Severe Weather Planning for Schools

National Clearinghouse for Educational Facilities

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Understanding the Danger

Scenario 1. Lightning Strike

It's a warm afternoon and the football team is on the field practicing. Some parents and a few other spectators sit in the bleachers watching the play. The sky to the west is darkening and a warm breeze has picked up. The rumble of thunder can be heard in the distance. Keeping a watchful eye to the sky, the coach figures he can get through most of the practice before the rain comes. There is a big game on Saturday and only one practice left. He can't afford to let up now.

The practice continues, the thunder gets louder and the sky a bit darker. A cool, gusty wind now blows in from the west, but still no rain. A parent walks over to the coach and asks about the chance of practice being called early. The coach smiles and says, "I've been watching that storm and it appears to be passing north of us now." The sky begins to lighten to the west and a couple sun rays beam down from beneath the towering clouds. Suddenly, a white streak hits the goal posts in the end zone with a deafening roar. Players, near that end of the field, tumble to the ground.

There is confusion. What happened? Where did the lightning come from? The storm was at least 5 miles away and none of the previous strokes were anywhere near the school. It seemed to just come out of the blue!

In 1988, eleven players on the Silver City, New Mexico, football team where taken to the hospital after lightning struck their practice field. Fortunately none where killed, but four were seriously injured. Every year lightning hits ball fields during little league and soccer games. Many games are not called until the rain begins, and yet it is not the rain that is dangerous. Ball fields provide a lot of potential lightning targets such as poles, metal fences, and metal bleachers. The fields themselves are wide open areas where players are often the tallest objects around.

Lightning is the most common thunderstorm threat. Nationally, lightning kills an average of over 70 people annually and injures hundreds more. This number may not seem high, yet when you look at the individual cases, most could have been prevented. The basic rule of thumb is "If you can hear thunder, you are close enough to the storm to be struck!" Thunderstorms extend 5 to 10 miles into the atmosphere. Winds aloft can blow the upper portion (anvil) of the storm many miles downstream. Lightning can come out of the side or anvil of the storm, striking the ground 10 to 15 miles away from the rain portion of the cloud.

These are the strokes that are the most lethal — the ones that happen away from the core of the storm. A good idea is to use the rule many community pools use: Go inside at the first rumble of thunder, and stay indoors until at least 15 minutes after the last rumble is heard. Getting indoors, and not seeking shelter under trees or under open air pavilions to "get out of the rain", is what will keep you safe. "When thunder roars, go indoors!"

Scenario 2. Flash Flood

Heavy rains from thunderstorms had been occurring all day in the Virginia foothills and the National Weather Service issued a Flash Flood Watch around noon. The rain had let up by the time the children loaded the buses at Hillboro Elementary School. With a full load of children, Fred started the bus and pulled out.

Fred had been driving this route for over five years and had never encountered any flood problems. He didn't expect any today. About halfway through his route, he turned onto Dark Hollow Road. The road crosses a small stream. This afternoon the stream was out of its banks and flowing across the road. Fred slowed the bus as he approached the water. If he turned around, it would take

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him an extra hour to get the remaining children home. The water looked less than a foot deep. Certainly, the bus could safely cross that. He decided to move forward.

The bus moved easily through the water, but as it approached the bridge, the front tires fell into a hole. With murky water over the road, Fred hadn't seen that the pavement had been undermined. He attempted to back out, but the bus wouldn't budge. What was worse, the water was continuing to rise and was now more than a foot and a half above the road! Fred knew he better act fast. There were still eleven children on the bus.

About fifty yards away was higher ground, a hillside. They would head there. The current was picking up. He would have to carry the smaller ones. His third and last trip from the bus to the hill was a hard one. In just ten minutes, the water had risen to waist deep and he could barely keep his footing. Grabbing on to trees and bushes along the way, he pulled himself and the last child to the hillside and out of the water. He was exhausted. He wouldn't have made it if he had to carry one more. As he turned around to look back at the bus, the bus overturned and washed into the raging waters.

Nationally, floods are the number one weather-related killer, with over half the fatalities from drowning in automobiles. *Never enter flooded waters!* If caught in rising water, abandon your vehicle immediately and move to higher ground. Fred and the children were lucky. He acted quickly and got them to safety, but he never should have attempted to cross the flooded area to begin with. A good motto is "Turn around, don't drown."

Scenario 3. Tornado

It is 1:30 p.m. and the principal has just learned that the National Weather Service has issued a Severe Thunderstorm Watch. Thunderstorms are building to the west and are expected to hit the school district in less than an hour. He decides to cancel all outdoor activities and makes an announcement to teachers and staff.

At 2:05 p.m. it begins to get very dark outside and there is a rumble of thunder. The principal steps out to have a look. The sky appears as if its boiling and has taken on a green tinge. The wind picks up and the trees begin to sway. A cool blast hits him and a cloud of dust blows across the parking lot. "This storm doesn't look good." He reenters the building and is told the National Weather Service has just issued a Severe Thunderstorm Warning for their county. Suddenly he hears a roar of wind and a crash. The storm has let loose a downburst — a sudden, strong rush of wind.

He rushes toward the source of the noise. A tree branch had shattered a classroom window and a few children were injured from the flying glass. Two will need stitches. He evacuates the classrooms on the windward side and moves the children into the interior music room, which has no windows. They will be safe there.

Hail begins to fall and grow larger in size. The physical education instructor is barely heard above the roar of the hail striking the gymnasium roof and skylights. She moves the students into the locker rooms where it is safer. Large hail can impact at 100 mph. Suddenly, the skylights shatter. The principal decides to play it safe and move all students into the interior hallways. Lights flicker and the power goes out. He can't announce it on the PA system so he grabs a bull horn and begins rapidly moving through the school. The students and teachers empty out of the classrooms, a little confused. Some are excited by the commotion and some are scared by the storm. The hallways are noisy with anxious voices but they quiet down when a roar, similar to the sound of a train drowns them out. Teachers yell "Get down! Drop to your knees and cover your head!" Glass is heard breaking somewhere in the building.

It was all over quickly. Only ten minutes had passed since the thunder began. A tornado had struck the school. The classrooms on the south side of the school were destroyed. The cafeteria and gymnasium roofs were gone. Children and teachers were shaken but injuries were relatively minor. Because the principal in this scenario took the proper actions, lives were saved. No one was killed.

Lessons Learned

Flash floods, severe thunderstorms, and tornadoes occur with rapid onset and often no warning. Decisions must be made quickly and actions taken immediately.

Don't wait to decide what must be done to save lives. Prepare a severe weather plan for your school and train staff and students to carry it out effectively.

Preparing for Severe Weather Emergencies

How to Get Weather Information

Tornadoes and severe thunderstorms can occur with little, if any, warning, so minutes and even seconds can mean lives. In just five minutes a tornado can travel two to four miles. From the time the National Weather Service (a part of the National Oceanic and Atmospheric Administration, or NOAA) issues a warning to the time the warning appears on a commercial radio or television station, ten minutes may have elapsed, and unless you are listening at the moment the warning is first announced, a much greater amount of time may pass.

The fastest, most accurate, and most reliable means of receiving critical weather information at your school is with a ***public alert radio*** (also called a hazard alert or weather radio). Public alert radios tune to NOAA Weather Radio All Hazards, a nationwide network of radio stations broadcasting all-hazards information 24 hours a day, 7 days a week. Broadcasts include alerts and safety steps on a wide range of emergencies, such as an approaching tornado, a telephone outage disrupting 911 emergency services, local roads overrun by flash floods, a derailed train posing a hazardous material threat, or the urgent need to be on the lookout for an abducted child.

Public alert radios use a "tone alert" to indicate that a hazard warning is forthcoming. Built-in Specific Alert Message Encoding (SAME) allows users to set their radios to sound the tone alert only when their specific geographic area is affected. The federal government provides public alert radios to all public and private schools in the United States. The radios also can be purchased at electronics stores for under $100.

If your school is not located in a reliable NOAA Weather Radio All Hazards broadcast listening area (because of interference from mountains or other sources), and if attaching an exterior antenna does not help, there are two alternatives:

- If your school has cable television access, the Weather Channel issues hazard warnings immediately upon receipt from NOAA Weather Radio All Hazards, with warnings continuously scrolled across the bottom of the screen. Some cable companies include a channel with a local National Weather Service radar display and use NOAA Weather Radio All Hazards broadcasts as a voice-over.

- You can monitor local radio and television stations for Emergency Alert System messages relayed from NOAA Weather Radio All Hazards broadcasts.

The phone "call-down" systems used in some localities are *not* advised for relaying severe weather emergency warnings due to the time elapsed in relaying information, the chance of incorrect or incomplete information being passed, the lack of reliability of phone systems during storms, and the National Weather Service's advice not to use telephones during electrical storms.

Locate the public alert radio in the school's main office. When it sounds a tone alert, listen for the type of weather warning and where it is in effect. School staff must know what to do based on this information. Have a map nearby to track severe weather movements. There is no need to take emergency action if the warning is not for your area, but be prepared in case the severe weather moves your way.

Alerting Teachers and Students

Most schools utilize a public address system to talk directly to students and teachers. Electric power may be lost during a storm, so it is important to have an emergency backup power source or a manual alerting device such as a compressed air horn or megaphone.

If your school has portable classrooms or other detached buildings that are not on the public address system, make specific notification arrangements. Sending "runners" outside may not be advisable if the weather hazard is near, so consider some form of wireless communication, such as cell phones or walkie-talkies.

Handicapped or learning-disabled students may require special attention. Assign staff members to see that each student is moved to safety.

Determining Safe Areas of Refuge

This may be the most time consuming and important phase of preparing a severe weather plan. The Metropolitan Emergency Managers Association publishes a *Checklist for Determining Severe Weather Shelter Areas in Buildings*, but buildings are so complex and diverse that it is best to **seek the help of an**

engineer or architect familiar with your school's design.

Portable classrooms are extremely vulnerable to high winds from a tornado, hurricane, thunderstorm downburst, or strong pressure surge behind a cold front. They should never be used as areas of refuge in severe weather.

The next most vulnerable locations are large rooms with expansive roofs such as cafeterias, gymnasiums, and auditoriums. The collapse of a room's outer wall can lead to failure of the adjacent roof. Roofs can also fail from strong upward wind pressures that they were not designed to resist.

Large windows may shatter from wind pressure or being struck by airborne missiles — a dangerous situation for those nearby. Windows on the side of the school facing the storm are most susceptible, but as the storm passes, other windows can shatter. Once wind enters a building, additional damage is likely. This is one of the reasons that you should *close all windows when a storm approaches*.

Small interior rooms and interior hallways away from exterior doors offer the best protection. Close as many interior doors as possible. Interior rooms with short roof spans provide better protection than those with long roof spans. If the school has more than one level, evacuate the upper floors; the lowest level is always the safest. It may be difficult to find areas of refuge in open-plan schools because they have fewer interior walls and corridors.

Fortunately, the majority of tornadoes will not destroy a well-constructed building. Damage in about 75 percent of cases does not go beyond roofs.

For more detailed building information, see Chapter 6, "Making Schools Safe Against Winds," in FEMA 424, *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds*.

Activating a Severe Weather Plan

When deciding to activate your plan, gather as much information as possible about the type of weather hazard, its expected time of arrival, and its potential impact on your school.

The plan may work best with several phases of activation. For instance, outdoor activities are the most susceptible to severe weather hazards, with lightning the greatest threat. If thunder is heard or lightning is seen, outdoor activities should be delayed with students and spectators moved to safety immediately. Do not wait for rain. The delay in activities should last until the storm has safely passed. This means that thunder is not heard and lightning is not seen for 15 minutes. During a tornado or severe thunderstorm watch, outdoor activities should be postponed.

As the weather hazard approaches, prepare to move students from the most susceptible areas of your school, such as portable classrooms and gymnasiums, to safer areas, even though a local warning has yet to be issued. For potentially severe thunderstorms, consider posting spotters to watch the storm's approach.

If a severe thunderstorm warning is issued, all of the above actions are warranted. In addition to strong damaging winds, severe thunderstorms may contain large hail, and students should be moved out of areas with skylights and large exterior windows.

If a tornado warning is issued and you have determined that your school is in its path, issue an immediate and complete "Call to Action." Move students to safer areas and post a spotter to keep an eye on the storm's approach. From your drills you should know approximately how long it will take to move students into tornado-safe areas. As the tornado or storm begins to hit, all students should be in the designated safe areas.

Winds may pick up at the onset of a storm and may or may not drop off prior to the tornado. It may get very dark out. Rain, lightning, or hail may or may not occur. Large hail is a signal that you are near the part of the storm in which the tornado could occur. If there is no warning and students and teachers are still in their classrooms, the safest thing for everyone to do is to drop beneath their desks and cover their heads. Once the storm has passed, stay alert for the possibility of additional storms.

If a "Call to Action" is given during a class change, the halls will be crowded and students may not know where to go, so it is best to hold classes beyond their regular dismissal times until the weather threat has passed. Likewise, at the end of the school day, students may need to be held from boarding busses.

When to Hold Up the Departure of School Buses

Busses provide no protection from severe storms, so consider holding the departure of students to buses whenever severe weather watches or warnings are in effect. There are two considerations:

- After busses depart, how long will it take before all students are safely at home, including the time it takes for students to walk from the bus to their house?

- How much time do you have before the storm could reach your school? Severe thunderstorm and tornado watches are sometimes issued several hours in advance of their development and usually cover large areas. But there may be a rapidly developing situation with less than an hour to prepare.

If there is not enough time to get students home safely, hold up bus departures.

Discourage parents from picking up their children in severe weather. They need to understand that children are far safer at a school with a severe weather plan in place than on the road.

Also consider the number of children living in mobile homes, which are extremely susceptible to high winds, even when properly anchored and tied down. Schools provide a far safer environment. A storm that would produce minor damage to a school could completely destroy a mobile home and kill its occupants.

School Bus Actions

Train your bus drivers to handle severe weather conditions, particularly tornadoes and flooding, but also high winds, unexpected heavy snow or ice, extreme heat, and extreme cold and wind chill. In most cases, these conditions are forecast in advance, but there are times when they are not.

Tornadoes. *Never attempt to outrun a tornado!* If bus drivers have reason to believe a tornado is approaching, they should:

- Try to get the students into a well-constructed building or house as fast as possible. Move them into the interior or basement, away from windows and doors.

- If no shelters are available, look for a ditch or low lying area, preferably one without water. Stop the bus downwind from the location selected so the bus cannot roll in that direction. Unload the students and move them to the ditch or low-lying area and have them assume a protective position with their hands over the head.

Flooding. *Never attempt to drive through flood waters!* If the bus route crosses small streams and creeks or runs along a river and flood waters are encountered, seek an alternate route or return to the school. Major river and coastal flooding is well forecast in advance, so schools and drivers can plan their strategy prior to putting the students on the bus. But flash flooding — a sudden, dramatic and dangerous rise in water levels — can sometimes occur without warning. Drivers need to understand what to do in a flash flood before they encounter it.

In general, shallow ponds of water on the roadway are usually not a problem, but otherwise:

- Do not enter road sections that cannot be seen beneath the water. They may be undermined or the water may be deep enough to stall the bus.

- Never enter flooded underpasses.

- If water appears to be flowing *across* the road, do not proceed. The bus could act as a barrier and the water could lift and move it.

- If water is flooding over or around a bridge, do not cross it; the foundation of the bridge may be compromised and the bridge could collapse from the weight of the bus.

Water levels can rise extremely rapidly, and the force of the water against an automobile or a bus can be amazingly powerful. If the driver is caught in an unavoidable situation, seek higher ground immediately. If the bus stalls and water is rising, abandon the bus and take children to higher ground before the situation gets out of control.

Exposure. Children awaiting the school bus in the morning, standing exposed to a cold wind without proper clothing for protection, may develop hypothermia. School bus drivers and teachers should be taught to recognize symptoms of hypothermia and frostbite.

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On hot, humid days when the heat index exceeds 100 degrees F., some children may have difficulty handling the heat. They may be boarding the bus from an athletic event or coming from a hot classroom. A child may be dehydrated and starting to show signs of heat exhaustion. Drivers and teachers should be taught to recognize symptoms of heat stress.

Severe Weather Plan Checklist

Ensure that your school's severe weather plan accounts for the following:

■ Is the plan designed so teachers and students anywhere on the school grounds can be quickly alerted and follow a preset plan of action to maximize safety?

■ Who is responsible for activating the plan? Is there a back-up person?

■ What is the primary means of receiving severe weather information? A public alert radio (see page 3) is recommended.

■ What method will be used to alert teachers and students? Is there a back-up that does not require electricity?

■ How will teachers and students in portable classrooms be contacted and relocated?

■ How will students in the cafeteria or gymnasium be contacted and where will they go?

■ How will students with disabilities be moved to safe locations? Will an adult be assigned to each student to ensure his or her safety?

■ How will students who are outside, including those in after-school activities, be notified and moved to safe locations? Remember, if you can hear thunder, it is time to take action. Those outside are at risk from lightning, large hail, severe winds, and wind-borne objects.

■ Can your school building withstand the following natural forces:
– Forces caused by winds and the airflow around the building.
– Forces caused by objects such as fragments of glass, wood, and metal hitting school walls and windows.
– Pressure differences caused by a tornado.
– Gas leaks and electrical hazards after the storm. Make key staff knowledgeable about turning off electric power and gas.
– Wind tunnel effects. Objects blown by tornado-strength winds can cause serious injury when accelerated in relatively narrow hallways in schools.

■ Are school staff prepared for the following thunderstorm hazards?
– Lightning, which may pose a threat well before strong winds or rain affect the area. Athletic teams out on open fields need to be especially cautious.
– Large hail, which can break windows and skylights.
– Heavy rains and flooding. Are there flood-prone areas near the school?
– Damaging "straight-line" winds. A thunderstorm does not have to produce a tornado to pose a severe threat to schools and students.

■ Are the best shelter locations known and is staff trained to move students to them? The safest places in a school with no underground shelter are:
– Interior hallways on the lowest level, preferably hallways at a right angle to the approaching tornado's path (to avoid the wind tunnel effect).
– Rooms away from windows, the smaller the better.

■ Has an engineer or architect located safe areas of refuge within your school?

■ Have you contacted the nearest National Weather Service office or local emergency services organization for assistance in developing your plan?

■ Have you integrated the severe weather plan in your school's crisis plan? See Practical Information on Crisis Planning: A Guide for Schools and Communities and Mitigating Hazards in School Facilities.

Periodic Drills and Training

An effective severe weather plan includes periodic drills and training. Drills not only teach students and instructors the actions they need to take, but allow you to evaluate your plan's effectiveness. Did everyone hear the message, did they understand what to do, and were they able to get to designated safety areas in a reasonable amount of time? It is best to conduct drills in conjunction with a severe weather education and awareness program so students and teachers understand the dangers of severe weather and better comprehend the actions to undertake.

The National Weather Service, in conjunction with state offices of emergency management, runs statewide weather awareness campaigns. Tornadoes are usually publicized the last week in March, before the onset of the severe weather season. These campaigns are coordinated through local emergency management agencies and news media and usually include a proclamation from the governor. It may be an opportune time for your school to conduct emergency training and drills.

Contact your nearest National Weather Service office or local emergency management office if you would like a speaker to come to your school and discuss severe weather safety.

Conduct severe weather drills at least twice yearly — at the beginning of the school year in September and again in March. The September drill will instruct new students about procedures and act as a refresher for returning students. The March drill will get everyone ready for the start of the severe weather season. Although severe thunderstorms and tornadoes are often advertised as springtime or summertime events, in the Mid-Atlantic and Southeast, outbreaks of severe thunderstorms and tornadoes often occur in October and November.

Resources

National Weather Service (NWS) and National Oceanic and Atmospheric Administration (NOAA):

- *A Guide to Developing a Severe Weather Emergency Plan for Schools*, http://www.erh.noaa.gov/lwx/swep/swep.pdf
- NWS Homepage, http://www.nws.noaa.gov
- NOAA Weather Radio All Hazards, http://www.crh.noaa.gov/Image/lot/nwr/NWR-FactSheet.pdf
- Public Alert Radios for Schools, http://public-alert-radio.nws.noaa.gov
- National Weather Radio Receiver Consumer Information, http://www.weather.gov/nwr/nwrrcvr.htm
- NOAA Weather Radio, County-by-County Coverage, http://www.weather.gov/nwr/indexnw.htm
- The Weather Channel, http://www.weather.com
- Metropolitan Emergency Managers Association, *Checklist for Determining Severe Weather Shelter Areas in Buildings*, http://www.severeweather.state.mn.us/Documents/TornadoShelterAreaDetermination.pdf
- NOAA Emergency Alert System, http://www.nws.noaa.gov/om/NWS_EAS.shtml
- National Weather Service, Offices and Centers, http://www.weather.gov/nwr/indexnw.htm
- National Weather Service, Local Contact Information, http://www.nws.noaa.gov/stormready/contact.htm
- National Weather Service, Education and Outreach, http://www.nws.noaa.gov/education.php

U.S. Department of Education, Office of Safe and Drug-Free Schools:

- *Practical Information on Crisis Planning: A Guide for Schools and Communities*, http://www.ed.gov/admins/lead/safety/emergencyplan/crisisplanning.pdf

National Clearinghouse for Educational Facilities (NCEF):

- *Mitigating Hazards in School Facilities*. Includes 25 NCEF Assessment Guides, http://www.edfacilities.org/pubs/mitigating_hazards.pdf
- *NCEF Safe School Facilities Checklist,* http://www.edfacilities.org/checklist/index.cfm
- NCEF resource list, *Disaster Preparedness for Schools*, http://www.edfacilities.org/rl/disaster.cfm
- NCEF resource list, *School Preparedness for Natural Disasters,* http://www.edfacilities.org/rl/natural_disasters.cfm
- NCEF resource list, *State and Local School Emergency Planning Guides*, http://www.edfacilities.org/rl/statelocal_emergency.cfm
- NCEF resource list, *Assessing Flood- and Wind-Damaged Schools,* http://www.edfacilities.org/rl/assessing_flood_damaged_schools.cfm

Federal Emergency Management Agency (FEMA):

Chapter 6,"Making Schools Safe Against Winds," FEMA 424, *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds*, http://www.fema.gov/plan/prevent/rms/rmsp424.shtm

Appendices

The following appendices provide detailed weather-related information, most of which is not school-specific:

Appendix A
Severe Weather Safety

Tornadoes and Severe Winds

The greatest danger is from flying debris (airborne missiles) and the collapse of a building's roof and/or wall structure. The following actions are designed for protection from these dangers. Take action if a tornado approaches or a tornado warning is issued.

In the school, move to interior rooms or hallways on the lowest level. Stay away from windows and exterior doors. If at all possible, get under something (such as a table) and place something over your head (such as a pillow, mattress, blanket, or coat) for added protection.

Do not remain in portable classrooms or any type of temporary shelter. Get out. Look for a low area, preferably a ditch or ravine if nearby. Take the protective position on your elbows and knees with your hands over your head.

Do not try to outrun a tornado in a vehicle. Stop. Get out. Move away from the vehicle so it does not topple on you. Find a low area, preferably a ditch or ravine if nearby. Take the protective position on your elbows and knees with your hands over your head.

If on foot with no well-constructed shelter nearby, find a low area preferably a ditch or ravine if nearby. Take the protective position on your elbows and knees with your hands over your head.

If a tornado has struck your neighborhood, turn off gas at the main switch to your building. If live electrical wires are down, turn off power at the main switch. Instruct people not to touch loose electrical wires or broken utility lines. Do not touch electrical equipment in wet areas until it has been dried and tested. Food, clothing, shelter, and first aid will be available at Red Cross shelters.

Hail (from Thunderstorms)

Hail larger than golf balls, or even smaller hail driven by strong winds, begins to damage vehicles and windows. To avoid getting hit with hail, one needs only to move inside. However, there are other considerations such as staying away from skylights. Hailstones that are large enough can go through a vehicle's windshield. Hailstones driven by a storm's high winds may shatter a building's side windows.

Even more importantly, hail is a signal that you are experiencing a very strong thunderstorm — one that may be ready to produce a damaging burst of wind — or even a tornado if conditions are right. If you see hail larger than penny-sized, it is a good idea to activate the plan you have in place for severe thunderstorm warnings.

Lightning

All thunderstorms produce lightning, by definition. *If you can hear thunder, you are close enough to the storm to be struck. Take protective actions. Move inside.* It need not be raining! Lightning can strike 10 to 15 miles away from the rain portion of the storm! These lightning strokes come out of the upper portions of the thunderstorm cloud, which extend 5 to 10 miles into the atmosphere.

In general, lightning will travel the easiest route from the cloud to ground which means that it often strikes the highest object. Therefore, a simple rule is *do not make yourself the tallest object or stand near the tallest object in your immediate surrounding*. For instance, do not stand in an open field, on a beach, or on a hill top. Do not stand under an isolated or large tree or near a pole. Do not stay out on a boat.

When lightning strikes, its electrical current travels along the easiest route. *Stay away from metal objects* such as fences, poles, equipment, pipes, etc. *Get rid of metal objects on your body* such as coins, money clips, hair pins, jewelry, etc. *Stay away from water.* Inside, *stay away from electrical appliances, televisions, and telephones.* Only use the phone in an emergency.

If caught outside and a thunderstorm approaches:

- Move into a building. Stay away from doors and windows.
- If a building is not available, get inside a car (hardtop, not a convertible) and keep the windows rolled up.
- If there are no cars or buildings: in a forest, look for a low area under thick growth of small trees; in an open area, go to a low place, preferably a ravine or valley.
- If in a group of people, spread out, keeping several yards apart from each other.

■ If you feel your hair stand on end, you are in immediate danger of being struck. Unless you can instantly jump inside a shelter, drop to a crouching position, bending forward and keeping your feet close together with your hands on your knees. The object is to be as low to the ground as possible and yet have as little of your body surface touching the ground.

First Aid. If a person is struck by lightning, check to see if the person is breathing. If not, begin mouth-to-mouth resuscitation. If no pulse is present, begin CPR (cardiopulmonary resuscitation). Lightning often has a paralyzing effect that is temporary. Even though a person appears dead, they may be resuscitated. Victims may experience temporary paralysis of legs, be stunned and disoriented, or have burns on their body. Give first aid for shock and stay with the victim until help arrives.

After the storm, instruct people not to touch loose electrical wires or broken utility lines. Do not touch electrical equipment in wet areas until it has been dried and tested.

Flooding

Flash floods are the most dangerous. A flash flood is rapid rise of flood waters allowing little time for action. Flash floods can move at tremendous speeds, tearing out trees and moving boulders. The debris moves with the flood wave and sometimes destroys buildings and bridges in its path. Debris may cause a temporary dam, and when broken a wall of water moves downstream. Walls of water (such as in Virginia with the remnants of hurricane Camille) can reach 10 to 20 feet. Floods and flash floods are the number one weather-related killer in the United States.

When a flood warning is issued or the moment you first realize that a flash flood is coming, act quickly to save yourself. You may only have seconds.

Get out of areas subject to flooding. This includes dips, low spots, canyons, washes, areas along streams and creeks. This also includes urban areas where storm drains become clogged with debris and rain, unable to be soaked up by the paved ground, rapidly builds the flow of runoff. Some underpasses can be extremely dangerous, rapidly filling with water.

Do not enter floor waters. Do not attempt to cross flowing water in a car or truck. Find an alternate route. Almost half of all flood deaths occur in automobiles. Water depths can be very deceptive; the road beneath may even be undermined. The force of flowing water on a vehicle is very powerful and a foot of water may be all it takes to drag a car into deeper waters or flip it over. Many cars stall once entering the water. Electrical systems in the car may fail causing electrical window and doors to not operate, trapping the victim inside as the water continues to rise.

If the vehicle stalls, abandon it immediately and seek higher ground. Rapidly rising water may engulf the vehicle and sweep it away.

After the storm, if a flood has struck your neighborhood, turn off gas at the main switch to your building. If live electrical wires are down, turn off power at the main switch. Instruct people not to touch loose electrical wires or broken utility lines. Do not touch electrical equipment in wet areas until it has been dried and tested. Do not touch fresh food that has come in contact with flood waters. Boil drinking water before using until water has been tested for purity. Food, clothing, shelter, and first aid will be available at Red Cross shelters.

Hurricanes and Storm Surge

Hurricanes are essentially large complexes of thunderstorms. Therefore, they include all of the dangers that can come with thunderstorms: lightning, flash floods, downbursts, and tornadoes. For coastal areas, the added threat is flooding from high tides and the storm surge. The storm surge is a dome of water (perhaps only 2 feet high or maybe 15 to 20 feet high and often 50 miles across) that comes sweeping across the coastline just to the right (north) of the area where the eye of the hurricane makes landfall.

Preparations for a hurricane should begin well in advance of the storm. Contact your local Emergency Management or National Weather Service for more information of Hurricane Preparedness. Listen to local authorities and evacuate when requested. Know your evacuation routes before the hurricane comes.

Hurricanes can produce widespread damage with trees and flood waters blocking roads, cutting off communications and electricity for days. Have at least a 3-day supply of food (non-perishable) and water (fill bathtub and other containers). Have plenty of batteries for use in flashlights and portable radios or televisions. Have a first-aid kit and extra baby supplies or prescription medicines, if needed.

If caught in the storm, follow safety rules described above for tornadoes/severe (damaging) winds, lightning, and flooding. Stay away from dangling or downed electrical wires and turn off gas (there could be a leak).

Winter Storms

The most severe winter storm is generally considered to be a blizzard (strong winds and blinding snow), but any heavy snow storms or ice storms can become life threatening. Most winter storm-related deaths (about 60%) occur in automobiles. Some occur from exposure to cold (see Extreme Cold, below), heart attacks from overexertion, fires from improper use of heaters, and other types of accidents.

Be prepared for the storm before it strikes. Listen to NOAA Weather Radio. If a Winter Storm Warning is issued, stay at home or, if need be, at work or school. Do not venture out into the storm. Winter storms (ice and snow) can close roads and disable phones and electrical power for hours or days in a bad storm. Have extra batteries, flashlights and a battery-powered, portable radio on hand.

If caught in the storm, try to stay dry and warm. If in a car, bus, or truck, stay there, unless shelter can be seen close by. Disorientation in cold and snow occurs rapidly. Run the motor sparingly for heat. Open windows slightly to prevent carbon monoxide poisoning. If trapped at home, school, or work, and without heat, close off unneeded rooms. Stuff towels, rags or extra clothes in cracks under doors. Cover windows at night. If using an alternate heat source, such as a fireplace, woodstove, space heater, etc., follow directions, use fire safeguards, and ventilate properly.

If caught outside without shelter, make one. Dig a snow cave. Find an area protected from wind. Build a lean-to or wind break out of sticks and branches. Build a fire and place stones around the fire to absorb and reflect back heat. Do not eat snow for water. It will drop your body temperature. You must melt it first. Exercise periodically, by rapidly moving arms, legs, fingers, and toes to keep blood circulating and to keep warm. If there is more than one person, sleep in shifts and help keep each other warm.

Extreme Cold

The people most often effected by cold are the elderly and babies. However, if proper precautions are not taken, anyone can find him/herself suffering from hypothermia or frostbite.

Wind chill combines the rate of heat loss (from exposed skin) caused by wind and cold temperatures. As the wind increases, heat is carried away from a person's body at an accelerated rate driving down the body temperature. A 20 degree F. temperature combined with a 20 mph wind produces a wind chill of -10 degrees F.

Hypothermia occurs when the body temperature drops. Warning signs are uncontrollable shivering; loss of memory; disorientation; incoherence; vague, slow, slurred speech; frequent stumbling; drowsiness; apparent exhaustion or inability to get up from rest. If a person's body temperature drops below 95 degrees, seek medical help immediately.

If unable to get medical help, wrap the person in a warm blanket covering the head and neck. Do not give the person alcohol, drugs, hot liquid, or hot food (warm is better). The person needs to be warmed slowly. *Do not warm extremities (arms, legs, hands, etc.) first!* This drives the cold blood toward the heart and can lead to heart failure. Warm the body core first. If needed, use your own body heat to help.

Frostbite is when the body tissue freezes, damaging the tissue. Frostbite causes a loss of feeling and a white or pale appearance in extremities, such as fingers, toes, ear lobes, or the tip of the nose. If symptoms are detected, get medical help immediately. If you must wait for help, slowly rewarm affected areas.

To prevent hypothermia and frostbite, stay inside during extreme cold spells or heavy snow storms. If you must go out, dress appropriately. Wear loose-fitting, light-weight, warm clothing in several layers. Trapped cold air insulates. Avoid overexertion. The strain from the cold and hard labor (such as shoveling wet snow, walking through drifts, etc) may lead to a heart attack. Sweating can lead to a chill and hypothermia. By wearing layers of clothes, if perspiration occurs, layers can be removed and then added back when needed. Outer garments should be tightly woven, water repellent, and hooded. Wear a hat. Half of your body heat loss can be from your head. Cover your mouth (using a scarf, etc.) to protect your lungs from extreme cold. Mittens, snug at the wrist, are better than gloves for protecting the hands. Try to stay dry.

Extreme Heat

The human body dissipates heat by varying the rate and depth of blood circulation, by losing water through the skin and sweat glands, and (as the last extremity is reached) by panting when blood is heated above 98.6 degrees. The skin handles about 90 percent of the body's heat dissipating function. However, sweating does not cool the body unless the water is evaporated. Evaporation is a cooling process.

On hot days where the temperature is above 90 degrees F. and the relative humidity is high, evaporation slows. The body attempts to do everything it can to maintain 98.6 degrees F. inside. The heart is pumping a torrent of blood through dilated circulatory vessels; the sweat glands are pouring liquid, including essentials such as salt, onto the surface of the skin.

Heat disorders generally have to do with a reduction or collapse of the body's ability to shed heat by circulatory changes and sweating, or a chemical (salt) imbalance caused by too much sweating. When heat gain exceeds the level the body can remove, or when the body cannot compensate for fluids and salt lost through perspiration, the temperature of the body's inner core begins to rise and heat-related illness may develop.

Other heat factors:

Cities can add to the hazard. Stagnant air conditions trap pollutants in urban areas and add the stresses of severe pollution to the already dangerous stresses of hot weather. Temperatures over large paved areas are much warmer than that of parks and grassy areas.

Sunburn can significantly retard the skin's ability to shed excess heat.

People on certain **medications or drugs** (such as tranquilizers and anticholinergics) and people overweight or with an alcohol problem are particularly susceptible.

What should be done to prevent heat disorders:

- ***Slow down***. Reduce, reschedule, or eliminate strenuous activity.
- ***Dress for the summer***. Wear lightweight, light-colored clothing.
- ***Drink plenty of water.***
- ***Do not get too much sun.***

Heat index combines the effects of high temperature and relative humidity. Using the current temperature and relative humidity, calculate the heat index using the chart provided. Exposure to full sun can increase these values by up to 15 degrees. The National Weather Service issues Excessive Heat Warnings for life-threatening conditions when the heat index is exceedingly high. In these events, instances of heat disorders such as heat exhaustion and heatstroke rise sharply. Outdoor activities should be canceled. Heat Advisories are issued for hot days where the heat index does not quite reach warning levels.

Cases of heat-related illness are certainly possible, especially with prolonged exposure. The actual level of what heat index constitutes a warning or advisory varies regionally, and sometimes even seasonally. Early season heat waves tend to be more dangerous than in the late season, when people have become acclimated to the hot weather.

First Aid:

Heat cramps are painful spasms usually in muscles of legs and abdomen. Use firm pressure on cramping muscles, or gentle massage to relieve spasm. Give sips of water unless nausea occurs.

Heat exhaustion symptoms include heavy sweating; weakness; cold, pale clammy skin; and/or fast but weak pulse. Fainting or vomiting may occur. Get victims out of the sun, lay them down and loosen clothing. Apply cool wet cloths. Give sips of water unless nausea occurs. If vomiting continues, seek immediate medical attention.

Heatstroke (sunstroke) is when the body temperature reaches 106 degrees. Symptoms are hot dry skin, rapid pulse, and the possible loss of consciousness. Heatstroke is a severe medical emergency; summon medical help immediately or take the victim to a hospital. While awaiting medical help, move the victim to a cooler environment. Reduce body temperature with a cold bath or sponging. Use fans or air conditioners. Do not give fluids.

Appendix B
Thunderstorms and Lightning

Nature provides clues that can help you realize that threatening weather is approaching and that action needs to be taken. Understanding these clues can be the difference in getting to safety in time when weather suddenly turns for the worse.

Basic Facts about Thunderstorms

Thunderstorms occur in all 50 states. They can occur, at any time, day or night, throughout the entire year. Thunderstorms are most common in the late afternoon and evening during the warm months. Approximately 1800 thunderstorms are in progress at any given moment around the world and lightning strikes the earth 100 times every second. Thunderstorms are basically beneficial, providing necessary rainfall. In the United States, only about five percent of thunderstorms become severe, and only about one percent of thunderstorms produce tornadoes.

What Makes a Typical Thunderstorm

Thunderstorms range between 5 and 25 miles in diameter, making it a very localized storm. There are three essential ingredients necessary to grow a thunderstorm:

Moisture. Moisture is necessary to form the cloud and rain.

Instability. Warm air is less dense (lighter) than cold air. The sun warms the ground and the ground warms the air above it. Evaporation of moisture from the ground or bodies of water increase the humidity. The warming of the air and the increase in humidity cause the air mass to destabilize. If there is cooler, drier air above, the tendency is for the air to overturn, with cooler air sinking and warmer air rising. This is instability.

Lift. This is the trigger that starts air rising and focuses storms. Examples of lift are air moving up a mountain and air colliding with a front. A front is a boundary between two different air masses. Where the air masses collide, the less dense air (warmer or more humid) will rise over the other. Cool air blowing from an ocean or lake can form a sea-breeze front as it collides with the warmer air inland. The cool outflow from a thunderstorm forms a “gust front” which may in turn cause the development of a new thunderstorms. These are all sources of lift. If instability and moisture is the fuel, than lift is the spark that ignites the storm.

The Thunderstorm Life Cycle

Towering cumulus stage. Imagine a parcel of air like a balloon. If the air in the balloon is warmer than the environment around it, it will rise. As the balloon (air parcel) rises, the air cools, eventually cooling to its condensation point. A cloud

becomes visible. As the air condenses, heat is released which helps the air parcel remain warmer than its surrounding environment, and so, it continues to rise, building up speed. This rising air forms the updraft, a thermal. A towering cumulus cloud has grown with crisp, hard edges forming a puffy or cauliflower look to the cloud. The height of the cloud is usually equal to or greater than the width of the cloud's base.

Mature thunderstorm stage. The warm air continues to rise until eventually it has cooled to that of its surrounding environment. This is often not until it hits the tropopause and the more stable air of the stratosphere. The storm may now have reached a height of 5 to 10 miles above the ground. The rising air has been moving at speeds near 40 mph. Now as it slows, the upper level winds begin to fan out the cloud forming the anvil. With strong winds aloft and longer lasting storms, anvils can spread 100 miles downwind.

A thunderstorm's updraft can carry 8000 tons of water aloft per minute! The water vapor condenses to cloud droplets which collide and grow in the rising updraft. Eventually, the weight of the droplet overcomes the rising air and it falls. The falling rain droplets begin to drag the air down around them and a downdraft forms. The rain also is falling into unsaturated air and so some evaporation occurs. Evaporation is a cooling process (your body cools when sweat evaporates from your skin). This rain-cooled air is now cooler than its surrounding environment and it sinks, helping to form and intensify the downdraft. A thunderstorm with concurrent updrafts and downdrafts is considered mature. As little as 20 minutes has elapsed since the cloud began to form.

Dissipating stage. As the downdraft hits the ground, the rain-cooled air begins to spread out in all directions. Eventually, this more stable air (since it is cool) chokes off the warm inflow that was driving the storm's updraft. With no new fuel to keep the storm alive, it dies. The downdraft dominates and the storm rains itself out. Sometimes, all that is left is the anvil.

This entire thunderstorm life cycle from the growing cumulus cloud to the dissipated storm can take only 30 minutes. This is why thunderstorms can strike so quickly and with little if any warning. The National Weather Service predicts the likelihood of thunderstorms to develop, but does not warn for lightning nor general thunderstorms.

What Causes Thunder

A lightning stroke carries an electrical potential of 100 million volts. This tremendous release of energy is converted to heat. Air around the lightning channel explosively expands as it is heated to nearly 50,000 degrees F! After the discharge, the air rapidly cools and contracts. This sudden expansion and contraction of air molecules produces the sound wave which we identify as "thunder." Because the speed of light is a million times faster than that of sound, we see a lightning stroke before we hear it.

You can estimate the distance (in miles) to a lightning stroke by counting the number of seconds between seeing the lightning and hearing the thunder, then divide by five. Just remember that lightning can come from the anvil portion of the thunderstorm and strike the ground 10 to 15 miles from the rain portion of the storm. So, just because you are estimating lightning at a distance of 2 or 4 miles away, doesn't mean that the next strike won't be right next to you!

Understanding the Dangers of Lightning

If you are outside and there are thunderstorms within 10 miles, you are at risk of being struck. In rare cases, lightning has been known to travel as far as 15 miles from the storm. There are four different types of lightning: within cloud, cloud-to-cloud, cloud-to-air, and cloud-to-ground.

Lightning can occur from any portion of the thunderstorm cloud. Thunderstorms can extend up to 10 miles high in the atmosphere and they are often tilted by stronger winds aloft. High clouds above you may be part of a thunderstorms anvil. Often during the dissipating stage of a thunderstorm, lightning will strike from the upper reaches of the storm, including the anvil.

A study on lightning conducted in Florida found that the average distance between one lightning strike hitting the ground and the next was two to three miles. That means that (using the technique described in the section on thunder above) you may have just seen a lightning stroke in the distance and it took a full 15 seconds before the thunder reached you. It seemed a long way away and yet, on average, the next strike could be right next to you.

The most common mistake made by people is to let an outdoor activity continue because it appears as though a thunderstorm is too far away to be a danger. Many people think that if it is not raining, then they are okay, yet it is not the rain that can kill them. People who have been struck by lightning have noted that they heard some distant thunder, but there was blue sky overhead and so they perceived no threat.

The rule is simple: *If you can see lightning or hear thunder, take action immediately.* The activity can be resumed when it appears as though the storms have passed and lightning has not been seen nor thunder heard for at least 15 minutes.

Taking Shelter

Every one needs to move inside a building or a car. In buildings, do not remain standing in the door way and close windows and doors. Do not use telephones and computers. In a car, truck, or bus, windows and doors need to be closed. Convertibles, even with the tops up, are not protected. If an activity is postponed to let the storm pass, try not to allow spectators to linger in unprotected areas. At a Lacrosse game in the District of Columbia, the game was called as a thunderstorm squall line rolled into the city. The teams went

inside to the locker rooms to wait out storm. A group of spectators who had been watching the game took cover under a tree. The tree was struck. A 16-year-old boy was killed and 10 others were injured.

Lightning will be attracted to the tallest object. Tall trees are a prime example. Sports fields are a high risk area. The tallest objects may be the players or the goal posts; lightning can strike both at once. Metal bleachers, tall light poles for night-time play, and metal fences around ball fields are all at risk of being struck. Even the dugout is not safe.

Thunderstorm Clues

- Static on your AM radio.
- A sudden increase in wind or a sudden change in the wind direction. Leaves on trees may flip over so you see their underside. You might smell rain before it arrives or feel a sudden drop in temperature with the breeze.
- Darkening and billowing clouds or darkening haze.
- Distant flashes of lightning or the sound of thunder.

The Severe Thunderstorm

The more unstable the air mass and the stronger the lifting mechanism, the stronger the thunderstorm updraft becomes and the more likely the storm will be severe. Increasing winds with height also help to the storms ability to maintain itself. The longer a storm lasts, the greater chance it has of becoming severe. The National Weather Service defines a severe thunderstorms as a storm producing three-quarter inch or larger hail and/or winds greater than 58 mph. When thunderstorm updrafts reach speeds of 70 mph, they can support the growth of hailstones.

A **hailstone** is a lump of ice that falls from a thunderstorm. It can range from pea size to the size of grapefruit. Such large hail can impact the ground at nearly 100 mph demolishing crops, breaking windows, and damaging roofs, cars and airplanes. Hail begins as rain droplets which are carried by strong updrafts to high altitudes (well above the freezing level) where they are frozen into ice pellets. The ice pellets collide with more water droplets which freeze to the surface of the developing hail stone increasing its size. The stone continues to grow until the updraft can no longer suspend its weight and the hail falls to the ground.

Long-lasting thunderstorms, sometimes referred to as **supercells**, are more likely to be severe. For a thunderstorm to last, it must be able to sustain both its updraft and its downdraft. One way that this occurs is with increasing winds with height. If the horizontal wind, blowing into the storm, is stronger in the middle and upper reaches of the storm, the rising updraft becomes tilted. Now the rain is carried downwind of the updraft instead of collapsing upon it. Another important factor is if the horizontal wind, blowing into the storm, veers with height (changes direction in a clockwise motion), the storm's updraft may begin to rotate. The combination of veering and increasing winds with height can produce a tilted and rotating updraft. This rotating thunderstorm, called a **mesocyclone**, is able to maintain its updraft and warm inflow region independent of the storms rain-cooled outflow. The rotating updraft of this type of thunderstorm is where the tornado can form and descend to the ground.

The Downburst

So far, we have discussed how strong updrafts can produce hail and rotating updrafts can produce tornadoes, but what about downbursts or damaging straight-line winds from thunderstorms? A **downburst** is a powerful, concentrated downward burst of air, that occurs in the downdraft region of the thunderstorm. Looking at the map view of a severe thunderstorm above, it tends to occur in the moderate to heavy rain region of the storm. One theory for how downbursts originate is that a layer of drier air, between perhaps 10 and 20 thousand feet high, is entrained into the thunderstorm. As rain falls through this drier air, it evaporates, rapidly cooling the air. This cold ball of air, now denser than its surrounding environment, descends toward the ground. The momentum of the winds in this mid-level dry layer (the wind blowing into the storm) is now tilted downward and is accelerated by gravity. The burst of rain-cooled air smacks the ground and spreads outward. Wind speeds produced by downbursts can reach over 100 mph and produce damage similar to a tornado. However, downbursts damage paths are usually broader than tornado paths.

The term **straight-line wind** when referring to a thunderstorm wind is the rain-cooled air of the downdraft as it spreads out and away from the thunderstorm. The wind is moving in a straight-line as opposed to rotating like a tornado. Therefore, straight-line damaging winds from a thunderstorm is generally caused by a downburst. In aviation, the term wind shear is used. **Wind shear** is the change of wind speed and direction. A downburst is extremely dangerous to aircraft on takeoff and landings because of the strong wind shear. Wind speed and direction is in constant flux and the pilot can not compensate fast enough. A **microburst** refers to a small downburst (less than 2 miles across). A downburst larger than that would be called a macroburst.

Appendix C
Spotting Severe Thunderstorms and Tornadoes

Your local National Weather Service Office provides severe weather spotter training under a program called SKYWARN. It is provided free of charge with the request that when you do encounter severe weather, you report it to the National Weather Service. The spotter training class includes 100 slides that help you learn how to pick out visual clues from clouds to help determine the severity of a storm. It is highly recommended that at the least one person from your school, preferably the "Severe Weather Coordinator" for your school emergency plan, take the training. The following information is not a substitute for official training.

Color. A very dark (black) thunderstorm or one taking an eerie look (brownish, green, or yellow cloud colors) may be an indication of a severe thunderstorm. The colors and darkness of the cloud are caused by the storm's massive size and the blockage of sunlight. This storm may bring hail, very heavy rain, and damaging winds. Take protective action immediately.

Sound. The sound of a freight train is the roar of wind as it moves through trees and buildings. It may indicate an approaching tornado or severe downburst. The rapid rotation of winds in a tornado also sometimes make a high pitch whistling or whirling noise. In any of these cases, you should take protective action immediately.

Swirling Debris. Tornadoes are sometimes obscured by rain, low clouds, trees, or buildings that block your view of the funnel. A visible funnel need not even be touching the ground (it may only extend half or two-thirds of the way from the cloud toward the ground). But even with weak tornadoes, swirling debris or debris rising up in the air can often be seen. This is a sure sign of significant damaging winds and protective action must be immediate.

Shelf Cloud/Roll Cloud. The rain-cooled air flowing out of a thunderstorm forms the gust front. Warm air ahead of the gust front rises up into the storm forming a wedged-shaped cloud called a "shelf cloud" on the leading edge of the storm. The sharper or more defined this cloud is, the stronger the winds are below. As the cool wind continues to blow out ahead of the storm, the shelf cloud can become detached from the storm forming a "roll cloud". This horizontal cloud is not a tornado. It marks the gust front (the gust front is the leading edge of the rain-cooled outflow from the thunderstorm). If you see a well-defined roll cloud rolling toward you, prepare for strong and possibly damaging winds as it passes.

Mammatus Clouds (also known as Mamma). These clouds hang down from the anvil portion of the thunderstorm. They look like breasts (hence the Latin term) or like a cumulus cloud turned upside down. Mammatus clouds are often an indication that the storm is severe. Prepare for possible hail and damaging winds.

Rotating storms. Sometimes it is possible to see the entire thunderstorm rotating. Generally, to see this you are located south of the storm or behind it. The storm is usually then moving away from you. A rotating thunderstorm is likely severe and may produce a tornado. If the storm is, by chance, moving toward you, prepare for severe winds and hail. Otherwise, report your sighting to the National Weather Service.

Rotating Wall Cloud. This is a lowering of clouds from the rain-free cloud base (updraft region) of the storm. It is circular in shape and can be seen slowly rotating. Sometimes a tail forms from the wall cloud toward the rain area of the storm Air is moving in and rising up into this portion of the cloud. This is a sign of a tornadic thunderstorm. If a tornado is to form, it will generally descend from the storm near or within the wall cloud. Take cover immediately if this is approaching you. Otherwise, contact the National Weather Service with your sighting.

Funnel/Tornado. A funnel is a small rotating funnel-shaped cloud. It does not touch the ground. If the funnel-shaped cloud is touching the ground, it is a tornado. Only about 50 percent of funnels turn into tornadoes. It is possible for the rotating column of damaging winds from a tornado to be on the ground with the visible funnel only extending half-way to the ground. Look for debris, leafs and dust rising into the air and listen for the sound of a freight train.

Waterspouts. When a tornado moves over water, it is called a waterspout. Waterspouts can also occur in more benign situations and these are not severe but still may have winds of 35 to 50 mph.

Squall lines. Sometimes thunderstorms form a solid line of storms called a "squall line". The squall line thunderstorm can also become severe and is unlike the supercell thunderstorm discussed earlier (see diagram showing side and map views of a typical severe thunderstorm under section B). The supercell storm has its updraft on the right-rear quadrant of the storm. With a squall line, the warm air feeding the storm is all out ahead of it, so the updraft on the front (approaching) portion of the storm dominates. When a squall line approaches, you will see the shelf cloud which is the leading edge of the storm (see discussion on shelf clouds). Tornadoes rarely occur with squall lines and they tend to be less severe than those with supercell storms. Still, winds can reach 100 mph which is enough to damage roofs, break windows and drop trees. The tornado in this case will precede the rain. The tornado would be found in the updraft region of the storm behind the shelf cloud.
For additional information on severe weather spotting, see the Basic Spotter's Field Guide, http://www.nws.noaa.gov/om/brochures/basicspot.pdf.

Appendix D
The National Weather Service's Methods of Detecting and Tracking Severe Weather

The National Weather Service uses a combination of radar, satellite, lightning detection, and surface observations, including volunteer spotter reports for detecting and tracking severe weather. National Weather Service Doppler radars installed around the country in the early 1990s have greatly increased the National Weather Service's ability to pinpoint severe thunderstorms and possible tornadoes and warn the public as to where these severe storms are moving. Spotter reports give forecasters the ground truth that verifies what the radar is showing and adds details such as the size of hail, the amount of rain, the depth of flood waters over a road, if wind damage is occurring, or if a tornado is sighted.

It is the combination of surface reports from automated sensors and spotters and remote sensing tools such as radar, satellite and lightning detection that bring the entire picture together for forecasters and increases their ability to issue effective, informative, and timely warnings. While new technology has enhanced the meteorologist's ability to issue a timely warning, it will be of little use if the people do not receive the warning, or receive the warning but do not know what safety actions to take.

Doppler Weather Radar. The WSR-88D (Weather Surveillance Radar - 1988 Doppler) is the radar system used by National Weather Service and the Department of Defense (DOD). It is a very powerful radar designed specifically for the detection of weather phenomena and in particular, violent tornadoes. The computers that compile the radar data can produce as much as 100 different radar products every 5 minutes for forecaster to look at.

Typically radar has been used to tell meteorologists where precipitation is occurring, how intense it is, and where it is moving. The ability of Doppler radars to detect radial velocity (movement of radar targets, such as rain, toward or away from the radar-derived from the "Doppler Effect") allows meteorologists to see rotation of thunderstorm updrafts and sometimes the development of the tornado vortex.

Mesocyclones displaying strong radar signatures such as storm rotation (bright red nest to bright green in the picture) can sometimes mean 10 to15 minutes lead time on warning for a tornado before it touches down. Computer and mapping skills with this radar combined with automated rainfall gauges help meteorologists determine maximum rainfall amounts and pinpoint areas with potential flash flood problems.

Like all technology, radars have their limitations. Radar beams can not see through mountains. This means that weather within the valleys on the other side will not always be detected. Because of the curvature of the earth, as the radar beam moves away from its source, it gets higher and higher in the atmosphere and is no longer sampling the lower portion of the storm clouds. The National Weather Service compensates by using trained severe weather spotters which help forecasters to fill in the gaps.

Satellites. Geostationary satellites (stationary above a point over the equator) and polar orbiting satellites allow meteorologists to watch the development of clouds and weather systems. Satellites are extremely useful for tracking weather systems over the vast ocean areas where there is no radar and few surface observations. For example, satellites greatly improve meteorologists' ability to detect the formation and movement of hurricanes over the tropical waters. Satellites also help meteorologists to track movement of air masses that are either very dry (such as off the mountains) or very moist (such as northward from the Gulf of Mexico). This can greatly influence a storm's development. Cloud patterns also tell forecasters about the strength and movement of the jet stream which plays a large role in storm development. Meteorologists can watch the formation of cumulus clouds along boundaries and their growth into thunderstorms. They can watch the change in cloud top temperatures to help determine if thunderstorm complexes are growing or weakening.

While satellites provide meteorologists with much information, they too have their limitations. A satellite is viewing a cloud from above. Only in very rare cases can you tell that a tornado has formed below. You or softball size hail is falling, or water is flooding a bridge.

Lightning Detection. Lightning detection systems map where cloud-to-ground lightning strikes are occurring. While this allows meteorologists to know that thunderstorms are indeed in progress and the frequency of lightning strokes, it tells little about the severity of the thunderstorm.

Surface Observations. Surface observations are the "ground truth" for tools such as radar and satellite. Because thunderstorms are highly localized (the severe weather potion of the storm may only affect an area a mile wide) and it is impossible to have weather observers everywhere, most surface observations are automated, with ground-based sensors providing temperature, humidity, pressure and wind information. But sensors cannot report hail size, nearby tornadoes, or thunderstorm clouds.

Skywarn. Skywarn is a volunteer program of trained severe weather spotters. Some are also amateur radio operators who use their added skills to pass information on to the National Weather Service. They provide critical details to forecasters about what the storms are doing. Skywarn training is conducted by the National Weather Service at no cost and all are welcome to take the basic spotter training class. For more information about Skywarn, check out its webpage at http://www.weather.gov/skywarn or contact your local National Weather Service office.

Appendix E
What to Listen For from the National Weather Service

The National Weather Service uses the Watch/Warning system for *all* weather threats, so you need to understand it. Think of it as a traffic light. Most days are green-light days — it may be sunny, rainy, etc., but no overly hazardous weather is expected. Yellow lights are ***watches***. Watches are cautionary; they warn you about a specific weather threat. Watch out and keep apprised of weather conditions. Red lights are ***warnings.*** Warnings mean you need to take action! A warning tells you the weather threat is occurring now in your community or will be very soon. Take action to protect against the weather threat. The National Weather Service also issues ***advisories*** for some events. Advisories are low-level warnings for nuisance events that are not particularly life threatening. You will never have a tornado advisory — there are no "nuisance" tornadoes. But a Winter Weather Advisory would be issued for a minor snow event, while a Winter Storm Warning would be reserved for a more dangerous snow storm.

More specifically:

Watches. Meteorologists have determined that conditions appear right for the development of the hazard. Probability of occurrence is greater than 60 percent in the watch area. Watches generally cover larger areas than warnings. In the case of thunderstorms, less than 30 percent of the watch area may experience the hazard. However, with larger storms such as hurricanes and winter storms, the entire watch area may be affected. Severe thunderstorm and tornado watches are usually issued 1 to 2 hours before the event begins. With flash floods, it can be 3 to 12 hours. For hurricane, river flood, and winter storm watches, lead-times are usually 12 to 36 hours.

Warnings. The hazard (tornado, flash flood, etc.) is imminent. The probability of occurrence is extremely high. Warnings are issued based on eyewitness reports or clear signatures from remote sensing devices such as radar and satellite. Lead-time for thunderstorm type events is generally 30 minutes or less. Lead-time for hurricanes, river floods, and winter storms can be 6 to 18 hours.

Advisories. An advisory is issued for weather that is expected to be a disruption to the normal routine and an inconvenience, but it is not expected to be life-threatening. Advisories are issued for 1 to 3 inches of snow, dense fog, minor street flooding, etc. The time frame is similar to that of a warning.

Statements. Statements are issued to update current weather situations or highlight significant changes to come. Statements are also used to explain why watches, advisories, or warnings have been issued. Three special types of statements are:

Outlooks or **Potential statements.** During the warm season, the National Weather Service Forecast Offices issue "Thunderstorm Potential Statements" each morning discussing where and if storms will develop that afternoon and how intense they may be. When a winter storm may develop in the next 2 to 4 days, "Winter Storm Potential Statements" are issued. Outlooks may also be issued for possible heavy rain and flood events. The National Hurricane Center issues "Tropical Outlooks" for the potential for tropical storm and hurricane development. The National Severe Storms Forecast Center issues special statements when there is the potential for a severe thunderstorm or tornado outbreak.

Public information statements. These statements provide information of special interest such as a summary of recent records set, snowfall, weather safety information, special weather related activities that may be occurring, etc.

Forecasts. Forecasts for the next seven days are issued at least twice daily around 4 a.m. and 4 p.m., and more frequently when needed. Special weather events are highlighted with headlines at the top of the forecasts such as "The heat index is expected to reach 105 to 110 degrees today;" "Wind chill temperatures will drop to 30 below zero tonight;" or "A flash flood watch is in effect until 8 AM EDT Wednesday."

Short-term forecasts are issued to highlight forecast conditions over the next few minutes to 6 hours. These forecasts are for specific counties, and sometimes even parts of counties. They are updated as needed on a weather-driven basis and are used to forecast individual thunderstorms, fog, abrupt wind and temperature shifts, etc.

Appendix F
Glossary of Weather Terms

See http://www.weather.gov/glossary for a complete listing.

Thunderstorm Terms

Anvil. The spreading out (by strong winds) of the upper portion of the thunderstorm. It usually has a fibrous or smooth appearance. With long lasting thunderstorms, the anvil may spread 100 miles downwind.
Cumulus cloud. A cauliflower shaped cloud with a flat base and sharp edges. Tufts are rising columns of air condensing. As the cloud and cloud droplets grow in size, the base will begin to gray.
Downburst. A sudden rush of cool air toward ground that can impact with speeds over 70 mph and produce damage similar to that of a tornado. It usually occurs near the leading edge of the storm or may occur in heavy rain.
Downdraft. A column of cool air that sinks toward the ground. It is most often accompanied by rain.
Eye. The center of the hurricane where winds are light and skies are clear to partly cloudy. The eye is rimmed by massive thunderstorms producing torrential rains and extreme winds.
Eye wall. A wall of thunderstorms around the eye.
Flanking line. A line of cumulus clouds connected to and extending outward from the most active portion of a parent cumulonimbus, usually found on the southwest (right, rear) side of a storm. The cloud line has roughly a stair step appearance with the taller clouds adjacent to the parent cumulonimbus. It is most frequently associated with strong or severe thunderstorms.
Funnel cloud. A funnel-shaped cloud extending from a towering cumulus or thunderstorm. It is associated with a rotating column of air that has condensed to form a cloud.
Gust front. The leading edge of the thunderstorm's downdraft of air as it spreads out away from the storm. It is usually felt as a change to gusty cool winds and often precedes the thunderstorm's rain by several minutes.
Hail. Precipitation in the form of balls or clumps of ice.
Hook echo. A radar pattern sometimes observed in the southwest (right, rear) quadrant of a tornadic thunderstorm. The rain echo forms the hook pattern as air rotates around the strong updraft. The updraft is the hollow portion of the hook (looks like a backwards "J" or a 6) and is where the tornado would most likely be found (if the storm were to produce one).
Hurricane. Evolves from a tropical storm. Rotary circulation has become pronounced and an eye is detectable. Constant wind speeds are 74 mph or greater.
Macroburst. A larger downburst effecting an area greater than 2.5 Km in diameter.
Mammatus (or mamma clouds). These clouds appear to be hanging, rounded protuberances or pouches on the underside of the cloud. With thunderstorms, they are usually seen under the anvil and often accompany severe thunderstorms.
Microburst. A small downburst effecting an area less than 2.5 km in diameter.
Precipitation shaft. A visible column of rain or hail falling from the base of the cloud.
Rain-free base. The dark underside of a cloud (its base) that has no visible precipitation falling from it. This marks the updraft of a thunderstorm.
Roll cloud. On rare occasions, a shelf cloud may turn into a roll cloud. The motions of the warm air riding up and over the cool air moving down and under creates a swirling of air or an eddy. The cloud takes on the shape of a horizontal tube that appears to be rolling. It is detached from the thunderstorm on its leading edge.
Severe thunderstorm. A thunderstorm producing damaging winds or winds greater than 58 mph and/or hail three-quarters of an inch or greater.
Scud clouds. Low cloud fragments often seen in association with and behind thunderstorm gust fronts. These clouds are ragged and wind torn and are not usually attached to the thunderstorm.
Shelf cloud. A low-level, wedge-shaped cloud attached to the thunderstorm. It forms above the gust front as warm air ahead of the storm rides over the cool outflow from the thunderstorm.
Squall line. A solid line or band of active thunderstorms.
Thunderstorm (cumulonimbus). The towering cumulus cloud has continued to grow in height and width and now lightning is occurring. The storm may extend 5 to 10 miles high into the atmosphere and 5 to 25 miles across. Heavy rains and gusty winds often accompany the storms.
Tornado. A violently rotating column of air in contact with the ground and extending to the thunderstorm base, often seen extending from near the wall cloud. It can be a few yards across to a mile wide.
Towering cumulus cloud. A cumulus cloud that continues to grow so that its height is taller than or equal to its width. It is first stage to growing into a thunderstorm. It may be producing a shower.
Updraft. Warm, moist, rising air. As the air rises, it condenses into a visible cumulus or cumulonimbus cloud. The updraft fuels the storm. In an ordinary thunderstorm, air rises at 40 mph, and in a severe thunderstorm, speeds may reach over 100 mph.
Wall cloud. This cloud appears as an abrupt lowering of the cloud base from the relatively flat rain-free base. It is attached to a thunderstorm and may be rotating. This is the portion of the thunderstorm from which the tornado often descends.

Hurricane Terms

Tropical disturbance. A moving area of thunderstorms in the Tropics that maintains its identity for 24 hours or more.
Tropical depression. A cluster of thunderstorms in the tropics that maintains its identity and shows rotary circulation at the surface with constant wind speeds of 38 mph or less.
Tropical storm. Evolves from a tropical depression or may be a hurricane in its dissipating stage. Rotary circulation is distinct and constant wind speeds range from 39 to 73 mph.
Spiral bands. Bands of thunderstorms that appear to spiral in toward the hurricane's center.

Storm surge. A dome of water often 50 miles wide that sweeps across the coastline near the area where the eye of the hurricane makes landfall.

Flood Terms

Bankfull. The maximum height of the river before it overflows its banks.
Coastal flood. High tides, persistent onshore winds, or a hurricane storm surge can cause flooding along coastal areas.
Flash flood. A flood that occurs suddenly during or shortly following heavy rains or from a sudden release of water, as in a dam break. Small streams and creeks usually react the fastest to heavy rains and rise several feet in hours or even minutes.
Flood crest. The highest height that the river reaches during a flood event.
Flood stage. The height of the river at which property damage begins to occur. The river may overflow its banks into the flood plain without reaching flood stage.
River flood. A flood on large river takes a tremendous amount of rain and usually develops over a period of one to two days. Rain water first runs into the small streams which flow into the larger branches and eventually ends up in the main stem of the river. A flood crest from heavy rains in West Virginia, for instance, may take 2 days or more to reach Washington, D.C.
Urban flood. Pavement which causes rapid runoff (rain can't soak into the ground so it runs downhill) and poor drainage can lead to flooded roadways and underpasses and even become deadly.

Winter Weather Terms

Blizzard. Strong winds (greater than 35 mph) and heavy snow or blowing snow combine to produce very poor visibility.
Blowing snow. Wind-driven snow that causes reduced visibility and sometimes significant drifting. Blowing snow may be snow that is falling or snow that was once loose on the ground and picked up by the wind.
Drifting snow. Winds are strong enough to blow falling snow or loose snow on the ground into mounds causing uneven snow depths. The wind carries the snow near the ground causing no restriction to visibility.
Freeze. Used when temperatures at or near the surface (ground) are expected to be 32 degrees F. or below. Sometimes used with adjectives "killing," "severe," or "hard". A freeze may or may not be accompanied by frost.
Freezing drizzle. Drizzle that falls onto a surface with a temperature below freezing causing it to freeze to the surface forming a thin coating of ice or rime. Drizzle is a very light precipitation with little accumulation, but even a small amount of ice can sometimes cause a problem.
Freezing rain. Rain that falls onto a surface with a temperature below freezing causing it to freeze to the surface forming a coating of ice or glaze.
Frost. The formation of ice crystals in the forms of scales, needles, feathers, or fans, which develop under conditions similar to dew, except that the temperature has dropped to at least 32 degrees F.
Frostbite. Frozen body tissue.
Heavy snow. Snow accumulating to six inches in 24 hours. These values will be a couple inches higher for mountainous regions, New England, or near the Great Lakes where higher snowfall is more common.
Hypothermia. When body temperature drops below 95 degrees F.
Ice storm. Significant and possibly damaging accumulations of ice are expected during freezing rain situations. Significant ice accumulations are usually accumulations of .25 inches or greater, but may vary from region to region across the country.
Sleet. Ice pellets or granules of frozen rain. Occurs when rain falls into a layer of air with temperatures below freezing. Sleet usually bounces when hitting a surface and does not stick, but can accumulate on roadways causing a hazard to motorists.
Snow. A steady fall and accumulation of snow for several hours or more. It may be modified by terms such as "light," "intermittent," or "occasional" to indicate intensity or periodic snow.
Snow flurries. Light snow falling for short durations. No accumulation to a light dusting (or trace) is expected.
Snow showers. Snow falling at varying intensities for brief time periods. Some accumulation is possible.
Snow squalls. Brief, intense snow showers, accompanied by strong, gusty winds. Accumulations may be significant.
Wind chill (wind chill factor). Combines the rate of heat loss caused by wind and lowering temperature. As the wind rises, heat is carried away from a person's body at a more accelerated rate driving down the body temperature.