Quick Response Report #116 WARNING RESPONSE AND RISK BEHAVIOR IN THE OAK GROVE - BIRMINGHAM, ALABAMA, TORNADO OF 08 APRIL 1998

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ABSTRACT

On 08 April 1998, a long-track violent tornado killed 32 people and injured 300 in Jefferson County, Alabama, near Birmingham. Within one week of the disaster, field surveys were collected from persons residing or working within the damage area (n=65) regarding their actions, and the actions of those in their care or company (n=232). Similar data were obtained for the fatalities (n=32). The purpose of the field operation was to collect spatial, demographic, behavioral, and attitudinal information from a sample of survivors, and to the fullest extent, for all victims. Morbidity and mortality data were analyzed for significant trends in warning access, source, compliance, and lead-time as well as shelter availability, cultural and architectural variables, hazard perception, and self-assessment of warning systems. Goals were to catalog significant differences between victim and survivor traits, to identify successful warning operations and media practices, and to characterize emergent risk factors for death, injury, and damage. Major risk factors for death included living in a wooden house, a house with

walls not anchored to the foundation, becoming airborne, and being elderly. Risk factors for survival included taking shelter below ground, having access to, and consulting televised warning information, being aware of the tornado watch, and familiarity with sources of weather information in general.

INTRODUCTION

On the evening of 08 April 1998, a series of severe thunderstorms and tornadoes moved through northern portions of Mississippi, Alabama, and Georgia. The most destructive of these storms struck greater Birmingham, in north-central Alabama. At approximately 7:50 pm CDT (Central Daylight Time), or 0050 UTC (Universal Time-Coordinated) 04/09/98, a large violent tornado touched down just east of the Black Warrior River and entered Jefferson County, southwest of the community of Oak Grove. This tornado, up to a half-mile (0.8 km) wide at many points, moved northeast, remaining on the ground continuously for more than 30 miles (48 km) before finally dissipating near the Birmingham International Airport, a short distance from downtown. In roughly 40 minutes, 32 people were killed or mortally injured, and approximately 300 were injured.

The tornado destroyed 1,100 homes and damaged at least 1,000 more. In addition, one school complex, two fire stations, 15 churches, 13 commercial buildings, 20 apartment units, and 4,000 acres of woodland were destroyed. Significant to severe damage occurred in the communities of Oak Grove, Concord, Rock Creek, Pleasant Grove, Sylvan Springs, Maytown, Wylam Heights, Edgewater, McDonald Chapel, Minor, Sandusky, West Ensley, and Pratt City, as well as a small part of the north-western fringes of Birmingham proper. The event is officially referred to as the "Oak Grove - Birmingham Tornado" by the National Oceanic and Atmospheric Administration (NOAA). Damage on the *Fujita Damage Intensity Scale* (Appendix F) was F-3 to F-4 in many places, with significant areas of F-5 damage, primarily in

Oak Grove, Wylam Heights, and Edgewater (NWS 1998c).
The consensus, including surveys we conducted, is that this event was successfully forecasted with most of the public warned early and updated often for this tornado. The Storm Prediction Center (SPC) in Norman, Oklahoma issued numerous *Tornado Watches* that afternoon, and the National Weather Service (NWS) - Birmingham Weather Forecast Office (WFO), located in suburban Alabaster, issued numerous *Tornado Warnings* for Jefferson County, with lead-times ranging from five to 30 minutes (NWS 1998c). Additionally, radio and television (TV) dissemination of warnings took high profiles, as numerous TV stations provided live breaks in programming with extensive coverage. Tornadoes also caused major damage shortly before this disaster to the southwest in Tuscaloosa County, and shortly after to the northeast in St. Clair County, where two people were killed when their mobile home was destroyed near Moody.

STUDY AREA

SETTING

Human Environment

Birmingham, the seat of Jefferson County, was founded in 1871 and is a major regional industrial and transportation center in north-central Alabama (Wilson and Ferris 1989). Northwestern Jefferson County is a semi-rural area of metropolitan Birmingham. The damage track includes small towns, old company town sites associated with a coal mining district, and numerous "bedroom communities." The total population of Jefferson County is approximately 300,000 people with an estimated 6,000 living within five miles (8 km) of the damage path (BRPC 1992). The demography of the damaged communities is a mix of middle and low income households, and includes neighborhoods that are predominately Black, predominately White, as well as communities of mixed racial composition.
Residents normally have ready access to emergency medical services

and a "Level One Trauma Center," owing to their proximity to Birmingham. Emergency response organizations include both paid and volunteer fire departments. The area is served by all major television networks, cable TV including CNN and The Weather Channel, and numerous AM and FM radio stations. *NOAA Weather Radio (NWR)* is available in the area, and is broadcast from VHF transmitters located in Birmingham (KIH-54) and Tuscaloosa (KIH-60).

Physical Environment

Downtown Birmingham is located at 33.3 North latitude, 86.5 West longitude, at an elevation of 630 ft (182 m) msl. The tornado track stretches through tightly-spaced rolling hills and valleys situated parallel to, and between, the escarpments of the Rock Mountain and the Shades Mountain Ranges - a southern extension of the *Valley and Ridge Province of the Appalachian Highlands* (Fenneman 1946). The vegetation scheme, where not recently altered by human intervention, is Oak-Hickory-Pine, with Loblolly Pines (*Pinus taeda*) the primary tree in the damaged areas. The more developed areas commonly have lawns or small pastures cleared of most trees, save the occasional hardwood shade tree or ornamental. Outside town limits, the more rugged terrain and flood plains are densely forested.

Climatology

The Birmingham area has a humid subtropical climate with mean annual precipitation of 54.6 in/yr (138.7 cm/yr), and an average of 59 thunderstorm days per year (Ruffner and Bair 1982). Official NOAA statistics for the period 1953-1991 indicate Alabama averaged 20 tornadoes and 11 tornado days per year; ranked fourth among all states in total killer tornadoes (48); and third in total tornado deaths (242). It is noted that "violent" tornadoes are not rare in the region, and the climatological risk posed by tornadoes is among the highest in the world, comparable to areas of the Great Plains (Grazulis 1993). Several killer tornadoes have struck the Birmingham area in modern times. On 04 April 1977, a tornado killed 22 and injured 120 in northern Jefferson County, just east of the 1998 damage area. During the 03/04 April 1974

"Super-Outbreak," tornadoes killed 51 people in northern Alabama alone. A tornado on 15 April 1956, with a track again eerily similar to the 1998 storm, struck McDonald Chapel and Pratt City killing 25 and injuring more than 200 (Grazulis 1993). It is difficult to assess the impact from these historical events on the tornado risk perception and behavior of the current population, but clearly many residents are not strangers to coping with severe weather.

By any measure, the Oak Grove - Birmingham Tornado of 08 April 1998 (hereafter "OGB-98") was one of the worst ever to strike Alabama, both in terms of intensity and damage. Some recently reported damage totals approach 300 million dollars, which if accurate would, according to *Grazulis et al*. [1998], rank it as the tenth most damaging tornado on record in North America. We suspect the damage total is closer to 200 million than 300 million dollars, but reliable final totals remain unavailable.

OAK GROVE - BIRMINGHAM TORNADO

CHRONOLOGY

Pre-Impact

The evidence is overwhelming that this event was well-forecast and, in every way examined, the warning system performed to near-maximum capability. The NWS and associated organizations were in a high state of readiness internally and expressed their concerns early via bulletins to local media and public safety agencies, who in turn, disseminated information on the impending threat to the public, and prepared for emergency operations. WFO Birmingham mentioned severe weather in their forecast products issued the day before (07 April 1998). SPC and NWS public weather forecasts issued the morning of the storm (08 April 1998), including those re-broadcast by local TV stations, alerted listeners to the threat of severe weather before noon CDT (1700 UTC). SPC posted a *High Risk* for severe weather that included the probability of tornadoes in the *Convective Outlook* (Appendix C). At 2:00 pm CDT

(1900 UTC), SPC issued a *Tornado Watch (#188)* for the area valid until 8:00 pm CDT (0100 UTC). When severe storms developed in Mississippi in the late afternoon, a second *Tornado Watch (#194)* was issued replacing the original for the same general region, valid until 2:00 am CDT (0700 UTC - 09 April 1998 - See Appendix D). Aside from broadcast information regarding the watches specifically, many area residents were aware of the weather threat from media coverage of tornadoes already occurring "upstream" in Mississippi and Tuscaloosa County, as the storms continued a steady march toward metropolitan Birmingham.

Impact

The *NWS Service Assessment* conducted for this event concluded that the storms presented "strong, persistent, and unmistakable radar signatures," which allowed forecasters to be highly confident and expedient in constructing and disseminating accurate warnings (NWS 1998c). WFO-Birmingham issued *28 tornado warnings* between the 7:01 pm CDT (0001 UTC) Tuscaloosa County tornado southwest of Birmingham -- including warnings for the ~8:00 pm CDT (~0100 UTC) Oak Grove - Birmingham Tornado -- and the 8:49 pm CDT (0149 UTC) St Clair County tornado northeast of Birmingham (Appendix E). Warning lead-time for the OGB-98 Tornado was eight to 15 minutes for the area of the first Jefferson County fatalities, and significantly more for other areas along the storm's path. Our field work corroborated this and indicated that most people were aware of the warnings for Jefferson County, and that an unprecedentedly high percentage of people were aware of the potential for severe weather earlier in the day.

Area media responded to the approaching storms with most radio and television stations relaying the watch and warning information in routine fashion. As the severity of the situation became increasingly evident, most major local TV stations broke regular programming with increasing frequency as the storms neared metropolitan Birmingham. Two TV Stations were identified in our survey as the primary stations consulted by those who received televised warning information. Both provided continuous severe weather programming that included radar summaries and projected storm paths, starting well before the tornado touched down at Oak Grove. Despite NWR availability, few survivors reported having access to an NWR receiver, and none reported it as their primary source of information. Some survivors noted that there are intermittent reception problems with NWR, allegedly related to topography and atmospheric conditions.

Post-Impact

Storm damage was up to two miles (3.2 km) wide in some areas, with the most severe damage from one quarter to a half-mile (0.4 km to 1.2 km) wide, concentrated in center portions of the path. Devastation ranged from minor shingle loss to foundations completely swept of their structures. Under the current system of tornado damage taxonomy (Fujita Scale), the OGB Tornado was rated "violent," and is therefore among the highest two percent of all tornadoes based on damage intensity. Most of those who perished were killed instantly, suffering the types of trauma common in a tornado disaster, only in most cases to the severest degree. Many victims were thrown far afield from their residence.

Emergency response was immediate, though compromised in most locations by downed trees and power lines that impeded access to the scene by search and rescue (SAR) teams with their usual vehicles. There is some evidence from recordings of the 911 Telephone System and public safety agency radio transmissions that first responders tended to see the damage in their given sector of operations as the worst in terms of damage magnitude. Understandably, this resulted in a brief time-lag before the overall response was coordinated, and neighboring jurisdictions understood the severity and areal extent of the disaster. At approximately 8:55 pm CDT (0135 UTC), the Jefferson County Emergency Management Agency declared a full-scale emergency and the Alabama State Emergency Management Agency (AEMA) activated the *State Emergency Response Plan*, dispatching mutual aid teams and National Guard units to the scene to augment local SAR teams already engaged.

In Concord, two of three fire stations were destroyed by the tornado.

Fire rescue teams resorted to entering the scene on foot, often walking three miles or more to get to victims and bringing them out on stretchers crossing similar distances. Helicopters and repelling teams were required to remove some of the bodies in Edgewater and Wylam Heights. "Emergent" SAR volunteers became an important part of the response due to the difficulties of site access. Personally-owned pick-up trucks were used to transport both official SAR teams and *ad hoc* stretcher teams. Other volunteers became directly involved by giving first aid, while others cleared paths with chainsaws or heavy equipment. Mutual aid from most area fire departments included manpower and equipment from Birmingham as well as from as far away as Montgomery. Shortly after the tornado, myriad local, state, federal and private organizations were on scene to render assistance. The Federal Emergency Management Agency (FEMA), the Department of Health and Human Services (HHS), and the Small Business Administration all set up field offices as did the American Red Cross, Salvation Army, and numerous other relief groups. A few days after the tornado, President Bill Clinton declared Tuscaloosa, Jefferson, and St. Clair counties Federal Disaster Areas.

LITERATURE REVIEW

EPIDEMIOLOGY

Tornado Disasters

A key concept of natural hazard epidemiology and medical geography is that the morbidity and mortality of disasters do not occur randomly. Rather, various trends, both spatial and temporal, emerge to reveal patterns within affected populations. Tornadoes are no exception, and numerous epidemiological-based studies have examined tornado victims in relation to age (Carter et al. 1989; Schmidlin and King 1995), gender (Glass et al. 1980; Schmidlin 1993), race (Perry 1982), marital status (Schmidlin 1997), housing type (Liu et al. 1994; Brenner and Noji 1995), and socioeconomic status (White and Haas 1975). Such demographic variables combined with attitudes about a hazard, are thought to play significant roles in public compliance with mitigative intent of warnings (Gruntfest 1987). Little is understood regarding victim and survivor perceptions of tornado risk, the effects of previous experiences with tornado hazards, access to and use of warnings, shelter availability, and mitigative behavior.

Alabama Setting

As previously noted, the relative tornado risk in Alabama is as high as anywhere. Alabama ranks first among all states in percentage of tornadoes that are "significant." A *significant tornado* is defined as one that resulted in F-2 or greater damage, caused a fatality, or both (Grazulis 1993). The significant tornado data base is considered the optimal measure of tornado climatology for risk studies since some elements of actual human risk are incorporated. High casualty rates in Alabama may be a function not only of tornado intensity and frequency, but of the historical difficulties associated with detecting them in the region owing to low visibility from trees, topography, high humidity, and darkness during peak tornado season (early Spring). Most killer tornadoes in Alabama have occurred at night. *Kessler and Lee* [1978] theorized that the Southeast may experience a higher frequency of violent tornadoes than other regions, and *Grazulis*' [1993] observations echo those of *Linehan* [1957], who noted that the "Southeastern United States is characterized in superlatives," -- meaning many outbreaks, many storms, many disasters, and many deaths -- both cumulatively and per event.

WARNING AND RISK BEHAVIOR

Warning in Behavioral Frameworks

Attempts to characterize the behavior of victims and survivors stress two primary sets of personal profiles. The first, *Cognitive Factors* -- are attitudinal variables and behavioral characteristics that *influence risk* *perception* -- such as religious beliefs, parental responsibilities, and personality traits. The second, *Situational Factors* -- are physical and demographic variables that *affect a person's range of choices* in dealing with the risk -- such as shelter availability or personal mobility (Tobin and Montz 1997). An example of a cognitive factor influencing warning compliance is seen in the *Cry Wolf Effect* -- where subjects ignore warnings after becoming conditioned due to warned events of the past where no personal impact followed (Burnham 1992). Examples of situational factors affecting warning choices include cases where subjects are precluded from complying with a warning because of inability to afford shelter, or mental or physical impairment. Elderly persons are less likely to heed warnings due to compromised mobility, situational communication factors, and previous experience with the risk agent (Gruntfest 1987).

Additional scenarios include failure to heed a warning due to being completely unaware of the risk owing to preformed attitudes about the hazard, perceptions that it "won't happen to me" (cognitive), or failing to understand the warning due to a language or age barrier (situational). To elicit mitigative response, a warning must convey that the threat is real. If there is significant doubt about its validity, it will be ignored. If it is only given marginal credibility, it is likely to evoke *Confirmation Behavior* -- by which recipients seek other sources (such as often happens with tornadoes) -- by dangerously venturing outside or to a window to look for the tornado (Drabek and Stevenson 1971).

Regional or Cultural Risk Factors

Efforts to explain the apparent clustering of tornado casualties in Alabama and "The South" have led to investigations of risk behavior, personality, and culture, as related to the nature of warning systems. *Sims and Baumann* [1972], proposed that culturally-controlled variables, different from those of other regions of similar tornado frequency, were responsible. They concluded after surveys that Southerners' (Alabamians) interactions with nature (and tornado risk) were determined by external forces. They suggested this was due in a large part to religious convictions promoting an *External Locus of Control* --

where individuals present with fatalistic attitudes regarding moderation of risk posed by *Acts of God* -- and manifested by a neglect of the benefits to be derived from government and technology, such as warning systems.

Although these theories persist in contemporary hazard literature, *Biddle* [1994] found that Southerners had similar access to warning systems and equal understanding of tornado risk, when compared to residents of other tornado-prone areas of the country. In comparing survey data taken from Alabama college students to that of college students from the "Midwest" (Illinois) and the "Great Plains" (Oklahoma), religious and cultural differences that might exist were not expressed in perceptions of the tornado threat, understanding of weather terminology, mitigative strategies, or knowledge of, access to, and use of warning systems. In particular, *Sims and Baumann* [1972] argued that few Alabama respondents utilized warning information disseminated via television. Conversely, *Biddle* [1994], found that most Alabama respondents utilized TV warning information extensively. Data collected from OGB-98 further suggests that Alabamians largely embraced available warning technologies, and the existence of a unique southern culture of fatalism and warning ambivalence has continued to erode, or never existed.

It is more likely that local, rather than regional factors, such as the serendipitous nature of tornado paths and the misfortunes of vulnerable communities, play more tangible roles, than regional cultural attitudes. Community vulnerability is not only a function of the probability of impact, but also the degree to which the community can endure the impact. As with most disasters, the poor remain at highest risk due to factors related to cultural architecture, education, shelter availability, community infrastructure, family logistics, and access to services. Ultimately, risk is not connected solely to a lack of awareness among the poor, disenfranchised, and elderly. Rather, the more common concerns of daily life usually overshadow considerations of the low probability event, no matter how catastrophic or lethal its potential. This is especially true if individuals perceive little control over its probability (Drabek 1987).

Tornado Warning Systems

Grazulis et al. [1998] found that the NWS severe weather watch and warning system, including advancements in tornado forecasting, data processing, communications technology, and overall public awareness, have had a definitive impact on tornado casualties, saving at least 5,800 lives nationally since programs were begun by the Weather Bureau in 1953. *Doswell and Moller* [1998], estimated more than twice this number were saved for the same period. In recent years the NWS has undergone a *Modernization and Associated Restructuring (MAR)* that includes the deployment of a Doppler radar network (WSR-88D) nationwide (McCarthy 1993). The Birmingham WFO utilizes the WSR-88D as well as the associated technology brought by MAR. In addition, numerous Birmingham TV stations have the ability to display graphics from the WSR-88D, as well as from additional radars of their own. Most employ professional meteorologists with severe weather training and experience, and assume high marketing profiles based on these severe weather warning services.

The warning chain is no stronger than its weakest link. The reduction of tornado casualties is dependent upon several variables that constitute the warning system: early and accurate detection of tornadoes by meteorologists; efficient and clear communication of warnings to the public via multiple media; and expedient and successful mitigation reactions among the warned community. Consequently, this research aims to provide insight on the relationships between human behavior, and warning system characteristics that affect the capability and efficacy of warnings. It is hoped that analyzing the human ecology of this tornado disaster, combined with a growing body of similar studies will yield details about what works and what does not, and facilitate the design of future warning systems.

RESEARCH QUESTIONS

What spatial, demographic, behavioral, and situational factors

related to increased risk for damage, injury, and death?
Did survivors receive the tornado warning(s), and if so, by what means and with how much lead-time?
What did survivors do when they received a warning or learned of the tornado?
What were survivor attitudes about tornado risk, tornado preparedness, and warning systems?

FIELD METHODS AND DATA ANALYSIS

ON SCENE ACTIVITIES

We arrived in Birmingham on 11 April 1998 (three days after the tornado) and spent five days touring the disaster scene, and interviewing survivors and public safety officials. The first day a cursory tour of the entire damage path was made with Tim Marshall, a damage expert from Haag Engineering of Dallas, Texas, and Brian Peters, the Warning Coordination Meteorologist for WFO Birmingham. Subsequent days were spent interviewing survivors at various locations along the path. Surveys were obtained from 65 respondents self-identified as "head of household," or otherwise representing 232 total survivors of the storm. In addition, data were collected separately for the 32 fatalities, primarily from the reports of the Jefferson County Medical Examiner's Office, supplemented by interviews with emergency response personnel and neighbors.

The purpose of the field operations were to gather information on casualties and survivors, with an emphasis on determining attitudes about tornado risk, warning sources and lead-time, shelter availability, mitigative behavior, and damage parameters. A questionnaire was developed with the assistance of Thomas Schmidlin of Kent University, to produce data amenable to comparison with that of other similarly studied tornado disasters. Permits to enter the disaster area were received from the Jefferson County Sheriff's Office. Matt Biddle, assisted by local resident Jeff Wright, drove along the damage path stopping when residents were observed outside working on damaged homes or interacting with public safety or relief officials. No one declined to submit to a survey, and usually detailed information and photographs of damaged structures were obtained. We spread out the survey to include locations encompassing the entire spectrum of damage severity, with gaps in areas where housing was sparse. It is acknowledged that this did not represent a true random sample, as we spent more time in the areas most severely damaged, representing areas of higher morbidity and mortality.

NOTES ON PREVIOUS STUDIES

For purposes of data comparison, we refer numerous times to other contemporary tornado studies. On 22-23 February 1998, a tornado outbreak in Central Florida killed 42 people (NWS 1998b) and was studied by *Schmidlin et al*., [1998]. This is hereafter referred to as the "FLA-98" event. Numerous tornadoes between Austin and Waco, Texas killed 30 in what is known as the "Central Texas Tornadoes of 29 May 1997" (NWS 1998a). This event is referred to by us as "CTX-97." On 01 March 1997, a tornado outbreak killed 26 people across Arkansas (NWS 1997), and was studied by *Schmidlin and King* [1997]. This is referred to as the "ARK-97" event. On 27 March 1994, tornadoes killed 40 people in northern Alabama and Georgia in what is known as the "Palm Sunday Outbreak of 1994," (NWS 1995). This event was also studied by *Schmidlin and King* [1995], and is called the "PSO-94" event. A Kansas tornado outbreak on April 26, 1991 killed 19 in and around Wichita (NWS 1991a), and is referred to as "KAN-91." *Brenner and Noji* [1995] surveyed the "Plainfield - Crest Hill Tornado," that killed 29 people outside Chicago on 28 August 1990 (NWS 1991). We label this event as "ILL-90." Numerous violent tornadoes killed 91 (including Canada) in the "Ohio - Pennsylvania Outbreak of 1985" (NWS 1986). This outbreak was studied by *CDC* [1986], and is referred to as "OPO-85."

STATISTICAL METHODS

Survivor and fatality data were evaluated by computing cross-

tabulations of appropriate variables. Fatalities were considered as a population since all victims were included in the analysis. Survivor data were treated as a sample since not all possible respondents were contacted. *Practical significance* -- whether the observed data showed any important or meaningful relationships between the variables -- was used to decide whether relationships among fatality data were important. Statistical significance via *Chi-square Tests* were used in conjunction with practical significance to determine relationships among groups. *SPSS (Statistical Package for Social Sciences)* was used to compute the descriptive statistics and cross-tabulations.
Relationships among interval/ratio data (e.g. age), were evaluated using a *Standard t-test* for significance. In cases where fatality data were used, the variance from fatality data were not used as a population estimate, but rather a pooled variance was computed from both fatality and survivor data, owing to the small number of fatalities. Population proportions (e.g. gender and race), were evaluated using a *Standard Z-test* (Burt and Barber 1996). Statistical significance for other comparisons (e.g. place) was attempted (Chi-square Test) where fatality data represented expected frequencies. Copies of the survey questionnaire are available from the authors.

DEMOGRAPHICS

Data for people representing those from households located within the general damage path ("respondents") were obtained (n=65). The respondents also represented "survivors" (n=232) -- the people in company with the respondents -- whose situation and behavior were included where appropriate. As much data as possible were collected for each fatality (n=32) using similar methods and criteria as for survivors. Below are summaries of the demographic data. The data for fatalities may not compare directly in all cases to that of survivors with regard to damage and physical risk. Survivor data was more random and variable, and fatality data were obviously from areas of severe damage involving higher injury potential where behavioral factors were difficult to assess. No random sample or cluster sampling techniques were attempted due to accessibility issues dictated by the extensive damage.

The differences in mean age between respondent and fatality groups were not statistically significant at any level. Gender differences between the two groups were statistically significant at the 0.001 level. This is because more females than males were killed, but more males were interviewed as respondents. This is assumed to be a sampling bias due to the fact that more males were contacted outside their property (usually working in the debris) by our survey team. Racial differences between the two groups was also statistically significant at the 0.001 level, but the difference is quite small and believed related to the relatively different sample sizes. Responses of "unsure" or "refused" were treated as missing. Percentage values expressed in our discussions may not add up to 100% due to rounding.

Age	VICTIMS	RESPONDENTS	SURVIVORS
(Mean) (n=140)	54.1(n=32)	55.2 (n=50)	31.5
(High)	89 (2)	97	97
(Low)	04	22	01
00-03	00 (0%)	00 (0%)	12 (9%)
04-11	02 (6%)	00 (0%)	16 (11%)
12-17	01 (3%)	00 (0%)	16 (11%)
18-35	02 (6%)	08 (16%)	38 (27%)
36-50	10 (31%)	17 (34%)	25 (18%)
51-65	03 (9%)	14 (28%)	20 (14%)
66-80	09 (28%)	08 (16%)	10 (7%)
81+	04 (12%)	03 (6%)	03 (2%)

There is no significant difference between victim and respondent ages, and the large drop in mean survivor age is due to the large number of children included in this population. There are no children in the respondent population since we did not interview minors as a head-of-household. The most striking aspect of age data is the fact that 40% of the fatalities were at least 66 years of age, compared to only 9% and 22% for the respondents and survivors, respectively.

Gender	VICTIMS	RESPONDENTS	SURVIVORS
Female	20 (62%)	26 (40%)	87 (55%)
Male	12 (38%)	39 (60%)	70 (45%)

Race	VICTIMS	RESPONDENTS	SURVIVORS
Black	09 (28%)	15 (21%)	N / A
White	23 (71%)	49 (75%)	
Other	00 (0%)	01 (02%)	

Two-thirds (six) of all Black fatalities occurred in one home. Nonetheless, the racial make-up of the victim and respondent sample populations is quite similar.

Marital Status	VICTIMS	RESPONDENTS	SURVIVORS
	(n=31)	N / A	N / A
Never	04 (13%)		
Married	20 (65%)		
Divorced	01 (3%)		
Widowed	06 (19%)		

While we were able to obtain marital status information for all but one of the fatalities, obtaining such from respondents proved difficult. Attempts to use closed-ended questions regarding marital status resulted in some ambiguity, as various cultural and legal interpretations of "married" and "divorced" seemed to result in significant confusion to the respondents. We did not wish to cause duress among those we surveyed, but rather to define any situational relationships of family structure to risk. We soon abandoned the collection of marital status information as it became apparent that the above four categories did little to define the myriad family structures and attitudes that exist. Therefore comparing fatality and respondent data is not warranted, and cross-comparisons to the marital status findings of other studies should be done with caution. All four victims that were never married were juveniles. Our results from OGB-98 were significantly different than for ARK-97 (Schmidlin and King 1997) who found that of 26 deaths, 17% were never married and 22% were divorced. The mean age in ARK-97 was 43, with 52% female, whereas in OGB-98 the numbers were 54 and 62% respectively.

Place	VICTIMS	RESPONDENTS	SURVIVORS
Sector W	09 (28%)	11 (17%)	(17%)
Sector M	10 (31%)	14 (22%)	(22%)
Sector E	13 (41%)	40 (62%)	(62%)

The tornado track was divided into thirds from west to east based on breaks in areas of housing density and spacing. In general: Sector W = Oak Grove / Concord / Rock Creek; Sector M = Pleasant Grove / Maytown / Sylvan Springs; Sector E = Wylam Heights / Edgewater / McDonald Chapel / Pratt City. We were able to obtain detailed demographic information for portions of each sector by using 1990 Census data based on Zip Codes. The areas do not match up exactly, but do provide a general idea of the situation for each sector of the disaster area.

	W	M	E
ZIP Code	35023	35118	35214
Females (%)	50	53	53
Black/White (%)	16.4 / 83.1	13.1 / 86.7	56.2 / 43.4
Median Age	35.4	38.1	35.6
Avg. Family Size	2.66	2.73	2.74
Median Family Income ($K)	29.6	27.2	26.0
Below Poverty Level (%)	9.2	11.5	16.9
High School Grad (%)	36.4	37.8	29.4
Unemployment (%)	5.0	7.2	7.9
Med. Yr, Home Built	1968	1965	1966
Mobile Homes (%)	21.1	9.8	3.2

All victims 16 years of age or younger died in Sector M. All Black fatalities occurred in Sector E, where they accounted for 69% of Sector E's deaths. All those killed in Sector W and Sector M were White. Six victims died in one Edgewater (Sector E) home, and two in another two doors down.

Number in Party

Respondents were asked how many people were at their location when the tornado hit, or took shelter at the same location: 19% were alone; 14% with one other person; 52% in a party of three to five people; 8% in parties of six to nine; and 2% with 10 or more. More than half of the parties included children under the age of 18.

For fatalities, as stated, six people (20) died in one home (two survived at this site) in Edgewater, for the most at one location. There were two locations where 3 people (20%), both involving at least one parent and one child, were killed. Two were killed at five different locations (31%), with single fatalities for the remaining ten deaths (31%). Cumulatively, fatalities occurred at 18 different locations, and 44% involved multiple fatalities.

CONSTRUCTION AND SHELTER

Building Type

In the FLA-97 event, 41 of 42 deaths (98%) were among those in mobile homes or parked recreational vehicles (Schmidlin et al. 1998). Remarkably, we confirmed only three fatalities associated with a mobile home (9%). The very first victims, living west of Oak Grove (Sector E), were killed when they were blown completely across the street as their mobile home disintegrated. The number of mobile homes in the area is thought to be less than the average for other "blue-collar" areas of Alabama due to the availability of older housing associated with the area mining history. At least 100 mobile homes or "manufactured homes" were destroyed, with many occupants making narrow escapes or receiving injuries. While the majority of deaths were in frame homes, most occurred in house-types prone to disintegration at wind speeds similar to, or barely exceeding, that of most mobile homes (Marshall 1999).

Sector E was dominated by single story residences (68%). Dominant styles were *shotguns, hall and parlors, bungalows, and pyramid-style* company homes (Appendix G), with very few two story homes encountered in this area. In Sector W, respondent homes were highly variable in architecture, as was Sector M, though there 30% of respondent homes were *split-level* styles of composite materials. In *Schmidlin and King* [1997], only 16% of fatalities in the ARK-97 event were killed in a house, with 56% in mobile homes. None had access to a below ground or windowless shelter. For the PSO-94 event, 75% were in mobile homes (Schmidlin and King 1995).

In the Edgewater and McDonald Chapel areas of Sector E, damage ranged from light to complete within the same block (See Appendix H). Many of the homes in this area were mining company pyramids on pier and beam foundations, all made of wood. Most were of sub-standard construction in spite of the era of construction (circa 1930's), often with exposed eaves and pine stud framing only one inch in thickness (BHS 1993). Often, to compensate for unexcavated natural topography at the plat site, one end of the home is raised up several feet, while the other end is nearly on the ground. The end result is that in such situations, certain homes may have increased or decreased wind failure thresholds owing to these angled elevations. The neighborhoods with significant numbers of pyramids were among the most devastated, yet we were unable to attach any patterns for risk of death to this style of architecture.

Split-level houses, while offering some below-ground shelter, were particularly prone to losing only their roof. This is apparently due to the attached garage, which feature large doors prone to failure at lower wind speeds, as the wind gains access to the interior walls of the structure and blows off the roof from the inside out. (Marshall 1999).

While many were destroyed, a substantial number survived. We surmise that this variability was due to the highly variable topography and differing orientations of the residences, resulting in each dwelling having different "faces to the wind." We feel that the circumstances surrounding the "angle of attack" of the wind and missiles versus the situation of the structure (foundation, slope, surface area, etc) are very important and can be significantly different for two building build nearly identical, but on different lots. We feel similar factors are involved in the vulnerability and damage patterns for automobiles and other vehicles.

Building Material

Severely damaged and destroyed respondent homes in Sector E, had a strong tendency to be wooden (82%) with wood, aluminum, or vinyl siding. In Sector M, half (50%) of the respondents' severely damaged and destroyed homes were brick facia. In Sector W, structures were highly variable. Curiously, no clear relationship between F-scale damage and construction material emerged from our data. We attribute this to sampling bias and the extreme nature of the storm, which in many places destroyed housing of any and all type.

Foundations

Sector M was the only location with a remarkable percentage of respondent damaged or destroyed homes (63%) that used wall-plate foundation anchors. It was however, the only sector to have a significant number of observed homes with *any* foundation anchorage. Only 19% of all homes in our survey had any type of foundation anchoring.

Available Shelter

At the time of impact, 3% of survivors took shelter in a crawlspace, 6% in storm shelters, 17% in first floors with windows, 22% were in a basement, and 39% in first floors without windows. Only 2% reported finding no shelter at all. About half (49%) of all survivors reported being inside and ready to move to the best available shelter when they felt conditions warranted, with 7% reporting that they went to shelters at locations away from their residence, usually a neighbor's. Wood homes tended to have first floor rooms as the only shelter available. It is speculated that wood structures were less likely to have basements based on cultural architecture (the style of the era for older homes) or economic factors limiting their construction. Most fatalities (84%), were in traditional single story homes with no below ground shelter.

Female survivors took shelter in basements 17% of the time, and first floors without windows half the time. Males found shelter 27% of the time in basements, with 35% in first floors with windows. Black survivors had shelter that was generally limited to first floors (67%), of which only half were without windows. In Sector M, most survivors were in a basement (50%), compared to first floor shelters that predominated in Sectors W and E.

Damage

Estimates by AEMA [1998] of homes severely damaged or destroyed for various portions of the track were as follows: Oak Grove (4 sq mi/6.4 sq km) - 31% of homes severely damaged or destroyed, with a maximum of 74% in the center square mile section; Rock Creek (5 sq mi/8 sq km) - 43% with a maximum in a southeastern section of 86%; Sylvan Springs (5 sq mi/8 sq km) - 20% with a maximum of 70% in a southeastern section; Edgewater / McDonald Chapel (7 sq mi/11.3 sq km) - 25% with a maximum in a northeastern section of 52%; Wylam Heights (1 sq mi/1.6 sq km) - 94% severely damaged or destroyed; Pratt City (3 sq mi/4.8 sq km) - 11% with a maximum of 27% in a northeastern section. Grand totals for this assessment indicated 1102 of 5134 homes (21%) were severely damaged or destroyed, with the worst being the Wylam Heights section where eight fatalities occurred. There were 129 mobile homes in the AEMA survey, 27 (21%) which were destroyed. This rate is exactly the same as the rate for homes of all types in the survey.

In Sector W, fewer homes were assessed as "completely destroyed," with most whose owners were interviewed having only "significant damage." Access difficulties precluded getting to many sites in these sectors. Most residences where a fatality occurred were assessed by us as "blown away" (69%) or generally as having F-5 damage (e.g. no walls standing or swept foundation). A small number of victims (19%), died in homes that simply collapsed or suffered less than complete damage. Brick, at least upon cursory inspection, seemed to present lower F-scale damage than wooden structures. While this may seem logical, it likely represents a bias on our part based on the difficulties of F-scale assessment. Unanchored brick and metal structures tended to fit lower F-scale criteria, while anchored masonry structures tended to fit higher F-scale criteria.

Most of the unanchored structures that were in the F-4 or F-5 damage areas were often disintegrated and not readily observable in our spot surveys. Aside from the intrinsic mass and resistance of brick and masonry-walled homes, they also tended to be anchored to the foundation more often than homes built of other materials. Failed brick walls were observed both with and without foundation anchors. Very few wooden or metal "manufactured homes" had adequate anchoring. Thus, it is probable that brick structures offered more protection not only because of their material strength, but because they were more often anchored. This is in keeping with the observations of *Marshall* [1993].

WARNING AND BEHAVIOR

Warning Access

"Access to warnings," was assessed based on both the quantity and quality of readily available warning information. Those with access to specialized warning sources such as police and fire radio receivers, or who otherwise were directly involved in monitoring warning information (e.g. volunteer firefighters, off-duty police officers) were given the highest ratings. Those with access to multiple warning sources were also assigned higher ratings. Those with access to media sources dedicated to timely updates of warning information, such as TV or NWR, were given high ratings. Those relying on third parties or siren systems were given moderate ratings. Those unsure about the warning process, and those alone with no media access, were given low ratings. Extremely high access ratings were assigned to 15% of the survivors. High access was given to 62%, and moderate access to 17%. Two percent of survivors received no warning, and only 2% were assessed as having low access. Most who took shelter in a first floor location at the time of tornado impact had no secondary warning source, whereas most of those who took shelter in basements received warnings (and confirmation information) from multiple warning sources and had higher access. Though Blacks tended to have slightly less access to warnings, especially based on quantity (none were rated "very high"), they still had 67% rated "high." Whites had 83% rated as "high" or "very high." No females were rated with the highest access, but 23% were rated with high access. Males tended to have access to multiple warning sources

(84%), and were more apt to consult secondary sources (41)%.
A strong majority (85%) of survivors reported becoming aware of the approaching tornado via TV. Only 9% first learned of the tornado by seeing or hearing it. This varies considerably from previously studied events. In particular, *Schmidlin and King* [1995], found that roughly half of the survivors of PSO-94 became aware of approaching tornadoes by seeing or hearing them, and only 16% via televised warnings. They also reported 61% and 68% learned of the tornado by seeing or hearing it, and 21% and 10% from TV, in ARK-97 (Schmidlin and King 1997) and FLA-98 (Schmidlin et al. 1998) respectively.

Primary Warning Source
Not surprisingly, television played a huge role as a warning source, both over all (85%) and primarily (68%). TV was also reported most as the secondary warning source (17%) when it was not the primary source. TV as the primary warning source most often led to longer lead-times, giving half (50%) of respondents 10 minutes or more warning. *Schmidlin and King* [1997], found that in ARK-97, previous TV warnings for dozens of counties in the viewing area earlier in the day may have caused a "numbing" effect among the public. We encountered only a few who commented on similar feelings in OGB-98, and many reported monitoring the severe weather coverage for extended periods. Here, it appears that the more the TV coverage highlighted the impending threat, the more serious and "tuned in" the public reacted. Two-thirds of Blacks (67%) and 80% of Whites used TV as the primary warning source. Of those who used TV as the primary source, 54% were male and 46% were female. There was a problem with the data in assessing the telephone as primary warning source. However, most of those who received their warning via the telephone were females. There were no significant trends in primary warning source based on location (sector).

Secondary Warning Source
After TV, the most common secondary warning sources were siren systems (26%) and the telephone (11%). Females tended to list the

telephone (22%), as a secondary warning source. For males TV (16%) was most common, followed by NWR (14%), with few using the phone (5%). Use of a secondary warning source in Sector E was rare, and was mostly sirens (18%), while in the remaining two sectors the sources were highly variable.

Warning Lead-Time

Warning lead-time (based on initiation of mitigative action rather than official NWS times) varied from a half-hour among some of the most aware, down to no warning at all (2%). Most (40%), had warning of more than 10 minutes, with others reporting six to 10 minutes (11%), two to five minutes (17%), a "couple" minutes (5%), and "seconds" (5%). In ARK-97, 60% had less than one minute warning prior to becoming aware of the tornado (Schmidlin and King 1997). As previously stated, lead-time was significantly higher among those with access to TV. There was no relationship with lead-time for survivor injuries, nor from sector to sector. As expected, those who had longer lead-times had higher warning access (multiple or more-detailed warning sources), and were more apt to relay the warning to a third party.

Morbidity

Only 15% of respondents reported an injury among those at their location. Most of these injuries were minor. In most cases where severe injuries occurred, we were unable to obtain information. As expected, and in line with previous observations, most of the injuries among survivors we contacted occurred in wooden structures (62%). Most of the injuries reported in our survey were in areas of higher F-scale damage. We believe that this also may be a sampling bias due to our operating more in the worst damaged areas where people tended to congregate, making them more likely to be contacted. There were no observable relationships between injuries and primary warning source, warning lead-time, or respondent assessments of the warning system. We are aware of no other injury studies related to this storm conducted by epidemiologists or public health officials, nor of any comprehensive reporting system at any of the area hospitals. This proved to be a critical data gap.

Mortality

Four victims (13%) were identified by the Medical Examiner with "Mechanical Asphyxiation" (MAX) as the cause of death. This related directly to the number crushed by the debris of their residence. Three MAX victims were in one home. The majority (87%) were killed by "Blunt Force Trauma" (BFT) -- most commonly the result of being carried aloft and subsequently hitting the ground. Of the 28 fatalities with BFT as the major cause of death, surveys indicated 89% were in structures with floors or foundations that likely went airborne. In 71%, evidence was conclusive that the victim went airborne. MAX never occurred in victims with homes assessed as blown away (F-5). Blacks were killed only by BFT, and all MAX deaths were White. None of those killed are believed to have died with missile-generated trauma as a major contributor to the cause of death.

Warning Relay

One third (33%) of those surveyed reported that they, or someone in their company, relayed warning information to a third party. There was no relationship between the party size at a given home, and the relay of tornado warnings to a third party. As expected, short lead-times generally led to no relay of warning. Warnings were received from a third party by 22% of respondents, with the telephone accounting for two-thirds (67%) of the relays, and the other third (33%) from someone coming to their location to inform them.

Plan

Three-quarters of the survivors indicated they had previous plans about what to do and where to go in a tornado warning, or had taken shelter at the same location in the past. Among them most tended to report higher warning access. Those with plans were generally warned first by TV, NWR, or the phone, whereas those without plans were usually warned first by radio, or seeing or hearing the tornado, or in person by a third party. Those with a plan generally had lead-times of more than 10 minutes (40%). Only 10% with a plan reported having two minutes or less lead-time. Lead-time was much more variable for those without a plan.

Watch Awareness

More than 85% of survivors reported being aware of the tornado watch. People who claimed to have been aware of the tornado watch tended to have longer lead-times, and most who claimed to have severe weather plans also claimed to be aware of the watch.

Warning Assessment

Respondents were asked to assess the performance of the overall warning system. Ratings of "excellent" (9%), "good" (35%), and "adequate" (34%) were reported by most with only a few reporting "inadequate" (3%), or "bad" (3%). In general, those with higher access to warnings tended to rate the overall performance of the warning system more favorably. Also, those with longer warning lead-times gave higher ratings of overall warning system performance.

Weather Awareness

Respondents were asked to define how they normally become aware of the threat of severe weather. Few reported that they were usually unaware or incapable (5%). One person claimed to wait until he "got a funny feeling." Five percent (5%) stated when they hear a siren, and 11% when a third party they rely on informs them. Nearly half (49%), stated they became vigilant when a watch is posted for their locality, while others stated they become aware when a warning is issued somewhere in the metropolitan area (9%).

Less than five percent (4%) stated they did not know the difference between a watch and a warning. Those who claimed to be aware of the tornado watch also usually claimed to be diligent in monitoring forecasts and weather awareness in general. Those who rated themselves as regular monitors of severe weather forecasts and/or watches, not surprisingly had longer lead-times. A few (6%), reported they regularly monitor severe weather forecasts for information prior to the issuance of watches.

EMERGENT RISK FACTORS

CONSTRUCTION AND SHELTER

As expected, housing style and construction appear directly related to morbidity and mortality. Due to the magnitude of damage where fatalities occurred, determination of structure style and construction type were problematic. **Of particular note was the high frequency of death associated with two house types: the Shotgun, or the Hall and Parlor Dwelling -- both generally of wood construction, featuring simple roofing with exposed eaves** (see Appendix G). Both styles are common to the humid South, and also tend to occur in areas historically settled by middle-to-low income families (McAlester and McAlester 1988). For the most part, at least in the most heavily damaged areas, geography played a bigger role in damage than architecture or building material. **There were two foundation types identified with failure, damage, morbidity, and mortality -- the *concrete slab*, and the *pier and beam system*** -- which are also common to the South as well as rural areas. Wooden single-story structures on either type of foundation comprised the majority of locations where deaths occurred (88%). These foundations were commonly unanchored, or anchored ineffectively (Marshall 1999). With the masonry pier system, houses are situated on blocks for the purpose of raising the floor joists and wall bases off damp or flood-prone earth, and to thwart termites. This not only made for frequent wall failure, but gave the wind easy access to the underside of flooring. With the slab, often the only thing holding the structure to the foundation is gravity. Strong winds on large flat surfaces, such as walls, easily negate this. In both cases, the result was often that these houses became airborne at low wind thresholds, perhaps in many cases at wind speeds less than 100 mph (160 km/hr).

Given this, the violent rating of the tornado becomes less important than the construction and architectural characteristics of the buildings. It is suggested here that even in a significantly weaker tornado, most of those killed would have still likely perished, but simply would not have been thrown as far downstream from their original home sites. This parallels the findings of *Schmidlin and King* [1995], who found that when flooring was removed from a foundation, the risk of death and injury rose dramatically. We were not able to determine the extent of anchoring involved at the lone mobile home fatality site.

Three people from one family (9%), were killed after taking shelter in the basement of their contemporary split-level home, when the wind disengaged an entire wall from the foundation, collapsing it down upon them. It is important to note however, that the overall protection offered from basement shelters remains significant. Only 9% of fatalities took shelter in a basement, and assessments at CTX-97 showed 100% of those killed at Jarrell, Texas had no below ground shelter (NWS 1998a). Tragedies of this type can usually be avoided by training occupants to take cover in the center of the basement, with secondary shelter under a staircase or heavy furniture.

Only one person was killed in an apartment, but we were unable to determine what floor the person lived. We noted a lack of multiple family housing in most of the damage path. This may have helped to keep the fatality rate down as most apartment complexes lack significant shelter. In ILL-90, 33% of the deaths were in apartments (NWS 1991). It is also significant to note that none of the 32 OGB-98 fatalities were killed in a motor vehicle and only 3 (9%) were in a mobile home (NWS 1998). This is anomalous compared to both historical and recent records. *SPC* [1999] data for the period 1985 - 1997 indicate 38% of all tornado deaths have been in mobile homes, and 11% in vehicles. In KAN-91, 13 of the 19 killed (68%) were killed in mobile homes in the same mobile home park. This was in spite of an available shelter and at least a seven minute NWS warning (NWS 1991a). *Schmidlin* [1995] reported that some studies have counted as much as 60% of all tornado fatalities in vehicles for a given event, and *Schmidlin et al*. [1998b] reported 15% fatalities in vehicles from 1975 - 1995. In ILL-90, 10% of the deaths were in vehicles, as were 6 of 7 (87%) fatalities in a 1993 tornado at

Catoosa, Oklahoma (Biddle 1994).

WARNING AND BEHAVIOR

Due to the difficulties in interviewing survivors that were severely injured, and the scarcity of people who could advise us on the actions of those who were killed, most behavioral and situational factors related to morbidity and mortality are speculative. Many people survived in homes that were completely demolished or in casualty-prone locations such as churches or schools with large-span roofs. A few people we did not survey, survived the tornado in vehicles that were heavily damaged. Conversely, *many* unoccupied vehicles were observed that were thrown long distances, smashed by trees, or full of missile-generated debris, where survival would have been very unlikely.

It was determined that most of the OGB-98 victims died instantly. In two other studied events involving violent tornadoes, OPO-85 (CDC 1986) and ILL-90 (Brenner and Noji 1995), most of the victims were also thought to have died instantly. The historically high fatality rate for violent tornadoes (Biddle 1998), is accountable for about two-thirds (67%) of all tornado deaths, and is again identified as a major factor for mortality. However, it seems the more violent the tornado, the more "blurred" the signals for situational and behavioral elements of risk factors for death become.

Obviously, the high percentage of those who received warning and the general length of lead-time played major roles in reducing the number of casualties. The success of televised warnings was paramount, as was the performance of the NWS warning system. We speculate that this is at least partially due to the high level of cooperation between WFO - Birmingham and the Birmingham area media, various recent public relations efforts by WFO - Birmingham and AEMA, and the generally high severe weather awareness among much of the area public, that is likely due to recent highly publicized tornado disasters that have occurred in the region.

We are unable to construct any explanation for the apparent paradox related to warning awareness and compliance heightened by heavy TV severe weather coverage among those we surveyed in the Birmingham area, with that of the "numbing effect" reported from heavy TV coverage among survivors of other events. The high level of weather awareness and knowledge of mitigative action also were important, though with the exception of previously noting the potential impact of area tornado disasters of recent history, we found nothing that stands out in terms of NWS approach or media coverage that is substantially different from other areas of "Tornado Alley." The time of the tornado (early evening), may have resulted in more people being able to readily receive warnings, as did its proximity to a large metropolitan area.

ANECDOTAL INFORMATION

St Clair County Tornado

Two adults were killed and three children seriously injured near Moody in the tornado subsequent to the OGB-98 storm, when the mobile home they lived in was destroyed and blown 100 yards (91 m) into a field. The family had no access to radio or TV warning information, and sirens were allegedly not audible at their location. They were without power or telephone, which had been cut off for some time. Relatives reported that they knew to evacuate the mobile home for a tornado warning, but that they likely were unaware due the lack of electrical and telephone services.

Oak Grove High School

A cheerleader squad of approximately 25 girls was practicing in the *Oak Grove High School* gymnasium at the time the tornado struck. Upon impact they sought shelter in the lobby to the gym as the entire roof and its large steel beam support system collapsed. The support beams were bent in from the center to the ground leaving an inverted V-shaped space over the lobby area, the only part of the structure to escape collapse (Appendix H). This is again a case of miraculous escape. Huge shards of glass, bricks, concrete block, bleachers, metal lockers, and all manner of debris filled the gym, in places three feet deep. We can conceive of *no worse place* for a group of people (much less juveniles) to have been in all of Oak Grove at the time of this tornado!

The potential of school auditoriums and gymnasiums to be the site of tragic mass casualty events has not gone away with modernized warnings, and public awareness campaigns at schools must stress this continually. **When a tornado watch is issued it is imperative that someone of authority with a school system monitor the weather and any warnings**, and be in a position to notify whomever is supervising children to either refrain from activities in certain school facilities, or to take shelter in the designated areas. It was also disturbing to note that the hall ways between the classrooms, which we were told were the designated shelter areas for many of the students for tornado drills, were filled with bricks, concrete block, and other "chunky" debris. Were school in session, many casualties would have been likely.

Churches

At least 20 churches were severely damaged or destroyed in the three counties of Tuscaloosa, Jefferson, and St Clair. Most were unoccupied, but at the *Open Door Baptist Church* near Minor, approximately 67 people were gathered for Wednesday Night Prayer Meeting. One church member, home recovering from surgery was following weather reports on TV and telephoned the church, prompting the group to seek shelter in a long hall way some 15 minutes prior to tornado impact. The tornado made a direct hit on the church, completely collapsing the roof and exterior walls. The hall way remained largely intact, with only a few missile-generated injuries to the group. Many of the cars in the parking lot were thrown into a nearby ravine.

At about the same time at the *Bethel Baptist Church* in Moody (St Clair County), what was to be a group of about 100 people were gathering at the church for Easter Pageant practice. At about 8 pm CDT (2100 UTC), church administrators who were aware of media reports of tornadic activity near Birmingham, made a decision to send everyone home, many whom had reported in their costumes. At approximately 9 pm

CDT (2200 UTC), the church complex was destroyed. The mobile home where the two St Clair County fatalities occurred was located near the church.
Unlike the situation at Oak Grove School, church administrators showed exceptional insight in assessing the weather risk and making decisions to move people on to lower risk locations. Both of these close calls demonstrate the importance of the media in disseminating warnings and in having someone monitor the weather at such gatherings when severe weather is possible. We are unable to confirm this, but we surmise that awareness was high at least in part due to publicity surrounding the tragedy of PSO-94, where 20 people were killed in the collapse of the *Goshen United Methodist Church* near Piedmont, Alabama (NWS 1994).

Birmingham Barons Baseball Game

During the height of the storms of 08 April 1998, the *Birmingham Barons*, the area's AAA professional baseball team was trying to complete a game with the *Carolina Mudcats*. Apparently, there was no policy in place at Hoover Metropolitan Stadium, located on the south side of Birmingham, for monitoring the weather nor receiving tornado warnings, or such policies were not followed. The sirens that sounded throughout most of the county were allegedly ignored. As debris from the tornado was swirling in the sky not far from the stadium, play continued as umpires refused to postpone the game. It was finally suspended when wind and rain from the storm that killed 32 people just a few miles west made play impossible, as fans were "left to the safety of the upper concourse." Play eventually resumed when the rain moved on, at about the time two people were killed in St. Clair County, just northeast of Birmingham (Grazulis 2000).
Grazulis et al. [1998], suggest this is all too common a scenario and raise concerns about the probability of a mass casualty event that is the result of a tornado tangling with a major sporting event. The Barons and the community should consider themselves very lucky that this was not that event. It is imperative that those supervising and organizing public

events have contingency plans in place, and consider weather information as important on a daily operational basis as parking and traffic or TV timeouts. Progress is made from time-to-time, as it was reported in the newspaper that at the 09 May 1998 Barons' game, 7000 people were evacuated to the concourse during a tornado warning, in accordance with the stadium "tornado policy."

Concord Fire Department

Two of Concord Fire Department's (CFD) three fire stations, the western (Oak Grove) and the central (Rock Creek), were destroyed by the storm. Some responding fire and rescue personnel attempted to extricate apparatus from the collapsed stations, while others mobilized in areas near their own residences. CFD Assistant Chief Robbie Miller indicated that he was unable to respond to the scene in his vehicle, and he entered on foot less than 15 minutes after the tornado came through. Command posts were set up at opposite ends of Warrior River Road, which is essentially the only throughway transversing the community. Using the *Incident Command System (ICS)*, search and rescue, patient care, and mutual aid was coordinated at the two command posts.

Vehicle access to the scene remained impossible well into the night until crews with heavy tree removal and utility pole moving equipment from Alabama Power and Light (APL) and the Alabama Department of Forestry (ADF) cleared the way. CFD teams eventually got one rescue truck out of the debris of the west station, but Chief Miller noted that their response was only marginally affected by the damaged fire stations, as even if the equipment were not trapped in the buildings it would not have been able to progress down Warrior River Road a significant distance for some time. He added that he was generally pleased with the overall response given the conditions, that mutual aid was extensive, and that the department has replaced the damage CFD vehicles and rebuilt one of the stations with construction of the third pending.

UAB Regional Trauma System

A *Regional Trauma Coordinating System* for metropolitan Birmingham, operated by the University of Alabama-Birmingham Medical Center, is credited with saving numerous lives and limbs. The system evaluated field triage reports and coordinated transportation to area hospitals via a modern computer data and two-way radio communication system that linked helicopter and ground ambulances to multiple hospitals and each other. The demonstrated success of this operation in OGB-98 has led to plans to fund and implement the system statewide.

Alabama EMA Training

In July 1997, some 80 Jefferson County EMA and associated area personnel attended a week-long disaster training program at the FEMA Training Center in Maryland. An exercise scenario for this training had multiple tornadoes hitting the greater Birmingham area, causing 35 deaths and numerous casualties. Numerous emergency response personnel cited this training, and the fact that Jefferson County EMA had gone on a heightened alert status the day prior to the tornado in response to NWS forecasts, as critical in their ability to cope with the situation. Quite simply, severe weather was anticipated and the plans to respond to it were engaged well before the storm.

Environmental Impacts

In the months following the tornado, particularly in the Summer of 1998, numerous environmental problems were faced that were directly related to the damage caused by the tornado. Drainage channels and streams were choked with debris of all sizes, primarily brush and timber. This resulted in a flood hazard. The resultant drainage problems created an expanded mosquito habitat, particularly for the Asian Tiger Mosquito (*Aedes albopictus*), a vector associated with *viral encephalitis*. ADF reported in excess of 4000 acres of downed timber, which not only created a fire hazard, but also prime breeding ground for the Southern Pine Beetle (*Dendroctonus frontalis*) which if left unchecked, poses a threat to larger areas of healthy forest. Estimated costs for handling these problems alone was around one million dollars.

CONCLUSIONS / RECOMMENDATIONS

We found few unanticipated findings, with the exception of the unprecedented numbers of those who received warnings (73%), those who received warnings via TV (85%), and those who were aware of the watch (86%). In most ways this disaster mirrored both the characteristics of many previous tornado disasters, as well as the cumulative historical data, in that morbidity and mortality were concentrated among the poor and those in housing most vulnerable to the destructive forces of the wind. The collective body of previous forensic examinations of tornado disasters have identified few consistently significant risk factors for death, with the exceptions being living in a mobile home, or being in a vehicle. In OGB-98, both of these risk factors were uncharacteristically low. Demographic characteristics associated with increased risk are largely spurious, save for low socioeconomic status (inversely related), and certain age groups (chiefly the elderly), which again was the general situation in OGB-98. Below is a review of the more conclusive findings with some recommendations for future research and policy initiatives for further clarifying of tornado risk and increasing the efficacy of warning and mitigative efforts.

NOAA Weather Radio

If NWR is to serve the public as marketed, major problems with poor reception must be resolved. Efforts to educate the public about its availability and benefits, and to increase the listener population should continue. NWS Birmingham and the AEMA have given considerable attention to public education on this issue, perhaps more so than most areas of the nation. Yet for elusive reasons, NWR usage remains low. A radio system that is unavailable to many, unutilized by most, and unreliable to the few who do attempt to use it, is of limited value. The potential of NWR remains largely unmet.

Warning Sirens

Warning sirens appear to be both available, and utilized, in inconsistent and ineffective manners. Surveys indicate many people seek to use them, but are unsure of their placement and range, especially when in locations other than their own home or job site (often). If it is determined that warning sirens will be a continued part of the tornado warning system, local, regional, and federal authorities should examine standardization policies that stress public knowledge of their availability. Public awareness campaigns should note their availability, placement and range, potential for failure, and alternative warning sources to seek in concert with, or in lieu of, siren systems.

Telephone Warning Relays

The apparently common behavior of many people to utilize the telephone to relay warning information to others they perceive as in danger, is an important factor for emergency planners to consider. If it can be determined that such activities do not compromise the operation of telephone systems in threatening weather situations, policies may be in order that include messages to the public in various broadcast weather statements regarding those in the path of a given storm should be called, and those who should not. This could prove problematic, but the effectiveness of telephone-relayed warnings in this disaster cannot be ignored.

Availability of Shelters

In addition to socioeconomic status, cultural architecture, and being elderly, the general lack of shelters appears to have been a significant risk factor. Most people we contacted acknowledged the importance of shelters and commented that: 1) they would build one during the reconstruction of their home; or 2) they would build an unattached shelter or reinforced room for their current residence; or 3) that they would like to have one, but simply could not afford one. Of those who could not afford one, just under 90% stated they would support their local government or school district in the development of a community shelter that their family could use in the future. It is our *opinion*, that shelter interest is not lower in the areas where they are not affordable, and programs that enable these populations to obtain regular access to shelters would significantly lower the risk for these areas.

Building Codes Versus Socioeconomic Considerations

Here, as with most tornado disasters, or many disasters of any cause, it is easy to point to mandated building codes as a mitigative solution. Despite the fact that much of the housing that was destroyed by OGB-98 was built in the early part of this century, many of those living in the disaster area would face significant financial hardship in rebuilding were strict building codes required. This is particularly true with regard to building materials, and restrictions on mobile homes. On the other hand, many engineering controls such as hurricane clips (roof-to-wall anchors) and foundation anchors, are relatively cheap. For those looking to upgrade, most insurance policies (among those who can afford homeowners insurance) do not reward policy holders for investing in wind resistant engineering or shelters. This has been the *status quo* for some time (McDonald 1979). The mitigation of risk factors from tornadoes, or any natural hazard, is not as simple as zoning, building codes, or engineering. True mitigation planning must consider the entire spectrum of the human ecology of populations at risk.

Future Modifications of NWS Watch / Warning System

There have been numerous modifications of NWS operational programs under the NWS modernization (MAR), and other changes have been proposed. Among them is the "decentralization" of watch issuance, transferring these duties to NWS WFO's and away from SPC, and relegating SPC's role to that of guidance. The anecdotal evidence is that *virtually no one* desires this change. SPC is understandably comfortable with its historical role in issuing watches. Most NWS personnel we have consulted not only are satisfied with the SPC role, but already complain of being significantly understaffed, especially in times of severe weather. The prospects of having to provide forecasts for and construct watches at the local level does not please most.

At times among various factions involved in weather forecasting or product use, there has been discussions of a radical overhaul of the watch system, based on speculations that people do not pay attention to watches anymore. We do not believe this to be the case, and are aware of no contemporary scientific evidence to support this notion, at least for tornado watches (it may be true to some extent for severe thunderstorm watches). We reiterate the apparent overwhelming success of the tornado watches for the OGB-98 event, as more than 85% of survivors reported being aware of the tornado watch, and this was associated directly with longer warning lead-times. We also report that over 90% stated they understood the difference between a watch and a warning. We believe any future major modifications of the watch system should not occur without significant national studies of watch perception and utility. This includes any replacement of the current "box" format to other spatial constructs such as county outlined areas.

Importance of Standardized Surveys for Tornado Disasters

While there has been an increase in the number of tornado disasters forensically studied with regard to risk factors for morbidity and mortality, particularly by *Schmidlin et al.*, many efforts (including ours) suffer from logistical limitations and a lack of coordination with other groups studying the aspects of these events. Cross-comparisons are statistically and subjectively problematic. Currently, event research is piecemeal and episodic. A much larger percentage of overall events need to be surveyed to expand the levels of statistically significant data. Better coordination is warranted between epidemiologists, geographers, disaster engineers, and the meteorological community in comprehensive studies, particularly to include injuries. We call for more funding into such studies and for the NWS to become more pro-active in their involvement, since such inquiries are directly related to understanding the success of their current operations and the development of future NWS warning technologies and policies.

NWS Service Assessments

The *NWS Service Assessments* (NOAA 1998a-d) incorporate a new format replacing the more comprehensive *Natural Disaster Survey Report* that NOAA formerly prepared for many larger-scale weather-related disasters. This new format represents a significant content change (much less), and while it may provide beneficial information for NWS operations, the overall document fails to provide much useful information for extra- or inter-organizational applications. The old format provided a significant volume of useful data for outside agencies regarding the overall organizational, physical, and societal impacts of a given event. Data from these surveys were often used by emergency managers, local planners, media, and researchers for forensic review, exercise scenarios, and response planning. We find this format change unfortunate, and the result is a skeletal document providing little service other than to internal causes of NWS. A return to something more comprehensive would likely be of benefit to local jurisdictions, and other agencies that are a part of the warning chain, and still benefit the NWS by aiding those who utilize the *NWS Family of Services*.

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Gumprecht (Bad Cop Editor) commented on the draft reports, and Melany Dickens and Charles Edwards digitized our imagry. Kaye Carter at OU, Mark Herndon of Norman, and Doris Grazulis from the Tornado Project provided logistical support that made it possible to enter the field. Information provided by the Jefferson County EMA, Jefferson County Office of the Medical Examiner, and Jefferson County Sheriff's Office was invaluable. Thanks to Roger Edwards of the Storm Prediction Center and Asst. Chief Robbie Miller of Concord Fire Department for supplemental information. We also express our gratitude to the survivors who took time out from their activities in trying times to share their experiences. This work is inspired by the late T. T. "Ted" Fujita -- the conceptual pioneer of comprehensive tornado investigations -- and is dedicated to the victims and their families.

REFERENCES

Alabama Emergency Management Agency (AEMA), 1998: *Preliminary Damage Surveys of Oak Grove - Birmingham Tornado*. Birmingham AL

Biddle, MD, 1994: *Tornado Hazards, Coping Styles, and Modernized Warning Systems*. Thesis, Department of Geography, The University of Oklahoma - Norman. 143 p.

Biddle, MD, 1996: Re-examining Tornado Risk Coping Styles and Other Tornado Warning Issues Under the Modernized National Weather Service. *Preprints: 18th Conference on Severe Local Storms, San Francisco, CA*. American Meteorological Society. pp. 605-608.

Biddle, MD, 1998: Some Geographical and Climatological Aspects of North American Violent Tornadoes. *Preprints: 19th Conference on Severe Local Storms, Minneapolis, MN*. pp. 297-300.

Birmingham Historical Society (BHS), 1993: *The Birmingham District - A Survey of Cultural Resources*. Birmingham, AL.

<u>Birmingham News</u> - April 9 - 17, 23, 30, May 10, 1998. Birmingham, AL.

Binder, S and LM Sanderson, 1987: The Role of the Epidemiologist in

Natural Disasters. *Annals of Emergency Medicine* 16:9:1081-1084.
Birmingham Regional Planning Commission (BRPC), 1991: *Socioeconomic Data for Counties in the Birmingham Region*. Birmingham, AL. 47 p.
Brenner, SA and EK Noji, 1995: Tornado Injuries as Related to Housing in the Plainfield Tornado. *International Journal of Epidemiology* 24:1:144.
Burnham, MW, 1992: *Cry Wolf - Repeated Warnings Without Events*. Hydrologic Engineering Center, University of California-Davis. 2 p.
Burt, JE and GM Barber, 1996: *Elementary Statistics for Geographers*, 2nd ed. Guilford Press, New York, 640 p.
Centers for Disease Control (CDC), 1986: Tornado Disaster - Ohio/Pennsylvania. *Morbidity and Mortality Weekly Report* 35:233-235.
Carroll, R, 1998: A Killer Tornado at Night. *Southern Building* Jul/Aug: 4-5.
Carter, AO, ME Millson and DE Allen, 1989: Epidemiologic Study of Deaths and Injuries Due to Tornadoes. *American Journal of Epidemiology* 130: 129-1218.
Duclos, PJ and RT Ing, 1989: Injuries and Risk Factors for Injuries from the May 29, 1982 Tornado, Marion, Illinois. *International Journal of Epidemiology* 18: 213-219.
Doswell, CE, III and AR Moller, 1998: Storm Spotting and Public Awareness Since the First Tornado Forecasts of 1948. *Weather and Forecasting* (submitted).
Drabek, TE, 1987: *Human System Responses to Disaster: An Inventory of Sociological Findings*. Springer-Verlag: New York, NY.
Drabek, TE and S Stevenson, 1971: When Disaster Strikes. *Journal of Applied Social Psychology* 2:187-203.
Fenneman, NM, 1946: *Physical Divisions of the United States*. (Map). US Geological Survey: Washington DC.
Glass, RI, RB Craven, DJ Bregman, BJ Stoll, N Horowitz, P Kerndt, and J Winkle, 1980: Injuries From the Wichita Falls Tornado: Implications for Prevention. *Science* 207: 734-738.
Grazulis, TP, 1993: *Significant Tornadoes, 1680-1991*. Environmental Films: St Johnsbury, VT. 1326 p.

Grazulis, TP, CA Doswell III, HE Brooks, and MD Biddle, 1998: A New Perspective of the Societal Impacts of North American Tornadoes Covering Two Centuries. *Preprints: 19th Conference on Severe Local Storms, Minneapolis, MN*. American Meteorological Society: pp. 196-199.
Grazulis, TP, 2000 (in press): *Tornadoes of the United States*. University of Oklahoma Press: Norman.
Gruntfest, E, 1987: "Warning Dissemination and Response With Short Lead-Times," in *Hazard Management - British and International Perspectives*. J Handmer (ed.). Geo Books: Norwich, UK. pp. 191-202.
Kessler, E and JT Lee, 1978: Distribution of the Tornado Threat in the United States. *Bulletin of the American Meteorological Society* 59:61-62.
Lillibridge, SA, 1997: "Tornadoes," in *The Public Health Consequences of Disasters*. EK Noji (ed.). Oxford University Press: New York, NY. pp. 228-244.
Linehan, U, 1957: *Tornado Deaths in the United States*. US Weather Bureau: Washington, DC.
Liu, S, L Quenemoen, J Malilay, E Noji, T Sinks, and J Mendlein, 1996: Assessment of a Severe Weather Warning System and Disaster Preparedness, Calhoun County, Alabama, 1994. *American Journal of Public Health* 86:87-89.
Marshall, TP, 1993 : "Lessons Learned From Analyzing Tornado Damage," in *The Tornado: Its Structure, Dynamics, Prediction, and Hazards*. C Church et al., (eds.). Monograph # 79. American Geophysical Union: Washington, DC. pp. 495-500.
Marshall, TP, 1999: "Wind Speeds and Damage in Tornadoes," presented at *N W S - Lubbock / Texas Tech University Severe Weather Conference 1999*. Lubbock, TX.
McAlester, V and L McAlester, 1988: *A Field Guide to American Houses*. Alfred Knopf Co: New York City. 525 p.
McCarthy, DM, 1993: Warning Operations in a Modernized NWS Forecast Office: Experiences at WSFO Norman, OK. Preprints - *17th Conference on Severe Local Storms, St. Louis, MO*. American Meteorological Society. pp. 371-374.

McDonald, JR, 1993: "Damage Mitigation and Occupant Safety," in *The Tornado: Its Structure, Dynamics, Prediction, and Hazards*. C Church et al., (eds.). Monograph # 79. American Geophysical Union: Washington, DC. pp. 523-528.
Missouri State Census Data Center, 1999. University of Missouri Website for 1990 Alabama Census Standard Extracts
http://www.oseda.missouri.edu/
NWS (National Weather Service), 1986: Natural Disaster Survey Report - *Ohio - Pennsylvania Tornadoes of May 31, 1985*. US Department of Commerce: Silver Spring, MD.
NWS, 1991a: Natural Disaster Survey Report - *The Wichita - Andover Kansas Tornadoes of April 26, 1991*. US Department of Commerce: Silver Spring, MD. p.
NWS, 1991b: Natural Disaster Survey Report - *The Plainfield - Crest Hill Tornado of August 28, 1990*. US Department of Commerce: Silver Spring, MD.
NWS, 1994: Natural Disaster Survey Report - *Southeastern United States Palm Sunday Tornado Outbreak of March 27, 1994*. US Department of Commerce: Silver Spring, MD.
NWS, 1997: NWS Service Assessment - *March 1, 1997 Arkansas Tornado Outbreak*. US Department of Commerce: Silver Spring, MD.
NWS, 1998a: NWS Service Assessment - *Central Texas Tornadoes of May 27, 1997*. US Department of Commerce: Silver Spring, MD.
NWS, 1998b: NWS Service Assessment - *Central Florida Tornado Outbreak, February 22/23, 1998*. US Department of Commerce: Silver Spring, MD.
NWS, 1998c: NWS Service Assessment - *Southeastern United States Tornadoes, April 8, 1998*. US Department of Commerce: Silver Spring, MD.
NWS, 1998d: NWS Service Assessment - *Spencer, South Dakota Tornado, May 30, 1998*. US Department of Commerce: Silver Spring, MD.
Perry, RW, MK Lindell, and MR Greene, 1982: Crisis Communications: Ethnic Differentials in Interpreting and Acting on Disaster Warnings. *Social Behavior and Personality* 10: 97-104.

Ruffner, JA and FE Bair (eds.), 1981: The Weather Almanac (3rd ed.). Gale Research: Detroit MI. p. 336. Sanderson, LM, 1989: "Tornadoes," in *The Public Health Consequences of Disasters* (2nd ed.). M Gregg, (ed.). Centers For Disease Control: Atlanta, GA. pp. 39-49.
Schmidlin, TW, 1993: "Tornado Fatalities in Ohio 1950-1989," in *The Tornado: Its Structure, Dynamics, Prediction, and Hazards*. C Church et al., (eds.). Monograph # 79. American Geophysical Union: Washington, DC. pp. 529-534.
Schmidlin, TW and PS King, 1995: Risk Factors for Death in the 27 March 1994 Georgia and Alabama Tornadoes. *Disasters* 19:170-177.
Schmidlin, TW and PS King, 1997: *Risk Factors for Death in the March 1, 1997 Arkansas Tornadoes*. Quick Response Report # 98. Natural Hazards Research Applications and Information Center: Boulder, CO. 6 p.
Schmidlin TW, PS King, BO Hammer, and Y Ono, 1998a: *Risk Factors for Death in the 22-23 February Florida Tornadoes*. Quick Response Report # 106. Natural Hazards Research Applications and Information Center: Boulder, CO 8 p.
Schmidlin TW, PS King, BO Hammer, and Y Ono, 1998b: Tornado Effects on Motor Vehicles. *Preprints: 19th Conference on Severe Local Storms*. *Minneapolis, MN*. pp. 428-430.
Sims, JH and DD Baumann, 1972: The Tornado Threat: Coping Styles of the North and South. *Science* 176:1386-1392.
Storm Prediction Center (SPC), 1999: Archival Data Website - http://www.nssl.noaa.gov/~spc/archive/products/
Tobin, GA and BE Montz, 1997: Natural Hazards: Explanation and Integration. Guilford: New York, NY 387 p.
Wilson CR and W Ferris (eds.), 1989: *Encyclopedia of Southern Culture*. University of North Carolina Press: Chapel Hill. 1634 p.
White, GF and JE Haas, 1975: *Assessment of Research on Natural Hazards*. MIT Press: Cambridge, MA. 242 p.

APPENDIX A: Definitions

Convective Outlook - A forecast containing the area(s) of expected thunderstorm occurrence and expected severity over the contiguous United States, issued several times daily by the SPC. The terms approaching, slight risk, moderate risk, and high risk, are used to describe severe thunderstorm potential. Local versions sometimes are prepared by local NWS offices.

Doppler Radar - Radar that can measure radial velocity, the instantaneous component of motion parallel to the radar beam (i.e., toward or away from the radar antenna).

High Risk (of severe thunderstorms) - Severe weather is expected to affect more than 10 percent of the area. A high risk is rare, and implies an unusually dangerous situation and usually the possibility of a major severe weather outbreak (see *convective outlook*.)

Moderate Risk (of severe thunderstorms) - Severe thunderstorms are expected to affect between 5 and 10 percent of the area. A moderate risk indicates the possibility of a significant severe weather episode (see *convective outlook*).

Slight Risk (of severe thunderstorms) - Severe thunderstorms are expected to affect between 2 and 5 percent of the area. A slight risk generally implies that severe weather events are expected to be isolated (see *convective outlook*).

Tornado - A violently rotating column of air in contact with the ground and extending from the base of a thunderstorm. A condensation funnel does not need to reach to the ground for a tornado to be present; a debris cloud beneath a thunderstorm is all that is needed to confirm the presence of a tornado, even in the total absence of a condensation funnel.

Tornado Warning - issued by the National Weather Service or local emergency agencies when a tornado has been sighted by spotters or is indicated by NWS weather radar.

Tornado Watch - issued by the Storm Prediction Center or National Weather Service when tornadoes are possible in your area. Remain alert for approaching storms. This is time to remind family members where the safest places within your home are located, and listen to the radio or television for further developments.

APPENDIX B: Track and Area Map

APPENDIX C: Convective Outlook

STORM PREDICTION CENTER DAY 1 CONVECTIVE OUTLOOK

VALID 980408/1500 - 980409/1200 (1000 AM CDT APR 8, 1998 - 0700 AM CDT APR 9, 1998)

Parts not relevant to Southeastern United States Omitted. Emphasis Added.

ZCZC MKCSWODY1 000 COR
ACUS1 KMKC 081443
CONVECTIVE OUTLOOK...REF AFOS NMCGPH940
REF WW NUMBER 0183...VALID TIL 1900Z
THERE IS A HIGH RISK OF SEVERE THUNDERSTORMS THIS AFTERNOON AND EARLY TONIGHT ACROSS PARTS OF NORTHERN MISSISSIPPI...NORTHERN AND CENTRAL ALABAMA...NORTHERN GEORGIA AND SOUTHERN TENNESSEE. THIS AREA IS TO THE RIGHT OF A LINE FROM 35 SSE MKL 40 WSW CSV 35 WSW TYS 35 SSW 50 NW AND 20 S AND 30 E LGC 20 W AUO 35 SW CKL 45 ESE GWO 30 SE UOX 35 SSE MKL.

THERE IS A MODERATE RISK OF SEVERE THUNDERSTORMS THIS AFTERNOON AND TONIGHT ACROSS MUCH OF MISSISSIPPI...SOUTHERN ALABAMA...CENTRAL GEORGIA...CENTRAL AND WESTERN NORTH CAROLINA AND SOUTH CAROLINA...MUCH OF EASTERN AND CENTRAL

TENNESSEE NORTH OF THE HIGH RISK AREA. THIS AREA IS TO THE RIGHT OF A LINE FROM 35 N NCB 30 SW GWO 15 ESE MEM TO MKL TO BNA 20 ENE HSS 30 NNW GSO 10 NW RDU 15 E FAY TO FLO 35 ENE DHN 35 NNE MOB 35 ESE MCB 35 N MCB.
(SLIGHT RISK AND GENERAL THUNDERSTORM OUTLOOK AREA OMITTED)

...SIGNIFICANT SEVERE WEATHER OUTBREAK EXPECTED TODAY OVER MUCH OF THE SOUTHEASTERN US. A PUBLIC SEVERE WEATHER OUTLOOK WILL BE ISSUED AROUND 16Z.

...SEVERE THUNDERSTORM DISCUSSION...

POTENT SEVERE THUNDERSTORM PATTERN HAS EVOLVED OVER SOUTHEASTERN US WITH MARKED INCREASE IN INSTABILITY OVERNIGHT INTO THE AREA AHEAD OF STRONG UPPER SHORTWAVE TROUGH AND ASSOCIATED MID AND UPPER JET. SITUATION COMPLEX WITH SEVERE THUNDERSTORMS UNDERWAY WITH IMPRESSIVE BOW ECHO CURRENTLY MOVING INTO NORTHERN MISSISSIPPI AND ISOLATED SEVERE STORMS ALONG GULF COAST. MODELS AGREE SOMEWHAT THAT A MORE ORGANIZED SURFACE LOW WILL DEVELOP THIS AFTERNOON VICINITY OF TENNESSEE / ALABAMA BORDER AND DEEPEN NORTHEASTWARD TONIGHT. WITH **WIDESPREAD MODERATE INSTABILITY AND STRONG MID AND UPPER WINDS, CONDITIONS WILL DEVELOP BY MID AFTERNOON FOR SUPERCELLS AND TORNADOES ALONG AND AHEAD OF THE RAPIDLY MOVING LINE OF STORMS NOW MOVING INTO NORTHERN MISSISSIPPI**. THIS IS REFLECTED IN THE HIGH RISK WHICH WAS SHIFTED EASTWARD INTO GEORGIA AND NORTH-WESTWARD INTO SOUTHERN TENNESSEE FOR THIS AFTERNOON AND EVENING.

...HALES / REHBEIN...04/08/98

APPENDIX D : TORNADO WATCH

Tornado Watch #194

STORM PREDICTION CENTER TORNADO WATCH

VALID 980409/0030 - 980409/0700 (0730PM CDT 08 APR 98 - 0200AM CDT 09 APR 98)

Emphasis Added

BULLETIN - IMMEDIATE BROADCAST REQUESTED

TORNADO WATCH NUMBER 194 STORM PREDICTION CENTER NORMAN OK 653 PM CDT WED APR 8 1998

THE STORM PREDICTION CENTER HAS ISSUED A TORNADO WATCH FOR PORTIONS OF

NORTHERN AND CENTRAL MISSISSIPPI

NORTHERN AND CENTRAL ALABAMA

EFFECTIVE THIS WEDNESDAY NIGHT AND THURSDAY MORNING FROM 730 PM UNTIL 200 AM CDT.

THIS IS A PARTICULARLY DANGEROUS SITUATION WITH THE POSSIBILITY OF VERY DAMAGING TORNADOES. ALSO. . . LARGE HAIL TO 2 INCHES IN DIAMETER. . . THUNDERSTORM WIND GUSTS TO 80 MPH . . . AND DANGEROUS LIGHTNING ARE POSSIBLE IN THESE AREAS.

THE TORNADO WATCH AREA IS ALONG AND 95 STATUTE MILES EITHER SIDE OF A LINE FROM 20 MILES WEST-NORTHWEST OF GREENWOOD MISSISSIPPI TO 35 MILES EAST-NORTHEAST OF ANNISTON ALABAMA.

REMEMBER . . . A TORNADO WATCH MEANS CONDITIONS ARE FAVORABLE FOR TORNADOES AND SEVERE THUNDERSTORMS IN AND CLOSE TO THE WATCH AREA. PERSONS IN THESE AREAS SHOULD BE ON THE LOOKOUT FOR THREATENING WEATHER CONDITIONS AND LISTEN FOR LATER STATEMENTS AND POSSIBLE WARNINGS.

OTHER WATCH INFORMATION . . . THIS TORNADO WATCH REPLACES TORNADO WATCH NUMBER 188. WATCH NUMBER 188 WILL NOT BE IN EFFECT AFTER 730 PM CDT. CONTINUE . . . WW 187 . . .WW 189 . . . WW 190 . . . WW 192 . . . WW 193. . .

DISCUSSION . . . THUNDERSTORM CLUSTER WITH A HISTORY OF TORNADOES AND SEVERE WEATHER WILL CONTINUE OVER WATCH AREA AS AIR MASS VERY UNSTABLE WITH CAPES ABOVE 3000 J/KG. 90 KT MID LEVEL SPEED MAX WILL MOVE ACROSS REGION AHEAD OF SURFACE FRONT AND VIGOROUS UPPER TROUGH THUS MAINTAINING POTENTIAL OF TORNADIC SUPERCELLS.
AVIATION . . . TORNADOES AND A FEW SEVERE THUNDERSTORMS WITH HAIL SURFACE AND ALOFT TO 2 INCHES. EXTREME TURBULENCE AND SURFACE WIND GUSTS TO 70 KTS. A FEW CUMULONIMBI WITH MAXIMUM TOPS TO 500. MEAN STORM MOTION VECTOR 24040.
. . . ROGASH

APPENDIX E: NWS WARNING TEXT

(Jefferson County Tornado Warnings Only - Emphasis Added).

BULLETIN - EAS ACTIVATION REQUESTED
TORNADO WARNING
NATIONAL WEATHER SERVICE BIRMINGHAM ALABAMA
745 PM CDT WED APR 8 1998
THE NATIONAL WEATHER SERVICE IN BIRMINGHAM AL HAS ISSUED A **TORNADO WARNING EFFECTIVE UNTIL 835 PM CDT** FOR PEOPLE IN THE FOLLOWING LOCATION. . .
IN CENTRAL ALABAMA . . .
. . . JEFFERSON COUNTY . . .
AT 743 PM CDT. . . WEATHER RADAR SHOWED A **POSSIBLE TORNADO MOVING OUT OF TUSCALOOSA COUNTY INTO SOUTHWEST JEFFERSON COUNTY. THE STORM WAS MOVING EAST NORTHEAST AT 40 MILES PER HOUR AND WILL MOVE THROUGH THE ALLIANCE - OAK GROVE**

AREAS. THIS STORM HAS BEEN ASSOCIATED WITH SIGNIFICANT DAMAGE IN TUSCALOOSA COUNTY.
«Call to Action»
THIS IS A DANGEROUS STORM SITUATION. ACT QUICKLY. IF YOU ARE IN THE PATH OF THIS TORNADO MOVE TO A PLACE OF SAFETY BELOW GROUND IF AVAILABLE. OTHERWISE . . . GO TO A SMALL INTERIOR ROOM ON THE LOWEST FLOOR POSSIBLE. AVOID WINDOWS. ABANDON CARS AND MOBILE HOMES FOR A REINFORCED BUILDING OR GET INTO A DITCH OR CULVERT.
****

BULLETIN - EAS ACTIVATION REQUESTED TORNADO WARNING NATIONAL WEATHER SERVICE BIRMINGHAM ALABAMA 832 PM CDT WED APR 8 1998
THE NATIONAL WEATHER SERVICE IN BIRMINGHAM AL HAS ISSUED **A TORNADO WARNING EFFECTIVE UNTIL 905 PM CDT** FOR PEOPLE IN THE FOLLOWING LOCATION. . .
IN CENTRAL ALABAMA . . .
. . . JEFFERSON COUNTY . . .
AT 831 PM CDT. . . WEATHER RADAR SHOWED A **TORNADO LOCATED ABOUT 3 MILES WEST OF THE BIRMINGHAM AIRPORT MOVING EAST AT 40 MILES PER HOUR**. THIS WARNING EXTENDS THE PRIOR WARNING FOR JEFFERSON COUNTY. THERE HAVE BEEN **NUMEROUS REPORTS OF DAMAGE FROM THIS STORM**.
«CALL TO ACTION»
THIS IS A DANGEROUS STORM SITUATION. ACT QUICKLY. IF YOU ARE IN THE PATH OF THIS TORNADO MOVE TO A PLACE OF SAFETY BELOW GROUND IF AVAILABLE. OTHERWISE . . . GO TO A SMALL INTERIOR ROOM ON THE LOWEST FLOOR POSSIBLE. AVOID WINDOWS. ABANDON CARS AND MOBILE HOMES FOR A REINFORCED BUILDING OR GET INTO A DITCH OR CULVERT.

APPENDIX F: FUJITA DAMAGE INTENSITY SCALE

Fujita Scale (or F Scale) - A scale of wind damage intensity in which wind speeds are inferred from an analysis of wind damage:
F0 (weak) - 40- 72 mph, light damage - chimneys downed, tree branches broken
F1 (weak) - 73-112 mph, moderate damage - mobile homes pushed off foundation or overturned
F2 (strong) - 113-157 mph, considerable damage - mobile homes demolished, trees uprooted
F3 (strong) - 158-206 mph, severe damage - roofs and walls torn down, trains, cars thrown
F4 (violent) - 207-260 mph, devastating damage - walls leveled, homes off foundations
F5 (violent) - 261-318 mph, (rare) incredible damage - homes, autos thrown > 100 meters

APPENDIX G: ARCHITECTURE

APPENDIX H: PHOTOGRAPHS

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