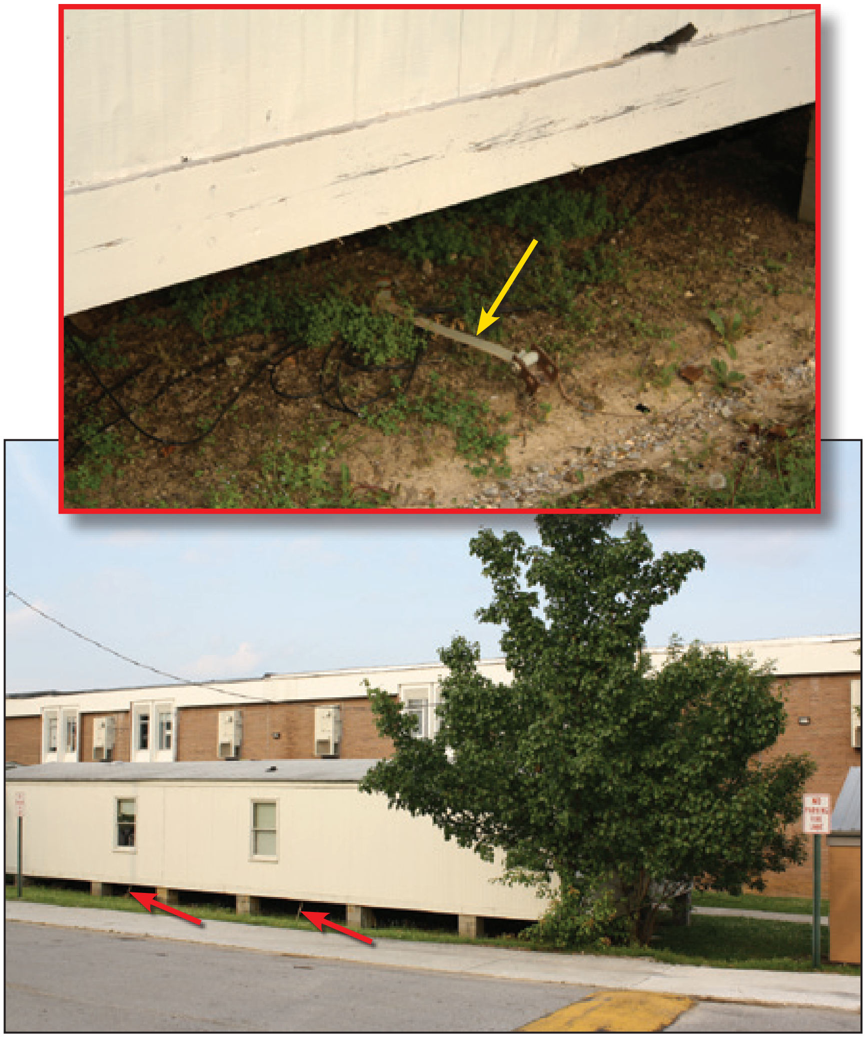


Figure 6-25:
View of one of the portable classrooms. The red arrows indicate anchor straps. The strap shown in the inset had corroded through (yellow arrow) (Ringgold, GA).

The school did not have a tornado safe room or storm shelter. However, as part of the emergency preparedness plan, tornado refuge areas throughout the building were pre-determined in coordination with the fire department, sheriff's office, the local emergency manager, and school system personnel. According to a rehabilitation contractor project manager, the following areas were to be used as tornado refuge areas during severe weather events: lower-level corridors, restrooms, and the band and chorus rooms. The band and chorus rooms did not have exterior windows. Doors along the corridor had glass vision panels. A pair of standard exit doors with glass vision panels and tempered glass lites above led from the corridor to the exterior. The MAT was unable to determine the amount of reinforcement in the CMU walls. It was also unclear what ceiling/floor system separated the refuge areas from the gymnasium above. After the tornado, the refuge areas were found to be free from damage and debris.

General Wind Damage: The tornado struck the south end of the high school (Figure 6-26). The most significant damage was to the gymnasium roofs (Figures 6-27 and 6-28), which resulted in water infiltration that caused damage to the wood floor. The wood gymnasium floor was then demolished (Figure 6-29).

Figure 6-26:
View of the 2008 auxiliary gymnasium (red arrow) and original gymnasium (yellow arrow on right). The yellow arrow on left indicates the location of a ballasted roof system. Most of the windows within the red oval were broken. The black band (included in the red box) is where EIFS blew off. The insets show the classroom wings that are beyond the gymnasium (left inset) and first floor glazing damage (right inset) (Ringgold, GA).

Figure 6-27:
View of the two gymnasium roofs. The red arrow shows the 2008 auxiliary gymnasium (see also Figures 6-26 and 6-28). The EPDM (black) membrane is over the original gymnasium. Note the displaced rooftop equipment. The red box shows a portion of the middle school beyond. The inset shows wind-borne debris damage to the EPDM roof (Ringgold, GA).

The roof of the original gymnasium shown in Figure 6-27 had a fully adhered ethylene propylene diene monomer (EPDM) membrane over wood fiberboard over an aggregate surface built-up roof. The primary failure mode was EPDM lifting and peeling. However, as shown by the inset at Figure 6-27, areas of the membrane were punctured by wind-borne debris. The old built-up roof acted as a secondary membrane and likely prevented little if any water from leaking into the gymnasium. However, rain entered the gymnasium where the rooftop equipment shown in Figure 6-27 was blown off the curb. Gas lines were broken at the displaced rooftop equipment shown in Figure 6-27. Damage to the EIFS was noted (Figure 6-26); in some areas the metal studs blew away, while in other areas the EIFS's gypsum board substrate blew away. There were also several broken windows.

The roof of the 2008 auxiliary gymnasium had a fully adhered single-ply membrane over polyisocyanurate insulation over an acoustical steel deck (Figure 6-28). The primary failure mode was membrane lifting and peeling. As shown in the inset at Figure 6-28, some of the decking lifted.

A lower roof adjacent to the 2008 auxiliary gymnasium (see Figures 6-24 and 6-26 for location) had an aggregate ballasted EPDM roof system (Figure 6-30). The winds were such that most of the aggregate on this roof was not scoured. However, the windows shown in the Figure 6-30 inset were likely broken by the roof aggregate. An adjacent roof had a fully adhered single-ply membrane over polyisocyanurate insulation over steel deck. This roof membrane blew away (oval area at Figure 6-30).

In addition to the above damage, the 2008 art center (shown in Figures 6-23 and 6-31) and the cheerleading/wrestling facility (shown in Figures 6-24 and 6-32) were damaged.

Figure 6-28: View of the roof of the 2008 auxiliary gymnasium (see also red arrow in Figure 6-27); inset shows lifted decking (red circle) (Ringgold, GA)

Figure 6-29:
The loss of the roof covering shown in Figure 6-28 led to water intrusion that damaged the floor below. The damaged floor needed to be removed and replaced (Ringgold, GA).

Figure 6-30:
View of the aggregate ballasted roof. The fully adhered roof membrane blew away; inset below (red box)shows broken windows (Ringgold, GA).

Figure 6-31:
The roof covering was blown off of the 2008 art center. The metal wall covering and insulation was also blown off the CMU. The art center was subsequently demolished (Ringgold, GA).

Figure 6-32:
At the wrestling facility, most of the metal roof panels were blown off, much of the steel framing was damaged, and a portion of the unreinforced CMU wall collapsed. This facility was subsequently demolished (Ringgold, GA).

MAT EF Rating: Using DI 16 (Junior or Senior High School), the MAT selected DOD 6 ("damage to or loss of wall cladding") for the school. Using the expected wind speed for DOD 6, the MAT derived the tornado rating as EF1 (86–110 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.

As shown in Figure 6-23, the NWS derived the rating as EF1 at the southern end of the high school, which correlates with the MAT EF1 rating for this building.

Some of the wind damage at this school was due to damage from wind-borne debris. The MAT judged other building damage to be due to inadequate wind resistance.

Functional Loss: According to a representative of the school district, the high school was repaired in time for the start of the 2011–2012 school year. A replacement cheerleading/wrestling field house was constructed and ready for occupancy in November. A replacement art center will be incorporated into a pending theater project that was in the planning stage prior to the tornado.

6.1.3.2 Ringgold Middle School

Facility Description: The middle school was constructed in 1955. Nine classrooms were added in 1978 and four were added in 1985. A second (auxiliary) gymnasium was added in 2008. Figure 6-33 is a view of the middle school prior to the tornado.

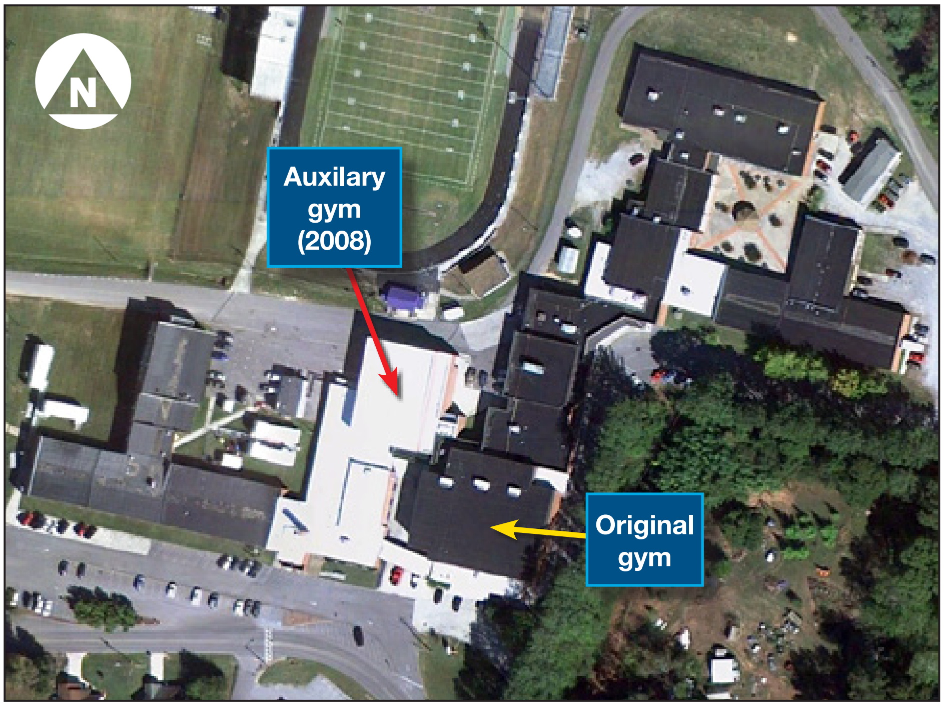


Figure 6-33: View of the Ringgold Middle School prior to the April 2011 tornado (Ringgold, GA)
SOURCE: © GOOGLE EARTH

One of the classroom wings has two stories, but most of the school is one story. Some of the roof decks are poured gypsum, others are cementitious wood-fiber, and the 2008 auxiliary gymnasium has a metal deck. The facility has a structural steel frame. Most of the exterior walls are brick veneer over CMU. Some walls are EIFS over metal studs.

There were six portable classrooms on the campus (one of which was a double-wide unit). The double-wide unit and two of the single-wide units were destroyed. The other three units had extensive roof and wind-borne debris damage. These three classrooms were demolished prior to the MAT's site visit.

The school did not have a tornado safe room or storm shelter. However, as part of the emergency preparedness plan, tornado refuge areas throughout the building were pre-determined in coordination with the fire department, sheriff's office, the local emergency manager, and school system personnel. After the tornado, the refuge areas were found to be free from damage and debris.

General Wind Damage: The damage experienced by the middle school illustrates the common wind vulnerabilities in schools of this era. The roof membrane blew off much of the building. Most of the gypsum roof deck blew off the portion of the classroom wing shown by the blue oval in Figure 6-34. Other damage is shown in Figures 6-35 to 6-38.

Figure 6-34: View of the Ringgold Middle School (the inset shows the left portion of the school). The 2008 auxiliary gymnasium (yellow arrow) and original gymnasium (red arrow) are shown. Most of the roof deck was lost in the area shown by the blue oval. The yellow box indicates an area where walls and glazing were damaged (Ringgold, GA).

Figure 6-35: This wing lost most of its roof decking, and a portion of the brick veneer and unreinforced CMU collapsed (Ringgold, GA)

The cementitious wood-fiber deck panels blew off the original gymnasium along one perimeter, resulting in standing water on the gymnasium floor (Figure 6-37). Cementitious wood-fiber panels also blew off over some of the classrooms and overhang shown in Figure 6-38. Figure 6-38 also shows a wall that blew in (the damaged wall is shown in the blue oval of Figure 6-34). The wall was EIFS over metal studs. The stud track was attached to a concrete sill with powder-driven fasteners spaced at 23½ inches and 26½ inches. The fasteners only had about ⅜ inch of embedment. The two windows adjacent to the wall opening and the window at the right of Figure 6-38 were broken, as were several other windows at this wing.

MAT EF Rating: Using DI 16 (Junior or Senior High School), the MAT selected DOD 6 ("damage to or loss of wall cladding") for the school. Considering the building age and observed damage, the MAT assessed the wind speed as between the expected and lower-bound wind speeds 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 6-23, the NWS derived the rating as EF2 at the middle school, which is different from the MAT EF1 rating for this school.

Figure 6-36: View from within a classroom. The yellow arrow shows the area of the collapsed wall that is shown in Figure 6-35. In this area, the deck bulb-tees also blew off. The inset shows an area of this wing where some form-board (yellow arrow), a bulb-tee (blue arrow), and the gypsum deck (red arrow) were still in place (Ringgold, GA).

Figure 6-37: Deck panels blew off the original gymnasium. The inset shows the resulting standing water on the wood floor (Ringgold, GA).

INSET PHOTOGRAPH COURTESY OF CATOOSA COUNTY PUBLIC SCHOOLS

Figure 6-38: EIFS wall failure, glazing damage, and roof deck blow-off (Ringgold, GA)

Some of the wind damage at this school was due to damage from wind-borne debris. The MAT judged other building damage to be due to inadequate wind resistance, which is reflective of the codes, standards, and design practices in the era when the majority of this school was constructed.

Functional Loss: According to a representative of the school district, the sixth and seventh grade students were able to return to their classrooms at the start of the 2011–2012 school year. However, the eighth grade students temporarily attended the high school while repairs were made to their classrooms. Two single-wide and one double-wide portable classrooms were brought to the site for the chorus and band.

6.1.4 Joplin East Middle School (Joplin, MO)

Location of Facility in Tornado Path: The location of the Joplin East Middle School is shown in Figure 6-2. Figure 6-39 shows an aerial view of the tornado track in the vicinity of the school as well as the NWS EF contour ratings in the vicinity of the school. The school was not occupied when the tornado struck (the tornado occurred on Sunday evening).

Facility Description: The Joplin East Middle School opened in 2009. The one-story school is over 130,000 square feet, with approximately 45 classrooms, an auditorium, four computer labs, a library, and a gymnasium (Figure 6-40). The auditorium and gymnasium had a single-ply roof membrane over polyisocyanurate insulation over steel roof deck supported by a steel roof structure. The auditorium and classroom wing (primarily one story) had brick veneer over reinforced CMU bearing walls. The gymnasium had brick veneer over insulation installed over precast concrete walls.

The middle school had a Tornado Evacuation Plan with six interior rooms designated as areas of “Tornado Safe Shelter” (Figure 6-41). Although these designated areas may have been the planned tornado refuge areas, they did not possess the wind pressure and wind-borne debris resistance specified in FEMA 361 (2008a) or ICC 500 (2008). Hence, they were not safe rooms or storm shelters (refer to Chapter 9 for additional discussion of safe rooms capable of providing life-safety protection for occupants).

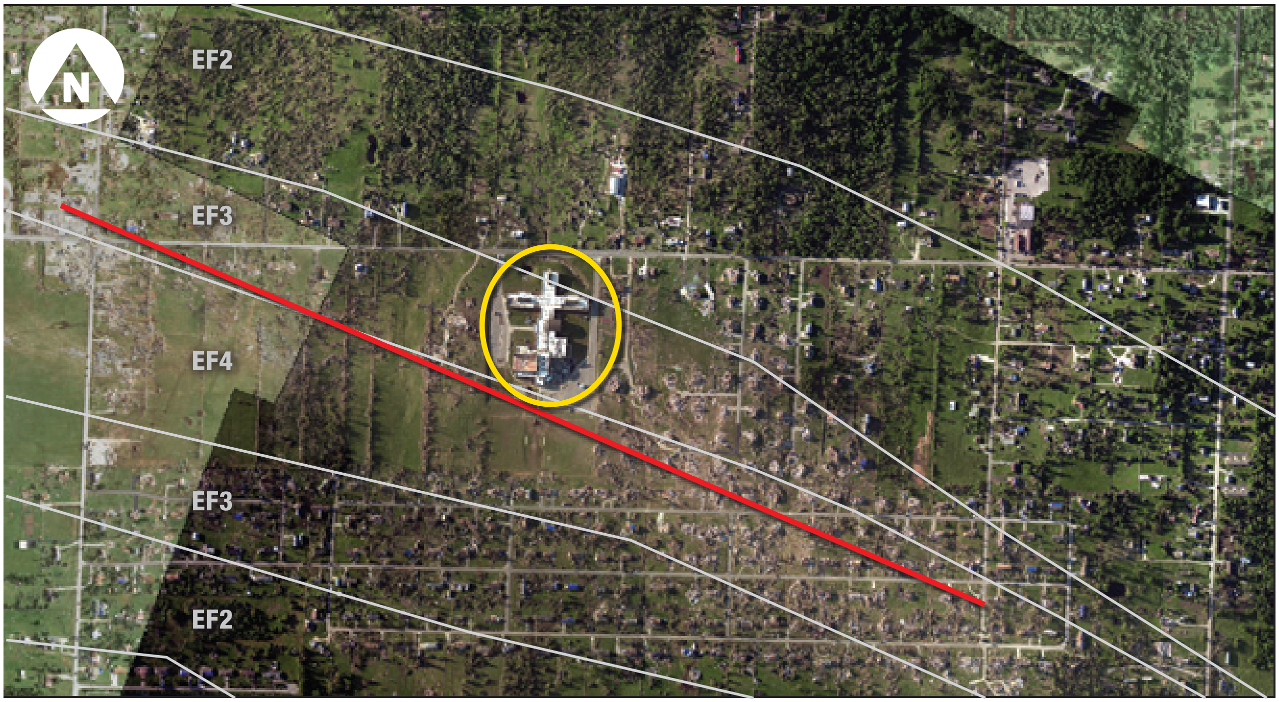


Figure 6-39: Aerial view of the tornado track in the vicinity of the Joplin East Middle School (yellow circle). The center of the damage swath is approximated by the red line. NWS EF contour ratings are also shown (Joplin, MO).

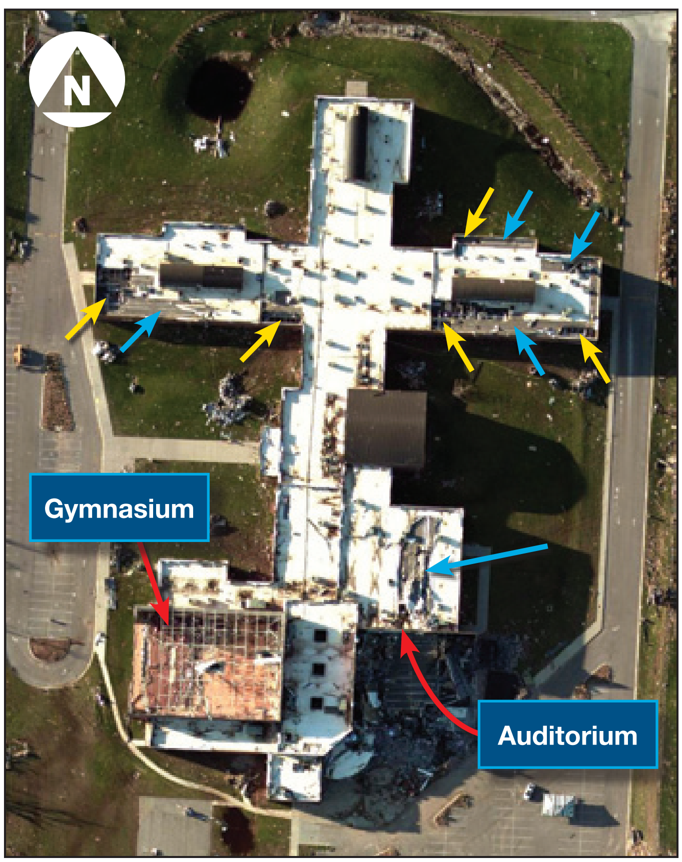


Figure 6-40: Close-up of Figure 6-39. Major areas of blow-off of the roof membrane and roof deck are shown by the blue and yellow arrows (Joplin, MO).

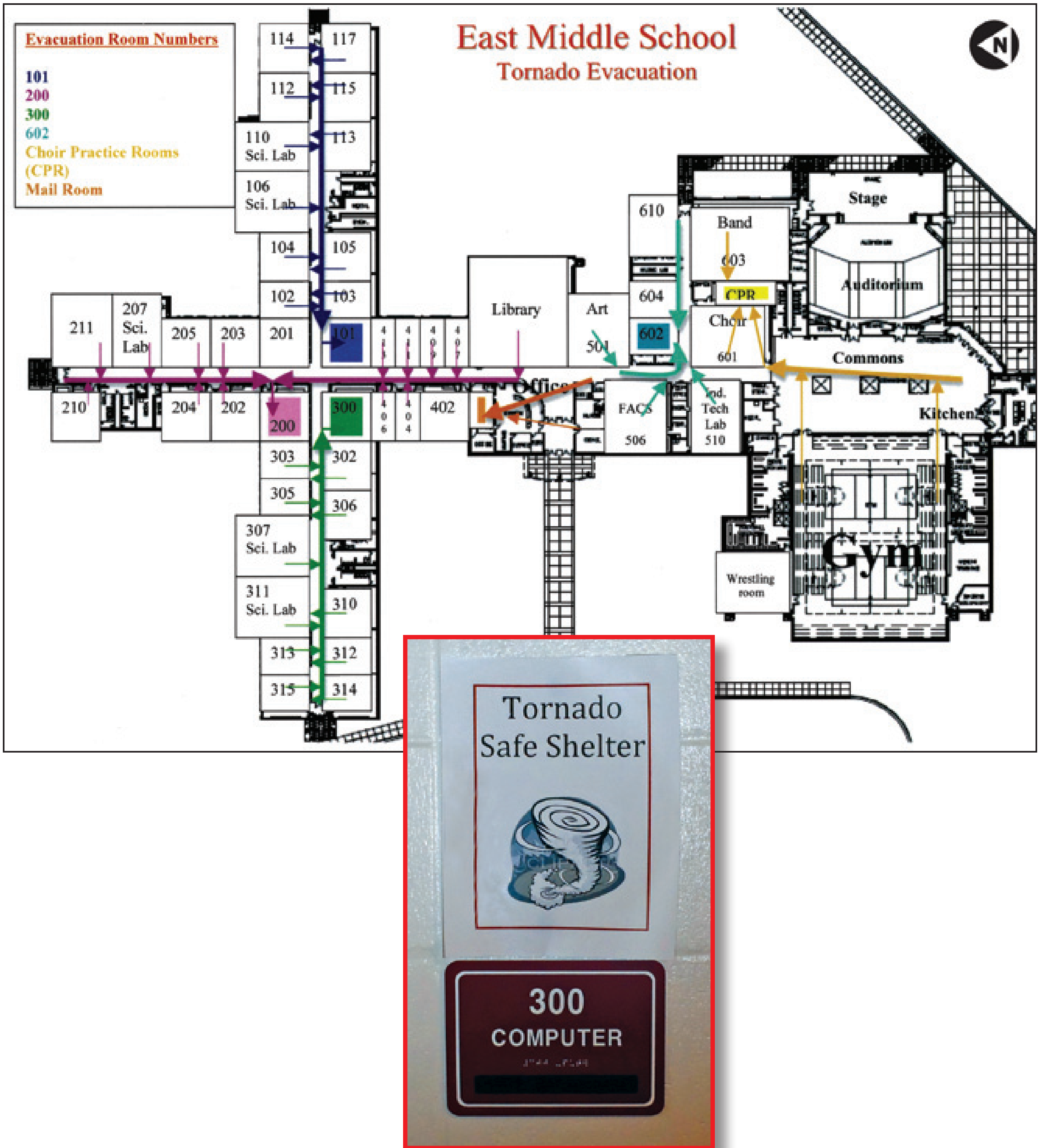


Figure 6-41: Interior rooms designated as "shelters" in the middle school's Tornado Evacuation Plan. The inset shows the "shelter" signage (Joplin, MO).

General Wind Damage: Figure 6-40 shows an aerial view of the damage at the middle school. The most severe damage occurred on the southern end of the school, where the auditorium and gymnasium were located, while the northern end suffered less damage. The auditorium roof and the two exterior walls collapsed (Figure 6-42). At the gymnasium, two roof trusses and an exterior wall collapsed inward upon loss of lateral bracing (Figures 6-43 to 6-46).

Figure 6-42:
View of the collapsed auditorium roof and both exterior walls (Joplin, MO)

Figure 6-43:
View of the gymnasium. The red box in the inset shows where the truss was attached to the wall. The yellow circle indicates the end of the collapsed truss shown in Figure 6-45 (Joplin, MO).

Figure 6-44:
View of the end of the collapsed truss (yellow circle) shown in Figure 6-43 (Joplin, MO)

Figure 6-45:
Roof truss and wall debris on the gymnasium floor (Joplin, MO)

Figure 6-46:
Brick veneer/insulation/ precast concrete wall on the gymnasium floor (Joplin, MO)

The remainder of the middle school received damage from wind-borne debris, including glazing damage, as well as water damage due to damaged roof covering, decking, and rooftop equipment (Figures 6-40 and 6-47). The rain intrusion caused damage to the HVAC equipment, ceiling boards, floor coverings, and furnishings.

Figure 6-47:
View of rain infiltration damage in a school corridor (Joplin, MO)

MAT EF Rating: Using DI 16 (Junior or Senior High School), the MAT selected DOD 7 ("collapse of tall masonry walls at gym, cafeteria, or auditorium") for the middle school. Considering the building age and observed damage, the MAT assessed the wind speed as between the expected and upper-bound wind speeds for DOD 7. Hence, the MAT derived the tornado rating as EF2 (111–135 mph) based on damage to this building.[10] Therefore, the estimated wind speed experienced by the building was above the basic wind speed of 90 mph the building was designed for.

As shown in Figure 6-39, the NWS derived the rating as EF3 at the middle school, which is different from the MAT EF2 rating for this school.

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

Functional Loss: According to the repair contractor that was on-site during the MAT's visit, power was restored within 10 days to most of the northern/classroom portion of the building and crews began repairs in an effort to have the facility functional by the start of the 2011–2012 school year. However, repairs were not completed in time due to the extensive damage. According to the school district's Web site, an industrial park warehouse was converted into a temporary school for the start of the 2011–2012 school year.

6.1.5 Joplin High School (Joplin, MO)

Location of Facility in Tornado Path: The location of the Joplin High School is shown in Figure 6-2. Figure 6-48 shows an aerial view of the tornado track in the vicinity of the school, as well as the NWS EF contour ratings in the vicinity of the school. The school was not occupied when the tornado struck since the tornado occurred on Sunday evening.

Facility Description: Joplin High School opened in 1968 and extensively renovated in 2003, including the addition of the library/media center. The school had one- and two-story classroom wings, two gymnasiums, a performance auditorium, cafeteria, library/media center, and a 1,300-square-foot television station (Figure 6-49). The north classroom wing contained a basement classroom section whose corridor was relatively undamaged during the tornado.

The high school had several construction systems:

- The north classroom wing had a built-up membrane roof system over lightweight insulating concrete over metal decking. The exterior wall consisted of brick veneer over unreinforced masonry infill walls. The exterior masonry extended approximately 4 feet above the floor. There was EIFS over metal studs between the masonry and floor or roof above.
- An addition to the north classroom wing had a membrane roof system over steel roof deck supported by steel joists. Exterior walls were brick veneer over reinforced CMU.

10 A team deployed by ASCE observed both the Joplin Middle School and High School (Prevatt et al. 2011a). This team performed a failure analysis by calculating estimated loads and resistance to determine EF ratings. The MAT's approach used the DI/DOD EF rating system. It should be understood that both methodologies involve some uncertainties, and therefore ratings of wind speed can vary.

Figure 6-48: Aerial view of the track in the vicinity of the Joplin High School (yellow circle). The center of the damage swath is approximated by the red line. NWS EF contour ratings are also shown (Joplin, MO).

- The library/media center had a membrane roof system over steel deck supported by pre-engineered bowstring trusses supported by steel columns. End walls were CMU bearing walls.
- The one-story classroom wing along the west side of the courtyard had a membrane roof system over steel deck supported by steel joists. The exterior walls were brick veneer over reinforced CMU bearing walls. The primary gymnasium had a built-up roof system over steel deck over steel joists supported by girders spanning east to west. The girders were supported on steel columns that were supported on concrete pilasters. The roof at the west wall was supported by steel columns at approximately 15 feet on center. There was brick veneer over unreinforced CMU between the columns.
- The second gymnasium had a membrane roof system over steel deck over steel joists that spanned between joist girders. The exterior load-bearing walls were brick veneer over reinforced CMU.
- The auditorium had a membrane roof system over steel deck over steel joists supported by a structural steel frame system. Infill walls were brick veneer over unreinforced CMU.

The high school did not have a tornado safe room or storm shelter. The lower level corridors on the northwest wing were the designated tornado refuge areas (Figure 6-50). The tornado blew some debris such as insulation and other building materials into the corridor, but the overall condition of this area of the building was relatively undamaged.

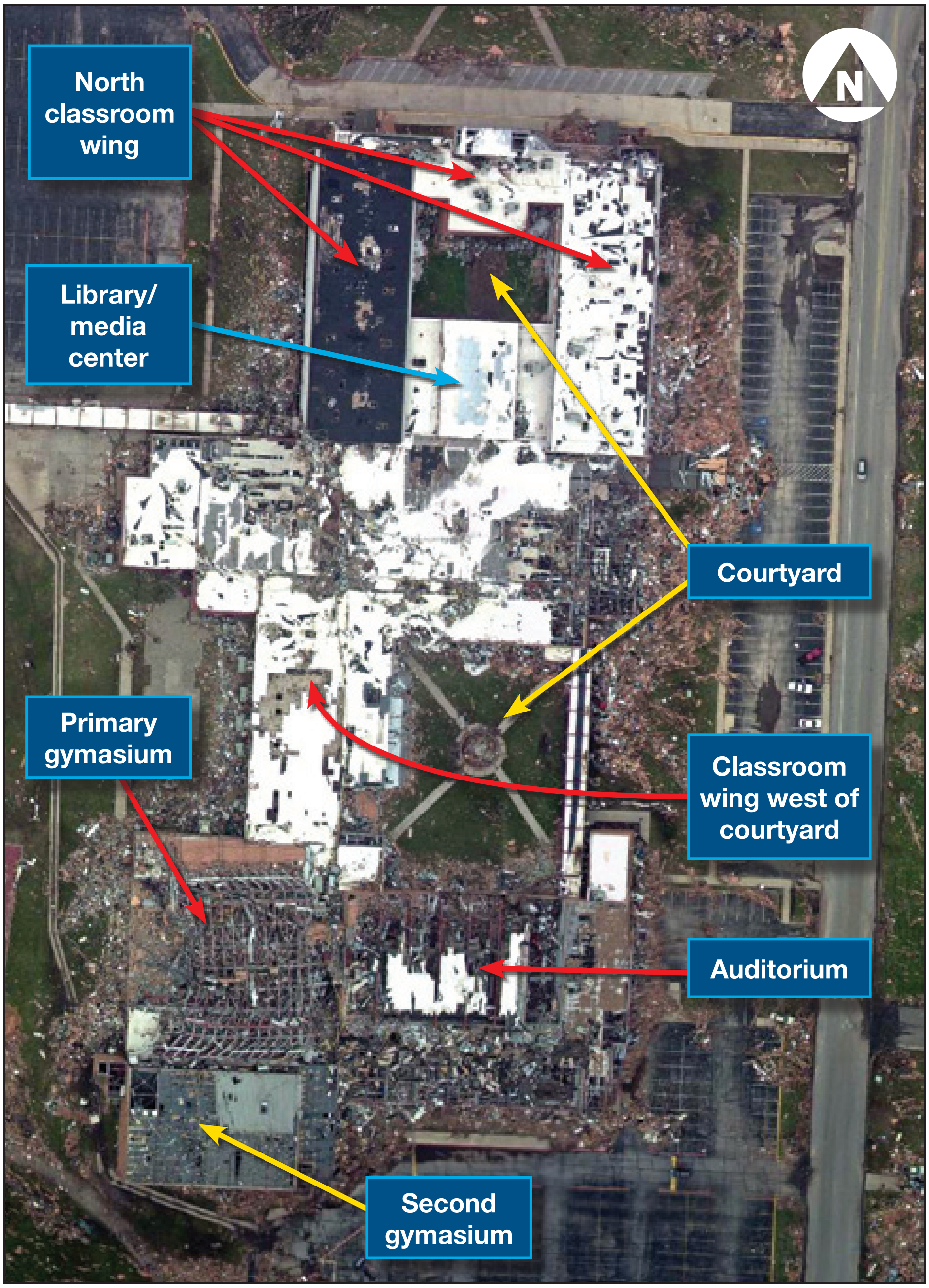


Figure 6-49: Close-up of Joplin High School shown on Figure 6-48 (Joplin, MO)

Figure 6-50:
View of a corridor designated as tornado refuge area. The debris was blown into the corridor during the tornado (Joplin, MO).

General Wind Damage. As shown in Figure 6-49, the primary gymnasium collapsed and portions of the auditorium collapsed. The long roof spans and unreinforced masonry infill walls contributed to the collapses at these areas. In other parts of the building, the exterior wall collapsed, the roof covering was damaged, and some glazing was damaged as described below.

North classroom wing: Extensive exterior wall damage occurred at this wing (Figure 6-51). In most locations the connection of the stud tracks to the CMU and floor or roof slab failed. In some instances the unreinforced masonry wall also failed. The roof system was damaged but most of the roof deck remained in place.

The exterior reinforced masonry wall and roof structure at the second floor corridor at the north end of this wing collapsed (Figure 6-52). The wall and roof assembly debris fell into the corridor (Figure 11-2). This portion of the building appeared to be an addition.

Library/media center: A portion of the roof covering was destroyed, which resulted in interior water damage. Some exterior glazing was also broken.

Classroom wing along the west side of courtyard: The east masonry wall collapsed into the courtyard (Figure 6-53). The CMU was connected with rebar dowels into the footing; at the top of the wall the CMU was connected to a ledger angle that was welded to the roof deck. There was an approximately 2-foot-tall parapet above the ledger angle. The majority of the angle stayed connected to the CMU, with the welded connections between the deck and angle failing. The angle was installed with expansion bolts into ungrouted cells. There was no connection between the exterior walls and the interior classroom transverse walls. This discontinuity in the load path contributed to the collapse of the exterior wall.

Figure 6-51:
North classroom wing. The inset shows a close-up of the opposite side of the wing (Joplin, MO).

Figure 6-52:
Collapse of the exterior brick veneer/reinforced CMU wall and roof assembly into the corridor at the north end of the north classroom wing (Joplin, MO)

Figure 6-53: Collapsed brick veneer/ reinforced CMU. The red arrow indicates where the ledger angle is still connected to the CMU. The yellow arrow indicates where the angle's expansion bolts pulled out of the CMU (Joplin, MO).

<u>Primary gymnasium</u>: The gymnasium shown in Figure 6-54 collapsed. The west wall was approximately 37 feet tall—it fell into the gymnasium. The connection between the pilasters and columns that supported the roof girders failed. The columns were connected with two 1½-inch diameter bolts, each 3 feet long, as shown in the inset at Figure 6-54. Most of the steel roof deck blew off. Only a small portion of it remained within the gymnasium space. Collapse of the brick veneer/ unreinforced CMU end wall and blow-off of the roof decking caused the failure. Once the integrity of the load path was disrupted, there was a progressive failure.

The second gymnasium, to the south of the primary gymnasium, had most of its metal roof panels blown off (Figure 6-55). The gymnasium had a wood floor.

<u>Auditorium</u>: The steel roof deck and several of the steel joists blew off (Figure 6-56). Portions of the 25-foot-tall brick veneer/unreinforced CMU wall collapsed (Figures 6-56 and 6-57).

Figure 6-54:
View of the collapsed gymnasium. The inset shows the base plate (red arrow) and an anchor bolt (yellow arrow) that connected the girder support column to the pilaster (Joplin, MO).

Figure 6-55:
Interior view of the second gymnasium (Joplin, MO)

Figure 6-56:
North wall of the auditorium (Joplin, MO)

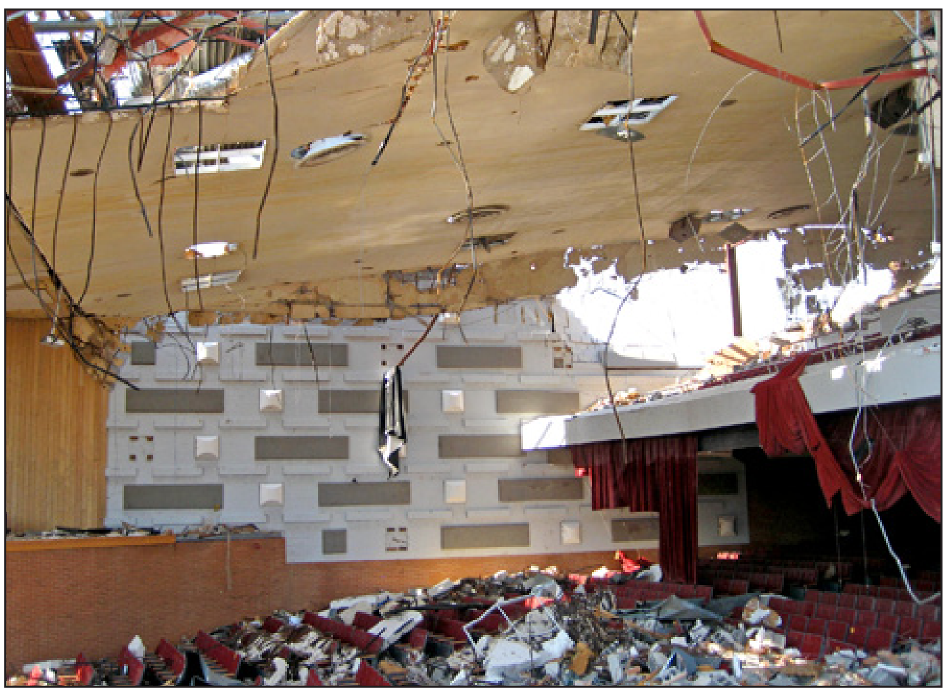


Figure 6-57:
South wall of the auditorium, showing collapse of the masonry infill wall (Joplin, MO)

MAT EF Rating: Using DI 16 (Junior or Senior High School), the MAT selected DOD 11 ("complete destruction of all or a large section of building) for the high school. Considering the building age and the observed damage, the MAT assessed the wind speed to be the lower-bound wind speed for DOD 11.[11] Hence, the MAT derived the tornado rating as EF3 (136–165 mph) based on damage to this building.[12] Therefore, the estimated wind speed experienced by the high school was substantially above the basic wind speed of 90 mph.

As shown in Figure 6-48, NWS derived the rating as EF4 at the southern end of the high school, which is different from the MAT EF3 rating for this school.

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

Functional Loss: According to a representative of the school district, school resumed in August 2011 in a temporary facility. The existing high school will be demolished and replaced with a new building.

6.2 Operational Issues

On March 1, 2007 at 1:12 p.m., a tornado struck a school in Enterprise, AL, resulting in the deaths of eight students (FEMA 2008a). During the tornado, students had sought refuge in hallways, away from windows, an area that is commonly used as a tornado refuge area in schools. In this case, the refuge area sought out by students and teachers in the Enterprise, AL, school was vulnerable to collapse. Following this tornado event and the school tragedy, the NWS published the results of their post-tornado investigation, in which it was determined that school officials in Enterprise had made appropriate safety decisions based on the information available. The report notes that due to multiple severe weather warnings throughout that day, there was no safe period of time in which they could have enacted an early dismissal. In their recommendations, the NWS stated that the benefits of using hardened safe rooms should be promoted, especially in non-residential buildings where many people gather, such as schools (NOAA 2007b).

In the violent tornadoes of April and May 2011, several schools were directly impacted. Fortunately, none of the schools were occupied at the time the tornadoes struck. The 2007 incident in Enterprise, AL, and the several near misses in the spring of 2011 brought to the forefront the importance of identifying a decision-making process for school administrators in the event of a tornado warning. To better understand current school decision-making processes in tornado-prone regions, members of the MAT held interviews with 10 school districts (Table 6-2) that were impacted in spring of 2011.

11 DOD 11 is for complete destruction of all or a large section of building. As shown on Figure 6-49, much of the southern end of the school collapsed. The collapsed areas were the primary gymnasium and auditorium. DOD 7 is "collapse of tall masonry walls at gym, cafeteria, or auditorium." However, in the judgment of the MAT, DOD 11 was appropriate based on proximity of and damage to these two areas.

12 A team deployed by ASCE observed both the Joplin Middle School and High School (Prevatt et al. 2011a). This team performed a failure analysis by calculating estimated loads and resistance to determine EF ratings. The MAT used the DI/DOD EF rating system. It should be understood that both methodologies involve some uncertainties, and therefore ratings of wind speed can vary.

Table 6-2: List of School Districts Interviewed by the MAT

Location	Number of Students
Alabama	
Decatur City	8450
Huntsville City	23,000
Walker County	8,000
Tuscaloosa County	18,000
Marion County	3,524
Cullman City	3,017
Limestone County	9,018
Georgia	
Catoosa County	11,009
Mississippi	
Monroe County	2,300
Missouri	
Joplin	7,911

The MAT asked representatives from each school district a series of questions related to school operational decisions during severe weather. These questions, grouped into three categories, were:

- Severe Weather Policy
  - What is the official severe weather policy in your school district?
  - Does the policy vary for different types of severe weather?
  - Who makes the final decision and how long is the process?
  - Is the decision based on hazardous weather probability and does it include input from local NWS or TV personnel or others?
  - Are there other factors that influence the decision?
- Severe Weather Communication and Decision Making
  - Is it the preference of the district to dismiss students early or keep them at school?
    - Does that depend on the type of severe weather?
  - Approximately how many students are in after-school programs?
- Are there areas of refuge designated in each school?
  - Where are these areas?

The interviews conducted by the MAT revealed that school district response plans for severe weather ranged from taking refuge within the school, early dismissal/delayed start, and closing the school.

Among the school districts interviewed, it was noted that regardless of the type of severe weather, the safe transportation of students was a common factor in decision making. Depending on the size of the district and the area covered, buses may require 45 minutes to 2 hours to complete their routes. Therefore, most of the districts interviewed stated that they prefer to dismiss school early if severe thunderstorm and tornado events are expected to occur near the end of the school day, and delay the start of school if such events are expected to occur in the morning.

6.2.1 Severe Weather Policy

The fundamental decision faced by school district personnel on days when tornadoes are forecasted is whether to dismiss students or have them take refuge at school. The following discussion presents some of the challenges that schools face and a summary of the findings for the 10 school districts interviewed by the MAT.

The school districts indicated that taking shelter within the school is the preferred option for schools that have a FEMA 361-compliant safe room or an ICC 500-compliant storm shelter. Of the 10 districts interviewed, only two stated they had safe rooms compliant or nearly compliant with FEMA 361(2008a) and a third district is in the process of applying for school safe rooms. During field assessments, the MAT found safe rooms at two of the 12 schools in one district and two of the 18 schools in the other.

The school districts stated that ***schools without a compliant safe room or storm shelter*** must follow the district's severe weather policy regarding whether to keep students in the school or dismiss them. The following is a summary of the actions taken in the school districts interviewed:

- ***Early dismissal:*** Seven of the 10 districts interviewed by the MAT stated that their policy is to dismiss students early, if possible. Based on the interviews, early dismissal is scheduled to provide ample time for busses to transport students to their residences in advance of impending severe weather. This approach disperses students over a wide area and decreases liability for school districts. Although the probability of a point location such as a school being directly hit by a tornado is lower than the probability of numerous homes being struck in an area, there was a general perception on the part of the school districts that the chances of a large number of student fatalities is lower when students are in their own residences versus gathered in one location at school.

- ***Sheltering in schools:*** When dismissing students early is not possible due to rapidly changing weather conditions, students and staff must take cover in portions of buildings that were not designed to withstand tornadoes. The school districts indicated that parents are permitted to pick up their children at their discretion in these situations. Students remaining in the schools are directed to take refuge in an area identified by the school.

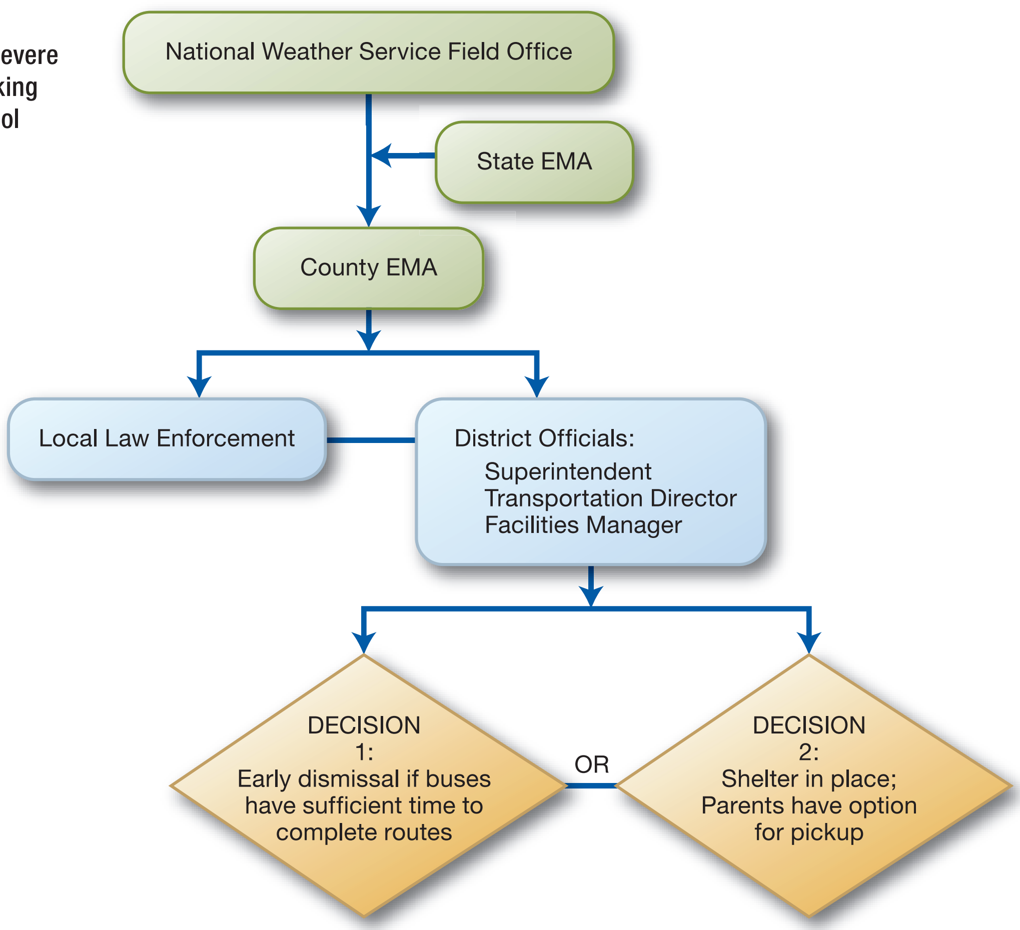
> FEMA Recovery Advisory 6, *Critical Facilities Located in Tornado-Prone Regions: Recommendations for Architects and Engineers* (Appendix F) provides guidance on identifying best available refuge areas.

The school districts that were interviewed stated that they are reviewing their severe weather policies to decide what is best for their given situation. For example, in the Catoosa County, GA, school district (Ringgold, GA), students who reside in manufactured homes or poorly constructed homes are encouraged to stay at school, while others are either picked up by their parents or dismissed early. Another consideration cited by school districts is whether there might be more student fatalities when students are sent home than kept at school, as children who are sent home early may have to make severe weather safety decisions on their own if their parents are not at home.

6.2.2 Severe Weather Communication and Decision Making

Alabama School Districts: The communication process used by the Alabama school districts was very consistent among those the MAT interviewed (Figure 6-58). The NWS field offices in Huntsville and Birmingham coordinate webinars and webcasts that are broadcast to State and County EMA personnel. The County EMA personnel then communicate directly with school superintendents, school transportation and facilities managers, or school severe weather decision teams. In smaller districts, the superintendent often makes cancellation decisions directly, while in larger districts, severe weather teams or facility managers make the decision. Sometimes district officials attend webinar sessions with County EMA personnel, while in other cases, County EMA personnel report to district officials who do not attend the webinar. In both cases, the line of communication starts with the NWS, and the urgency of the situation as it pertains to school closing is then relayed by State and County EMA, though these agencies do not directly make decisions regarding school cancellations. No specific severe weather thresholds or criteria exist for school cancellation; however, the districts report considerable pressure to monitor the proceedings of neighboring districts.

Figure 6-58: Flowchart depicting severe weather decision making process used by school districts in Alabama



Joplin School District: The Joplin, MO, district uses a severe weather team (SWT) of four individuals, each responsible for a school zone of several facilities (Figure 6-59). Each SWT member contacts five to six facilities to tell them to take refuge, with an estimated total phone time of 10 minutes. Refuge is sought if winds are forecasted to exceed 75 mph or if the facility is under a tornado warning. The individual schools monitor weather Web sites and a NOAA weather radio on severe weather days, and they work in conjunction with the district's SWT. The principal of a school can decide to direct the students and faculty to designated areas within the school before getting a call from the SWT. After the storm has passed, SWT members call facilities to provide the all-clear.

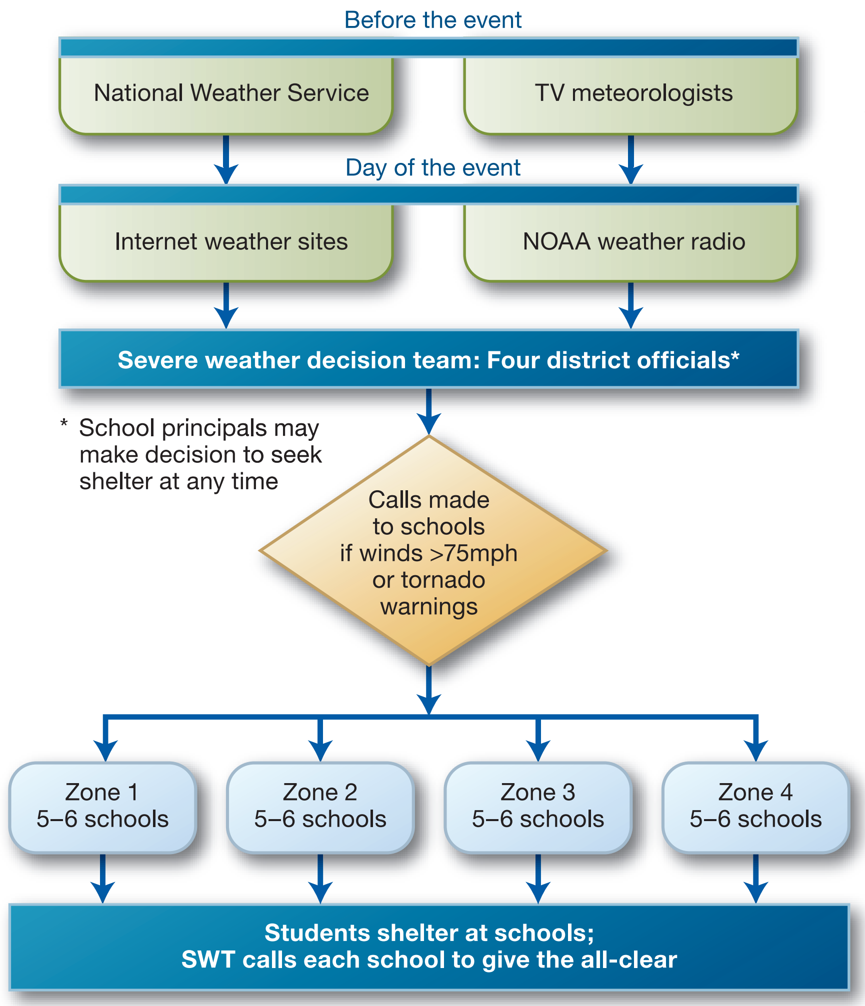


Figure 6-59: Flowchart depicting severe weather decision making process used by the Joplin, MO, School District

6.2.3 Changes for the Future

Out of the 10 districts interviewed, seven are satisfied with their tornado safety plans and do not intend to change them as a result of the events of spring 2011. Of these seven districts, one plans to increase communication with neighboring districts on days when tornadoes are forecasted. Another district is conducting more frequent drills, increasing focus on communication, and evaluating refuge areas.

In one Alabama district, the 2011 tornadoes resulted in discussions with law enforcement and utilities about severe weather information dissemination during and after the event. In this Alabama district, power was knocked out by severe weather on the morning of the April 27th, which disrupted normal avenues of communication. After the tornado, law enforcement and utilities personnel communicated with the schools. Thus, although the district may deem their policy satisfactory for actions to take before a tornado, they may need to adopt contingency plans for operating after a tornado.

The remaining three districts—Tuscaloosa County, AL; Monroe County, MS; and Joplin, MO— are planning to make changes in the future. According to a representative from Tuscaloosa County, the county is seeking hazard mitigation assistance for eight FEMA 361-compliant school safe rooms to be incorporated into existing and future building plans, which represents 25 percent of the schools in the district. In Smithville, MS (Monroe County School District), there are plans to construct a dual-purpose gymnasium and FEMA 361-compliant safe room that can be used by the entire district. In Joplin, MO, FEMA 361-compliant safe rooms were constructed at temporary locations for the schools that were destroyed by the tornado. At other schools in Joplin, schools have cleared basements to use as tornado refuge areas; however, not all students can fit into the basement areas. The schools plan to house students in interior rooms during tornado events as a last resort.

6.2.4 Summary

The MAT noted the following based on its interviews with school districts located in the impacted areas:

- School officials give considerable thought to closure decisions and the safety of students. This high level of attention results from: 1) the school district's responsibility for protecting students and staff, and 2) the school district's interest in having a strategy that minimizes liability.
- In the districts interviewed, there were no uniform severe weather thresholds or criteria for making school cancellation decisions.
- In the districts interviewed, there were no existing criteria in use for evaluating areas of the schools used for refuge during tornadoes.

6.3 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.