SEVERE WIND RESPONSE STRATEGIES

Executive Analysis of Fire Service Operations in Emergency Management

Severe Wind Response Strategies for South Kitsap Fire and Rescue

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CERTIFICATION STATEMENT

I hereby certify that this paper constitutes my own product, that were the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions, or writings of another.

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Abstract

The problem was that the South Kitsap Community had severe wind storms placing fire department personnel at risk for injury and death during response operations. The purpose of the research was to determine reasonable response strategies for severe wind events in South Kitsap Fire and Rescue. Action research was utilized through an extensive literature review, questionnaires sent to stakeholders and other departments, data mining and the analysis of weather and response information, and interviews conducted with key experts were conducted to answer the following research questions: How do other fire agencies operate during severe wind storms? What severe wind events have occurred and what type and severity of emergency events did they produce for SKFR during the past 5 years? How can SKFR get accurate weather information to predict severe wind storms and make operational decisions? When do wind conditions create unreasonable risk to SKFR employees?

The results of the research identified a lower wind speed threshold for incrementally reducing service levels during wind storms in the South Kitsap. Wind speeds at or above 40 mph create significant damage and risk to SKFR employees because of the type of trees, soil conditions, and logging practices. A draft SKFR Severe Wind Response Emergency Operating Procedure was developed to modify practices to reflect the risk to value response policy within SKFR.

Recommendations included the adoption of the Emergency Operating procedure; annual training of personnel; the purchase and installation of weather stations; a public education campaign on safe sheltering; an annual review of updated data; and the pointing of further research toward a quantification of the risk in the community from wind storms based upon the risk to wind throw and limb breakage to wind speed and response data.

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Severe Wind Response Strategies for South Kitsap Fire and Rescue

Introduction

Severe winds created by various weather disturbances injure people and create damage to communities across the United States (Past is Prologue, 2006; Windstorm, 1997). During such events, fire departments are requested to respond to varying types of emergencies. These responses place fire department personnel in dangerous environments for alarms that do not involve an imminent life risk.

The research problem is that the South Kitsap Community has severe wind storms placing fire department personnel at risk for injury and/or death during response operations. The purpose of this research is to determine reasonable response strategies in severe wind events for South Kitsap Fire and Rescue (SKFR).

Action research will be utilized through an extensive literature review, questionnaires sent to stakeholders and other departments, data mining and the analysis of weather and response information, and interviews conducted with key experts in order to answer the following research questions resulting in a draft SKFR Severe Wind Response Emergency Operating Procedure:

1. How do other fire agencies operate during severe wind storms?
2. What severe wind events have occurred and what type and severity of emergency events did they produce for SKFR during the past 5 years?
3. How can SKFR get accurate weather information to predict severe wind storms and make operational decisions?
4. When do wind conditions create unreasonable risk to SKFR employees?

Background and Significance

South Kitsap Fire and Rescue (SKFR) is located on the Kitsap Peninsula within the Puget Sound Basin covering the southern third of Kitsap County in the State of Washington. The community served covers a geographic area of over 154 square miles and has a current population estimated at 83,000 citizens growing at a steady pace. Because of population growth, property values in recent years have expanded resulting in an assessed value of over 7.5 billion dollars. The major employer in the area is the United States Navy with the Puget Sound Naval Shipyard, Submarine Base Bangor, and the Keyport Naval Underwater Warfare Facility.

SKFR is a full service fire department providing emergency services including fire, emergency medical response and transport, special operations, hazardous materials, and fire prevention and education functions. SKFR was created in 1946 as a rural fire protection district as authorized by the Title 52 Revised Code of Washington Fire Protection Districts (Washington State Legislature, n.d.). Over the past 20 years, SKFR has merged with other smaller fire districts and annexed the City of Port Orchard to establish its current geographical base. SKFR provides service as a substantially career department with all initial response and mitigation efforts being provided from seven staffed stations. The total career staffing includes 72 shift personnel, 4 daytime Chiefs and 14 administrative support and fire prevention staff. Complementing this career staff, volunteers respond from an additional 10 stations. Requests for service from SKFR have been steadily increasing from 7162 calls in the year 2000 to 8,956 calls in 2007 (SKFR, 2008).

The Puget Sound Basin has a long history of windstorm activity and damage. The Pacific Northwest region is vulnerable to wind storms because of its proximity to the Pacific Ocean. and the large number and size of trees resulting in downed power lines and generating large volumes of debris (Seattle Office of Emergency Management, 2008). One of the worst wind storms in the Pacific Northwest is known as the Columbus Day Storm which occurred in 1964. This storm is now the one which all windstorms are compared in the Pacific Northwest. The Columbus Day Storm is rated the number one weather event for Washington State from 1900 to 1999 (National Weather Service, 2008a). It created wind speeds from 65 to 100 miles per hour at different points within the Puget Sound Basin and was deemed a Mid Latitude Cyclone, were 46 deaths and injuries numbering into the hundreds (Wikipedia, 2008).

Previous to this severe wind event, other windstorms close to this magnitude have occurred throughout the recorded history of the Puget Sound including 1934 (Wikipedia, 2008a), 1921 (Wilma, 2005), and 1880 (Read, 2004a). Each of these windstorms caused severe amounts of damage, injuries, and deaths (Read, 2004a; Wikipedia, 2008a; Wilma, 2005).

Since the Columbus Day Storm, severe windstorms have continued to impact the Puget Sound region. Some notable storms include the 1979 storm that caused the Hood Canal Bridge to sink with wind speeds of 80 miles per hour (Long, 2006). In 1981, a windstorm produced winds of 59 miles per hour and in 1993, the infamous Inaugural Day storm created wind gusts recorded up to 64 miles per hour. The storm caused six deaths, two of them in South Kitsap. A total of 167 homes were destroyed, and 777 homes were damaged (Read, 2003a).

The two most recent severe wind storms occurred in 2006 and 2007. In December of 2006, gale force winds hit the Puget Sound region with gusts as high as 69 miles per hour (Wilma, 2007). Known as the Hanukkah Eve Storm, a total of 15 people died from the storm and its affects (Kamb, 2006). Two of its victims were killed from traffic accidents involving windblown trees. Another person was killed when a tree fell on his home (KOMOTV.com, 2006). Wind-snapped trees also took the lives of three others (Wilma, 2007). Contributing to the damage was a record rain fall which saturated the soils creating a weaker root support structure causing a high risk of trees falling over (Kamb, 2006). This storm caused approximately 1.5 million people to loose power (Wilma, 2007). This type and intensity of storm generally occurs only once in a 10 year period (Kamb, 2006), yet the next day the wind was forecasted to reach gusts of 65 miles per hour. During this storm, one of SKFR's aid units was trapped under a power line with personnel inside. The intensity of the storm restricted the Emergency Operating Centers communications with Puget Sound Energy resulting in 2 hours delay for power crews to arrive (M. Wernet, personal communication, March 19, 2008).

The last severe windstorm to hit the Puget Sound Basin was December 1 through 3, 2007. Known as the Great Coastal Gale (Read, 2008), two storms lasting over a 3-day period, blew through surpassing the Columbus Day Storm in terms of the duration of the high winds and duration (Read, 2008). Wind speeds were recorded at 48 miles per hour causing massive power outages from blown down trees throughout the region. During this event, a second close call occurred to an SKFR unit. A fire engine was standing by at a power line down with winds gusting. The lieutenant heard a loud crack, turned around and saw a 12-inch in diameter tree falling toward the fire engine. It landed within 30 feet of the engine and personnel (S. Smith, personal communication, March 15, 2008).

Overall, 91 fatalities were caused by severe windstorms in the Pacific Northwest since 1934. Windstorms in the Puget Sound have been, and will continue to be, dangerous and cause extensive damage (Read, 2003b, 2003c).

These windstorms reflect the highlights of severe wind activity in the Pacific Northwest. Many windstorms over the past 5 years have occurred in the Puget Sound region but are not documented above. Some of these storms created dangerous work environments for responders.

An example of one of these storms is a fairly minor windstorm in January of 2007. This storm was still strong enough to produce a near miss reported in the National Near Miss Reporting System (National Firefighter Near Miss-Reporting System, 2007). The incident occurred in the Pacific Northwest when winds were estimated to be 30 to 40 miles per hour. A Battalion Chief was assigned to respond with an engine company where trees were down over a roadway. Because of the condition of the wind and its affect on the trees surrounding them, the Chief ordered crews to leave the area and find shelter at the nearest fire station. While turning around, a tree fell on the command vehicle being driven by the Chief. No one was injured but the Chief wrote in the lessons learned area that a policy needed to be created for operations during severe wind events. The Chief also noted that several units were trapped because of trees falling restricting them from responding to other calls (National Firefighter Near Miss-Reporting System, 2007).

During severe windstorms, SKFR responds to all requests for Fire Department service. This includes alarms without any life or property risk. SKFR only prioritizes which alarms it responds to first. As a result, in severe storms SKFR personnel are in an environment of substantial risk without a reasonable benefit for the risk incurred.

The future is clear, because of the location of SKFR within the Puget Sound Basin and its proximity to the Pacific Ocean, it is predicable that powerful and severe storms will again (Washington State Military Department, Emergency Management Division, 2007). In Kitsap County, winds in the 40 to 50 miles per hour range can be expected every year and 75 to 90 miles per hour winds a couple of times every 50 years (Washington State Military Department, Emergency Management Division, 2007). With the growth of the area and the expectation placed onto SKFR to provide service, clear operating procedures need to be developed in order to assure that employee safety is managed in the context of a reasonable risk benefit analysis. If changes do not occur, the form filled out will not be a near miss, but a fire casualty, something SKFR has the responsibility to avoid.

This research has direct links to three areas. The first is to the mission of the United States Fire Administration (USFA). Its mission is: “to reduce life and economic losses due to fire and related emergencies, through leadership, advocacy, coordination and support” (USFA, 2008, p. 1 ¶8). This mission is directly advocated by this effort to develop and implement a procedure for the purpose of enhancing firefighter safety at severe wind events. The second link is to the USFA’s operational objectives, the first is to “Reduce the loss of life from fire-related hazards, particularly among these target audiences: 14 years and younger age group; 65 years and older age group; firefighters” (USFA, 2008, p. 2007). The reason for this research is to reduce the risk and vulnerablity of SKFR firefighters during severe windstorm events. The second USFA operational objective that is linked to this project is to help communities create a comprehensive all-hazard risk reduction plan (USFA, 2007). This emergency operating procedure will fill in a gap within SKFR’s all hazard risk reduction plan as well as an opportunity for many other fire agencies within the Puget Sound Region. The third link is to the Executive Fire Officer Program and specifically the Executive Analysis of Fire Service Operations in Emergency Management. An objective of this course is to create a community risk assessment that identifies and assesses the critical hazards and vulnerabilities in a community (USFA, 2007). The second objective linking to this research to the course is to evaluate your department’s capabilities to meet critical risks identified during the risk assessment (USFA, 2007). Close analysis of severe windstorm events will create a critical risk assessment to evaluate the actual impact and outcome of future storms. It will allow a more reasoned and thought out approach to mitigate these critical events decreasing the risk for SKFR employees. The last aspect that connects this research to the course content is the concept of firefighter safety. Throughout the course, incident objectives were one of the first items the Incident Commander had to develop with the Command staff during the simulated incidents. The instructors continuously reinforced that firefighter safety had to be one of those objectives. This research is focused around firefighter safety and the precarious positions they are placed because of the current severe wind operating strategies.

This research investigates the severe wind response actions and problems for fire departments with a focus on the Pacific Northwest where wind types, vegetation, topography, and fire department culture come together to create this distinct risk to fire department personnel. From this research, a draft SKFR Emergency Operating Procedure for response during severe windstorm events will be developed to manage this risk.

Literature Review

Wind and its Effect in the Puget Sound Region

The earth is encased in an envelope called air that creates the atmosphere we live within. This air has mass and when air molecules are stacked upon one another, weight is created at the bottom of the column of air because of the force of gravity acting upon it. The problem begins when other forces act upon this envelope creating an uneven blanket across the earth. The uneven heating of the atmosphere by the sun while being cooled at a different location or the force of the earth's rotation create uneven levels of atmospheric pressure (Cox, 2000). Wind is produced because of these pressure differentials that occur within the atmosphere (Pidwirny, 2008). As the differences in atmospheric pressures occur, air moves trying to equalize the pressure differences causing air to move from high pressures to lower pressure locations (KOMOTV, 2007). The larger the pressure differential, the faster the air moves to fill in the void

(Cox, 2000). According to Cox, only a 5% difference in pressure can cause enough air mass to move creating winds for hundreds of miles. The measurement of atmospheric pressure and wind speed are generally accomplished with instruments at a local location of interest. These devises are placed into the atmosphere a standard height of 10 meters above the ground surface.

Atmospheric pressure is measured by a barometer. This device measures atmospheric pressure based upon the height that a column of air at sea level will force a column of mercury up a tube that has no atmospheric pressure within it. This tube’s open end is placed into a pan of mercury. Atmospheric pressure exerts a force on the open pan of mercury and because of the lack of pressure within the tube, equalizes the pressure by forcing the mercury up the tube a given height. This measure is the baseline by which atmospheric pressure is measured. At sea level atmospheric pressure is 14.7 pounds per square inch. This pressure will raise the column of mercury 29.92 inches (Cox, 2000). In the study of atmospheric pressure, the measure millibar is often used. At sea level, atmospheric pressure which will raise a column of mercury 29.92 inches is equal to 1013.25 millibars. Because small changes can produce significant air movement, millibars allow a better reference point to measure and see the changes (Cox, 2000). A pressure gradient, the difference in atmospheric pressure measured from two separate locations, is measured by calculating the difference in atmospheric pressure between two weather stations. For the Puget Sound Region, gradients created from a North to South axis are the critical atmospheric pressure gradients that have the potential to create severe wind storms (Read, 2003d). When a gradient shows higher pressure from a southern weather station than northern, southerly winds will develop. On the Coast of Washington and Oregon from North Bend Oregon to Quillayute Washington, a gradient of 3.1 to 6 millibars can result in moderate wind events with 30 to 50 miles per hour winds (Read, 2003d) as long as some other factors are also present.

Gradients of 18 to 24 millibars can create moderate to strong windstorms with wind gusts from 50-70 miles per hour. Pressure gradients with 25-30 millibars produce the effects of the Columbus Day Storm with wind speeds 120-140 miles per hour. Gradient changes and wind speed do not have a perfect correlation because of many other factors present, but a gradient change in the right location can be an indicator of a severe wind storm (Read, 2003d).

Added to these factors, topography and friction influence the wind characteristics (KOMOTV, 2007). These characteristics include wind speed, gusts, and direction. Wind speed is the velocity that the mass of air is traveling horizontally through the atmosphere at a given location. It may be reported as a 2 minute average speed or an instantaneous gust. Gusts are rapid changes in wind speed of at least 10 knots between the fastest and slowest speed (National Weather Service, 2008b). Wind direction is usually communicated as the direction the wind is coming from (Pidwirny, 2008).

Winds are rated based upon their speed, gusts, and effects (Cox, 2000). A 5 mile per hour wind is generally considered light. From 15 to 25 miles per hour wind is considered breezy but usually does not create damage. It is considered windy when winds reach 20 to 30 miles per hour. At 30 to 40 miles per hour, it is considered very windy and above 40 miles per hour winds are described as strong, damaging, and dangerous or high. Winds become hurricane force at 74 miles per hour but are dangerous well before that speed (Cox, 2000).

The National Weather Service (NWS) is an organization of the National Oceanic and Atmospheric Administration (NOAA) which provides weather information to United States citizens from routine weather forecasts to the most critical and potentially life-saving alerts and warnings. National Weather Service is the sole official voice of the United States Government for issuing warnings during life-threatening weather situations (National Weather Service, 2008c). The mission of the NWS is:

> To provide weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas, for the protection of life and property and the enhancement of the national economy. NWS data and products form a national information database and infrastructure which can be used by other governmental agencies, the private sector, the public, and the global community. (p.1 ¶2)

This agency has developed definitions in to order qualify weather events and issue statements specifically about winds to prepare and inform the public. It defines 0 to 5 miles per hour winds as light and variable. Five to 15 miles per hour wind has no term applied. A 15 to 25 miles per hour wind is termed breezy or during the winter brisk or blustery. *Windy* is defined as winds reaching 20 to 30 miles per hour. The NWS will issue a wind advisory when sustained winds of 25 to 39 miles per hour and/or gusts up to 57 miles per hour are forecasted. Winds that are blowing 30 to 40 miles per hour are termed *very windy*, and any winds over 40 miles per hour are considered *strong, damaging, and dangerous*. *High winds* are further defined as having sustained wind speeds of 40 miles per hour or greater lasting for 1 hour or longer and/or winds of 58 miles per hour or greater for any duration. These winds are described as extremely life threatening. A high wind warning is issued from the NWS when these wind speeds or gusts are predicted (National Weather Service, 2008b). The Hazard Profile of the Washington State Hazard Mitigation Plan also defines a severe storm with the same criteria used by the National Weather Service (Washington State Military Department, Emergency Management Division, 2007).

Wind is also qualified internationally by the effects it has on the environment it impacts. In 1805, Sir Francis Beaufort of England developed a chart based upon detailed observations he had made at sea of the effects of wind on bodies of water and British war ships. The recommendations were later adapted to conditions on land and are outlined in Appendix A (Wikipedia, 2008b).

There are two general weather circumstances that bring strong winds into the Puget Sound Basin (KOMOTV, 2007). The first one occurs in the fall and winter when a strong low pressure center is developed because of a Mid-Latitude Cyclone. These cyclones exist for 3 to 10 days moving in an overall west to east direction and can travel 700 miles in a day. Mid-latitude cyclones are the result of warm tropical air meeting up with a cold polar air mass (Pidwirny, 2007). When these different weather forces collide, the warm air is lifted up and combines with the colder upper atmospheric air causing an energy transfer and production of the cyclonic features. Mid-latitude cyclones create a wide variety of precipitation and wind events. High winds, rain, freezing rain, hail, sleet, snow pellets, and snow are produced especially during the winter months. These powerful weather disturbances create large moving storms with centers of low atmospheric pressure. Mid-latitude cyclones cause less damage than tropical cyclones or hurricanes. In rare circumstances, these cyclones can have winds as strong as a weak hurricane (Pidwirny, 2007).

Mid latitude cyclones cause the most danger and damage in the Puget Sound Basin when they make landfall across the northern tip of Washington State or the southern tip of Vancouver Island. This type of storm produces the strongest wind storms within the Puget Sound (KOMOTV, 2007). As the storm moves inland aligning itself due north of the Puget Sound Basin, a direct path to the low pressure area is created from and through the Puget Sound where higher pressure resides to the south. Strong winds blow through the entire basin and are enhanced by the topographic features in the Puget Sound. The Puget Sound Basin is made up of the Olympic Mountains on the west side and the Cascade Mountains on the east side. This creates a narrow channel for the wind to move through to fill the low pressure area to the north. Because of this narrow bottleneck, the wind speed will accelerate creating even higher wind speeds (KOMOTV, 2007). Wind speeds from these conditions can exceed 80 miles per hour (Read, 2004b). These mid-latitude cyclones generally occur during the winter months and move in from the Pacific Ocean (Washington State Military Department, Emergency Management Division, 2007).

The second type of weather event affecting the Puget Sound Basin causes considerable winds on the western slopes of the Cascade Mountains. When high pressure is on the east side of the cascades mountains and a low pressure system is off the Washington Coast to the west, the air from the east side of the state rushes to balance the low pressure on the west side over the Pacific Ocean. Because the cascade mountain are blocking this airflow from occurring, the wind pours through the lower passes which have a restricted area causing the air to move rapidly. As a result, wind speeds accelerate to high wind velocities in those valleys. Because of SKFR's location, these events are generally minor (KOMOTV, 2007).

Recent dates when the first types of events have occurred from 2000 to 2007 include: January 15-16, 2000; December 14-16, 2002; December 15-16, 2002; December 17, 2002; January 29-30, 2004; November 5, 2005; December 25, 2005; January 1, 2006; February 4, 2006; December 14-15, 2006; October 18, 2007; and December 1-3, 2007 (Read, 2004a).

The effect of wind on fire service vehicles is well established. Both Scmidlin et al. (2002) and Pinelli and Subramamian (2003) have developed dangerous wind speed criteria for fire department vehicles at or exceeding those identified by the National Weather Service and developed by the International Association of Fire Chiefs (IAFC, 2008) as wind speeds that are extremely dangerous to pedestrians and firefighters. It should be noted that Pinelli and Subramamian added a safety factor into their threshold recommendations. Also identified by Pinelli and Subramamian were lower end wind speeds where driving would be more difficult. These recommendations identify where wind speeds make driving more difficult and graduate to dangerous as the wind speed increases. For ambulances, driving is more difficult at 30 miles per hour and graduated up to dangerous at 50 miles per hour. Scmidlin et al. (2002) developed different criteria and from the research found ambulance critical upset wind speed to be 135 to 150 miles per hour. Fisher (2004), Madigan (2005), and Weaver (1997) all concluded that the effect of wind on people is more of a limiting factor for emergency response than the effects of wind on vehicles.

Wind and it's Effects on Trees

Because trees are a predominant part of the Puget Sound landscape, they create a major component of the problem during windstorms (Robson, 1999). In the Puget Sound Region, winds produce significant damage to trees resulting in damage and a significant risk of danger to people and property (Robson, 1999; Seattle Office of Emergency Management, 2008; Washington State Military Department, 2007; Wikipedia, 2008a; Wilma, 2007). Winds apply forces to trees causing the failure of branches and the overturning of trees. These trees when falling impact electrical infrastructure creating the hazard of a high energy power transmission line being forced down to the ground where people can make contact with them. Another hazard is flying debris from branches and trees dropping (Jacobson, 2007), potentially hitting people.

The wind affects trees in many ways because of the diversity of variables associated with each species, location, and environmental conditions (Stathers, Rollerson, & Mitchell, 1994). Individual trees differ significantly in their ability to withstand damage from wind (Harris, 1989). A general observation has been noted in the Beaufort scale identified in Appendix A regarding the effects of wind on trees. Tree branches are affected by winds as low as 8 to 12 miles per hour when leaves and twigs are in constant motion. At Beaufort 6, large branches move. Beaufort 7, 32 to 38 miles per hour winds are observed that cause whole trees to be in motion. When Beaufort 8 is hit, 39 to 46 miles per hour winds are endured, and twigs are broken from trees. Beaufort 9, 47 to 54 miles per hour winds are punishing, causing branches to break. At scale 10, 55 to 64 mile per hour winds are howling, with trees uprooted. Finally at scale 11, widespread damage occurs. An average wind speed of 60 miles per hour places incredible forces on trees and swathing can result (Read, 2004b). *Swathing* is generally considered broad range destruction of a group of trees in the same area from wind (Read, 2003c). Trees in these circumstances can be hazardous to people, causing property damage, injury, or death from wind fall and large branches breaking (Harris, 1989; Jacobson, 2007).

Species type alone is not a good indicator of windfall risk because of the effects of site and stand characteristics (Stathers et al., 1994). The mechanics of wind throw, *the toppling of trees*, is complicated. The horizontal force of wind is applied on a tree and transferred down the trunk to the root system. When these forces exceed the ability of the root and soil system to hold the tree in place, the tree falls over (Coutts & Grace, 1995). Factors affecting wind throw include the individual tree, the stand, root and soil, topographical, and meteorological characteristics (Stathers et al., 1994).

Individual tree characteristics that affect wind throw include trees with large or medium density crowns. The crown is the area above the trunk where smaller and smaller branches, stems, and twigs form and foliage are present (Coutts & Grace, 1995). The foliage at the top of trees creates a sail resulting in the pressure from the wind being transmitted onto the tree (Coutts & Grace, 1995). The larger the crown, the more force applied (Stathers et al., 1994). Taller trees are also vulnerable because as the force is applied further away from the root and soil system more force is generated down to the roots, like a system of levers. Trees without a crown are less prone to wind fall because the energy from the wind is not as easi ly transmitted to the tree. Tree movement from wind is minimized when a tree is within a stand. The tree makes contact with other trees in the stand absorbing some of the force (Stathers et al., 1994). The stem or trunk of a tree also absorbs more or less force based upon its profile. A tree that is conical, *meaning it is wider at the bottom than the top*, absorbs less force than a cylindrical trunk that is evenly sized top to bottom (Stathers et al.1994). The actual turning moment of trees has been identified only marginally because of so many factors involved. Older and taller trees are at more risk of wind throw because of the forces being acted upon the tree at a higher level. A tree ages, stems and tops become heavier in relation to the rooting (Harris, 1989), increasing the chance of root disease infecting the tree and reducing its ability to hold fast (Stathers et al., 1994).

Trees within uniform stands are also more able to withstand wind effects because of the interlocking of their root systems and the effect of the crowns functioning together which reduces the amount of penetration (Stathers et al., 1994). Individual trees exposed to wind may develop a stronger resistance to wind throw because of the reactions of the wood and roots to the stress of swaying and the reduction of crown mass from wind damage (Harris, 1989).

One stand characteristic that increases wind throw is clear cutting. The size of the opening does not seem to matter with most of the damage occurring on the down wind and parallel sides of the winds direction. Thinning in many instances also increases the risk of wind throw (Stathers et al., 1994). Because of the risk of excessive damage, partially cutting stands of trees exposed to high winds is not recommended (Harris, 1989). Generally wind fall is common along cutting lines with the worst wind throw occurring in the first few years after cutting (Harris, 1989).

Soil characteristics also affect wind throw. Trees growing in deep and well drained soils develop large root balls allowing them the ability to hold up against the forces of winds. Water saturated soils, near bedrock, or excessively stony do not allow root development to occur resulting in a higher risk to wind throw. When shallow or wet soils are present, the roots have a tendency to form a flat pan type structure that remains shallow. This flat structure allows minimal anchorage, as long as unprecedented levels of forces from severe winds are not applied (Stathers et al., 1994). Soils with poor depths due to the water table, rocks, glacial till soil, or soil with root disease do not allow good root development, placing the tree at a higher risk for wind throw (Stathers et al., 1994).

Water saturated soils create a high risk of wind throw because of hydraulic fracturing of the roots. Once this fracturing has occurred it is easier to rock the trees resulting in more stress and eventual failure. In water saturated soils, winds as low as 17.8 miles per hour cause significant dynamic loading on a tree and the water pressure in the soil to rise (Coutts & Grace, 1995).

The largest factor regarding root systems and wind throw is the total volume of the root system and the size of its supporting roots. Good soil characteristics facilitate root growth and root depth and seem to contribute the most to the risk of wind throw (Stathers et al., 1994). Small increases in rooting depth and size can significantly increase the ability of a tree to resist overturning.

Topographical characteristics mainly affect wind throw by affecting and directing the wind itself. Different topographical features cause increased or decreased wind speeds and air turbulence resulting in altered forces upon trees.

Meteorological conditions also affect wind throw. Few trees can withstand a mean wind speed in excess of 67 miles per hour for more than 10 minutes. Significant wind throw can occur in some locations with wind speeds as low as 33 to 35 miles per hour. Prolonged winds usually cause more damage as the trees have more time to sway resulting in broken roots and loosened anchorages (Stathers et al., 1994; Wilma, 2007). In one study involving a thicket of spruce (Coutts & Grace, 1995), large scale destruction occurred with gusts at or above 89 miles per hour. Normal winter storm damage occurred with gusts at or above 67 miles per hour.

When soils are wet from previous heavy rainfall a reduction in root to soil adhesion and sheer strength reduces the roots ability to withstand wind forces (Stathers et al., 1994). Snow and ice add mass to the crown which increases the sail-like tendencies, allowing a better transfer of wind forces to roots.

All of these characteristics are factored into a risk classification for trees. Observed wind throw may be the result of many vulnerabilities and wind speeds, when classifying trees all factors and judgment must be used. Classifications of risk have many errors because of the numerous complexities identified (Coutts & Grace, 1995). High risk stands generally are those that have: poor root anchorage with less than .4 meters of rooting and soils, are located in areas where high wind occur, and tall trees that have large dense crowns. Moderate risk is seen where stands either have poor anchorage problems but low wind risk, or moderate anchorage with .4 to .8 meters of root and soils and a moderate wind risk, or good anchorage but high wind force potential. Low risk stands include those with good root anchorage including deep rooting and well drained soils of at least .8 meters, are protected from severe winds, and shorter trees with small size crowns and cylindrical trunks (Stathers et al., 1994).

Fire Department Emergency Response Decision Making and Risk Management

Decision making during fire service operations in the United Kingdom is managed by a risk management system that allows firefighters to function in dangerous environments resulting in a low ratio of firefighter deaths per population (Tissington & Flin, 2004). According to the Office of the Deputy Prime Minister (2004), only three firefighter deaths occurred in 2004 and one in 2003. This basic system is based upon the safe person concept. This concept requires that all fire service operation be based upon employee and citizen safety rather than on the working environment (Richardson, n.d.). As a result, control measures are put into place to manage the risk. Ultimately, it is the responsibility of the Fire Brigade to ensure firefighter safety (Northern Ireland Fire Brigade, n.d. a). This is done through a required risk assessment of situations identified in the British Fire Service as a dynamic risk assessment (Northern Ireland Fire Brigade, n.d. b). The concept of evaluating the situation to assure the risk is proportional to the benefit is considered throughout the process. An identification of all risks and who will be affected by them is also integrated (Northern Ireland Fire Brigade, n.d. b). Upon arrival at an incident, the Incident Commander is required to conduct a size-up of the risks to firefighters, the public, and the environment. With these considerations, the benefit of any action is weighed against the risk (Northern Ireland Fire Brigade, n.d. b). The correct perspectives in this evaluation are: risk lives a lot in a calculated manner to protect savable lives; risk life a little in a calculated manner to protect savable property; and zero risk for life or property already lost (Northern Ireland Fire Brigade, n.d. c). During this process of dynamic risk assessment, time cannot be used as a reason for implementing unacceptable levels of risk upon employees (Northern Ireland Fire Brigade, n.d. c).

In the United States Fire Service, risk based decision making has an early capturing of essence by Brunacini and Oppelt (1985). They were the first in the United States to outline the principle that significant risk can be taken to save a life, a little and very controlled risk can be taken to save property, and no risk will be taken to save nothing. The United Sates Department of Agriculture Forest Service recognizes fire suppression activities as inherently dangerous (USDA, 2005). Employees are expected to make “reasonable and prudent decisions” (Bunacini, n.d.) to accomplish the agency mission and minimize life loss and injuries. All firefighters are expected to manage and recognize the inherit risk within the firefighting environments.

The National Fallen Firefighters Foundation also identifies risk management to be an important consideration when operating at emergencies. In an instructors outline defining risk (National Fallen Firefighters Foundation, n.d.), the foundation states that a risk analysis must occur to identify the risk to personnel at an emergency and to determine how these risks can be removed or reduced. Advocated is the concept to risk lives considerably for a savable life; risk lives a little, in a calculated manner to save property; and zero risk lives to save what has been lost (National Fallen Firefighters Foundation, n.d.). Down the same path the Fulton County Fire Department has established a Standard Operating Procedure on the Rules of Engagement (Fulton County Fire Department, 2003). This document expresses that no property is worth the life of a firefighter and that no level of risk to responders is acceptable when there is nothing to save. A higher level of risk can only be assumed when there is a realistic potential to save endangered lives (Fulton County Fire Department, 2003).

In the State of Washington, several laws affect emergency scene risk decisions. The first law is the safe place standard (Washington Administrative Code, 1997). This requires an employer to do everything reasonably necessary to protect an employee's safety and health. During emergency fire ground activities, the Incident Commander is responsible for the safety and health of all personnel operating at an emergency scene (Washington Administrative Code, 1997). Departments are required to have a risk management policy in place and incorporated into the functions of incident command. This risk management policy must include direction to the Incident Commander on the level of risk that may be taken to save lives and property in as safe a manner possible (Washington Administrative Code, 1997).

South Kitsap Fire and Rescue has two policies that guide emergency scene risk management. These documents define the acceptable level of risk that may be taken at an emergency to save lives and property (SKFR, 2001). Some terms are identified to provide clarity. *Benefit* is defined as the presence of value based upon the ability to rescue people, stop property loss, and prevent environmental harm. *Risk* is defined as the combined probability and severity of loss in a given circumstance. *Risk assessment* is defined as a systematic evaluation of an emergency situation to identify hazards, determine severity, and to consider these risks in comparison to the benefits from actions taken (SKFR, 2001). Incident Commanders are responsible to determine and manage the level of risk assumed at an emergency scene. The level of risk assumed must be calculated and managed in a controlled manner (SKFR, 2006). To accomplish this, the Incident Commander is directed to continually identify risks and develop risk control strategies to reduce the risk to members. Operations are limited to those that can be safely performed by the personnel available at the scene. To assist Incident Commander in risk management decision making, three principles are identified.

- Significant risk shall only be taken where there is a high potential to save lives and the risk has been calculated and considered in relation to the benefit.
- Moderate risk may be taken to save property that is savable and of a measurable value. Actions and procedures shall be taken to reduce and avoid risks.
- Nothing shall be risked to save lives and property already lost or destroyed.

These same principles are also noted by the National Fire Protection Association (2006). Added to these is a fourth principle advising that where risk is excessive, operations should be conducted only from a defensive or outside of a building or risk area.

Fire Service Literature on Severe Wind Response Strategies

The fire service literature encasing emergency response strategies to severe wind storms nationally has a center around hurricane response procedures. Weaver (1997) establishes a foundation that seems to have structured some of the fire service research and practices into the 21st century. Weavers approach was to determine when it was no longer reasonable to respond during severe weather, specifically hurricanes. The department he was involved with did not have written procedures on how to operate during severe windstorms or when to stop operations. This left the decision up to the officer in charge causing inconsistency in response and service levels. Weaver's research was built around the effects of wind on people, vehicles, and debris generation. From this research, Weaver (1997) concluded that basing operational response decisions upon wind speed was a reasonable approach, but expressed concern over one wind speed as a standard for all departments. Weaver recommended that every department evaluate their local situation using good judgment to meet the needs of their circumstances and those decisions to stop operations should not be based upon sustained winds but upon gusts. Contrary to this recommendation, Hoecherl (2003) recommended that research and decision criteria should be based on sustained winds, not gusts. Hughes (1998) recommended that consideration be given to stopping operations at 50 miles per hour because of the danger of flying debris to fire fighters. Hughes indicates that high winds create debris that makes it too dangerous for firefighters to respond to emergencies.

Weaver (1997) also recommended that each department evaluate their vehicles and apply a formula to determine the safety of operating apparatus. The result of his research was that fire department vehicles similar to those within his department can operate safely up to wind speeds of 50 miles per hour, as long as there are no wind gusts over 70 miles per hour. From this, Weaver concluded that the effect of wind and debris on people are the limiting factors to make cease operation decisions, not the limits on vehicle operations. Weaver also reflected that firefighters may be able to arrive safely, but may not be able to operate safely at these wind speeds. If citizens are being injured and properties being damaged, how can firefighters operate safely without some form of protection.

In order to make good decisions, Weaver (1997) recommended wind velocities be measured locally, not miles away where conditions may be different. In Weavers situation, the closest weather station was at the county seat, many miles from the jurisdiction where he responded. He recommended installing weather stations so that officers could make local decisions regarding when to stop, and then resume operations.

In a similar manner, Hoecherl (2003) was concerned about public safety and the safety of personnel during and immediately following severe wind storms. In this research, Hoecherl identifies the cease operations and resume operations decision as critical command level function. If decisions were made incorrectly, the results would be the unnecessary exposure of emergency responders to dangerous and unpredictable conditions. If made too conservatively, this would suspend emergency response operations too early, increasing the risk to citizens who may need emergency assistance.

Hoecherl (2003) also recommended finding a reliable source of wind speed data scientifically valid for departments to make decisions on ceasing and resuming operations. No clear recommendation is given as to when to cease operations but 40 miles per hour winds are recommended as the wind speed to resume operations after a hurricane.

Because of the impacts of ceasing operations, which includes all emergency medical responses, Hoecherl (2003) recommended that medical instructions may need to be enhanced by dispatchers for those needing medical assistance.

Also identified by Hoecherl (2003) were downed electrical wires overwhelming fire agencies during significant storm resulting in a needed change in practice. There is no way one crew can be stationed at every power line and wait for the power company to arrive. As a result, Hoecherl recommended that an agreement be signed for the response changes with the power utility and the need for legal advice because of this change. SKFR’s attorney, Richard Gross, was consulted for this research. After explaining the possibility of suspending response operations, once determined to be too dangerous to respond for the value received, he expressed the need to have a clear written policy and reasonableness in the decisions being made. As long as the risk to employees was excessive and the corresponding value not present for the type of alarm, the liability is minimized. He also expressed the need to inform and prepare the public for any changes that would be implemented before the change occurred with recommended protective action for them to take during severe wind events (R. Gross, personal communication, May 8, 2008).

An unclear guideline for when officers should stop response operations during severe storms was also a concern of Fisher (2004). This research recommended that decisions to stop responding be based upon high winds, heavy rain, obstructions in roads, flooding in streets, poor visibility, and flying debris. Personnel were encouraged to use weather stations installed at all fire stations to gather weather data to determine when the storm would arrive.

Also outlined was a recommended procedure to follow during hurricanes to make the cease to respond decision. In these circumstances, everyone evaluates the safety of responding units. The level of risk to fire resources was to be based upon information from field units, weather reports, fire department weather station information, and communications. Decisions to cease operations for a station response area were to be based upon the recommendations of the station company officer with concurrence of the Battalion Chief. Decision to cease operations for an entire battalion was to be based upon recommendation from Battalion Chief with concurrence of the Division Manager (Fisher, 2004). Units operating in the field when the order to cease operations was given would complete their current assignment as quickly as safety permitted and return to their station. If the conditions were poor and the risk severe, units could take shelter in the nearest available station. Once the cease operation order was given, the dispatch center was assigned to keep a running list of pending responses and establish priorities for deployment once the environment was safe to reengage (Fisher, 2004).

Fisher (2004) identified debris in high winds creating danger for responders. Personal protective clothing provides minor protection from flying debris and winds gusts as low as 40 miles per hour begin to produce significant debris risks. In the research recommendations, Fisher advised that when trees are falling down, responses need to stop. Another item of concern addressed was power lines that hang low enough to make contact with people and responders due to debris pushing them out of position. This creates a significant risk to responders. All power lines must be considered energized until proven otherwise. Another concern identified with debris generation and trees down is what was termed the spring poled effect. This is described as follows: when a tree falls and is supported by another object, it bends in the center and has stored energy. This energy can be released suddenly if care and proper methods are not followed, creating a hazard to those trying to clear the debris (Fisher, 2004). Hoecherl (2003) recommended placing chain saws on all apparatus to remove debris and trees across roads. With the recommendation was the expressed concern over chainsaw injuries and the stored energy from fallen trees risking firefighters who are not trained to recognize the forces involved.

Madigan (2005) researched similar problems but focused on whether a change in policy from a centralized uniform decision making process, to a more decentralized and incremental guideline with latitude given to officers at the local level was effective. Problems were identified with the centralized system because storm conditions were different across the department and a unilateral decision did not work well. A change in policy was made to decentralize the decisions without evaluating or testing the changes. In 2005, the department changed its criteria to a modified procedures resulting in responders not being dispatched to down power lines, fire alarms, or public assists at 35 miles per hour sustained winds. From 35 miles per hour sustained to 45 miles per hour sustained, responses were limited to immediate life threat. Above 45 miles per hour sustained, responses discontinued with life threatening calls forwarded to the Battalion Chief who would make the response decision based upon weather conditions and local knowledge. Station officers also had discretion not to respond if they felt conditions were unsafe.

Madigan (2005) explained that during the next hurricane a couple of problems were observed with the changes. A structure fire was dispatched with one station responding but the second station didn't because of a different judgment of the risk. This led to inconsistent service delivery to the citizens and increased risk to responders. Another problem was a structure fire with no life threat was dispatched but a severe chest pain call was not dispatched. This begged the question, which event was more life threatening.

Recommendations from this research included developing guidelines for all levels of response decision making: exercise, train, and evaluate the procedures often; instal weather stations allowing all stations and command levels to view local weather data; provide Battalion Chiefs with up to date National Weather Service data; and implement a seek shelter procedure.

In January of 2008, the International Association of Fire Chiefs came out with a document which provided guidance to fire departments in developing policies regarding emergency responses during Hurricanes and coastal storms (IAFC, 2008). Identified in the document is one of the most difficult decisions for an Incident Commander to make during these events; determining when to halt emergency response operations. The problem identified is when winds reach a certain speed, debris becomes a lethal weapon that can cause severe injury or death. As a result, IAFC (2008) developed a model guideline based upon existing practice and reasonable principles that center on personnel safety. The intention of the document was to balance the need to protect both the emergency responders and the citizens they serve. The guideline outlines the need to maintain a safe work environment even during this type of uncontrolled event while still providing essential services to the public. Services were to continue as long as the safety of responders was not endangered by storm conditions. Also stressed is the need to utilize the National Incident Management System including the use of incident action plans to ease the recovery process and the gaining of federal reimbursement. The IAFC model policy then outlines basic preparations for a hurricane for preseason, 36 hours before arrival, 24 hours before arrival, and then actual operations. During hurricane operations, the IAFC (2008) recommends the following guidelines:

- Fire departments should provide service until the last moment possible. When condition exists to cease operations, a conscious and calculated decision must be made that takes into account the reality that some apparatus and equipment may be damaged or lost.
- All members must wear full protective clothing including eye protection for all responses for protection from flying debris and operated in teams of two.
- Aerial devises should not be operated when sustained winds are 35 miles per hour or higher.
- Prior to sustained wind speeds reaching 50 miles per hour or wind gusts over 65 miles per hour, any officer who feels that their situation is dangerous to the safety of their personnel may seek shelter. The officer must advise the incident commander and the dispatch center of the decision.
- Fire departments shall discontinue all responses when sustained winds reach 50 miles per hour or wind gusts are over 65 miles per hour. When the order to cease response is given due to hazardous wind conditions: Units responding or on the scene of an emergency shall continue their work until completed, and return to their assigned stations; units out of station but not on a call will return to their assigned station as soon as possible;
- Apparatus will be parked headfirst into the station to protect the windshield; Dispatch will relay all requests for service to the hurricane command post which will prioritize these requests for response when conditions permit; Operating companies must notify

dispatch and other responding companies of all hazardous conditions they encounter including high water, and road damage or blockage.

- Personal safety: Before walking through water, members must use extreme caution when walking through water. They must use a pike pole or stick to ensure the ground has not washed away or collapsed. Responders must also be aware of hazards in the water like live electrical wires and wildlife including snakes.
- Driving safety: Use extreme caution when driving and limit speed being cautious where the ground is saturated or flooded because the road could be washed away.
- Station safety: Generators must be outside and elevated to ensure the exhaust is ventilating to the outside. Generators should not be placed on the apparatus floor because of the risk of carbon monoxide accumulating in the enclosed room. If a station must be evacuated, the company officers will ensure utilities are shut off, the station is secure, and report to a predetermined safe location.
- When the eye of the storm passes, operations must be limited to what can safely be done to secure the station. Members should help citizens who come to the station when it would be dangerous to release them. The safety of department personnel will remain the primary consideration during these operations.

IAFC (2008) also includes guidelines as to how to resume operations after a storm has passed:

- The Chief or designee shall make the decision as to when the department can resume response operations. The decision to resume operations will be announced by dispatch.
- Officers who think it is safe to resume operations before receiving the resume operations order will contact their chain of command to describe the conditions at their location and

the reasons they recommend resuming operations. Command shall review the request and give clear directions. If officers are unable to contact command, the decision to begin operations will be the responsibility of the highest ranking officer at the station. Operations will only be performed if they can be conducted in a safe manner.

- Personnel conducting emergency operations after the hurricane passes must keep their own safety and wellbeing as the first priority. Hazards encountered after a hurricane passes include: live wires, gas leaks, structure fires, unstable buildings, flooding, hazardous materials, heat stress, traumatized victims, civil disturbances and displaced animals.
- An important function to perform at this stage is a damage assessment of each company's personnel, equipment, and facilities. Once completed, a windshield survey of the stations first due area must be conducted and damage communicated to command.

South Kitsap Fire and Rescue's operations during severe wind storms are reflected in two documents: Emergency Operating Procedures for Power Lines Down and the Changing Gears Policy. According to Gary Faucett the Deputy Chief of Operations for SKFR during the policies implementation, the Emergency Operating Procedure for Power Lines Down (SKFR, 1998) was developed because of the inability to manage the many power lines down calls for service during severe windstorm (G. Faucett, personal communication, March 24, 2008). The usual practice of standing by at a power line that was down was impossible because of the volume of requests. As a result, once fire department resources are overwhelmed, a change in procedure is directed. During wind storms, emergency crews are to use barrier tape to isolate the area to alert citizens of the hazard. If the power line is energized by the evidence of sparking, arching, or smoldering, the crew is to contact the Duty Chief who would make a decision as to whether to post the unit at the scene because of the risk present or release the responders to handle other pending events.

The *changing gears plan* is a policy of Kitsap County Department of Emergency Management (KCDEM, 2008), which directs how each fire departments area command within Kitsap County will operate in coordination with the Kitsap County Dispatch Center during events causing a large increase of alarm activity. It is built as a phased approach to incrementally be implemented in order to prioritize and coordinate alarms during wide scale emergency operations. The phases are as follows:

- The phase one activation is an alert phase identifying when a major storm is approaching that requiring notification of fire agencies to start preparing. During this phase, a ramp up of resources and call activity may be seen resulting in the need for coordination between the Duty Chiefs and the dispatch center. All power line down calls not deemed to be a hazard by the 911 call receiver, are directed to contact the electrical utility. If there is a hazard, a priority is assigned to the event and it is dispatched. All other phases handle the no hazard wires down calls in the same manner.
- Phase two is initiated when the demand for resources exceeds the resources available with multiple fire agencies being affected. Area Commands are set up by all fire agencies within Kitsap County and an enhanced operation is initiated. Priority 1 and 2 events are still dispatched while lower priority events are sent to the Area Command. Lower priority events are assigned to companies by the Area Command when units are available. If a higher priority event is dispatched, the units divert to the more imminent alarm. The Duty Officer for KCDEM and the Designated Kitsap County Fire Chief report to dispatch to assist with prioritization and logistical needs.

- Phase three is implemented during major catastrophic events that exceed local governments' ability to respond effectively. All 911 calls are processed and sent to the Department Area Commands for prioritization, assignment, and tracking.

Summary of the Influence of the Literature Review on this Research

The mechanics of most severe wind storms that hit the Puget Sound Region are low pressure systems that make landfall off the northwest tip of Washington State. These storms can be dangerous to lives and damaging to property. Identifying the conditions that create these environments and the weather criteria to evaluate when making decisions for preparations and operational deployment was identified as important by Fisher (2004) and Madigan (2005). What type of weather information and where to gather it for accurate decision making must be identified during the research procedures. Weaver (1997), Hoecherl (2003), Fisher (2004), and Madigan (2005), all identified the need for reliable local weather data in order to make response decisions. Departments that cover a large land mass need multiple local points for accurate and reliable decisions to be made (Madigan, 2005). This information influenced the need to add questions to other fire departments, the KCDEM, and Puget Sound Energy in order to determine the current methods available to collect local weather data.

Trees in the Puget Sound are what cause most of the danger to people and property damage during severe wind storms (Robson, 1999). This pushed research toward defining the risk of wind throw in South Kitsap according to the risk method outlined in the literature review.

The literature review identified water saturated soils as creating a higher risk of wind throw because of the loss of root to soil adhesion (Coutts & Grace, 1995). This concern identified the need to examine the wind history and effects with the additional element of rainfall during and prior to the wind event to see any associated trends.

The review of risk based decisions being taken by fire agencies created concern. In wind storms are the benefits worth the risk being taken? This needs to be evaluated based upon the types of calls SKFR is responding to during windstorms and categorizing them by the value being attained from the response. Secondly, environmental conditions need to be categorized based upon the risk to SKFR employees. A criteria needs to be established for when the environment is unsafe. These two elements need to be developed in order to determine what call types will be responded to in what wind conditions.

Clear procedures for making and managing severe wind response decisions was recommended by (Fisher, 2004), (IAFC, 2008), and (Madigan, 2005). A clear operating procedure must be directed in SKFR to identify alarm types that fall into what risk management category in order to provide reasonable risk management and continuity for emergency responders (Madigan, 2005). Hoecherl (2003) and IAFC (2008) describe the need for a policy of re-engaging after the storm passes. This identified the need to write the emergency operating procedure with clear and direct language describing distinct decision points as a critical element of this research.

Hoecherl (2003) recommended getting legal advice to implement a stop operations procedure. This directed the research to include an interview consulting SKFR's attorney regarding the legal risks the district may assume with any of the recommended changes.

Noted within current SKFR wind storm literature is that procedures are conducted to manage high call volumes at the dispatch center and SKFR during severe wind events. None of the procedures identify a risk assessment to the danger for employees operating in the environment as part of the process. A review of both elements needs to occur to bring them together so that both concerns are operationally compatible.

IAFC (2008) noted during hurricane responses, personnel should wear structural firefighting full protective clothing including eye protection. This created the need to identify when personnel will don the same protective clothing.

Procedures

This applied research project utilizes action research to develop emergency response strategies for severe wind events in the Pacific Northwest. The first aspect of this research was to conduct an extensive literature review in order to comprehend the findings of other research from published documents and gain a broad understanding of the subject matter. The purpose of these investigations was: to develop information about windstorms in the Puget Sound, identify strategies and procedures currently used, and develop a basis of understanding to conduct further research. An initial investigation was conducted to identify relevant documents and written sources through an extensive search from various locations. This search began on January 11, 2008 at the Learning Resource Center (LRC) at the National Fire Academy (NFA) in Emmitsburg, MD. Extensive holdings of fire service literature including fire service specific journals and magazines, books, and applied research projects completed by previous students are available. From their electronic index and search function, a search for information using the following terms was used: wind; wind storms, wind operations, wind storm response, and hurricanes. From this search, various applied research projects, articles, and books were identified for review.

The second area of electronic searching also started on January 11th , and continued through February 12, 2008. This review was conducted utilizing the search engines Google and Yahoo. The same terms as previously used during the search at the LRC were used in addition to the following: Fire department wind response; wind effects; wind effects trees; wind in the Puget

Sound; wind storms Washington State, risk benefit decision making, fire department risk management, United Kingdom Fire Brigade risk based decision making. From the search, many internet based articles, some references to books, and local news stories were found and utilized.

The third aspect of searching for relevant documents occurred during February of 2008. This search was conducted at SKFR's department library and intranet. This research was conducted by reading the table of contents of relevant texts that lead the author into various sources and by searching the SKFR intranet using the terms: risk, wind, wires, and changing gears.

The next electronic search was conducted at the national near miss data base. It was conducted in order to find any near miss information from severe wind storm responses from the web site located at http://www.firefighternearmiss.com/home.do. The data base search engine was used to find the term wind. Forty six options were identified and manually reviewed to remove those not dealing with severe wind storm emergencies.

From the first section of research, the following research questions were partially answered: Research question 1: How do other fire agencies operate during severe wind storms? Research question 4: When do wind conditions create unreasonable risk to SKFR employees? In addition to these findings, research direction was obtained during the literature review to answer other research questions.

The second type of research was conducted utilizing two questionnaires in a web-based format. The sending, collection, and reporting of information was completed using SurveyMonkey.com. All raw information and data were then available for analysis.

The first questionnaire was sent to all emergency response employees of SKFR using its e-mail server with a hyperlink attached to the Surveymonkey.com mechanism on April 3, 2008.

A cover page explained the research, the time needed to complete the questionnaire, and a statement asking them to complete the questionnaire by April 20, 2008 was provided. The questions were drawn from facts identified during the literature review and the research questions. The questions are outlined in Appendix B. All 74 career emergency responders and 24 volunteer emergency responders for SKFR were sent the questionnaire. This research was conducted in order to partially answer research question 4: When do wind conditions create unreasonable risk to SKFR employees?

A second questionnaire was sent to all fire departments in Western Washington with a population over 10,000 being served. This criterion was determined based upon the availability and access to e-mail addresses to deliver the questionnaire. These e-mail addresses were identified from the Washington State Fire Commissioners and Chiefs Fire Service Directory (Washington State Fire Commissioners and Chiefs, 2008). A total of 92 questionnaires were sent out with the name of the department and the position the questionnaire was sent identified in Appendix C. All questionnaires were sent to the fire chief of the respective department, a public contact e-mail address for the department, or a position close to the fire chief relevant to this research and identified from the department web site. All e-mail addresses were placed in the blind carbon copy area in order to provide security and privacy for those involved. The questionnaire itself was sent using SKFR's e-mail server with a hyperlink attached to the Surveymonkey.com instrument. A cover page explained the research, the time needed to complete the questionnaire , a mechanism to request a copy of the research, and a request to complete the questionnaire by April 20, 2008 was provided. The questionnaire was sent out on April 6, 2008 with the questions identified in Appendix D.

After sending the questionnaire, 12 e-mails were returned as not deliverable. Those returned were rechecked for entry accuracy. Four were not entered accurately and six needed an updated e-mail address accessed from the department specific web sites. From this corrected list a second e-mailing was sent on April 7, 2008 following the same process conducted on April 6, 2008. Two e-mail addresses were returned and researched with no viable method found to capture an accurate e-mail address.

This questionnaire was conducted in order to partially answer the research questions: How do other fire agencies operate during severe wind storms? How can SKFR get accurate weather information to predict severe wind storms and make operational decisions?

The third aspect of research conducted was interviews of local experts regarding severe wind response strategies within SKFR. The interviews were conducted from May 5, 2008 through May 31, 2008. Questions for the interview were carefully developed from the information derived from the literature review as relevant to form answers to aspects of the research questions. These interviews were conducted with a group of professionals who were chosen by the author because of their inherit knowledge of the overall subject, subject specific expertise pertaining directly to Western Washington State or Kitsap County, and those who have responsibility for windstorm mitigation. Interviews were conducted with: Phyllis Mann, Director of Kitsap County Department of Emergency Management; Mark Wesolowski, Emergency Planning Manager for Puget Sound Energy; and Jim Trainer, Community Forester and ISA certified arborist recommended by Phyllis Mann. Jim Trainers personal biography is identified in Appendix E.

The author contacted each of the interviewees by telephone to explain the research, the 30 minute time frame needed for an interview, and to explain the use of the results of the interview. From this conversation, Phyllis Mann agreed to a face to face interview and an appointment was made to meet within a 2 week period at her convenience. At the meeting, a brief overview of the wind storm risk and research was explained, followed by the general questions asked as outlined in Appendix F. Based upon her enthusiasm, interest, and background, the questions were modified as the interview progressed. During the interview, notes were taken and within 30 minutes of the interview. These notes were used to capture the discussions content.

Mark Wesolowski was not available for a face to face interview but was willing to respond to questions through e-mail. A list of questions identified in Appendix G was sent with electronic correspondence.

Jim Trainer was available for a telephone interview only. This interview was conducted on May 23, 2008. The interview started with a brief overview of the research followed by general questions asked as outlined in Appendix H. Based upon his enthusiasm, interest, and background, the questions were modified as the interview progressed. During the interview, notes were taken and within 30 minutes of the interview. These notes were used to capture the discussions.

The interviews were conducted in order to partially answer the following research questions: How can SKFR get accurate weather information to predict severe wind storms and make operational decisions? When do wind conditions create unreasonable risk to SKFR employees?

The fourth aspect of research conducted was needed in order to gather information about the recent history of local wind events within SKFR. The author contacted the National Weather Service Western Region Office using a telephone number from the National Weather Service official web site. From this number, contact was made with Jim Ashbey at the Western Region Office. Conversation with him revealed that recorded weather data was available from a weather station located within SKFR at the Bremerton National Airport and from a reliable station within the Puget Sound Region at the SeaTac International Airport. The data sets requested were basic weather data from 2001 through 2007. They were purchased for $120.00 each and sent electronically via e-mail to the author. After close inspection the data was found to be limited, especially from the Bremerton National Airport. Data was available for the years 2002 thru 2007 but very sporadic after 2005 with no rainfall totals recorded. The information was imported into Microsoft Excel and scrubbed. All text before the header was deleted. It was then sorted by date. Wind speed gusts over 35 miles per hours were identified as the predicate to record other specific types of information. The data recorded was: Wind speed gusts at or over 35 miles per hour and the corresponding sustained wind speed; the direction the wind was traveling referenced to the degrees on a compass; and the precipitation for the 24 hours preceding the wind speed threshold being exceeded. All data was recorded onto two tables reflecting the location of the readings. The SeaTac International Airport data is outlined in Appendix I and the Bremerton National Airport data is contained in Appendix J. This research was conducted in order to partially answer research questions: What severe wind events have occurred and what type and severity of emergency events did they produce for SKFR during the past 5 years? When do wind conditions create unreasonable risk to SKFR employees?

The fifth aspect of research was conducted by utilizing the SKFR's records management systems (RMS) in order to mine for relevant information needed to identify when wind storms have created damage in SKFR and to categorize the type of alarm activity into a value category. On March 1, 2008, an initial meeting was held with Terri Mooney, the Records Management

Systems Manager for SKFR. The meeting was conducted in order to determine how to retrieve the information from SKFR's RMS. From this meeting it was decided to search the RMS by the situation found code. The codes identified as relevant to wind storm activity were: 3720-Trapped by power lines; 4440-cable, phone, power lines down; 4441-Tree into cable, phone, and power lines; 4610-Building or structure weakened or collapsed; 8130-Wind Storm, tornado, hurricane assessment; and 8150-Severe weather, natural disaster. The date parameters for the search was 2002 to 2007 because of the limitations of SKFR's RMS prior to 2001.

These events were down loaded into a Microsoft Excel spreadsheet with the following data exported for each call type: the date, the time of call, the originating fire management area (where the incident occurred), and the incident narrative. These incidents were manually reviewed to determine if they were caused by wind storms. Those alarms determined to be caused by other means were washed from the data set. Those alarms that occurred during wind events that met the criteria of the 35 miles per hour wind speed threshold were then examined and a value typing applied. This value typing was developed to define the community value of an incident.

The author categorized the value of each incident through a manual review of the incident report narrative. A value was applied to the incident based upon the following criteria: protecting life and reducing disability, community risk reduction, and savable property. Three categories of value were developed: a high value typing was applied to those incidents where immediate and direct intervention must occur in order to save a life or reduce disability; a medium typing where a risk not normally encountered in the community was present and actions could be conducted to identify or reduce the risk or mitigate property loss; a low value typing was applied where minimal or no immediate life or disability risk was present and no property could be saved. This typing was then recorded onto Appendix I and J as to the number and value during the wind event.

The purpose of this research was to partially answer the research questions: What severe wind events have occurred and what type and severity of emergency events did they produce for SKFR during the past 5 years? When do wind conditions create unreasonable risk to SKFR employees?

The next area of research was initiated after information from the interviews and questionnaires were collected. From this information, additional options for accessing available local weather stations was identified. As a result, an electronic search was conducted starting on June 29, 2008. The following terms were placed into the search engine at yahoo.com: weather stations Port Orchard and weather stations Washington State. This search was conducted in order to partially answer the research question: How can SKFR get accurate weather information to predict severe wind storms and make operational decisions?

The final procedure conducted during this research was the development of an SKFR Severe Wind Emergency Response Procedure. This document was created after a synthesis of all information developed from the literature review, interviews, data analysis, and questionnaires. This document is contained in Appendix L.

Limitations and Assumptions

It is assumed that all authors cited in the literature review performed objective research and that the data and information attained is accurate; all data acquired from SKFR’s RMS is accurate and represents the needed data element as it was intended; and those interviewed and completing the questionnaires answered honestly with a motive to assist SKFR and the community to prepare for windstorm events.

The limitations of this research starts with the structured interviews of individuals with expertise or responsibility in the areas of this research. This group does not represent a statistical sampling of the total expertise within the field discussed. The individuals were selected to convey their attitudes, expertise, perspectives, and judgment. The interview had opportunity for misinterpretation and potential misunderstanding of the questions. The interview also had inherent bias because the group selected is responsible for aspects of event mitigation within South Kitsap. The interviews were also limited to the questions and answers provided and the dialog between the author and the interviewee. These questions may have been too limiting to the authors interpretation of essential items from the literature review to derive valid results.

Both questionnaires sent out have significant limitations. Each group was selected and asked to complete the questionnaires based upon their judgment and experience. Neither represents a statistical sampling of the total expertise within the field discussed. The groups were selected from both the ability to reasonably retrieve data (population server criteria), and there specific geographic location (Western Washington). The questions asked in the questionnaires may have been too limiting to the authors interpretation of essential items from the literature review to derive valid results. The questionnaires also had opportunity for misinterpretation and potential misunderstanding of the questions. An inherent limitation was placed because the group selected being limited to the scope defined. The questionnaires were also limited by the instrument itself. Utilizing this electronic method does not allow dialog between the author and the interviewee limiting the ability to clarify points and allow true communication and understanding.

The last limitation deals with the data derived from SKFR's RMS and from the National Weather Service's field weather stations. SKFR's RMS is inherently vulnerable to inconsistent interpretations of coding and the use of subjective narratives. During wind storms, call volume is high. Unfortunately some alarms may not be reported because of being lost or forgotten, complicated by personnel inputting large volumes of reports and not focusing on an accurate portrayal of the circumstances. The data from the National Weather Service was found to be limited at the Bremerton National Airport from the years 2002 to 2007, was sporadic from 2006 to 2007, and contained no rainfall information.

Results

Through action research while conducting a comprehensive literature review, RMS data analysis, weather specific data analysis, personal interviews and two questionnaires, the four research questions are answered. Fifty Western Washington Fire Departments completed and returned the questionnaire from the 92 sent out. The questionnaires sent to SKFR personnel had 57 completed and returned out of 96 questionnaires originally sent out.

Research Question 1

How do other fire agencies operate during severe wind storms? From the literature review, it was determined that Weaver (1997) found basing operational response decisions on wind speed was a reasonable approach but expressed concern over one wind speed as a standard for all departments and that every department needed to evaluate their own local situation. Weaver recommended that wind gusts should be used as the determinant. In order to make good decisions Weaver (1997) recommended that wind velocities need to be measured locally. From his research, Weaver concluded that the effect of wind on people and debris creation are the limiting factors to make cease operation decisions, not the limits on vehicle operations. Weaver also reflected that firefighters may be able to arrive safely but may not be able to operate safely at these wind speeds. If citizens are being injured and properties damaged, how can firefighters operate safely.

Contrary to these recommendations, Hoecherl (2003) suggested decision making criteria should be based on sustained winds, not gusts. In this research, Hoecherl identifies the cease operations and resume operations decision as critical command level function. If decisions were made incorrectly, unnecessary risk to emergency responders could occur. If decisions are made to conservatively and emergency response operations suspended to early, increased risk to citizens needing emergency assistance would occur. Hoecherl also recommended finding a reliable source of wind speed data, scientifically valid, for departments to make decisions on ceasing and resuming operations. No clear recommendation was given as to when to cease operations but a 40 mile per hour wind was recommended as the wind speed to resume operations after a hurricane.

Hughes (1998) recommended stopping operations at 50 miles per hour winds because of the danger of flying debris to fire fighters because high winds create debris that make it to dangerous for firefighter to respond.

Fisher (2004) found that decisions to stop responding should be based upon high winds, heavy rain, obstructions in roads, flooding in streets, poor visibility, and flying debris. Personnel were encouraged to use weather stations installed at all fire stations to gather weather data for decision making and to determine when the storm would arrive based upon the meteorological understanding of hurricanes. Fisher also recommended a procedure to follow during hurricanes and to make the cease to respond decision. In high wind conditions, everyone evaluates the safety of responding units. The level of risk allowed to fire resources is based upon information from field units, weather reports, fire department weather station information, and the dispatch center. Decisions to cease operations for a station response area were to be based upon the recommendations of the station company officer with concurrence of the Battalion Chief. Decision to cease operations for an entire Battalion was to be based upon recommendation from the Battalion Chief with concurrence of the Division Manager (Fisher, 2004). Units that were operating in the field when the order to cease operations was given would complete their current assignment as quickly as safety permitted and return to their station. If the conditions are poor and the risk severe, units can take shelter in the nearest available station. Once the cease operation order is given, the dispatch center was assigned to keep a running list of pending responses and establish priorities for deployment once the environment was safe to re-engage (Fisher, 2004). Fisher also identified debris creating danger for responders and that personal protective clothing provides only minor protection from flying debris at winds gusts as low as 40 miles per hour. At this velocity, significant debris begins to be produced creating risks for emergency responders. Fisher (2004) in the research recommendations advised that when trees are falling down, responses need to stop.

Madigan (2005) researched a change in policy from a centralized decision making process that ceased all operations when wind speeds reach 45 miles per hour to a more decentralized and incremental guideline with latitude given to officers at the local level. Problems were identified with the first system because storm conditions being different across the department creating different levels of risk. In 2005 the department changed its criteria to a modified emergency response procedures resulting in responders not being dispatched to down power lines, fire alarms, or public assists at 35 miles per hour sustained winds. From 35 miles per hour sustained to 45 miles per hour sustained, responses were limited to immediate life threats. Above 45 miles per hour sustained winds, responses discontinued with life threatening calls forwarded to the

Battalion Chief who would make the response decision based upon weather conditions and local knowledge. Station officers also had discretion not to respond if they felt conditions were unsafe (Madigan, 2005). Madigan explained during the next hurricane a couple of problems were observed resulting in inconsistent service delivery to the citizens and increased risk to responders because station officers made separate deployment decisions based upon judgments of risk and value.

The IAFC (2008) identified that when winds reach a certain force, debris becomes a lethal weapon that can cause severe injury or death. It is essential to maintain a safe work environment even during this type of uncontrolled event. During high wind hurricane operations, the IAFC recommends the following guidelines be followed: The National Incident Management System including the use of incident action plans; fire departments should provide service until the last moment possible; prior to sustained wind speeds reaching 50 miles per hour or wind gusts over 65 miles per hour, any officer who feels that their situation is dangerous may cease operations and return to quarters, the officer must advise the incident commander and the dispatch center of the decision; discontinue all responses when sustained winds reach 50 miles per hour or wind gusts are over 65 miles per hour; when the order to cease response is given, units responding to or on the scene of an emergency shall continue their work until completed and then return to their assigned stations; units out of station but not on a call will return to their assigned station as soon as possible; members must wear full protective clothing including eye protection for all responses; aerial devises should not be operated when sustained winds are 30 miles per hour or higher; apparatus will be parked headfirst to protect the windshield; dispatch will relay all requests for service to the hurricane command post which will prioritize these requests for response when conditions permit; operating companies must notify dispatch and other responding companies of all hazardous conditions they encounter including high water, road damage or blockage; before walking through water, members must use a pike pole or stick to ensure the ground has not washed away or collapsed, and be aware of hazards in the water such as down live electrical wires; use extreme caution when driving and limit speed being cautious where the ground is saturated or flooded because the road could be washed away; Fire station generators must be outside and elevated to ensure the exhaust is ventilating safely.

IAFC (2008) also recommended guidelines to resume operations after a storm has passed. The chief or designee will make the decision to resume response operations and it shall be announced by dispatch. Personnel conducting emergency operations after the hurricane passes must keep their own safety and wellbeing as the first priority and operations will only be performed if they can be conducted in a safe manner. An important function to perform at this stage is a damage assessment of each company's personnel, equipment, and facilities. Once completed, a windshield survey of the stations first due area must be conducted and damage communicated to command. Officers who think it is safe to resume operations before receiving the resume order will request approval through their chain of command. Command shall review the request and give clear directions. If officers are unable to contact command, the decision to begin operations will be the responsibility of the ranking officer.

The Interview with Phyllis Mann, Director of Kitsap County Emergency Management included a question asking if fire agencies in Kitsap County should have a policy to suspend operations during severe weather events. Director Mann responded with, *absolutely*, and followed with the explanation that Kitsap County Public works and Law Enforcement should also follow a similar criteria. When considering the liability and increased risk in the community from fire departments not responding, she described that when things are real bad from high winds, citizens intuitively shelter in place. This results in them not being exposed to the risk. The real risk increases when the wind speed drops and people think it is safe to go outside. They are then in an environment with potential risks not generally encountered. During this time period, it is essential to have identified, prioritized, and rapidly deploy resources to the most hazardous conditions especially near areas with high population densities. Director Mann also expressed that a good public education campaign would reduce the risk during and after a storm because citizens would be better informed of the hazards.

The questionnaire sent to Mark Wesolowski the Emergency Planning Manager for Puget Sound Energy produced some perspectives. When asked about the increased risk to the public if SKFR shelters in 40 to 50 mile per hour winds, he said if a wire was down and reported as live, Puget Sound Energy would think twice about not responding. If the event was an unknown wire down, they would prioritize it lower and would probably not respond depending on the conditions in the environment. He also reflected that when wind conditions are severe, the public will shelter because of the danger reducing the life risk. It is after the storm that people go outside exposing themselves to the risks.

The questionnaire sent to other Western Washington Fire Departments with over 10,000 population served found 56% of those who responded having a policy to guide deployment decisions during windstorms. There response strategies include: One agency that stopped operations when wind speeds exceeded 40 miles per hour, another at 45 miles per hour, four at 50 miles per hour, and eight at the discretion of the officer in charge. Two reduced service level to life safety events when it became dangerous for responders and five identified calling back off duty personnel as essential.

When asked specifically if they modify operational deployment based upon a wind speed, 67% responded with yes. Thirty nine percent used 50 miles per hour, 20% used 45 miles per hour, and 22% used 40 miles per hour. All of the wind speeds used for altering deployments were based upon sustained wind speeds.

When asked if any employees had been injured or had a near miss, 38% of those that responded replied yes. When asked to describe what occurred to include the approximate wind speed, 21 gave specific details. All but one event was caused by a flying limb or falling tree striking people, apparatus, or blocking apparatus. None of the events caused a fatality. Of the 21 events, only 8 included an estimated the wind speeds. Three occurred at an estimated 40 miles per hour wind, three at 50 miles per hour, and two at 60 miles per hour. Two of these events were power lines that fell on fire apparatus, seven with trees hitting apparatus, four with fire units trapped because of trees down, nine with debris or trees falling and almost hitting firefighters, and one incident where a limb struck and injured a firefighter. Of those who responded to the questionnaire, 76% required structural full protective clothing to be worn during severe wind events.

Research Question 2

What severe wind events have occurred and what type and severity of emergency events did they produce for SKFR during the past 5 years? The data obtained from the National Weather Services weather stations located at the Bremerton National Airport (BNA) and the SeaTac International Airport (STIA) along with the data mined from SKFR's records management system helps to answer this research question. The results of the data derived from this research are posted in Appendix J for BNA and Appendix I for STIA.

At the BNA, a total of 15 wind events occurred where the wind gusts exceeded 35 miles per hour from 2002 through 2007. During these incidents the highest recorded wind gust was 51 miles per hour. The highest sustained wind recorded was 36 miles per hour. BNA had three incidents where the sustained winds exceeded 30 miles per hour. All events noted above had a wind direction between 190 degrees and 230 degrees north on a compass. There are no wind events were sustained winds exceeded 40 miles per hour and only one event with gusts over 50 miles per hour. Six events occurred with at least a 40 miles per hour gusts. Of these events, all were blowing from 190 degrees to 210 degrees north on a compass.

There were 134 emergency calls identified as a direct result of these wind events. Of these calls, 4 were categorized as a high risk, 68 as moderate risk, and 73 as low risk events. The wind storm with the most events occurred on February 4, 2006 with a wind blowing at 200 degrees north on a compass with 49 miles per hour gusts and 33 miles per hour sustained winds. The total calls identified from this wind event were 51 alarms. Events recorded with over 35 miles per hour winds, three did not produce any alarm activity. These wind events had gusts below 37 miles per hour.

At the SeaTac International Airport (STIA), a total of 40 wind events occurred where the wind gusts exceeded 30 miles per hour from 2002 through 2007. During these incidents, the highest gust was 69 miles per hour. The highest sustained wind speed recorded was 46 miles per hour. STIA had seven wind incidents where the sustained winds exceeded 30 miles per hour. Each event noted above had a wind direction between 190 degrees and 230 degrees north on a compass. Only two wind events developed sustained winds exceeding 40 miles per hour and five events with gusts over 50 miles per hour. Eighteen events occurred with at least 40 miles per hour gusts with 12 of these events blowing from 180 degrees to 220 degrees north on a compass.

There were 286 emergency calls identified from these wind events. Of these calls, 2 were categorized as a high risk, 141 as moderate risk, and 143 as low risk events. The wind storm with the most events occurred on February 4, 2006. Winds blowing at 200 degrees north on a compass with 44 miles per hour gusts and 29 miles per hour sustained winds were recorded. As a result, 51 alarms were recorded. Of the wind events identified with over 35 miles per hour winds, 12 did not produce any alarm activity. All of these wind events had peak gusts below 43 miles per hour.

The literature review identified the following dates as when severe wind events occurred in the Puget Sound region from 2002 to 2007: December 14-16, 2002; December 15-16, 2002; December 17, 2002; January 29-30, 2004; November 5, 2005; December 25, 2005; January 1, 2006; February 4, 2006; December 14-15, 2006; October 18, 2007; and December 1-3, 2007 (Read, 2004a). These events and their corresponding weather and call activity data are recorded in Appendix K. A total of 15 storm days are accounted. Wind gusts ranged from 46 to 69 miles per hour. Five of the dates had the highest wind speeds at BNA, four at STIA, and six with data missing. During the top five wind gusts, the wind direction was between 200 and 230 degrees north on a compass. The top seven storms producing the most alarm activity, had a wind direction between 200 and 230 degrees north on a compass, all with wind speed gusts above 40 miles per hour. The highest sustained wind was 46 miles per hour at STIA and 30 at BNA. The questionnaire sent to Puget Sound Energy discovered no reasonable method or easily attainable records to track damage from wind storms within the company.

Research Question 3

How can SKFR get accurate weather information to predict severe wind storms and make operational decisions? During the interview with Phyllis Mann, the Director of Kitsap County

Department of Emergency Management (KCDEM), a service was identified that KCDEM currently utilizes and is available to fire agencies for accurate weather forecasting at a local level. Weathernet.com is a vendor used by KCDEM and Kitsap County Public Works to make operational decisions regarding weather within Kitsap County. The service breaks Kitsap County down into three main regions: North, Central, and South Kitsap County. When asked about service reliability and accuracy, Director Mann reflected great confidence saying, “when they cannot tell what the weather will do, they tell you they can’t predict the weather right now”. The service also provides alerts and warning. Kitsap County Public Works subscribed to it because the National Weather Service was unable to provide enough local weather information to make operational decisions.

The questionnaire sent to Puget Sound Energy showed they are using the National Weather Service in Seattle to make predictions and decisions about preparations and response. They have partnered up with a Warning Coordination Meteorologist. The National Weather Service calls Puget Sound Energy for local information and Puget Sound Energy calls the National Weather Service when they are unsure about impending weather. When the forecasted weather conditions are severe, the National Weather Service conducts *webnars (internet-based seminars),* with regional emergency managers and Puget Sound Energy.

The questionnaire sent to all Western Washington Fire Departments with a population over 10,000 responded with 50 departments answering the question: how does your department receive weather information about potential wind storms? Most departments used multiple methods. Twenty five use the National Weather Service information either from its web site, weather radio, or other means. Twenty two relied upon their Department of Emergency

Management. Thirteen utilized information provided by their dispatch center. Twelve accessed the local news. Only one used local weather stations installed at fire stations.

When asked what they used to monitor wind speeds during a storm, 10 used the local news service, 11 utilized the National Weather Service, 2 used their dispatch center, 8 utilized information from their Department of Emergency Management, 8 utilized weather station installed at fire stations, 12 used other weather stations with information available through the internet, and 2 utilized a private weather service. As with the first question, many departments utilized multiple means to get this information. When asked if the method used to attain weather information was reliable enough to make deployment decisions, 67% responded with yes.

The electronic search conducted to identify currently available, electronically accessible, local weather data produced five general options for current time weather information from within South Kitsap. The National Weather Services warnings can be attained at http://www.wrh.noaa.gov/warnings.php.?wfo=sew. From this address, all warnings and associated weather forecasts can be attained. The National weather Service also maintains weather stations which stream real time weather data with access via the internet. These weather stations can be accessed at: http://www.wrh.noaa.gov/mso/fwxmaps/icsew.php. In addition to these federally sponsored sites, two additional proprietary web sites are available to access current weather data. These sites include: www.wunderground.com and www.weatherbug.com. Both sites give access to streaming weather data accurate to make operational decisions. The last site identified is Washington Department of Transportations weather site. These weather stations are maintained and the data streamed onto their web page at important transportation corridors within South Kitsap. This information can be accessed from: www.wsdot.wa.gov/ *traffic/weather.*

Research Question 4

When do wind conditions create unreasonable risk to SKFR employees? The literature review partially answered this research question. During this review the following facts were identified. The National Weather Service issues wind advisories when sustained winds of 25 to 39 miles per hour or when gusts up to 57 miles per hour are forecasted. Any wind over 40 miles per hour is considered strong, damaging, and dangerous. High winds are further defined as sustained wind speeds of 40 miles per hour or greater lasting for 1 hour or longer and/or winds of 58 miles per hour or greater for any duration. These winds are described as extremely life threatening and dangerous to people and damaging to property (Cox, 2000). In the Puget Sound region, winds produce significant damage to trees resulting in damage and risk of danger to people and property (Robson, 1999; Seattle Office of Emergency Management, 2008; Washington State Military Department, 2007; Wikipedia, 2008a; Wilma, 2007). Also, because trees are a predominant part of the Puget Sound landscape, they create a major component of the problem during windstorm (Robson, 1999).

When wind speeds achieve a Beaufort 9 scale, 47 to 54 miles per hour, they are referred to as punishing causing branches to break. At scale 10, 55 to 63 mile per hour winds are considered howling with trees uprooted. An average wind speed of 60 miles per hour places incredible forces on trees and swathing can result (Read, 2004b). Trees in these circumstances can cause death, injury, or property damage due to windfall and large branches breaking (Harris, 1989; Jacobson, 2007). Significant wind throw can occur with wind speeds as low as 33 to 35 miles per hour (Stathers et al., 1994; Wilma, 2007).

Hughes (1998) recommended that consideration be given to stop operations when winds reach 50 mile per hour winds because of flying debris. Weaver (1997) concluded that the effect of wind on people and debris creation are the limiting factors to make cease operation decisions. Firefighters may be able to arrive safely but not be able to operate in high winds. He questioned, if citizens are being injured and properties is being damaged, how can firefighters operate safely without some form of protection? Fisher (2004) also identified that debris in high winds create danger for responders. Personal protective clothing provides minor protection from flying debris and winds gusts as low as 40 miles per hour begin to produce significant wind borne debris risks. In the research recommendations, Fisher advised that when trees are falling, responses need to stop. Madigan (2005) identified her department as changing deployment patterns when sustained winds were at 35 miles per hour or above. At this point the only time units were deployed was for immediate life threats. When sustained winds reached 45 miles per hour, life threatening calls were forwarded to the Battalion Chief for an individual value assessment.

The questionnaire sent to Puget Sound Energy (PSE) responded with a different point of view. PSE takes shelter by pulling off the road in a safe location when large limbs are breaking flying through the air and trees are falling. They do not have a set wind speed criteria but rely upon the judgment of the responders in the field using this criteria. PSE also expressed that during wind storms it was extremely rare to have an employee injured or killed during storms because of their heightened attentiveness. It’s during routine assignments, a mind wanders from the work, that tragic mistakes happen. Generally, it is the public that is affected by falling trees and branches or contact with power lines. PSE described severe winds as low as 35 miles per hour can create damage significant damage and the more severe the wind the worse the damage. Many variables are involved in creating damage including: rainfall totals and soil saturation before and during the wind event, the snow or ice load on branches, full deciduous trees capturing the wind forces, the first or strongest wind of the season. All of these factors can cause contribute to damage and create a higher risk level.

Jim Trainer expressed many of the same concepts of the other research venues. He stated that the risk in South Kitsap to wind throw and damage from windstorms is high. A lot of development in the South Kitsap area has placed trees previously in stands now exposed to winds and standing next to houses. Land development is a major contributor to wind throw because sites that were dry can become wet when water is diverted. Wet soil conditions weaken the root systems ability to withstand the forces of the wind against the tree. Saturated soils create more wind fall. Many fallen trees are the result being weakened by previous storms. Compaction of soils from machinery during construction damages root systems creating additional risk.

The questionnaire of SKFR emergency response personnel defined the current operating practice of SKFR, to always respond during windstorms, as violating the current risk policy of the department. Forty four percent of those employees who responded to the questionnaire reflected this concern. Comments regarding the reason the personnel felt it violated SKFR's current policy included: responders out in life threatening conditions to evaluate property and live already lost; personnel being placed in dangerous environments for low value incidents; it is a significant risk to have responders out in excessively dangerous environments with power lines dropping with trees and limbs falling for non urgent alarms; During the last storm, my unit responded to a tree into a deck when it was a dangerous environment; Some calls should wait until conditions improve; Power lines down is a power company issue, not the fire departments unless a person is trapped, the lines are causing a fire, or a life threat; Puget Sound Energy is not responding because of the danger, why are we?

The instrument also identified 49% of those that responded as having an injury, close call, or observed one during wind storms in the past 5 years. Of the 57 responders who answered the question, 29 explained details. Nine identified the wind speed around 40 miles per hour and five identified the wind speed as 50 miles per hour or higher. Twenty four of the injuries or close calls were from trees or branches falling, four were from close contact with power lines, either by falling on responding units or near working zones and not identified, transformers exploding near SKFR personnel, and one was from working in a large debris pile in close of proximity to other workers with power tools.

The wind speed that operating personnel thought SKFR should alter its responding practice had 56 responses. Thirty one percent identified 32 to 38 mile per hour winds, 39% thought 39 to 46 mile per hour winds, 12% recommended 47 to 54 mile per hour winds, and 18% thought the wind should be above 55 miles per hour prior to altering deployment. When asked what wind speed should protective clothing be worn, 32% identified 32 to 38 mile per hour winds, 39% identified 39 to 46 mile per hour winds, 12% recommended 47 to 54 mile per hour winds, and 18% thought the wind should be above 55 miles per hour.

The final result of this research is the development of an Emergency Operating Procedure for severe winds in SKFR. In it, direction is provided to continue services as long as the safety of responders is not endangered by storm conditions. South Kitsap Fire and Rescue will maintain a safe work environment even during severe wind emergencies with decision making based around the solid principle that risk and value being balanced in a reasonable context. This means providing essential services to the public during wind storms, as long as the value of the service is at least equal to the risk emergency responders are exposed. This procedure outlines the additional specific criteria for the various phases of the current changing gears plans (KCDEM, 2008). Outline in the process of phase 2 changing gears being implemented when wind speed gusts exceed 40 miles per hour. Phase three and a corresponding shelter in place provision is incorporated when sustained winds exceed 40 miles per hour or gusts of 55 miles per hour. A clear procedure is outlined as to how to shelter in place as well as required use of protective clothing for responders when wind speeds exceed 35 miles per hour. Finally, the process also incorporates the current Area Command, Power Lines down, and Changing Gears Procedure.

Discussion

Through the literature review and answering the research questions, wind storms were found to be a consistent annual risk with a vulnerability of a severe storm occurring like the Columbus (Wikipedia, 2008a) and Inaugural Day storms (Read, 2003a). In the Puget Sound region, winds produce significant damage to trees resulting in damage and risk of danger to people and property (Robson, 1999; Seattle Office of Emergency Management, 2008; Washington State Military Department, 2007; Wikipedia, 2008a; Wilma, 2007). Trees are a major part of the Puget Sound vegetation and create a major part of the problem during windstorm (Robson, 1999). During theses weather conditions, trees and debris topple onto power lines forcing them to the ground where people can make contact with them. The second hazard is that of flying debris from branches and trees dropping (Jacobson, 2007) and potentially hitting people. These storms create significant damage and expose SKFR personnel to considerable danger when operating according to the current deployment pattern. Wind speed was identified as a reasonable criterion to modify response operations by Fisher (2003), Hoecherl (2003), Hughes (1998), Madigan (2005), and Weaver (1997). The questionnaire sent to Western Washington fire departments and the Director of Emergency Management in Kitsap County.

The wind speed determined to be dangerous to responding personnel started in the literature review with the National Weather service identifying 40 mile per hour sustained winds as dangerous along with gusts at or above 58 miles per hour (National Weather Service, 2008a). High winds were further defined as having sustained wind speeds of 40 miles per hour or greater lasting for 1 hour or longer and/or winds of 58 miles per hour or greater for any duration. These winds are described as extremely life dangerous to people and damaging to property (National Weather Service, 2008a). These are rare for South Kitsap with only one event recorded in the Puget Sound Basin meeting this criterion from the past 5 years and none in South Kitsap Fire and Rescue as recorded at the Bremerton National Airport. Even though the winds speeds in SKFR are significantly lower than the National Weather Services dangerous criterion, much damage and many close calls are occurring in SKFR. Wind speeds from the Bremerton National Airport only identify one instance where a gust exceeded 50 miles per hour and at no time were sustained winds recorded over 40 miles per hour. During the worst event, in terms of the number of alarms from trees or limb damage, the highest gust was 49 miles per hour with a sustained wind of 33 miles per hour. This created a total of 51 requests for service from tree or limb breakage. At the SeaTac International Airport the highest number of alarms was caused by 40 four mile per hour gusts with sustained winds of 29 miles per hour. This indicates that the statements made during the research by Jim Trainer are accurate. He reflected that Kitsap County was at high risk to wind damaging trees especially where construction or logging has occurred in the recent past. The interview with Mark Wesolowski of Puget Sound Energy also reflected that as low as 35 mile per hour winds can create significant damage in the Puget Sound area. Also noted during the literature review is that wind throw does occur with wind speeds as low as 30 thee to 35 miles per hour (Jacobson, 2007; Stathers et al. 1994).

Of the 57 employees who responded to the question as to whether they had had or seen a close call or injury, 49% reported that they had. This is an alarming number of potential injuries and deaths when only five of all of these alarm types were found to be of a high risk nature to the community. Thirty four percent of the employees completing the questionnaire identifies 47 to 54 mile per hour winds, as reflected in the Beaufort Wind Scale (Wikipedia, 2008b), as the place to adjust operations.

The questionnaire sent to Western Washington fire departments found, 39% felt that 50 mile per hour winds should be the criteria to stop operations, 28% used 45 mile per hour winds, and 22% used 40 mile per hour winds.

The IAFC (2008) recommends suspension of all operations when wind speeds reach 50 miles per hour sustained or 65 mile per hour gusts. This criterion was developed for the hurricane states, in their geography, vegetation, and history. Fisher (2004) Identified debris as a major danger and hazard with 40 mile per hour winds. The Western Washington wind storm response data indicates to this researcher that a lower wind speed ceiling than that recommended by the IAFC is in order for adjusting deployment decisions. From the call response and wind speed data no statistical clarity was reached but at and above 40 mile per hour gusts, damage is occurring and risk increasing for emergency responders. The data showing damage at lower speeds may be a result of the actual risk of wind throw risk in Kitsap County. Soil depth and moisture saturation (Stathers et al., 1994), the number of large fir trees (Coutts, Grace, 1995), and the logging and development practices (Harris, 1989; Stathers et al., 1994) may create a larger risk than other areas of the country. This author cannot imagine how a Douglas fir tree, 180 feet tall with roots only 3 feet into the soil would handle winds above 50 miles per hour, much less those winds experienced in the hurricane states.

Weaver (1997) concluded that basing operational response decisions upon wind speed was a reasonable approach but expressed concern over one wind speed as a standard for all departments. Weaver also recommended that every department evaluate their local situation and use good judgment to meet the needs of their circumstances.

The policy of SKFR on risk and value decision making (SKFR, 2001) clearly identifies principles consistent with the other literature (Brunacini & Oppelt, 1985; Fulton County, 2003; National Fallen Firefighters Foundation, n.d.; USDA, 2005). All of these documents reflect the principles of risk must equal value. No value means taking no risk. The problem is that SKFR does not implement these principles to the windstorm environment. For example, there were only six instances of high value alarms during windstorms of the 420 evaluated. Yet SKFR responded to all alarms in an environment that at times was dangerous. Not generalizing the risk value principle from the structure fire environment into severe wind storms places SKFR personnel into the alley of danger with no value. This was not done intentionally, but simply where SKFR has drifted without analysis and focus.

The IAFC (2008), Madigan (2005), and Fisher (2004) recommend officers having the authority to shelter when in their judgment the risk does not meet the value, even if the wind speed criteria has not been met. SKFR (2006) also directs this risk value approach to emergencies. Fisher (2004) and Mark Wesolowski of Puget Sound Energy identified a reasonable recommendation to assist officers in evaluating their environment. Both describe common sense criteria applicable for fire agencies to determine if the wind is dangerous to responders. When trees are falling down or large limbs are breaking and flying through the air, it is dangerous. This simple yet effective message clarifies the judgment aspect for emergency responders who do not have weather data available when conducting operations.

The decision to suspend broader operations was considered a critical command level function by Fisher (2004), Hoecherl (2003), IAFC (2008), Madigan (2005), and Weaver (1997). If decisions were made incorrectly, the results would be the unnecessary exposure of emergency responders to dangerous and unpredictable conditions or if made to conservatively, would suspend emergency response operations to early increasing the risk to citizens who may need emergency assistance (Hoecherl, 2003). IAFC (2008) recommended a decision that would apply across the entire fire department. This did not take into account that wind conditions may be significantly different over large geographical area.

Weaver (1997) recommended that the decision be made locally with local weather data preferable from weather stations at each fire station. Weaver also experienced severe wind situations when the decision to suspend operations was without clear guidelines and left the decision up to the officer in charge. This caused inconsistency in response and service levels. Hughes (1998) and IAFC (2008) recommend a uniform procedure that once wind speed meets a certain criteria, all operations stop. Madigan (2005) found the blanket decision ineffective and utilized a more decentralized approach which caused inconsistent service levels. Fisher (2004) created a mechanism for decisions to be made locally but approved centrally. Both types of decision models seem to have problems and benefits.

On the one hand the blanket approach protects responders. On the other it limits service levels in some areas that may not be severely affected by the weather system. The more decentralized approach can create confusion because responder judgments regarding the current risk will be different from person to person.

It would seem that clear guidelines and good communications are essential (Fisher, 2004) from the command to the company level. Blanket procedures could create inefficiencies and the inability to meet the mission of the fire department. For SKFR the concepts developed by Fisher (2004) and Madigan (2005) seem to apply. A set and clear criteria would be followed in severe circumstances with the ability to utilized judgment at the local level as approved by the command level. Command would in severe situations suspend operations after consulting with regionally represented station officers and approve when to redeploy.

IAFC (2008) recommends sheltering at 50 miles per hour sustained or 65 mile per hour gusts. This criteria would certainly require sheltering of fire department resources in South Kitsap Fire and Rescue's environment. Conditions being different in SKFR than hurricane areas, an incremental approach to altering deployment as mentioned by Madigan (2005) may be the best option. The research showed significant damage from falling trees and limbs in South Kitsap with wind speed gusts of only 40 miles per hour. This information creates the need to change deployment criteria earlier than recommended by IAFC (2008). The decision itself would be best made in SKFR by its on duty Battalion Chief in consultation with company officers at different representative stations within SKFR.

IAFC (2008) includes guidelines instructing how to resume operations after a storm. The Chief or designee makes the resume operations and then clearly communicates it through dispatch. In SKFR, as reflected by Madigan (2005), a blanket approach may not be in the best interest of all stakeholders. Utilizing a consultation approach will work best in order to attain good local intelligence across the 154 square miles of SKFR. IAFC (2008) also recommends that officers who think it is safe to resume operations before receiving the resume operations order, to contact their chain of command, describe the conditions at their location and the reason's they recommend resuming operations. Command should review the request and give clear directions.

If officers are unable to contact command, the decision to begin operations is the responsibility of the highest ranking officer with operations being performed only when it is safe.

When protective clothing should be donned during wind storms was addressed by Fisher (2004) who recognized that at 40 mile per hour winds, enough force can be generated to break branches and develop loose debris which may fly through the air impacting firefighters. Fisher believed this would be a wind speed where protective clothing including eye protections should be worn. IAFC (2008) recommended that during severe wind operations, all members must wear full protective clothing including eye protection for all responses in order to protect responders from flying debris. The questionnaire sent to Western Washington Fire Departments found that 76% required protective clothing to be worn during wind storms. The questionnaires sent to SKFR personnel found that 31% thought protective clothing should be worn when winds reached 32 to 38 miles per hour and 38% thought mandatory protective clothing should be enforced in the 39 to 46 mile per hour range.

The data from the National Weather Service and SKFR's records management system reflects minimal alarm activity from wind events with less than 35 mile per hour gusts. This seems to be a natural threshold for mandatory wearing of structural firefighting clothing and eye protection. From a common sense perspective, the small pieces of debris generated at lower wind speeds may indicate the need for eye protection at a lower wind speed.

Attaining accurate weather information was first considered by Weaver (1997) who recommended wind velocities be measured locally. In Weavers situation, the closest weather station was at the County seat, many miles from his jurisdiction. As a result, Weaver recommended weather stations be installed so officers could make local decisions as to when to stop and then resume operations. Hoecherl (2003) also recommended finding a reliable source of wind speed data to make decisions on ceasing and resuming operations. Fisher (2004) recommended utilizing weather data from weather stations installed at all stations. Madigan (2005) recommended installing weather stations at all stations allowing personnel access to local weather data.

The questionnaires sent to Western Washington Fire Departments found diverse methods being used to attain impending weather information. Many departments used multiple means. Most used the National Weather Service, local Department of Emergency Management, or their dispatch center for weather alerts and predictions. Only one department used local weather stations installed at their fire station. When monitoring current conditions during a storm 8 used data from weather stations installed at their station, 12 used internet sources, and 2 subscribed to a weather service. The rest depended on local news. Sixty seven percent were comfortable with this data. From this information, it seems a multi-facetted approach would best cover the numerous possibilities. Utilizing the National Weather service's alert and warning system through the Department of Emergency Management works well to activate awareness of an impending problem. In projecting future needs, the subscription weather service available through the Kitsap County Department of Emergency Management would provide more local projections in order to determine staffing needs. Internet sources and local weather stations would serve best during the actual wind storms to identify real time local conditions. The investment in the fire station installed weather stations would be beneficial, especially if internet access was limit because of storm damage.

The organizational implications of this research and the implementation of the recommendations are tremendous in terms of firefighter safety and the professional deployment of reasonable, researched based, decision criteria. The risk for firefighters is tremendous based upon the employee questionnaires results. These close calls were all from the past 5 years in which no significant wind events have occurred. The real concern is the ability to recognize a severe risk event from wind conditions created by mid latitude cyclones like the Columbus (National Weather Service, 2008a) or Inaugural Day storms (Read, 2003a).

If SKFR does not implement a standardized system and train its personnel on its usage, serious risk to employees with injuries and even death are a potential result. SKFR must adjust its practices by first recognizing the tremendous potential of catastrophic storms, then acquiring the tools necessary to monitor wind speeds. From this information, SKFR will be ready to adjust deployments to the risk and value in the community resulting in a tragedy can be averted. Finally, during these unpredictable circumstances, community safety is critical. Fact based decisions must be made to keep the community risk at a reasonable level.

Recommendations

This research has identified the risk of the current deployment practices of SKFR during windstorms. The purpose of this research was to identify the risk and develop reasonable strategies to deploy and operate from during severe wind events. Based upon the results of this research, several recommendations are made for SKFR that will profoundly reduce risk to emergency responders and the community during severe windstorms:

- South Kitsap Fire and Rescue should adopt the Emergency Operating Procedure-Severe Windstorms posted in Appendix L.
- South Kitsap Fire and Rescue should conduct annual training on the Emergency Operating Procedure-Severe Windstorms.

- South Kitsap Fire and Rescue should purchase and install weather stations at all staffed fire stations so that accurate and timely local weather data can be attained by responding personnel.
- South Kitsap Fire and Rescue needs to conduct a public education campaign with the Department of Emergency Management to prepare citizens for the change in deployment and safe citizen sheltering practices during severe wind events.
- An annual evaluation of alarm data based upon wind speeds should be conducted to monitor any changes from items not identified.

Future readers and research should consider the following recommendations:

- Improper and inaccurate coding of data create extra work for collection and analysis. When conducting research with your agency's specific data, allow focused time to clean up your local records in order to create accurate reports.
- Intensive focus should be placed on identifying the wind throw and tree damage risk in each community. The types of trees, soils, logging practices, and topography should be considered and developed further to take the next step in quantifying this research effort.

References

Brunacini, A., & Oppelt, J. (1985). *Fire command.* College Park, MA: Productions.

Bunacini, A. (n.d.). *The IC's role in Save Our Own*. Retrieved March 3, 2008, from Public Entity Risk Institute Web site: https://67.192.124.97/peri/component/option,com _bookmarks.

Coutts, M. P., & Grace, J. (Eds). (1995). *Wind and trees*. New York: Cambridge University Press.

Cox, J. (2000). *Weather for dummies*. Hoboken, NJ: Wiley Publishing.

Fisher, E. (2004). *Research based guidelines for decision making in hurricane conditions: When do we stop responding?* Emmitsburg, MD: National Fire Academy.

Fulton County Fire Department. (2003). *Rules of engagement.* Retrieved March 3, 2008, from http://www.everyonegoeshome.com/resources/fultonroe.pdf.

Harris, A. S. (1989). *Wind in the forests of Southeast Alaska and guides for reducing damage*. Portland, OR: U.S. Department of Agriculture.

Hoecherl, R. (2003). *A contemporary approach to hurricane preparedness for the fire-rescue department.* Emmitsburg, MD: National Fire Academy.

Hughes, J. (1998). *Hurricane impact on fire department operations*. Emmitsburg, MD: National Fire Academy.

IAFC. (2008). *Model procedures guide for response of emergency vehicles during hurricanes and tropical storms*. Retrieved March 23, 2008, from http://www.iafc.org/associations/4685/files/safetyApp_IAFCmodelProcedsVehiclesInHurricanes.pdf.

Jacobson, A. (2007). *Douglas firs: Friend or foe*. Retrieved March 14, 2008, from http://www.plantamnesty.org/images/ALJ%20doug%20fir%20v2.pdf.

Kamb, L. (2006*). Wind, rain cause region havoc.* Retrieved January 26, 2008, from http://seattlepi.nwsource.com/local/296085_winda15ww.html.

KCDEM. (2008). *Changing gears plan*: *Appendix (1) to annex M*. Port Orchard, WA: Author.

KOMOTV. (2006). *Latest storm updates*. Retrieved March 22, 2008, from http://www. komotv.com/news/4921736.html.

KOMOTV. (2007). *What makes a Western Washington windstorm?* Retrieved March 5, 2008, from http://www.komotv.com/weather/faq/4306592.html.

Long, P. (2006). *Hood Canal Bridge sinks during a severe wind storm*. Retrieved March 22, 2008 from http://www.historylink.org/essays/output.cfm?file_id=5501.

Madigan, M. (2005). *Emergency response during severe wind associated with hurricances: When to "go/don't-go"*. Emmitsburg, MD: National Fire Academy.

National Fallen Firefighters Foundation. (n.d.). *Offensive versus defensive tactics.* Retrieved March 24, 2008, from http://www.everyonegoeshome.com/resources/docs/4offensivevsdefensive.doc.

National Firefighter Near Miss-Reporting System. (2007). *Report no. 07-0000652.* Retrieved January 28, 2008, from http://www.firefighternearmiss.com/home.doc.

National Fire Protection Association. (2006). *Fire Department Occupational Safety and Health Program* (NFPA 1500). Quincy, MA: Author.

National Weather Service. (2008a). *Washington's top 10 weather events of 1900s*. Retrieved March 22, 2008, from http://www.NWSPortland.htm.

National Weather Service. (2008b). *Defintions*. Retrieved March 5, 2008, from http://www.nws.noaa.gov/glossary/

National Weather Service. (2008c). *Mission*. Retrieved March 22, 2008 from http://nws.weather.gov/mission.shtml.

Northern Ireland Fire Brigade. (n.d. a) *The safe person concept.* Retrieved March 3, 2008, from http://www.safefromfire.org/section2_3.asp.

Northern Ireland Fire Brigade. (n.d. b). *Dynamic risk assessment.* Retrieved March 3, 2008, from http://www.safefromfire.org/section2_1.asp.

Northern Ireland Fire Brigade. (n.d. c). *Risk phases.* Retrieved March 3, 2008, from http://www.safefromfire.org/section2_2.asp.

Office of the Deputy Prime Minister. (2006). *Fire statistics, United Kingdom, 2004*. London, England: ODPM Publications.

Past is prologue: History demonstrates windstorms strike anywhere. (2006). *Record, 83*, 2.

Pidwirny, M. (2007). *Mid-latitude cyclone*. Retrieved March 5, 2008, from http://www.physicalgeography.net/fundamentals/7s.html.

Pidwirny, M. (2008). *Introduction to the atmosphere*. Retrieved March 22, 2008, from http://www. physicalgeography.net/fundamentals/chapter7.html.

Pinelli, J., & Subramamian, C. (2003). *Wind effects on emergency vehicles.* Melbourne, FL: Florida Institute of Technology, Wind, & Hurricane Impact Research Laboratory.

Read, W. (2003a). *The devastating Inaugural Day storm of 1993*. Retrieved March 22, 2008, from http://www.ocs.oregonstate.edu/storm_king_site/January1993.html.

Read, W. (2003b). *A breakdown of fatalities from Pacific Northwest windstorms*. Retrieved January 28, 2008, from http://www.ocs.orst.edu/storm_king_site/WindstormFatalaties.html.

Read, W. (2003c). *The strong windstorm of January 16-17, 1986*. Retrieved March 25, 2008, from http://www.ocs.orst.edu/storm_king_site/January161986.html.

Read, W. (2003d). *Pressure gradients, storm tracks, wind speeds*. Retrieved March 30, 2008, from http://climate.washington.edu/stormking/.

Read, W. (2004a). *The strongest windstorms in the Western Pacific Northwest*. Retrieved March 5, 2008, from http://www.ocs.oregonstate.edu/storm_king_site /PNW StormRanks.html.

Read, W. (2004b). *The storm king*. Retrieved March 22, 2008, from http://www.ocs.orst.edu/storm_king_site/index.html.

Read, W. (2008). *The great costal gale of December 1-3, 2007*. Retrieved March 22, 2008, from http://www.ocs.orst.edu/storm_king_site/December2007.html.

Richardson, P. (n.d.). *Protecting the part time firefighter?* Retrieved March 3, 2008, from http://www.fire.prg.uk/IFE/ife-agm/Richards.htm.

Robson, M. (1999). *Checking tree safety before winter storms.* Retrieved March 13, 2008. from Washington State University Extension Web site: http://gardening.wsu.edu/column/10-03-99.htm.

Scmidlin, T., Hammer, B., King, P., Miller, L., Thumann, G., & Wetherington, H. (2002). *Critical wind speeds to upset two styles of ambulances and a large city bus.* Palm Beach, FL: Division of Emergency Management.

Seattle Office of Emergency Management. (2008). *Wind storms*. Retrieved March 22, 2008, from http://www.seattle.gov/emergency/hazards/windstorms.htm.

SKFR. (1998). *Power lines down ES-04.* Port Orchard, WA: Author.

SKFR. (2001). *Risk management SOP 6-02.* Port Orchard, WA: Author.

SKFR. (2006). *Incident management procedures*. Port Orchard, WA: Author.

SKFR. (2008). *2007 annual report*. Retrieved March 21, 2008, from http://www.kitsapfire7.org.

Stathers, R., Rollerson, T., & Mitchell, S. (1994). *Windthrow handbook for British Columbia forests.* Victoria, BC: British Colombia Ministry of Forests:

Tissington, P., & Flin, R. (2004). *Assessing risk in dynamic situations: Lessons from fire service operations.* Birmingham, UK: Aston University.

USDA. (2005). *Fire suppression: Foundational doctrine.* Retrieved February 25, 2008, from http://www.wildlandfire.com/docs/ 2005/usfs_doctrinal _review.htm.

USFA. (2007). *Executive analysis of fire service operations in emergency management* (2nd ed). Emmitsburg, MD: National Fire Academy.

USFA (2008*) USFA and the National Fire Protection Association Release Report on Mitigation of the Rural Fire Problem in the United States* Retrieved March 30, 2008 from http://www.usfa.dhs.gov/media/press/2008releases/020508.shtm

Washington Administrative Code. (1997). *Safe place standard*. Retrieved February 25, 2008, from http://apps.leg.wa.gov/WAC/

Washington State Fire Commissioners and Chiefs. (2008). *Washington State fire service directory.* Olympia, WA: Washington Fire Commissioners.

Washington State Military Department. (2007). *Windstorm response after action report.*

Retrieved March 23, 2008 from http://www.wadisasternews.com/posted/1105/ FINAL_AAR_040407.153345.pdf.

Washington State Military Department, Emergency Management Division. (2007). *Washington State hazard mitigation plan*. Retrieved March 22, 2008, from http://emd.wa.gov/plans/documents/SevereStormNov2007Tab5.7.pdf.

Washington State Legislature. (n.d.). *Title 52 Revised Code of Washington Fire Protection Districts.* Retrieved March 21, 2008, from http://apps.leg.wa.gov/rcw/default. aspx?Cite=52.

Weaver, C. (1997). *Establishing criteria to determine fire department operations during high wind situations*. Emmitsburg, MD: National Fire Academy.

Wikipedia. (2008a). *Columbus Day storm of 1963*. Retrieved March 22, 2008, from http://en.wikipedia.org/wiki/Columbus_day_storm.

Wikipedia. (2008b). *Beaufort wind scale*. Retrieved March 5, 2008, from http: //en.wikipedia.org/wiki/Beaufort_scale.

Wilma, D. (2005). *The great blow down*. Retrieved March 22, 2008, from http://www.historylink.org/essays/output.cfm?file_id=5249.

Wilma, D. (2007). *Hanukkah eve wind storm ravages Western Washington on December 14 and 15, 2006*. Retrieved March 22, 2008, from http://www.historylink. org/essays/ output.cfm?file_id=8042.

Windstorm. (1997). *IRI Sentinel, 3*, 6.

Appendix A

Beaufort Wind Scale

Beaufort Number	Wind/Speed MPH	Description	Land Conditions
0	0	Calm	Calm, smoke rises straight up.
1	1-3	Light Air	Wind motion visible in smoke. Wind drift indicates direction of wind.
2	4-7	Light Breeze	Wind felt on exposed skin, leaves rustle.
3	8-12	Gentle Breeze	Leaves/Smaller twigs in constant motion. Light flags extend.
4	13-18	Moderate Breeze	Dust and loose paper raised. Small tree branches begin to move.
5	19-24	Fresh Breeze	Smaller trees with leaves begin to sway.
6	25-31	Strong Breeze	Large branches move. Whistling heard in overhead wires. Umbrella use becomes difficult.
7	32-38	Near Gale/Moderate Gale	Whole trees in motion. Effort needed to walk against the wind.
8	39-46	Fresh Gale	Twigs broken from trees. Generally impedes progress.
9	47-54	Strong Gale	Light structure damage, slate blows off roofs, branches break.
10	55-63	Whole Gale/Storm	Trees uprooted. Considerable structural damage.
11	64-73	Violent Storm	Widespread structural damage.
12	74-95	Hurricane	Considerable and widespread damage to structures.

Appendix B

Questionnaire for All SKFR Response Personnel

1) During windstorms, South Kitsap Fire and Rescue's current operating practice is to respond to all emergencies requests for service in the order of their severity regardless of wind speed and weather conditions.

SKFR's risk management policies and principles include the following statements:

> "Operations are to be limited to those that can be safely performed by the personnel available at the scene. To assist incident commander in risk management decision making, three principles are identified".
>
> - Significant risk shall only be taken where there is a high potential to save lives and the risk has been calculated and considered in relation to the benefit.
> - Moderate risk may be taken to save property. Actions and procedures shall be taken to reduce and avoid risks and a structured implemented to save property.
> - Nothing shall be risked to save lives and property already lost or destroyed.

Based on your judgment and experience, does the current operating practice for windstorm operations violate these policies or principles? Yes/No

If yes, please explain why.

2) During wind storms have you ever been injured or had a close call or near miss? Yes or No

If yes, please describe the situation, the call you were on, the wind conditions to include the estimated wind speed in miles per hour, and the event that occurred.

3) Based upon you experience and referencing the Beaufort Wind Scale below, what wind speed should SKFR adjust its operations because of the safety risk to its personnel:

Appendix C

Western Washington Fire Departments included in Severe Wind Response Questionnaire

Clallam County:	
Port Angles Fire Department	Fire Chief
Clallam County Fire District 2	Fire Chief
Clallam County Fire District 3	Public e-mail
Clark County:	
Camas Fire Department	Fire Chief
Vancouver Fire Department	Fire Chief
Clark County Fire District 3	Fire Chief
Clark County Fire District 6	Fire Chief
Clark County Fire District 9	Fire Chief
Clark County Fire District 11	Fire Chief
Cowlitz County:	
Longview Fire Department	Fire Chief
Cowlitz County Fire District 2	Fire Chief
Grays harbor County:	
Aberdeen Fire Department	Fire Chief
Island County:	
Oak Harbor Fire Department	Fire Chief
Island County Fire District 1	Fire Chief
Island County Fire District 3	Not available
Jefferson County:	
East Jefferson Fire and Rescue	Acting Fire Chief
King County:	
Bellevue Fire Department	Fire Chief
Bothel Fire Department	Fire Chief
Eastside Fire and Rescue	Fire Chief
Kent Fire Department	Public e-mail
Kirkland Fire Department	Fire Chief
Mercer Island Fire Department	Fire Chief
Redmond Fire Department	Fire Chief
Renton Fire Department	Fire Chief
Seatac Fire Department	Fire Chief
Seattle Fire Department	Fire Chief
Tukwilla Fire Department	Unavailable
Valley Regional Fire Authority	Administrator
King County Fire District 2	Public e-mail

King County Fire District 11	Public e-mail
Vashon fire and Rescue	Public e-mail
King County Fire District 16	Fire Chief
King County Fire District 20	Fire Chief
Enumclaw Fire Department	Director
Woodinville Fire and Life Safety	Fire Chief
South King Fire and Rescue	Fire Chief
Maple Valley Fire and Rescue	Fire Chief
Mountain View Fire and Rescue	Fire Chief
King County Fire District 45	Fire Chief
Kitsap County:	
Bremerton Fire Department	Fire Chief
Central Kitsap Fire and Rescue	Fire Chief
Kitsap County Fire District 2	Fire Chief
North Kitsap Fire and Rescue	Fire Chief
Poulsbo Fire Department	Fire Chief
Lewis County	
Riverside Regional Fire Authority	Fire Chief
Mason County:	
Mason County Fire District 5	Fire Chief
Pacific County:	
Pacific County Fire district 1	Fire Chief
Pierce County:	
Tacoma Fire Department	DEM
Puyallup Fire Department	Fire Chief
Lakewood Fire Department	Fire Chief
Pierce County fire District 3	Admin Services
Pierce County Fire District 5	Fire Chief
Central Pierce Fire and Rescue	Fire Chief
South Pierce Fire and Rescue	Fire Chief
Pierce County Fire District 16	Fire Chief
Pierce County Fire District 17	Fire Chief
Pierce County Fire District 18	Fire Chief
Pierce County fire District 22	Fire Chief
East Pierce Fire and Rescue	Fire Chief
Skagit County:	
Mount Vernon Fire Department	Fire Chief
Anacortes Fire Department	Fire Chief
Sedro-Wooley Fire Department	Fire Chief
Burlington Fire Department	Public e-mail

Skagit County Fire District 8	Public e-mail
Snohomish County:	
Arlington Fire Department	Fire Chief
Edmonds Fire Department	Fire Chief
Everett Fire Department	Fire Chief
Lynnwood Fire Department	Fire Chief
Mukilteo Fire Department	Fire Chief
North County Fire and EMS	Fire Chief
Snohomish County Fire District 1	Fire Chief
Snohomish County Fire District 3	Fire Chief
Snohomish Fire Department	Fire Chief
Snohomish Fire County District 5	Fire Chief
Snohomish Fire County District 7	Unavailable
Snohomish Fire County District 8	Fire Chief
Marysville Fire Department	Fire Chief
Snohomish Fire County District 17	Public e-mail
Thurston County:	
Olympia Fire Department	Fire Chief
Tumwater Fire Department	Fire Chief
SE Thurston Fire and Rescue	Fire Chief
Thurston county fire District 3	Fire Chief
East Olympia Fire Department	Fire Chief
Thurston County Fire District 9	Fire Chief
Little Rock Fire and Rescue	Public e-mal
Whatcom County:	
Bellingham Fire Department	Fire Chief
Lynden Fire Department	Fire Chief
Whatcom County Fire District 4	Fire Chief
Whatcom County Fire District 7	Fire Chief
Whatcom County Fire District 8	Fire Chief

Appendix D

Questionnaire Sent to Western Washington Fire Departments with Populations Over 10,000

1) How does your department receive weather information about potential wind storms?

2) During a severe wind storm, does your department monitor wind speed? Yes/no

If yes, how?

3) Is this method of monitoring weather conditions accurate and reliable enough to make decisions? Yes/No

4) Does your department have a written or unwritten operating policy/procedure to guide decision making and practice during severe wind conditions? Yes/no.

5) Briefly describe your operating policy/practices during windstorms.

6) Do you have a wind speed criteria that is used to modify responses?

If yes what is it and how does your department determine this wind speed.

7) Has your department had any employees injured or have a close calls/near miss during windstorms? Yes/No. If yes please describe what happened.

8) Do you require the wearing of full protective clothing structural firefighting clothing to be worn during windstorms? Yes/No. If yes, what are the criteria that it must be worn during a severe wind storm event?

Appendix E

Jim Trainer Professional Biography

Jim Trainer is a nationally known Community Forester. He has been recognized by the National Arbor Day Foundation to be the only forester in the United States to win both Tree Line USA and Tree City USA Awards. He is an International Society of Arboriculture Certified Arborist, Washington State University Master Gardner for 25 years and founding member of KiTSA, a non-profit tree organization. Jim has done tree presentations for Arbor Day Foundation in Nebraska, Seattle, WA, Tacoma, WA, Bellingham, WA, Olympia, WA Port Townsend, WA, Cle Elum, WA, and Ellensburg, WA. and many other cities in the state. Jim Trainer is a Champion Tree Hunter in Washington. He coordinates with the University of Washington Champion Tree Program on his finds. He has developed a Kitsap Trees Champion Tree Calendar for 2005, which has been distributed nationally. It was the first ever-Champion Tree Calendar for the State of Washington. Jim received the Man of the Year Award by the East Bremerton Rotary Club in 2006 for his environmental work with youth. Jim does volunteer environmental work for Kitsap Trees now KiTSA (Kitsap Trees and Shoreline Association) and Illahee Preserve and many other projects throughout Kitsap County where he is needed. Kitsap Trees in 2002 received The Earth Day Award from Kitsap County for their environmental stewardship. Starting January 2007 Jim became a part-time Naturalist Eco-Tour Guide for Local Escapes specializing in bear, eagle, elk, cougar and Heritage Trees. Recently, Jim was awarded a Certificate of Appreciation from Washington State Parks in 2007 for his dedication to Natural Resources throughout Washington State Parks.

Retrieved July 7, 2008 from http://treezinc.com/index.html

Appendix F

Interview Questions Asked of Phyllis Mann, Director Kitsap County Department of Emergency Management

1) What sources of weather information are currently available for government agencies within Kitsap County to monitor weather conditions?

2) How are they accessed? Are they available to Fire Departments within Kitsap County?

3) Does any Kitsap County Governments have criteria to alter service deliveries or shelter in place during windstorms? If yes what are they?

4) In your professional judgment, should Kitsap County Fire Departments modify their current practice during windstorms especially in a severe event like the Columbus Day or Inaugural Day Storm?

5) Should other Kitsap County Government agencies develop and implement a wind speed criteria?

6) From your point of view, what additional risk will the citizens of South Kitsap inherit during a severe wind storm if SKFR chooses to delay response or shelter in place?

Appendix G

Interview Questions Sent to Mark Wesolowski of Puget Sound Energy

1) Where does PSA get weather and wind data to predict and prepare a response

2) What criteria and what data does PSE utilize to make a decision to staff up and prepare for an incoming storm?

3) Historically do you have records of damaging dates, locations, and times to use to identify wind velocities that create or have created damage? If so what winds speeds have historically caused damage to PSE resources.

4) When do your employees shelter from a wind storm and how is this accomplished?

5) Have you have employees injured or killed during windstorms? If yes could you explain the general details.

6) When do you think fire departments should shelter?

7) How significant do you think the risk to citizens will increase if fire departments shelter in place incrementally? This will delay placing hazard the identification of a wire down or in severe risk situation the placement of a fire unit. This would only be done in the most severe circumstances when wind speeds exceed 40 to 50 miles per hour.

Appendix H

Interview Questions asked Jim Trainer, Certified Arborist in Kitsap County

1) What is the risk of wind throw and limb damage to trees in South Kitsap during wind storms?

2) What is the wind speed where damage is seen?

3) What type of trees pose the most risk to damage?

4) What are the soil characteristics within South Kitsap regarding a trees ability to withstand wind storms?

5) What conditions create high risk of damage and wind throw in South Kitsap?

Appendix I

SeaTac International Airport Wind Data and Associated SKFR Call Activity from 2002 to 2007

Date	Wind Direction	Wind Speed Gust/Sustain	24 hour Precipitation	Total Call	Low Risk	Moderate Risk	High Risk
04/14/02	230	36/22	1.51	3	2	1	o
11/16/02	210	39/26	.46	5	2	3	0
12/19/02	120	35/29	N/A	0	0	0	0
12/25/02	180	35/18	N/A	4	1	3	0
12/27/02	200	48/31	N/A	12	5	7	0
01/02/03	210	35/21	.5	3	3	0	0
03/05/03	220	35/28	N/A	0	0	0	0
10/12/03	190	36/17	N/A	2	0	2	0
10/16/03	210	37/24	N/A	14	3	10	1
11/18/03	200	35/22	.76	9	4	5	0
12/04/03	120	44/29	N/A	3	3	0	0
01/30/04	230	37/24	N/A	0	0	0	0
02/25/04	120	37/30	N/A	1	0	1	0
12/12/04	100	39/29	N/A	2	1	1	0
03/20/05	200	37/21	N/A	10	2	8	0
05/18/05	230	40/22	N/A	0	0	0	0
12/18/05	100	43/22	N/A	5	1	4	0
02/04/06	200	44/29	N/A	51	24	27	0
02/10/06	90	35/24	N/A	0	0	0	0
03/01/06	120	39/29	N/A	1	0	1	0
03/06/06	220	39/26	N/A	2	1	1	0
03/08/06	210	52/31	N/A	8	3	5	0
05/07/06	230	35/22	N/A	1	1	0	0
11/13/06	230	37/29	N/A	0	0	0	0
11/15/06	220	35/25	.34	8	5	3	0
12/11/06	210	44/24	1.2	2	1	1	0
12/13/06	240	46/26	.52	15	5	10	0
12/14/06	200	52/36	1.14	30	16	14	0
12/15/06	230	69/46	1.31	35	19	16	0
01/02/07	200	41/28	.91	6	4	2	0
01/05/07	200	36/22	.58	6	3	3	0
01/07/07	220	36/23	N/A	2	1	1	0
01/09/07	250	41/24	N/A	0	0	0	0
02/15/07	220	37/25	.12	4	3	1	0
02/19/07	210	35/24	.38	1	0	1	0
10/02/07	190	36/23	.11	0	0	0	0
10/18/07	210	53/34	N/A	15	10	5	0
10/19/07	210	38/25	N/A	4	3	1	0
11/12/07	200	54/43	.34	5	2	3	0
12/02/07	180	43/30	.48	4	3	1	0

Appendix I (continued)

Date	Wind Direction	Wind Speed Gust/Sustain	24 hour Precipitation	Total Call	Low Risk	Moderate Risk	High Risk
12/03/07	200	41/25	2.1	12	9	2	1
12/18/07	220	38/25	.41	0	0	0	0
12/19/07	210	38/29	.18	0	0	0	0
12/23/07	200	41/26	.30	0	0	0	0
12/28/07	200	38/25	N/A	1	1	0	0
12/29/07	220	43/29	N/A	0	0	0	0

Appendix J

Bremerton National Airport Wind Data and Associated SKFR Call Activity From 2002 to 2007

Date	Wind Direction	Wind Speed Gust/Sustain	24 hour Precipitation	Total Call	Low Risk	Moderate Risk	High Risk
11/16/02	210	37/25	N/A	5	2	3	0
12/27/02	220	40/30	N/A	12	5	7	0
01/02/03	220	35/29	N/A	3	3	0	0
01/03/03	210	37/23	N/A	1	0	1	0
01/04/03	210	36/23	N/A	0	0	0	0
10/12/03	210	40/21	N/A	2	0	0	2
10/16/03	190	35/23	N/A	14	3	10	1
11/17/03	210	37/25	N/A	0	0	0	0
03/18/04	230	37/24	N/A	7	6	1	0
04/27/04	220	37/25	N/A	0	0	0	0
04/01/05	220	39/29	N/A	4	2	2	0
12/25/05	200	42/29	N/A	19	9	10	0
02/04/06	200	49/33	N/A	51	24	27	0
10/18/07	210	51/36	N/A	15	10	5	0
12/03/07	200	43/26	N/A	12	9	2	1

Appendix K

Weather and Call Data for Wind Storms Identified During the Literature Review: 2002 to 2007

Date	Wind Direction	Wind Speed Gust/Sustain BNA	STIA	24 hour Precipitation BNA	STIA	Total Calls	Low Risk	Moderate Risk	High Risk
12/15/02	180	29/20	31/17	N/A	.66	0	0	0	0
12/16/02	200	28/25	27/18	N/A	.87	0	0	0	0
12/27/02	220	40/30	48/31	N/A	.10	12	5	7	0
01/01/04	30	24/17	NA/14	N/A	N/A	1	1	0	0
01/29/04	210	33/21	27/21	N/A	N/A	1	0	1	0
01/30/04	230	32/25	37/24	N/A	1.41	0	0	0	0
11/05/05	190	20/16	N/A	N/A	N/A	0	0	0	0
12/25/05	200	42/29	34/28	N/A	.68	19	9	10	0
01/01/06	180	N/A	33/24	N/A	.18	6	1	5	0
02/04/06	200	49/33	44/29	N/A	N/A	51	24	27	0
12/14/06	200	N/A	52/36	N/A	1.14	30	16	14	0
12/15/06	230	N/A	69/46	N/A	1.31	35	19	16	0
10/18/07	210	51/36	53/34	N/A	N/A	15	10	5	0
12/02/07	180	N/A	43/30	N/A	.48	4	3	1	0
12/03/07	200	43/26	41/25	N/A	2.1	12	9	2	1

Note. Wind direction reading taken from location with the highest gust.

Appendix L

Emergency Operation Procedure for Severe Winds in SKFR

South Kitsap Fire and Rescue

Emergency Operating Procedure-Severe Winds XX-XXX

Effective Date: 10/01/08

Scope: All Operations Personnel

Reference: IAFC (2008) Model Procedures Guide for Response of Emergency Vehicles During Hurricanes and Tropical Storms.

Responding on alarms during severe wind emergencies can place responders in unsafe environments. One of the most difficult decisions for an Incident Commander during these events is to determine when to halt emergency response operations. The problem for emergency responders is when winds reach a certain force, debris becomes a lethal weapon that can cause severe injury or death. The intention of the guideline is to balance the need to protect both the emergency responders and the citizens they serve. Services will continue as long as the safety of responders is not endangered by storm conditions.

South Kitsap Fire and Rescue will maintain a safe work environment even during severe wind emergencies with decision making based around the solid principle that risk and value must be balanced in a reasonable context. This means during wind storms, providing essential services to the public as long as the value of the service is at least equal to the risk emergency responders are exposed.

During severe wind operations the following general guidelines will be followed:

- During severe wind storms, the Area Command and Changing Gear procedures will be utilized.
- Operations shall provide service until the last moment possible. When condition exists to cease operations, a conscious and calculated decision must be made and clearly communicated.
- During severe wind storms, any officer who feels that their situation is dangerous to the may cease operations and return to quarters. The officer must consult with the incident commander of the decision. An indication of a dangerous wind environment includes when trees are falling and large limbs are breaking and flying through the air in the immediate area.
- During all phases, the Duty Chief shall actively monitor the storm from real time weather stations available on the internet at:
  http://www.wrh.noaa.gov/mso/fwxmaps/icsew.php
  www.wsdot.wa.gov/ traffic/weather
  www.wunderground.com
  www.weatherbug.com.

- All members must wear full protective clothing including eye protection when wind speeds exceed 35 MPH for all responses in order to protect from flying debris.
- Aerial devises should not be operated when sustained winds are 35 miles per hour or higher.
- Operating companies must notify the Area Command of all hazardous conditions they encounter including high water, road damage or blockage.
- Use extreme caution when driving and limit speed. Be especially cautious where the ground is saturated or flooded because the road could be washed away.
- Station safety: Generators must be outside and elevated to ensure the exhaust is ventilating to the outside. Generator should not be placed on the apparatus floor because of the risk of carbon monoxide accumulating in the enclosed room.

SKFR shall incrementally reduce service levels during wind storms that correlate to the phases of ACC and Changing Gears Operational Plans:

Phase one activation: This is an alert phase which identifies that a major storm is approaching requiring the notification of SKFR to start preparing. During this phase, the Duty Chief is notified by DEM of the potential event and then consults with DEM and verifies the information from the following sources:

- Weathernet.com
- National Weather Service at http://www.wrh.noaa.gov/mso/fwxmaps/icsew.php.

Based upon this information the Duty Chief shall project future needs and make staffing decisions to call back personnel and have volunteer's staff stations. An indicator of the need to call back personnel is when wind gusts are estimated to be above 40 MPH in South Kitsap. Additional consideration should be given to ramp up resources if considerable rain or the first major wind event of the season is occurring.

The Duty Chief shall instruct all stations to top off all fuel levels; start and prepare generators; acquire extra hazard tape and flares; and all personnel to review this emergency operating procedure, the Area Command procedure, and the Power Lines Down procedure.

During this phase, all power line down calls not deemed to be a hazard by the 911 call receiver will be directed to contact the electrical utility. If there is a hazard, a priority will be assigned to the event and it will be dispatched. All other phases handle the no hazard wires down calls in the same manner.

Duty Chief shall communicate conditions and actions with the Fire Chief or designee and company officers.

Phase two activation: Initiated when the demand for resources exceeds those available and/or when wind gusts exceed 40 MPH. The Area Command shall be set up and enhanced operation initiated. Dispatch alerts via tone for priority 1 and 2 events. Lower priority events are sent to the Area Command via fax or e-mail. These lower priority events shall be ranked in order of their value with priority given to not assign them to companies until the wind speed decreases below 40 MPH gusts for a 15 minute period. If through consultation with a company officer a response is warranted based upon the value and the local wind conditions, they shall be assigned to respond. If a higher priority event is dispatched, the unit shall divert from those lower priority assignments given to them from the Area Command.

Phase three activation: Implemented when a major catastrophic event occurs exceeding local governments' ability to respond effectively. All 911 calls are processed and sent to the Department Area Commands for prioritization, assignment, and tracking and/or when alarm activity is overwhelming or sustained winds exceed 40 MPH and/or gusts exceed 55 MPH. All units shall shelter in place within their assigned station. All calls shall be forwarded to the Area Command who shall prioritize the events according to value. The Duty Chief shall review all high value requests for service and make a risk value decision in consultation with the station officer involved in order to have the best local weather and risk information.

The Area Command shall institute the seek shelter order via radio with confirmation of all units via phone or radio contact.

When the seek shelter notification is given:

- Units responding to or on the scene of an emergency when the seek shelter notification is given, shall continue their work until completed, and then will return to their assigned stations. Units out of station but not on a call will return to their assigned station.

- Apparatus will be parked headfirst into the station to protect the windshield.

Area Command shall monitor weather information for rapid deployment once the weather moderates. The criteria to resume operations will utilize the same incremental criteria as used to reduce service levels. When sustained winds are below 40 MPH and gusts are below 55 MPH, SKFR will drop back to Phase 2 operations. When gusts are below 40 MPH, SKFR will drop back to Phase 1 operations.

Resumption of Operations:
Area Command shall make the decision as to when the department can resume response operations. The decision to resume operations will be announced by dispatch.

Officers who think it is safe to resume operations before receiving the resume operations order will contact their chain of command to describe the conditions at their location and the reason's they recommend resuming operations. Command shall review the request and give clear directions. If officers are unable to contact command, the decision to begin operations will be the responsibility of the highest ranking officer. Operations will only be performed in a safe manner.

Personnel conducting emergency operations after a severe wind event must keep their own safety and wellbeing as the first priority. Hazards encountered include: live wires, gas leaks, structure fires, unstable buildings, flooding, hazardous materials, traumatized victims, civil disturbances and displaced animals.

An important function to perform at this stage is a damage assessment of each company's personnel, equipment, and facilities.