1 Introduction

1.1 Purpose

The number of tornadoes that occurred on May 3, 1999, in Oklahoma and Kansas, their severity, and the level of devastation they caused have not been seen in a generation within the United States. One of the missions of the Federal Emergency Management Agency (FEMA) that directly supports the *National Mitigation Strategy* is:

> *to significantly reduce the risk of loss of life, injuries, economic costs and destruction of natural and cultural resources that result from natural hazards.*

In response to the disasters caused by the May 3 tornadoes, FEMA deployed a Building Performance Assessment Team (BPAT), composed of national experts to Oklahoma and Kansas. The mission of the BPAT was to assess the performance of buildings affected by the tornadoes, investigate losses, and describe the lessons learned. This report presents the BPAT's observations, conclusions, and recommendations, which are intended to help communities, businesses, and individuals reduce future injuries and the loss of life and property resulting from tornadoes and other high-wind events.

1.2 Team Composition

The BPAT included FEMA Headquarters and Regional Office engineers and staff; a meteorologist; planners; architects; wind engineers; structural engineers; and forensic engineers. The members of the BPAT are listed in Appendix A.

1.3 Methodology

The FEMA Mitigation Directorate deployed the BPAT to Oklahoma and Kansas on May 10, 1999. The team inspected both residential and non-residential buildings, as discussed below. By assessing the performance of these buildings, the team was able to develop technical guidance concerning new construction and post-tornado reconstruction for state and local governments, building owners, architects, engineers, and contractors.

In addition to assessing building performance, the BPAT:

- inspected designated shelter areas in public buildings (e.g., schools, churches, day care centers, nursing homes),
- investigated successes and failures of existing shelters used during the tornadoes, and
- evaluated existing tornado response plans within buildings intended for high occupancy, such as schools and private industry facilities.

Field investigations began on May 10 and were conducted through May 18. In Oklahoma, inspections were made in Bridge Creek (about 50 miles southwest of Oklahoma City); the Oklahoma City Metroplex, including the suburbs of Moore, Del City, and Midwest City; the Project Impact community of Tulsa; and Stroud and Mulhall. In Kansas, inspections were made in unincorporated Sedgwick County, the City of Haysville, and Wichita.

BPATs frequently conduct aerial assessments of damaged areas to gather general data on damage sites, acquire aerial photographs of those sites, and determine the focus and final composition of the BPAT. For the May 3 tornado disasters, adequate information was provided to the team by the FEMA Disaster Field Offices (DFOs) and by state and local government agencies. Therefore, the BPAT did not conduct an aerial assessment of the damage areas.

The BPAT inspected the following types of residential buildings:

- single- and multi-family, one- to two-story residences
- manufactured and modular homes
- accessory structures

Many of the houses inspected in Kansas were constructed on basement or crawl space foundations; most of the houses inspected in Oklahoma were constructed on slab-on-grade foundations. From its observations, the BPAT formed conclusions concerning the structural performance of residential buildings exposed to the May 3 tornadoes. The BPAT also formed conclusions regarding exterior architectural systems, such as roof coverings, brick veneer and other siding materials, windows, garage doors, and masonry chimneys.

The non-residential building types observed included the following:

- tilt-up pre-cast concrete walls with steel joists
- load-bearing masonry walls with steel joists
- load-bearing masonry with pre-cast concrete hollow-core floor and roof slabs
- pre-engineered metal buildings (light steel frames)
- buildings constructed of laminated wood arches with wood framing
- buildings with masonry veneer and pre-cast concrete floors

- industrial plants
- a regional shopping outlet mall
- public use buildings, which included a hospital, a nursing home, day care centers, hotels, and schools

Other important issues such as windborne debris (missiles), personal protection, and sheltering were investigated and are discussed in individual sections of this report.

FEMA encouraged the participation of state and county government officials and locally based experts in the assessment process. Their involvement was critical and:

- ensured that state and local building code and other requirements were properly interpreted,
- increased the likelihood that local construction practices were fully appreciated and understood,
- established positive relationships among Federal, state, and local governments and the private sector, and
- encouraged development of recommendations that were both economically and technically realistic.

Under this premise, the BPAT met with local government officials upon arriving in Oklahoma and Kansas to partner in the overview and identification of damage areas (Figures 1-1 and 1-2). Team members were briefed by staff members of the FEMA regional DFOs and representatives of state, county, and local government agencies on the extent and types of damage. GIS maps were provided and reviewed to select field investigation sites and establish an itinerary.

FIGURE 1-1: BPAT meeting with State of Kansas and local government officials in Wichita, Kansas.

FIGURE 1-2: Meeting with local fire official in Midwest City, Oklahoma.

Collectively, the team spent over 1,500 hours in the field conducting site investigations and inspecting damage. Documentation of observations made during the site visits consisted of field notes and photographs. The BPAT's mission did not include recording the numbers of buildings damaged by the tornadoes, determining the frequency of specific types of damage, or collecting data that could serve as the basis of statistical analysis.

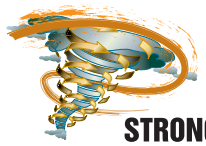
1.4 Presentation Of Findings

The observations, conclusions, and recommendations in this report are grouped to address issues concerning (1) residential property protection, (2) non-residential property protection, and (3) personal protection and sheltering.

Table 1-1 correlates the BPAT's findings with the Fujita damage scale (which ranks tornadoes according to the damage they cause) and general tornado intensity in terms that will be used throughout this report. For the purposes of this report, tornado intensity is referred to by the three categories listed in Table 1-1: weak, strong, and violent. When appropriate, damage observations in this report are presented in terms of the Fujita scale ratings. Table 1-1 is intended to help the reader better understand tornadoes, the damage associated with them, and how mitigation efforts can reduce the property damage and loss of life caused by tornadoes. Further discussions regarding the makeup of a tornado, the damage associated with the winds of a tornadic event, and the Fujita scale are presented in Chapter 2.

This report provides information related to mitigation efforts that communities, businesses, and individuals can undertake to reduce future injuries and the loss of life and property. This report is not intended to reclassify the strength of the May 3 tornadoes or the ratings of the damage observed, or to debate the magnitude of the wind speeds associated with those tornadoes. The Fujita scale ratings mentioned in this report are based on ratings issued by the local National Weather Service (NWS) offices in Oklahoma and Kansas after the tornado outbreaks. The National Severe Storms Laboratory (NSSL) in Norman, Oklahoma, provided additional information regarding the tornadoes.

TABLE 1-1: The BPAT Damage Assessment Table

Fujita Scale	BPAT Characterization	Windborne Debris	Property Protection	Personal Protection	Sheltering
F5 F4	 VIOLENT	Large, medium, and small airborne and rolling debris	Protecting entire buildings other than critical facilities is uneconomical and impractical.	Must have an area specifically engineered for extreme wind protection such as that described under "Sheltering".	To attain near absolute protection, a shelter should be constructed that is built in accordance with FEMA 320: *Taking Shelter From the Storm*, or the *National Performance Criteria for Tornado Shelters*, within or adjacent to a home, office, or business.
F3 F2	 STRONG	Medium and small airborne and rolling debris	Voluntary retrofitting and strengthening of homes and buildings with existing technology.	Additional strengthening of building structure and envelope may reduce risk; a specifically engineered area is suggested such as that described under "Sheltering".	
F1 F0	 WEAK	Small airborne and rolling debris	Constructing to newer building codes and standards strengthens buildings.	Constructing building envelope to newer building codes and standards, such as those described under "Sheltering", minimizes risk and injury.	