# RESEARCH BASED GUIDELINES FOR DECISION MAKING IN HURRICANE CONDITIONS: WHEN DO WE STOP RESPONDING?

EXECUTIVE ANALYSIS OF FIRE SERVICE OPERATIONS IN EMERGENCY MANAGEMENT

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## ABSTRACT

Orange County lies in East Central Florida but its nearest point to the coast is fifteen miles. In spite of this distance, Orange County has the potential to experience significant effects from a tropical storm or hurricane. The problem was that, although Orange County, Florida is potentially subject to significant effects of tropical storms and hurricanes, the Orange County Fire Rescue Department (OCFRD) did not have clear guidelines for its officers and administrators to use in the decision making process when faced with ceasing emergency incident responses due to their approach. The department last updated the Disaster Operations Guidelines pertaining to hurricanes four years ago. The update failed to take into account new technology available since then. It also used subjective terms which OCFRD personnel might have trouble interpreting properly since few had experienced a hurricane.

The purpose of this research was to provide Orange County Fire Rescue officers and administrators with research based information on wind and its effects to assist in decision making for scaling back and shutting down emergency incident responses as tropical storms or hurricanes approach. This was done through Disaster Operations Guidelines updates and the development and implementation of training.

Descriptive research was used to study the present situation and formulate a basis for a course of action to shape the future. Action research attempted to solve the problem by developing a product based on new information and technologies to guide and improve organizational performance.

This paper addressed the following questions:

1. What wind criteria do fire service agencies use for ceasing emergency incident responses as tropical storms or hurricanes approach?

2. Does research support the chosen criteria as appropriate?

3. How can Orange County Fire Rescue use these findings to guide its officers and administrators in decision-making to cease emergency incident responses appropriately, when a tropical storm or hurricane threatens?

Information was collected through interviews with manufacturers' vendors, fire departments in hurricane prone areas, Orange County Emergency Management officials, and a power company representative. The literature review involved a general web search for information on wind effects and a search of the National Fire Academy's Learning Resource Center.

The author's original premise for this paper involved wind's effects on apparatus as a limiting factor to emergency incident responses as a tropical storm or hurricane approached. Supporting information, other than anecdotal, proved difficult to find. A previous applied research project pointed out that wind's effects on people and debris generation played a greater

role. That applied research project led to an expanded viewpoint as well as a recently completed scientific study on the effect of wind on emergency vehicles.

The result of the research included science supported information on the effects of wind on apparatus, people, and debris generation with people being the most susceptible. It also found new technology available through the Orange County Office of Emergency Management: computer-linked weather stations in each fire station allowing local monitoring of current conditions. Recommendations resulting include updating Orange County Fire Rescue's Disaster Operations Guidelines to take into account the new technology and training for officers and administrators on specifics of wind effects to assist them in the decision making process.

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## INTRODUCTION

Located in east Central Florida, Orange County is not a coastal community. However, with its eastern boundary only fifteen miles from the Atlantic and its farthest point only sixty miles from the coast, the entire jurisdiction is susceptible to the fierce weather conditions accompanying a tropical storm or hurricane. The problem is that, although Orange County, Florida is potentially subject to significant effects of tropical storms and hurricanes, the Orange County Fire Rescue Department (OCFRD) does not have clear guidelines for its officers and administrators to use in the decision making process when faced with ceasing emergency incident responses due to their approach. The purpose of this research is to provide Orange County Fire Rescue officers and administrators with research based information on wind and its effects to assist in decision making for scaling back and shutting down emergency incident responses as tropical storms or hurricanes approach. This will be done through Disaster Operations Guidelines updates and the development and implementation of training.

Descriptive research was used to study the present situation and formulate a basis for a course of action to shape the future. Action research attempts to solve the problem by developing a product based on new information and technologies to guide and improve organizational performance (National Fire Academy [NFA], 1998, pp. 3-26, 3-27, 3-28).

This paper will address the following questions:

1. What wind criteria do fire service agencies use for ceasing emergency incident responses as tropical storms or hurricanes approach?

2. Does research support the chosen criteria as appropriate?

3. How can Orange County Fire Rescue use these findings to guide its officers and administrators in decision-making to cease emergency incident responses appropriately, when a tropical storm or hurricane threatens?

## BACKGROUND AND SIGNIFICANCE

The Orange County Fire Rescue Department provides fire and emergency medical services to the unincorporated portions of Orange County, Florida with contracts to provide service to four small municipalities. The cities of Orlando, Apopka, Winter Park, Maitland, Ocoee, and Winter Garden, along with the Reedy Creek Improvement District (encompassing the Walt Disney World property) have their own fire departments.

Founded by the consolidation of 14 fire control districts in 1981, OCFRD is now one of the largest fire departments in the state. It employs over 1000 personnel and has 37 stations covering approximately 1000 square miles. It provides fire suppression, advance life support emergency medical services (EMS) including transport, hazardous materials and specialty rescue responses, and fire loss management including inspections and prevention. OCFRD also coordinates county wide emergency management serving over 1.6 million residents and roughly 43 million visitors a year (Newman, 2002).

Although Orange County lies fifteen miles from the Atlantic at its closest point and is not subject to storm surge, it is still subject to the effects of damaging winds from tropical storms and hurricanes (Orange County Fire Rescue [OCFRD], 2000). Hurricanes frequently cover large areas, with effects up to 200 miles from the center of the storm and hurricane force winds 50 miles from the eye (Hoecherl, 2003). They move ashore maintaining their damaging effects sometimes for thousands of miles. On September 21, 1938 an unnamed storm (hurricanes did not receive names until 1953) came ashore on Long Island, New York. It was 500 miles wide and blew down entire forests as far inland as the White Mountains of New Hampshire and the Green Mountains of Vermont. In 1954, Hurricane Hazel made landfall near Myrtle Beach, South Carolina. She remained a strong storm for nearly 900 miles and, after crossing Lake Ontario, produced wind gusts of 110 mph and 8 inches of rain that killed 69 people near Toronto (Sheets & Williams, 2001).

When Hurricane Alicia struck Houston, 50 miles inland, on August 16, 1983, her winds blew gravel like bullets from skyscraper roofs breaking many windows designed to withstand the winds but not the flying debris (Sheets & Williams, 2001).

Paul Mauger, Deputy Chief of Chesterfield, Virginia Fire & E.M.S. reported that during Hurricane Isabel, in September, 2003, they experienced 40 to 50 mph sustained winds with gusts to 70 mph. Chesterfield lies two hours from the coast (Mauger, personal communication, June 9, 2004).

Central Florida had its own recent brush with disaster. In September 1999, Hurricane Floyd bore down on the state. It was a huge storm, almost dwarfing the southeastern United States in satellite photographs. With 150-mph winds, it was larger and stronger than Andrew was. On the night of September 15, its track projected its landfall in Brevard County, Florida, home of the Kennedy Space Center and fifteen miles from Orange County. Meteorologists measured wind gusts of 185 mph (www.members.aol.com/smplepage/Floyd.html). Ninety-five nautical miles east of Cape Canaveral it turned north, coming ashore in North Carolina the next day, weaker but still causing 40 deaths and $1 billion in damage. The uncertainty of its track led to the largest peacetime evacuation in United States history with 3 million people all along the southeast coast fleeing inland and to higher ground (www.hurricanehunters.com/floyd.htm).

When Hurricane Floyd occurred, the author held the position of assistant to the deputy chief of operations. The afternoon before Floyd's projected landfall, the author was present during a senior staff meeting where they discussed at what point to cease emergency responses. The chiefs considered various wind speeds with no apparent basis other than what others used. It surprised the author that they had not decided the matter previously and that wind speeds considered had no researched backing. In addition, personnel had no training in weather observations and no way to obtain localized conditions. This experience provided impetus for this applied research project.

Although Central Florida has not received the direct impact of a hurricane in years, the threat remains. According to a research article from the National Hurricane Center's online library, twenty four of the sixty five deadliest, costliest, and most intense hurricanes to affect the United States in the past century struck the Florida peninsula (Hoecherl, 2003). Dave Marsh, WESH NewsChannel 2, Orlando Chief Meteorologist, reports that in the last half century Hurricanes Erin, David, Gladys, and Donna have all directly threatened the Orlando area (Marsh, 2004).

Based on years of research, Sheets and Williams present the probabilities of any hurricane and of a strong hurricane with winds of 111 mph or greater passing within 75 miles of various U.S. coastal communities in any given year.

| | Any | Strong |
|---|---|---|
| Cocoa Beach, FL | 14.3 | 4.2 |
| Cape Canaveral, FL | 14.3 | 3.9 |
| Daytona Beach, FL | 11.1 | 2.6 |
| Ft. Lauderdale, FL | 27.0 | 10.0 (2001) |

This research demonstrates the need for Central Florida emergency services to plan and prepare for potentially a significant impact from a tropical storm. In addition to direct effects from a storm, due to its size, location, and provisions of the state-wide disaster plan, planners anticipate the Metro Orlando area receiving up to 1 million evacuees (Orange County Sheriff's Office [OCSO], 2003) to protect in addition to its residents.

Gratz, in his book *Fire Department Management: Scope and Method,* calls pre-planning an essential management responsibility. He points out that it has succeeded with fires but is underutilized with disasters, perhaps due to their infrequent occurrence (1985). National Fire Protection Association (NFPA) Standard 1600 charges local government with the responsibility for an emergency management plan including a mitigation plan to eliminate hazards or reduce their impact (2000). NFPA Standard 1201 (2000) echoes the charge stating:

> The fire department shall have a viable plan for the protection of the community from the anticipated risks associated with natural and technological emergencies that are more severe than the scale of most fires and hazardous materials incidents and have the potential to exceed the resource capabilities of a particular jurisdiction (p. 1201-20).

Historically, OCFRD used one criterion at one point in time to stop incident responses. "At such time as wind speeds reach sustained speeds of 50 miles per hour, Communications will issue and [*sic*] alert tone and staff page announcing that all operations will cease until the storm passes" (OCFRD, n.d., p. 47). Although there is a provision for communications system failure stating that Company Officers and Field Commanders should use their best judgement (OCFRD, n.d.), it neglects to take into account the effects of wind gusts or the fact that different portions of the county will receive the storm's impact at different times. Yet this same, single, decision driving parameter occurs in hurricane plans all along the east coast of the United States (Weaver, 1997).

A policy statement issued by the American Meteorological Society in September, 2000 concludes with, "One out of every five people in the United States is at direct risk of hurricane impact and the number is growing daily" (Sheets & Williams, 2001, p. 280). Yet few, including OCFRD employees, have actually experienced one.

Until recently, little scientific research existed to assist fire service officers and administrators in deciding when to cease emergency incident responses as a hurricane approached. They had to rely on their experience and subjective evaluation of the risk (Pinelli & Subramanian, 2003). However, the last hurricane to directly affect Orlando was Erin in 1995 with 80 mph winds (Ask Dave, 2004). OCFRD has hired over half its current personnel since that time. Even its officers, with more time on the department, have little to no experience with hurricanes.

OCFRD currently has rather broad decision-making criterion for scaling back and ceasing responses to emergency incidents. It asks officers and administrators to consider the conditions created by high winds, heavy rains, obstructed roads, flooded streets, poor visibility, and flying debris (Appendix A). The Disaster Operations Guidelines ask them to evaluate the safety of responding units and personnel based on subjective observations with no objective criteria as guidelines. Typical fire service personnel take risks others would not. Many of these risks are calculated and based on training and experience. OCFRD lacks hurricane experience. Therefore, it is incumbent upon the agency to provide the best training possible based on the best research available to reduce the uncalculated risk.

To provide accurate, regional information, readings must be taken throughout the jurisdiction (Weaver, 1997). As of early 2004, all OCFRD fire stations have computer-linked weather stations. Any station can view the current conditions at any other station, overseen by the Office of Emergency Management. The Disaster Operations Procedures in place (Appendix A) fail to consider this new technology.

According to Hoecherl, the International City Management Association's (ICMA) book *Emergency Management: Principles and Practices for Local Government* calls preparedness a continuous process and points out the necessity to keep plans current stating that an out of date plan may be worse than no plan at all (2003). In addition, at the conclusion of his Applied Research Project, Hoecherl admonishes others to learn from agencies that have experienced a direct hit from a hurricane (2003).

Information and new technology are available. To serve the public and its personnel best, OCFRD needs to integrate it into its disaster plan and training.

The problem of inadequate decision making guidelines for tropical storms and hurricanes relates to the Executive Fire Officer Program's *Executive Analysis of Fire Service Operations in Emergency Management* course in a number of ways. It addresses Emergency Operations, Community Risk Assessment, Capability Assessment, and coordination with the Emergency Operations Center. It also relates to the basic tenets of the Executive Fire Officer Program itself in that it involves a move from being reactive to proactive and emphasizes risk reduction (NFA, 1999).

This paper relates to the United States Fire Administration's operational objective of promoting within communities a comprehensive, multi-hazard risk-reduction plan led by the fire service (United States Fire Administration [USFA], 2002). Any program that develops a fire officer's assessment skills and provides him/her with tools for sound judgement contributes to risk reduction.

## LITERATURE REVIEW

1. What wind criteria do fire service agencies use for ceasing emergency incident responses as tropical storms or hurricanes approach?

The literature review revealed few guidelines for ceasing emergency incident responses when a hurricane approaches. Most agencies with the potential to experience the impact of a hurricane have a policy but the majority cite a specific wind speed for the trigger point. In some cases, the wind speed chosen resulted from experience but none specify any scientific data for its selection and few provide broader guidelines.

It appears that the majority of fire service agencies use 50-mph sustained winds as the trigger point for ceasing emergency incident responses. In his research, Weaver found this criteria "from Miami, Florida to Hampton Beach, Virginia" (1997, p. 3). During Hurricane Andrew, Metro-Dade Fire Department's internal procedure also called for terminating responses at 50 mph (Paulison, Montes, Castillo, & Brown, 1993). Until Hurricane Isabel struck in September of 2003, Virginia Beach, Virginia's policy had 55 mph sustained winds as its trigger point. However, experience with the storm caused them to back that off to 50 mph (Poulin, personal communication, June 18, 2004). Ft. Lauderdale gives its officers more discretion allowing them to base a decision on weather conditions but provides no specific guidelines for doing so (Ft. Lauderdale, 1993).

Hurricane Isabel struck the state of Virginia in September, 2003. In an interview, Deputy Chief Paul Mauger of the Chesterfield, Virginia Fire Department related his recent personal experiences. It was interesting to note that, in this case, the fire service and law enforcement defined the risk/benefit of responding in high winds very differently leading to some significant dilemmas (Mauger, personal communication, June 9, 2004).

2. Does research support the chosen criteria as appropriate?

Research for this paper began with interviews with apparatus vendors at the Fire Rescue East Conference in Jacksonville, Florida in January, 2004 (Appendix B). The conference provided an opportunity to speak personally with representatives of a large number of apparatus manufacturers in a very short period. The vendors universally reported that, to their knowledge, winds up to hurricane strength did not adversely affect the handling of their vehicles with a cautious driver. They emphasized that the same did not hold true for elevated aerial apparatus, which should not be raised in winds above 45 mph (Aiken, personal communication, June 18, 2004).

Jeff Aiken, Engineering Manager for the apparatus manufacturer Emergency One, one of the largest apparatus manufactures in the southeast United States, reported that he did not know of any research specifically addressing wind effects on fire apparatus handling but suggested looking into work done on class 8 tractor/trailers as cross winds sometimes blow them off the road (Aiken, personal communication, June 17, 2004). Unfortunately, attempts to obtain specific information from the trucking industry proved disappointing.

The value of seeking further information from the trucking industry came into question when one considered that most of it looks at winds on vehicles traveling on highways at constant speeds and in straight lines. Work done gives little consideration to changes in vehicle or wind speed or direction, factors readily present in emergency incident responses during tropical wind storms (Weaver, 1997). However, Pinelli and Subramanian (2003) specifically addressed the issue of wind effects on emergency vehicles with their variations in speed and travel direction as well as in size and style.

At this point the question remained, is vehicle performance the critical factor in the selection of this benchmark? In addition, is the benchmark of 50 mph appropriate? John Harris, Engineer of Structure Maintenance for the Florida Department of Transportation, reported that at 40-mph transverse winds, most vehicles become unstable, particularly trucks and high profile vehicles. However, FDOT leaves the decision on when to shut traffic down, particularly on coastal high arch bridges, to law enforcement agencies including the Florida Highway Patrol and United States Coast Guard (Harris, personal communication, January 7, 2004).

One work discovered specifically addressed the subject. For one of his Applied Research Projects at the National Fire Academy, Carl Weaver of the Brevard Community College in Cocoa, Florida wrote "Establishing Criteria to Determine Fire Department Operations During High Wind Situations." In his paper, he both provided suggestions for decision-making criteria and posed new questions. Through his research he found that most emergency vehicles can operate safely with 50 mph sustained winds but that those winds have detrimental effects on human performance and produce dangerous debris (1997). This expanded viewpoint led to an extremely productive interview with Weaver. He provide contact information for Pinelli and Subramanian (2003) whose work appears to be the first to scientifically address wind effects on emergency vehicles but is so recent that its current distribution remains limited (Weaver, personal communication, February 12, 2004).

Weaver's paper led to a review of information on wind effects on people's ability to function safely and effectively. In his book *Hurricanes!* Chaston provided a personal account of the effects of winds on people. He journeyed to the top of Mt. Washington, New Hampshire, which is known for experiencing extreme winds. He stated that he tried to stand at the summit in sustained winds over 100 mph. He could not and he was thankful there was no debris present to pelt him. Based on this experience he postulated that windblown debris from a hurricane such as trash cans, roofing material and tree limbs could become deadly missiles (Chaston, 1996).

Durgin found that at wind speeds of Beaufort 9 or greater (47 to 54 mph) people have difficulty walking and working (Durgin, 1990). Melbourne concurred pointing out that pedestrian activities are dangerous and unacceptable at 54 mph but that wind gusts over two seconds long are more dangerous and can knock a person down (Melbourne, 1978).

Even what most would consider a light wind can have detrimental effects. A study cited in a 1990 issue of *Journal of Wind Engineering and Industrial Aerodynamics* reported that gusts of as little as 18 mph could pull items from people's hands (Williams, Hunter, & Waechter, 1990).

In addition, Weaver's work led to a consideration of debris, both as a windborne hazard and as impedance to response. Many have written on the destructive capacity of tornadoes and much exists on post storm debris handling and removal. Finding information on tropical windstorm debris generation proved difficult. Most relates specifically to building failures (Sheets & Williams, 2001). For the purpose of this study, building failures were looked at only from the perspective that they lead to debris generation and impedance to emergency incident response.

For example, conventional roof shingles fail at wind speeds of less than 65 mph. (Pielke, 1997). While the impact of Hurricane Andrew resulted in much more stringent building codes with higher failure thresholds, much area construction took place pre-Andrew. In addition, codes do not guarantee the quality of construction (Weaver, 1997).

Researchers have found that hurricane winds generate life threatening debris even inland from the coast (Pielke, 1997). For example, in August, 1983, the American Society of Civil Engineers met to discuss the effects of Hurricane Alicia, which hit the Texas coastline. They found that of the hundreds of windows broken in Houston, 50 miles inland, few broke due to wind pressure. Most were shattered by gravel blown from nearby rooftops. Engineers developed the windows to withstand hurricane winds, not flying gravel. Some of those that did not break were sucked off whole (Sheets & Williams, 2001).

In addition to the preceding information on building failures, one can project debris generation by inference from the Beaufort (Appendix C) and other wind scales. Brinkman (1975), Erickson (1988), and Penwarden (1975) all present interpretations on the destructive effects on vegetation of various wind speeds.

3. How can Orange County Fire Rescue use these findings to guide its officers and administrators in decision-making to cease emergency incident responses appropriately, when a tropical storm or hurricane threatens?

OCFRD must consider wind's effects on its apparatus and personnel as well as the debris it generates. Pinelli and Subramanian (2003) provide research based guidelines for various emergency vehicle types. Chaston (1996), Durgin (1990), Melbourne (1978), and others all studied wind effects on human performance. And Pielke (1997), Erickson (1988), Brinkman (1975), and Penwarden (1975) all present information on debris generation.

In addition, OCFRD must consider how it will address hazards and obstacles it will likely encounter responding in a storm. Progress Energy, Florida supplies electric power to much of the state. David Sauerman, Resource Foreman for Distribution Operations and Support related his company's capabilities and policies when dealing with a major storm. With a goal to provide maximum service without unnecessarily endangering its personnel or equipment, Progress Energy can remotely shut down power to damaged areas but will continue to send crews out to confirm lines are de-energized as long as they can safely do so (Sauerman, personal communication, July 12, 2004).

An interview with Deputy Chief Renzy Hanshaw, emergency manager for Orange County, Florida, provided region specific information about past hurricane experiences and the new technology to track weather fire station by fire station. This new technology could prove key to balancing the risk/benefit of emergency incident responses neighborhood by neighborhood as a storm moves across the county (Hanshaw, personal communication, March 9, 2004).

Important lessons from the literature review include the fact that maximum wind gusts in a storm are always stronger that the one minute average sustained wind speed. But wind meteorologists report wind speed at its one minute average. Therefore, even with a relatively low and acceptable wind speed reported, gusts can create severe damage and danger (Pielke, 1997).

In addition, one must consider that the force exerted by wind is proportional to the square of its speed. In other words, a 100 mph wind exerts four times the force of a 50 mph wind (Sheet & Williams, 2001).

Even if one is aware of the actual ambient wind speed for a particular area, obstacles easily channel and deflect wind which may produce extreme variations (Brinkman, 1975).

## Summary

The original research hypothesis for this paper focused on wind effects on emergency vehicles as the potential limiting factor for responses but Weaver's paper (1997) influenced broadening the considerations to include wind effects on people and debris generation.

The findings of Melbourne (1978), Durgin (1990), and Williams et al. (1990) pointed to wind's effects on people as being more of a limiting factor than vehicles.

The interview with Hanshaw (personal communication March 9, 2004) introduced the concept of using the new technology of the fire station weather stations as decision making tools for selecting a time to take shelter.

All of these findings played a major, unexpected role in the training "Quick Drill" ultimately developed.

## PROCEDURES

Research began at the Fire Rescue East Conference in Jacksonville, Florida January 23-24, 2004. The conference, sponsored by the Florida Fire Chiefs' Association, attracts chief officers and fire administrators from throughout the southeastern United States. A large vendor show accompanies the conference. All apparatus vendors, and those with related services such as insurance, were interviewed on whether or not their company had done any research on wind effects on apparatus. They were also asked if they knew of any sources for information on the subject. All fourteen vendors present provided interviews.

In addition, informal conversations held with chief officers from coastal communities who attended the conference documented their standard operating procedures and experiences.

The results of the interviews with the vendors and chiefs led to some Internet research based on their leads including the Federal Highway Administration, Texas Transportation Institute, and other trucking industry websites. They proved not to have pertinent information or to required membership to conduct a site search.

Information was sought through personal contacts from other departments within range of hurricane impacts, particularly on their practices, the rationale behind those practices, and their experiences with storms, if they had any. Mauger (personal communication, June 9, 2004) provided a valuable interview. Others simply sent a copy of their response plan, most of which either provided a fixed wind speed stopping point or allowed subjective discretion in decision making.

The literature review took place primarily after the interviews and was shaped by dilemmas they revealed.

A web search of the National Fire Academy's Learning Resource Center (LRC) led to some beneficial information. The LRC holds an extensive and unique collection of fire and emergency service publications including many previous Applied Research Projects. The LRC search produced Weaver's paper which significantly shaped this paper. The original premise of this applied research project involved wind effects on emergency vehicles as the limiting factor in emergency responses during tropical storms. Weaver pointed out that, although wind may affect emergency vehicles significantly, one must also consider its effects on people and debris generation (1997). A subsequent interview with Weaver in February of 2004 led to Pinelli and Subramanian's recent work which specifically and scientifically address the effect of wind on emergency vehicles (2003).

Additional websites consulted included the National Hurricane Center, the Louisiana State University Hurricane Center, and National Oceanic and Atmospheric Administration. A general web search under "wind effects" led to several universities with wind research centers.The search provided both background information on wind and some specifics on its effects on vehicles, people, and debris.

Pertinent information was also collected from Orange County Fire Rescue documents including past and current disaster operations guidelines and historical documents. Supplemental information came from the author's personal library including Sheets and Williams work (2001) and the Orange County Sheriff's Office Hurricane Preparedness Plan (2003).

In addition to the vendors and chiefs previously noted, interviews with key local emergency management officials, including Renzy Hanshaw, Orange County's Emergency Manager, provided additional policy and historical information. Hanshaw also provided information on the newly installed weather stations in each fire station and their capabilities (personal communication).

The "Guidelines for Conducting Personal Interviews" Section of the *Executive Development Student Manual* provided guidance when speaking with the individuals consulted (NFA, 1998). Each was asked key questions specific to their areas of knowledge but most also supplied additional insight into the problem either by posing related questions or expanding on the information provided.

The definition of action research is "taking action to solve an existing problem and/or to improve performance" and the purpose is to "apply new information…to actual organizational problem(s)" (NFA, 1998, p. 3-28). Providing officers and administrators with solid decision-making criteria based on new research data and technologies available is the goal of this research project. The department based the current approach on information readily available and available at the time. The plan has not been tested because no significant storms have made landfall near Central Florida since Hurricane Erin in 1995 (28). Considering recent progress will provide a better foundation.

## Limitations

This paper has a number of limitations. Many relate to scope. It does not consider a plan for the resumption of emergency incident responses following the passage of a storm. Agencies must have a plan in place. However, due to considerations of the well being of personnel, damage assessment, debris clearance, infrastructure collapse, and many other issues likely to be present, it is beyond the scope of this paper.

It does not take the performance of elevated aerial apparatus into account. A great deal of research has been done on performance and safety issues. However, this paper considers only parameters pertaining to emergency incident response and on scene operations excluding elevated aerial apparatus.

It does not cover wind's significant effects on fire behavior nor does it address flooding. Finally, it does not consider wind effects on structures beyond their propensity to fail and create debris. A great deal of research, well covered in the literature, exists on these subjects.

The interview process resulted in probable bias. Those consulted fall into what Borg and Gall call "convenience sampling." They were those who could be contacted and were willing to answer questions (1989). In addition, members of apparatus manufacturers' engineering departments would have been better interview subjects on company research. The vendors were interviewed as a convenience.

## Definitions

**Aerial apparatus**-fire truck with an integrated ladder that elevates, rotates, and extends or with an articulating boom.

**Andrew**-Hurricane Andrew which came ashore near Homestead, Florida on August 24, 1992 with wind gusts over 170 mph. It was the third strongest recorded storm to hit the United States mainland and caused $34.3 billion (2000 dollars) in damage and over forty deaths.

**Beaufort wind scale**-the scale used to describe wind speed, devised in 1806 by British Admiral Francis Beaufort to classify winds at sea.

**Cyclone**-an area of low pressure with winds blowing around it, counterclockwise in the Northern Hemisphere.

**Eye**-the calm center of a hurricane that is more than one-half surrounded by a wall of clouds.

**Feeder band**-tightly curved banding of humid air, clouds, and often precipitation that spiral toward the tropical cyclone's center and form a dense wall of clouds that surround the eye.

**Hurricane**-a tropical cyclone in which the fastest sustained surface wind is 74 mph or faster.

**Hurricane season**-the time of year when hurricanes are most likely. From June 1 through November 30 in the Atlantic.

**Hurricane warning**-an alert stating that sustained hurricane force winds of 74 mph or greater are imminent or expected on a coastline in twenty-four hours or less.

**Hurricane watch**-an alert stating that a coastline may be hit by a hurricane in thirty-six hours or less.

**Landfall**-when and where the center of a hurricane crosses from sea onto land.

**RACES**-Radio Amateur Civil Emergency Services. Specially trained civilian ham radio operators who voluntarily work with emergency services in cases where the emergency services' primary means of communications may fail.

**Saffir-Simpson Scale**-a 1 through 5 scale developed by Herbert S. Saffir and Robert H. Simpson that measures hurricane intensity (Appendix D).

**Springpole**-the condition that occurs when a tree falls on a branch or another tree, bending it and loading it with energy. The springpole now supports the weight of the tree under tension, which must be released gradually, with small cuts and extreme care.

**Storm surge**-the dome of water that builds up as a hurricane moves over water. When it comes ashore with the hurricane, the quickly rising water causes widespread coastal flooding, sometimes a mile or more inland. The height is the difference between the observed level of the sea surface and the level that would occur in the absence of a cyclone. Storm surge for a major hurricane may exceed 20 feet above normal.

**Sustained wind**-the mean average wind speed during the previous 60 seconds.

**Tropical depression**-a tropical cyclone with fastest sustained surface winds less than 39 mph.

**Tropical storm**-a tropical cyclone with fastest sustained surface winds of 39 to 73 mph. Also used to refer to both tropical storms and hurricanes.

**Wind gust**-the peak wind increase lasting less than 20 seconds.

## RESULTS

1. What wind criteria do fire service agencies use for scaling back and shutting down emergency incident responses as tropical storms or hurricanes approach?

Agencies have selected a variety of wind criteria for determining when to scale back or shut down emergency incident responses. Most look primarily at ceasing responses at a particular wind speed.

The research found that most agencies plan to cease operations when wind speeds reach 50 mph sustained. Examples include Hampton Beach, Virginia and Miami, Florida (Hampton Div. of Fire Rescue, 1995; Paulison, Montes, & Castillo, 1992) although during Hurricane Andrew the Miami Fire Department continued to responded to calls that were "deemed appropriate when considering the facts" (Paulison et al., 1992, p.13). At the same time, an internal procedure terminated all responses for the Metro-Dade Fire Department, adjacent to the City of Miami, when wind speeds approached 50 mph (Paulison, Montes, Castillo, & Brown, 1993). Nearby Coral Gables stopped responding about the same time because "…high winds and debris in the air made it too hazardous to respond" (Teems, 1993, p. 84).

The Kennedy Space Center battens down and closes its gates 24 hours before anticipated 50 knot (58 mph) winds (NASA/USAF Fire Services, 2003).

While researching their paper "Wind Effects on Emergency Vehicles," Pinelli and Subramanian found that fire and rescue departments use a variety of wind speed benchmarks to determine when to terminate responses including 35 mph, 45 mph, 55 mph, or 60 mph (Pinelli & Subramanian, 2003). It is notable that they did not include 50 mph, the most commonly found benchmark, in their cited list.

Other emergency service agencies follow similar guidelines. The Orange County Sheriff's Office curtails responses upon the arrival of 50 mph sustained winds or when conditions become too dangerous to carry out their mission (OCSO, 2003).

Ft. Lauderdale, Florida allows its officers similar discretion stating "…a Stop Action order shall be instituted when Fire Command judges weather conditions too dangerous for outside operations" (Ft. Lauderdale, 1993, p. W-10).

Seminole County, Florida also permits its officers leeway recommending that they "assess the need to terminate alarm responses until adverse conditions subside" (Seminole County, 2003).

Progress Energy of Florida, a major power company, determines its stopping point based on reports from the field (Sauerman, personal communication, July 13, 2004).

Some agencies base their stopping points on experience with actual storms. The Summerville, South Carolina Fire Department ceased all responses during Hurricane Hugo when winds reach hurricane strength (Rhodes, 1990).

According to an e-mail from Battalion Chief Tom Poulin, prior to Hurricane Isabel in September, 2003, Virginia Beach, Virginia had as its shut down trigger point sustained winds of 55 mph. However, during the storm, the fire department ceased responding when winds reached approximately 50 mph based on observations from the field. From their experiences, the department considered stopping small vehicle responses as low as 35 mph sustained winds in the future but has opted not to adopt a fixed figure. The current policy states that, at the discretion of the Fire Department Command Center, responses will cease if wind conditions "make travel extremely hazardous" (Poulin, personal communication, June 18, 2004).

In some areas, fire departments must scale back or cease their responses due to access considerations. Departments on the barrier islands of Brevard County, Florida must limit their responses when winds reach tropical storm strength because County Emergency Management closes the causeways connecting them to the mainland (Weaver, 1997). However, coastal communities must consider storm surge where Orange County does not. Volusia County, Florida closes the bridges to its barrier islands at 55 mph requiring curtailment of responses (Volusia County, 2003).

2. Does research support the chosen criteria as appropriate?

Information provided by Weaver (1997) suggested three areas to consider when looking at wind speed as a benchmark for scaling back and shutting emergency incident responses: wind effects on vehicles, wind effects on people, and debris generation.

Few have written on wind effects specific to fire rescue apparatus. The majority of information comes from the trucking industry and that information proved difficult to obtain. But the value of that research also came into question when Pinelli and Subramanian (2003) pointed out that it considers vehicles traveling at a constant speed in a straight line. Looking specifically at fire service vehicles, in his Applied Research Project Weaver (1997) noted that they have different centers of gravity which plays a major role in how they handle in high winds. This results in the need to consider tailoring guidelines to specific vehicle types.

A recent work specifically evaluated wind effects on emergency vehicles. Commissioned by the Florida Department of Community Affairs and conducted by the Florida Institute of Technology's Wind & Hurricane Impact Research Laboratory (WHIRL), the study considered three basic types of fire service emergency response vehicles: a typical fire truck, box-style ambulance, and sport utility vehicle (SUV). The study's authors opened with the premise that it is "important to define the threshold wind speed beyond which vehicles should not be allowed to operate" (Pinelli & Subramanian, 2003, p. 10).

In his book *Road Vehicle Aerodynamic Design,* Barnard points out that vehicle accidents in severe weather involve overturning, course deviation, or collisions with fallen trees or other debris. Course deviation occurs when the wind blows a vehicle off course. He defines overturning as when the rolling momentum exceeds the momentum provided by the mass of the vehicle indicating that different speeds of the wind and vehicle, and angles of the wind can all play a role in determining the critical point. Barnard also point out that a vehicle may overturn when a driver overcompensates for a sudden wind gust (2001).

Due to its configuration, a box-style ambulance displayed the lowest threshold. Traveling at 27 mph, a 90° crosswind of as little as 58 mph may result in an unintentional course deviation. Traveling at 55 mph, a wind gust of as little as 34 mph can cause a course deviation, possibly resulting in a collision leading to overturning. The ambulance risks overturning at 90-mph winds even without a collision. The critical wind speeds here fall between 35 and 50 mph, largely because of the unit's volume to mass ratio (Pinelli & Subramanian, 2003).

The sport utility vehicle displayed intermediate tolerances. However, it is notable that with wet roads, a frequent situation during tropical storms, a stationary SUV will begin to slide sideways with an 83 mph wind (Pinelli & Subramanian, 2003). This can occur under tropical storm conditions as gusts may measure up to 30 mph faster than sustained winds (Chaston, 1996). Critical values for the SUV occur between those of the fire truck and the ambulance. A careful driver traveling at slower than normal speeds should have reasonable control up to approximately 77 mph winds (Pinelli & Subramanian, 2003).

Through their wind tunnel studies and road tests Pinelli and Subramanian (2003) found that a typical fire truck is unlikely to overturn due to high winds alone but may if a course deviation results in striking an object at just the wrong angle. At common travel speeds, winds below hurricane strength, particularly sudden gusts, can cause a fire engine with an empty water tank to swerve. They find the critical wind speed for these trucks to lie between 64 and 70 mph.

In conclusion, they recommend that decision-makers consider wind speed to determine safe driving conditions. They point out that different models of vehicles have different handling characteristics, and tire design and quality could play a key role. They emphasize that units in the field have no way of knowing what the actual wind conditions in their immediate area are. Taking into account a safety factor they present the following table:

| | **Critical** | **Seek Shelter** |
|---|---|---|
| Fire Truck | 50-70 mph | 70+ mph |
| Ambulance | 30-50 mph | 50+ mph |
| SUV | 60-70 mph | 70+ mph |

As for wind's effect on people, one must consider two aspects. The first is the strength of the sustained wind.

Penwarden calls 11 mph winds the "onset of discomfort", while 20 mph affects performance, 34 mph affects control of walking, and 44 mph may prove dangerous (1975). According to Durgin (1990), winds greater than Beaufort 9 (47-54 mph) create significant difficulty walking and working, and will knock a frail person to the ground. In his book *Hurricanes!*, Chaston presents the following information. In a 70-mph wind, a person must lean 45° to avoid being blown to the ground. At 80 to 100 mph, one cannot walk without holding on to a rail, and at 130 mph the wind will lift the average person off the ground (1996).

Experiments have shown that pedestrian comfort is a function of not only the mean wind speed but its gustiness as well, both the difference between the sustained wind speed and the speed of a gust, and the duration of a gust (Hunt, Poulton, & Mumford, 1976). Lawson and Penwarden (1975) found that gusts lasting more than three seconds create unacceptable conditions for pedestrians. Relatively sudden exposure adversely affects people's ability to adjust to strong winds (Hunt et al., 1976).

When looking at wind speed one must also consider debris generation. Windborne debris poses hazards to both personnel and apparatus while debris on roadways can cause significant delays in response. Pinelli and Subramanian's research showed that collisions with debris would contribute significantly to the odds of a vehicle overturning (2003).

Post-Andrew building codes require construction able to withstand 100 mph winds but much in Florida was built pre-Andrew and codes are no guarantee of quality (Weaver, 1997). In general, sheathing, outbuildings, and shingles fail first; shingles fail as low as 65 mph (Weaver, 1997). Following Hurricane Andrew, roofing nails produced hundreds of flat tires, primarily on smaller emergency response vehicles (Hoecherl, 2003). Eighty to 100 mph winds blow roof gravel off with enough force to break window glass.

The Beaufort Scale tells us that at Force 10 (55-63 mph) trees are uprooted and considerable structural damage occurs (Erickson, 1988). It is notable that the only fire service line of duty death attributed to Hurricane Andrew was a firefighter using a chainsaw to clear a fallen tree. He unknowingly cut a branch that had **springpoled**.  The suddenly released energy caused the tree to shift striking him in the head, killing him instantly (Hoecherl, 2003).

In addition to creating debris themselves, falling branches and tress often bring power lines with them. If the power company has ceased its field responses and communications failures prevent relaying word that a power grid has been deactivated, a downed line could trap a vehicle and its crew in the open (Sauerman, personal communication).

Gusts can create windborne debris even when sustained winds do not exceed acceptable levels (Weaver, 1997). Chaston tells us that in 120-mph winds objects such as trashcans, tree limbs, and lawn chairs become missiles that can kill (1996). Keeping in mind that gusts can measure up to 65 percent greater than the sustained wind speed, apparent winds of roughly 70 mph can produce deadly results.

Real life experience may provide more valuable information. During Hurricane Andrew, the Coral Cable, Florida Fire Department terminated operation when winds reached around 50 mph because "debris in the air made it too hazardous to respond" (Teems, 1993, p. 84). Isabel caused the Chesterfield, Virginia Fire Department to reach a similar conclusion. However, in Chesterfield, law enforcement continued to respond after the fire department had taken shelter and several times patrol cars became trapped by fallen trees or power lines necessitating a fire department response beyond its threshold level (Mauger, personal communication, June 9, 2004).

3. How can Orange County Fire Rescue use these findings to guide its officers and administrators in decision-making to cease emergency incident responses appropriately, when a tropical storm or hurricane threatens?

Orange County's current "Hurricane Response Plan" instructs personnel to consider high winds, heavy rains, obstructed roads, flooding, poor visibility, and flying debris when deciding when to cease operations (OCFRD, 2000). These terms are both vague and subjective. Some research-based guidelines may assist in effective decision making, particularly now that each fire station has a weather station capable of displaying localized conditions. In addition, all weather stations are linked. Although observers can view only one location at a time, they can consult any station from any other station, including the base at the Emergency Operations Center. This allows both officers responding in the field and in command positions to "look ahead" at approaching conditions (Hanshaw, personal communication, March 9, 2004).

Much of Pinelli and Subramanians' research can be applied to OCFRD's fleet. The study field tested a 1991 Emergency-One Protector model to obtain typical values for a fire truck. Emergency-One has renamed the Protector model the Cyclone (2003). Orange County Fire Rescue currently has a number of Cyclones and is in the process of buying more (Hitchcock, personal communication, June 28, 2004). In addition, OCFRD's SUV's are very similar to those used in the study. Only the EMS transport units vary significantly.

So, at roughly 50 mph one should consider ceasing fire truck responses. Various departments' recent experiences with tropical storms indicate that travel becomes hazardous at this level (Rhodes, 1990; Poulin, 2004). Pinelli and Subramanian's research (2003) shows that the trucks become difficult to safely control with the gusts possible at this sustained speed. Because of their volume to mass ratio, the large SUV's that Orange County's chief officers, EMS supervisors, and safety officers drive may follow the same guideline. However, because of their similarity to box-style ambulances, managers may want to consider removing OCFRD's rescue trucks from the street sooner; perhaps at 35 to 40 mph sustained winds (Pinelli & Subramanian, 2003).

As far as the wind's effect on personnel, one must consider lower sustained wind speeds. Penwarden tells us that winds as low as 20 mph affect performance and 44 mph can prove dangerous (Penwarden, 1975).

OCFRD must take wind gusts into consideration: the relative difference from the sustained wind speed and its suddeness (Hunt et al., 1976) as well as the gust's duration (Lawson & Penwarden, 1975).

As for debris generation, once trees start falling, units should be off the road. Even under the best of circumstances, it is extremely dangerous to cut a fallen tree, particularly one with a springpole (Hoecherl, 2003). Adding high and gusty wind to the formula provides potential for disaster. Once trees start falling, power lines will too. Progress Energy can remotely de-energize damaged areas but communication problems common in disasters may make confirmation difficult. The company uses similar decision making criteria to remove its utility trucks from the road so face to face contact may not be possible (Sauerman, personal communication, July 13, 2004).

## DISCUSSION

The research found a variety of approaches other fire service agencies use to determine when they will cease emergency incident responses when a tropical storm or hurricane approaches. Many stop at 50 mph sustained winds (Paulison et al., 1992; Hampton, 1995; OCSO, 2003). Some rely on their officers' discretion (Ft. Lauderdale, 1993; Seminole County, 2003; Sauerman, 2004).

The Kennedy Space Center closes its gates and has all but a skeleton ride out crew leave 24 hours prior to a storm's impact (NASA/USAF, 2003). However, a facility such as the space center has the ability to order non-essential personnel to leave well in advance of a storm, a luxury no municipality will ever have.

A few departments such as Summerville, South Carolina (Rhodes, 1990), Coral Gables, Florida (Teems, 1993), and Virginia Beach, Virginia (Poulin, 2004) have first hand experience with hurricanes and found 50 mph an appropriate guideline

The trigger points other agencies used to determine their cease response time did not prove critical to this project since it has as its goal to provide decision making guidelines. However, in spite of the fact that few could state the reason for their selected speed except those with recent storm experience, the benchmark of 50 mph for fire trucks appears to have validity.

The research by Pinelli and Subramanian supports the finding that 50 mph sustained winds provides a good benchmark for considering ceasing emergency incident responses with fire trucks. They also found similar tolerances for SUV type response vehicles. However, box-style ambulances, due in part to their differential volume to mass ratio, should seek shelter at lower wind speed (Pinelli & Subramanian, 2003). This means departments should consider vehicle style when considering at what point to stop responses.

Weaver pointed out that looking at wind's effects on emergency vehicles is not enough: one must also consider its effects on people and debris generation (1997). This led to some interesting and eye opening research. There were various departments' experiences to consider (Rhodes, 1990; Teems, 1993; Poulin, 2004). Pinelli and Subramaninan (2003) provided important, science-based research. But the limiting factor appears to be wind's effects on people. Penwarden noted that winds as low as 20 mph can affect performance (1975). Durgin found that winds at the threshold limit for fire trucks and SUV's created significant difficulty walking and working (1990). This makes intuitive sense when one considers differences in mass and the fragility of the human body.

Debris generation also warrants consideration but with destructive speeds beginning at tolerances higher than the human body's (Weaver, 1997), it is not the primary concern.

OCFRD can apply this information to provide guidelines to its officers and administrator. The results of Pinelli and Subramanian's work (2003) applies because of the similarity of the apparatus tested to the OCFRD fleet (Hitchcock, personal communication, June 28, 2004). Using information available from the fire station weather station, they can make regionalized decisions and project ahead across the county for weather to come (Hanshaw, personal communication, March 9, 2004).

It is important to stress the variability of wind over even a small area. Maximum wind gusts in a storm are always greater than the sustained winds; over flat grass up to 35 percent greater and around woods or in cities, up to 65 percent greater. Therefore a 100 mph sustained wind can have gusts from 135 to 165 mph (Pielke, 1997). And sudden gusts, even at "low" wind speeds, can have significant detrimental effects (Hunt et al., 1976).

This information could be used additionally to make sound service resumption decisions because it makes sense to do now those things which hasten recovery after the storm (Pielke, 1997).

## RECOMMENDATIONS

OCFRD now has a wealth of both experience and research available through which to train its officers and administrators in key factors to look for when making a decision on scaling back or ceasing emergency responses. Fortunately, the agency has not suffered any losses due to the limited information previously available. It now has an opportunity to take the new technology of the weather stations and combine it with trained personnel to maximize service to the public while minimizing the risk to fire service personnel and equipment.

Much of the study involved models in wind tunnels but the researchers field tested a 1991 Emergency-One Protector (now called a Cyclone) to obtain typical values for a fire truck. Therefore, OCFRD should consider the values obtained in Pinelli and Subramanian's research (2003) as applicable due to the similarity of its fleet. Its SUV's are also similar to those in the study. And, although they are not the same, due to their similarity to the box-style ambulances tested OCFRD needs to consider scaling back its rescue truck responses earlier than its fire trucks and SUV's.

Based on these findings, the author will modify OCFRD's current Disaster Operations Guidelines (Appendix A) as in Appendix E to reflect the need to consider the greater vulnerability to wind of the rescue trucks.

The author will present the proposed updates to the fire department administration accompanied by this applied research project as rationale, making allowances for its limitations, i.e., the failure to address flooding. The author will have Orange County Emergency Management evaluate the proposal. Based on feedback from both the administration and Emergency Management, the author will implement any necessary changes and submit the revision for the necessary approvals.

OCFRD uses a series of computer based training packages to provide certain types of training to its wide spread personnel. The format lends itself to imparting the type of information officers and administrators need to make sound decisions on when to scale back or shut down emergency incident responses based on their observations. See Appendix F for a sample "Quick Drill."

OCFRD should issue the revision of the Disaster Operations Guidelines along with a training package, including its rationale. The material must be required training for all potential decision makers to achieve maximum effectiveness and facilitate understanding between parties when a storm strikes.

Telling someone what to look for has its limitations. At a later date, the OCFRD should develop a training video showing examples of the effects of various wind speeds on apparatus, people, buildings, vegetation, and other common items. When ready, this video should accompany an annual review of the DOG and the Quick Drill prior to the beginning of hurricane season.

Should Orange County experience a hurricane, the After Action Report will provide an opportunity to evaluate the effectiveness of the training in providing fire officers and administrators with the guidelines they needed to make sound decision on ceasing responses.

For those interested in more information on wind effects on emergency vehicles, Pinelli and Subramanian's study goes into a great deal of detail on the anticipated handling characteristics of typical vehicles under various conditions. Though highly technical, many of the study's charts and findings prove easily understood.

For an excellent perspective on Hurricanes Andrew and Floyd see http://lwf.ncdc.noaa.gov/img/climate/extremes/1999/september/double_pg.JPG.

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**Appendix A**
**Orange County Fire Rescue Department**
**Disaster Operations Guidelines**
**Tab 3.0 Hurricane Response Plan**
**Revised 07/01/00**

**Section 6.0 Emergency Period-EMCON 4**

A. As the storm approaches and conditions begin to deteriorate Field Operations will become increasingly dangerous and, at some point, impossible to continue. The possibility exists that communications may fail leaving Company Officers to make independent decisions. This section provides general guidance for operations during the storm.

B. Firefighters, company officers, district chiefs *(sic)* and division managers must evaluate the safety of responding units and personnel. The level of risk to responding units and personnel will be based on information gathered from field personnel, weather reports and communications. The decision to cease emergency responses will be based on recommendations of the company officer with the concurrence of their *(sic)* district chief if he can be contacted. The decision to cease responses, for the entire district, will be based on the recommendation of the district chief with concurrence of the division manager.

C. The decision to cease emergency responses will be based on those districts effected *(sic)* by the severe weather emergency. The effects of the severe weather may be, but is not limited to:

1. High winds
2. Heavy rains
3. Obstructed roads
4. Flooding of streets
5. Poor visibility
6. Flying debris

A. Once emergency responses have been terminated, dispatchers will maintain a record of all requests for response and establish a priority response list in accordance with subsection 7.3.

B. In the event the radio systems are inoperable, the message will be transmitted by the RACES operator. If the back up systems fail, Company Officers and Field Commanders should use their best judgement to determine when to cease operations.

C. Upon receipt of orders to cease operations, units will complete current assignments as quickly as safety permits and return to quarters, or if conditions necessitate, to the nearest available station.

## Appendix B
## Vendors Interviewed at Fire Rescue East Conference, Jacksonville, Florida, January 24-24, 2004

Brock Butts
Unlimited Mobility
LaGrange, GA 30241

Kenneth H. Crease II
Sutphen
Amilin, OH 43002

Bill Dixon
Emergency Services Insurance Program

Neil Dixon
Hackney Emergency Vehicles
Washington, NC 27889

Joel A. Domangue
Ferrara Fire Apparatus, Incorporated
Holden, LA 70744

Dennis Graves
Deep South Truck & Equipment Sales, Inc.
LaFollette, TN 37766

Louis J. Klein
VFIS
York, PA 17405

Phil Lincoln
Hallmark Fire Apparatus
Ocala, FL 34478

Paul M. Marshall
Osage Ambulances
Linn, MO 65051

Robert B. Milnes
Fire Fighting Innovations, Inc.
Coral Gables, FL 33134

Lee Potter
Emergency Vehicles, Inc.
Lake Park, FL 33403

Bob
Spartan/Crimson

R. Gregory Showalter
Wheeled Coach
Winter Park, FL 32792

John D. Thompson
Ten-8 Fire Equipment Inc.
Bradenton, FL 34203

Brian Wolfe
American LaFrance
Ocala, FL 34475

## Appendix C
## Beaufort Scale

Scale used to describe wind speed, originally devised in 1806 by British Admiral Francis Beaufort to classify winds at sea.

| Force | Description | Miles per hour | Indicators |
|---|---|---|---|
| 0 | Calm | <1 | Smoke rises vertically |
| 1 | Very light | 1-3 | Direction of wind shown by smoke drift but not wind vane |
| 2 | Light breeze | 4-7 | Wind felt on face; leaves rustle |
| 3 | Gentle breeze | 8-12 | Leaves and small twigs in constant motion: wind extends light flag |
| 4 | Moderate breeze | 13-18 | Raises dust and loose vapor: small branches are moved |
| 5 | Fresh breeze | 19-24 | Small trees in leaf begin to sway: crested wavelets form on inland water |
| 6 | Strong breeze | 25-31 | Large branches in motion; telephone wires whistle |
| 7 | Near gale | 32-38 | Whole trees in motion; inconvenience felt in walking against wind |
| 8 | Gale | 39-46 | Breaks twigs off trees; generally impedes progress |
| 9 | Strong gale | 47-54 | Slight structural damage occurs |
| 10 | Storm | 55-63 | Trees are uprooted; considerable structural damage occurs |

| | | | |
|---|---|---|---|
| 11 | Violent storm | 64-75 | Widespread damage |
| 12-17 | Hurricane | >75 | Devastation occurs |

from *Violent Storms* by Jon Erikson

## Appendix D
## Saffir-Simpson Hurricane Potential Damage Scale
## Wind Component

A relative strength rating system for hurricanes originated in 1971 by Robert Simpson and Herbert Saffir.

Category 1
Winds 74-95 mph (64-82 kt). No real damage to buildings. Damage primarily to unanchored mobile homes, shrubbery, and trees. Some damage to poorly constructed signs.

Category 2
Winds 96-110 mph (83-95 kt). Some roofing material, door, and window damage. Considerable damage to shrubbery, and trees with some trees blown down. Considerable damage to mobile homes and poorly constructed signs.

Category 3
Winds 111-130 mph (96-113 kt). Some structural damage to small residences and utility buildings with a minor amount of curtain-wall failures. Damage to shrubbery and trees with foliage blown off trees and large trees blown down. Mobile homes and poorly constructed signs are destroyed.

Category 4
Winds 131-155 mph (114-135 kt). More extensive curtain-wall failures with some complete roof structure failures on small residences. Shrubs, trees, and all signs are blown down. Complete destruction of mobile homes. Extensive damage to doors and windows.

Category 5
Winds greater than 155 mph (135 kt). Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. All shrubs, trees, and signs are blown down. Complete destruction of mobile homes. Severe and extensive window and door damage.

## Appendix E

| | Orange County Fire Rescue Department<br>Standard Operating Procedures | | |
|---|---|---|---|
| **Division:** | Operations | **Issue Number:** | |
| **Initiated:** | Carl L. Plaugher, Fire Chief | **Effective Date:** | 01/01/1994 |
| **Approved:** | Carl L. Plaugher, Fire Chief | **Revision Date:** | 07/19/2004 |
| **Subject:** | Disaster Operations Guidelines Hurricane Response Plan | | **Page of** |

**6.0 Emergency Period-EMCON 4:**

B. Firefighters, company officers, **battalion chiefs** and division managers must evaluate the safety of responding units and personnel. The level of risk to responding units and personnel will be based on information gathered from field personnel, weather reports, **fire station weather stations**, and communications. The decision to cease emergency responses will be based on recommendations of the company officer with the concurrence of **his/her battalion** chief if he can be contacted. The decision to cease responses, for the entire **battalion**, will be based on the recommendation of the **battalion** chief with concurrence of the division manager.

C. The decision to cease emergency responses will be based on those **battalions** affected by the severe weather emergency. The effects of the severe weather may be, but is not limited to:

1. High winds
2. Heavy rains
3. Obstructed roads
4. Flooding of streets
5. Poor visibility
6. Flying debris

**Personnel are encouraged to make use of the station weather stations to track conditions in their immediate area as well as "look ahead" to the conditions at stations already receiving the effects of the storm**

**Appendix F**

# ORANGE COUNTY FIRE RESCUE

***"30 Minutes or less"***

Title: Decision Making Guidelines for Tropical Storm Conditions

Date: July 19, 2004

Use the following IST categories to record this Quick Drill in TERMS:
- **Level 1 – Office of Emergency Management**
- **Level 2 – Disaster Operations**
- **Level 3 – Hurricane Response Plan**

**Course Description – Tropical Strom conditions QD** –

In spite of its location 15 miles from the coast, Orange County still could be significantly affected by a tropical storm or hurricane. Affects could include high winds, heavy rains, obstructed roads, street flooding, poor visibility, and flying debris. Storms of this nature will likely have an negative impact on OCFRD's communications systems requiring offices in the field to make independent decisions on when to stop emergency responses and take shelter in the station.

OCFRD now has the new technology of weather stations in each fire station. Take some time to look at your station weather station and become familiar with its display. The displays from other stations are available on your station computers. Spend some time looking at the conditions at other stations.

Should a tropical storm or hurricane impact Orange County and the communications system fail, officers in the field will need to determine when to take shelter based on their local conditions and of the weather approaching. Below are some guidelines to assist in that decision making process.

## Apparatus

Typical engines, tankers, woods trucks and ladder trucks will maintain their ability to remain on the road up to hurricane strength winds (74 mph). However, drivers must reduce their speed to account for poor visibility due to wind, rain, and debris. They must also slow down because wind gusts have a greater affect at higher driving speeds.

All drivers must use extreme caution when confronted with flooded streets.You cannot see submerged obstacles, you cannot tell how deep the water is, and in many cases you cannot determine where the roadway is. If a piece of apparatus leaves the pavement onto flooded ground, it's stuck.  During a storm it may prove impossible to free the vehicle until after the danger has passed.

Consider removing rescue trucks from the road before engines. Their greater volume to mass ratio (they don't weigh much and have a big "sail") makes them more vulnerable to high and gusty winds. Rescue trucks could become unstable on the road with sustained wind speeds as low as 40 mph.

### People

High winds have significant detrimental affects on people. Winds as low as 34 mph, tropical storm strength, can make walking difficult and dangerous. Wind gusts are a major consideration. They may be 30 mph faster than the sustained winds. Anything that deflects the wind may provide an area of shelter but it will also channel the wind creating locally worse conditions.

### Debris

High winds create dangerous debris. Personnel must watch for flying debris as well as debris on the ground. Personal protective gear will provide some protection from flying debris. Winds, including momentary wind gusts, over 40 mph begin to produce significant debris.  All power lines are considered energized until proven otherwise.

It is critical that we keep our personnel and equipment safe. Although it will be difficult to remain in quarters knowing that there are people in need, we can better serve them by protecting ourselves and our apparatus from the brunt of the storm and being ready and able to respond when it passes.

**This Weeks Quick Drill authored by:**
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