disaster preparedness report

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SPECIAL ISSUE

National Weather Service

American Meteorological Society's 10th Severe Local Storms Conference Addresses Warnings and Preparedness

Last October, the American Meteorological Society (AMS) held its 10th Severe Local Storms Conference in Omaha, Nebraska. As part of this conference, two sessions were devoted to THE WARNING SYSTEM -- pre-disaster planning, hazard detection, warning decision, dissemination, and public response. A summary of these sessions and reprints of four of the papers presented are attached. A complete conference preprint volume can be obtained from the American Meteorological Society, 45 Beacon Street, Boston, Massachusetts, 02108. The cost is sixteen dollars for AMS members and twenty-one dollars for non-members.

Summary of Sessions 11 and 12 of the American Meteorology Society's Tenth Severe Local Storms Conference (Omaha, Nebraska: October, 1977

The "Warning System" involves much more than simply disseminating information about a hazard agent. It also includes predisaster planning, hazard detection, warning decision, and, most importantly, public response. The "system" is, therefore, only as strong as its weakest link. Sessions 11 and 12 tried to place this complete system in perspective, and to address some of the reasons for success or failure of warning systems.

Frank Makosky (NWS, Little Rock Forecast Office) emphasized the importance of predisaster preparedness programs (NWS, state police, board of education, state emergency services offices, etc.), and the importance of local NWS offices in weather hazard detection and warning dissemination. Based on a survey of 30 Weather Service Forecast Offices, Makosky addressed some critical operational problems (e.g., the use of "severe thunderstorm" warnings).

Carl Reber (NWS, Southern Region Headquarters, Fort Worth) addressed the use of the Amateur Radio Service in developing supplemental storm spotter networks. In addition to relaying reports of tornadoes, severe thunderstorms, and heavy rainfall/flooding to NWS offices, amateur radio provides a reliable and relatively noise free backup communication system for distances up to about 30 miles. It was a local amateur radio group that provided on-the-scene observations of a developing tornadic thunderstorm that enabled the Fort Worth NWS office to give a 30-minute warning to Dallas on May 26, 1976.

Another important observation technique, involving the cooperation of NWS offices and powerline companies in detecting tornadoes, was discussed by Walter Schulz (NWS, Jackson Forecast Office). In this effort power companies notify NWS offices when a major powerline break occurs; such breaks usually indicate tornadic winds. NWS offices can then locate the radar cell(s) capable of causing the damage. Benefits include earlier and more accurate warnings and faster restoration of power.

Joe Minor et all (Texas Tech University) addressed the effects of tornadoes on structures. In reviewing the literature on tornado wind speed estimates, they found several to have questionable values because of a failure to account for one or more attributes of the structure(s) being studied. Some evidence was presented to suggest that F5 tornado wind speeds are on the order of only 240 mph. The myth of "exploding" structures was shattered, too.

Dennis Mileti (Colorado State University) and E.L. Quarantelli (Ohio State University) emphasized the sociological aspects of the warning system (i.e., public and community response). Both noted the highly complex nature of public response to weather dangers. The following are some important considerations:

- How is the danger determined?
- How are warning messages formulated and transmitted?
- How do people interpret and respond to warnings?

The experience level, education level, and other "people" factors have to be considered in warning the general public. Message content and display were discussed by Conrad Johnson (WMT Broadcasting, Cedar Rapids).

Economic realities of the disaster and recovery were addressed by Don Connelly (Hartford Insurance Group) and by Roy Popkin (American National Red Cross) respectively.

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THE FORECAST OFFICE'S SEVERE WEATHER ROLE

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1. INTRODUCTION

The National Weather Service is committed to reduce loss of life, injuries, and property damage due to violent weather. In an effort to achieve its goals, the Forecast Office has been assigned responsibilities in disaster preparedness and the watch/warning programs. The framework of these programs has been established at the national level, but there is some latitude as to how each Forecast Office approaches its objectives. This is only natural since not every Forecast Office has the same types of weather problems with which to cope. Some need to be concerned with hurricanes or coastal storms. Others are located where severe winter storms are problematic. This report, however, will relate only to the Forecast Office's role in contending with severe local storms.

1.1 Definition of Severe Local Storm

A severe local storm will be defined broadly as a thunderstorm that produces (1) a tornado, (2) damaging winds, (3) large hail, (4) excessive cloud-to-ground lightning, and/or (5) abnormally heavy rain. In most instances though, unless reference is made to one of the others specifically, preparedness and watch/warning procedures described will pertain mainly to tornadoes.

1.2 Definition of Severe Local Storm Belt

Tornadoes, damaging winds, lightning, hail, and abnormally heavy rain have occurred in every state in this country. However, for the purpose of this report, the severe local storm belt will be referred to a broad expanse of the United States that stretches from the lee of the Rockies eastward to the eastern seaboard excluding those states east of the Appalachians and north of North Carolina. Some may disagree with this definition, but it was decided to include only those states that had a death rate due to severe local storms -- particularly tornadoes -- high enough to be a governing factor in the Forecast Offices' preparedness and watch/warning policies and priorities.

1.3 Meteorologist in Charge (MIC) Survey

In order that the views presented herein were not totally a reflection of the Little Rock Forecast Office, it was decided to send a questionnaire to all MICs in the severe local storm belt. They were asked to respond to a number of questions concerning their preparedness and watch/warning techniques and philosophies. Their answers will be summarized throughout this report. The questionnaire was sent to 30 MICs. Responses were obtained from 29.

2. THE FORECAST OFFICE'S DISASTER PREPAREDNESS PROGRAM (DPP) AND ITS GOALS

In Arkansas, as elsewhere in the United States, weather-related fatalities have been decreasing with time. This is true despite an ever increasing number of reported tornadoes and an apparent growing personal vulnerability to them due to expanding population and the proliferation of mobile home living. How can this diversity be explained? The National Weather Service's Severe Weather Watch/Warning System can take some credit for the divergence of these numbers. Prior to 1952 before the establishment of the National Severe Storms Forecast Center (NSSFC) and before a local warning radar net had been established, tornadoes killed on the average 25 Arkansans per year. Since 1952 the number of tornado deaths has steadily declined. The annual rate stands at 9 today. This dramatic 60% reduction in the annual tornado death rate cannot, however, be totally attributed to a sophisticated warning system. The very nature of tornadoes makes this deduction inconceivable. A study by the Little Rock Forecast Office described the typical Arkansas tornado as having a life expectancy of about 6 minutes. Even if the Forecast Office knew the exact moment a tornado touched down (and this would be rare indeed) it would normally take about 6 minutes with today's communication system for the warning to reach the public's ear. By this time the warning would do little good.

Fortunately, the National Weather Service's more successful warnings have been associated with the not-so-typical more destructive, longer lasting, but more easily detected tornado -- the maxi tornado. An example of this type of tornado is the one that struck Cabot, Arkansas March 29, 1976. The National Weather Service's Severe Weather Watch/Warning System worked to near perfection that day. The National Severe Storms Forecast Center issued a Tornado Watch for much of Arkansas early that afternoon. The watch area and weather conditions were broadcast frequently by the media for several hours before the tornado occurred and therefore, a large portion of the populace had certainly developed the proper awareness. At 3:00 P.M. a suspicious echo that was being monitored by the Forecast Office's radar approximately 10 miles to the north of Little Rock was brought to the attention of a local CB-equipped Severe Storm Spotter group. The warning forecaster asked for a report, and the nearest spotter was dispatched to the approximate area. At 3:08 P.M., the spotter saw the funnel and notified the Forecast Office. At 3:10 P.M., the warning was transmitted on the NOAA Weather Wire to the media. A few minutes later all radio and television stations in the area interrupted their programs to broadcast the warning. The warning forecaster plotted the position of the tornado and determined quickly that the town of Cabot would be hit if the tornado stayed on the ground and followed its present direction. At 3:12 P.M., the mayor of Cabot was called from the Forecast Office and he activated the only siren in town. At 3:21 P.M., the tornado roared through the center of this town of 5,000 and it leveled the entire downtown section to rubble.

Five people were killed, but how many more would have been killed had the town not been given 9 minutes to take cover? Even with adequate warning, and considering the almost total destruction of the populated downtown area, why were not more people killed? The answer is that when people heard the Tornado Warning they knew what to do. Prior disaster preparedness efforts by the Forecast Office were apparently successful.

With these thoughts in mind, it would be more logical to explain at least the greater portion of the 60% reduction in the annual tornado death rate to individuals taking proper actions when threatened by a tornado whether or not a warning was issued. Therefore, it is the goal of all Forecast Offices within the severe local storm belt to develop their disaster preparedness program to the point where these quick, positive, lifesaving actions are a conditioned response of every individual when he is threatened by a severe local storm. By what means have the Forecast Offices been achieving this goal?

2.1 The Disaster Preparedness Program

The Forecast Office, with the help of local officials and the media, are making strides in increasing public awareness of the severe weather threat. The necessary information to enhance public awareness is furnished by the Forecast Office, but the dissemination of severe weather information is primarily accomplished through the media. A common media method of channeling information to the public prior to and during severe weather season is the printing and airing of interviews with Weather Service officials. The interviews stress severe weather problems and statistics unique to the local area. Where the interest in, and the magnitude of, the severe weather problem is especially great, the public is literally bombarded with severe weather data. The "30 Second Spot" is a favored method of reaching the public. This communication vehicle is used to stress (1) the difference between a Severe Weather Watch and a Severe Weather Warning, (2) what to do when a Watch is issued, (3) what to do, where to go and why one must do so when a Tornado Warning is issued, (4) lightning safety, and (5) flash flood safety. Weather Service officials record a majority of these spots, but in some areas Red Cross, Civil Defense, State Police, Board of Education, city mayors, and even the governors of some states have participated.

Staff members of the Forecast Office are heavily committed to speaking engagements during this time. Community leaders' attention is being gained through talks to the Rotary Club, Lions, Kiwanis,... etc. Often the interest in a community severe weather plan is stimulated by one of these talks. Schools, hospitals, and businesses are also visited. Talks, slides, and films generally stress the need for each building to have a plan to follow when a Severe Weather Watch is issued. Areas to be evacuated and the safest locations during a Tornado Warning are identified. The Forecast Office recommends that at least one person in the building be trained and used as a Severe Storm Spotter when a Watch affects the area.

The Forecast Office recommends, promotes, and backs community groups in their efforts to make tornado drills in schools mandatory; or, in seeking legislation that would require mobile home tie-downs; or, in using city fire sirens as a tornado warning device. With respect to the latter, the fire siren sounded by the mayor of Cabot was credited with saving many lives. Consequently, the Little Rock Forecast Office, with aid from the Office of Emergency Services (Civil Defense), conducted a statewide survey that located all fire sirens that might be sounded in a tornado emergency. It is now office policy that the warning forecaster, whenever possible, call all towns that might be in the path of a tornado and ask that the sirens be sounded.

As part of the preparation for the coming severe weather season, most Weather Service Offices run a mock drill to insure that the staff understands all watch/warning procedures, and that all observation equipment and communication systems are functioning properly. Agreements with state, county and local officials, law enforcement personnel, and the media are reviewed and revised if necessary.

2.2 Severe Storm Awareness/Preparedness Week

Approximately 62% of the Forecast Offices surveyed are involved in an intensive preparedness campaign carried out for an entire week. Often this special week begins with a proclamation by the governor and is usually sponsored jointly by the National Weather Service, state agencies, and the media. For example, last spring the Little Rock Forecast Office called its special week Severe Storms Awareness Week. It was co-sponsored by the National Weather Service, the State Police, the Board of Education, the Office of Emergency Services, and the media. Each day was named for a certain type of severe weather such as Tornado Day, Flash Flood Day, Lightning Day, ... etc. The information disseminated by recorded telephone messages, teletype, radio broadcasts, and media interviews concentrated on the facts, statistics, and safety tips concerning that day's theme.

An Open House was held at the Forecast Office for the entire week. Tornado and flash flood films were shown, office tours conducted, and severe weather pamphlets were distributed. A meeting was held in Little Rock one evening and the public was invited. The meeting featured a panel discussion with all sponsors represented. Television weathercasters played an important role in this meeting and in making the entire week a success.

The format at other Forecast Offices is similar and judging from the MIC's remarks Severe Storm Awareness/Preparedness Weeks are a very effective means of getting the public's attention.

2.3 Severe Storm Spotter Training

As part of the DPP, the Forecast Office trains Severe Storm Spotters. Each community is encouraged to organize a dedicated group of local individuals who can be trained by the Forecast Office to act as official Severe Storm Spotters. Normally these groups are equipped with HAM or CB radios or both. In Arkansas, over the past five years, it has been estimated that 3,000 individuals have received formal spotter training either by the National Weather Service or by the Office of Emergency Services (Civil Defense). The latter was initially given comprehensive spotter training techniques by the Forecast Office. Two civic-minded groups of Severe Storms Spotters have become an integrated part of the warning team in the Little Rock office. The 250 member Central Arkansas Radio Emergency Associated Citizens Teams (REACT) is equipped with CB radios and the approximately 500 members of the American Relay League form a statewide net of amateur radio enthusiasts. The Forecast Office telephones a member of each group when a Severe Weather Watch is placed into effect. Each group has radio equipment in the office and both monitor weather reports by headphones.

The use of organized CBers and/or HAMs is common throughout the severe local storms belt. In the MIC survey, 93% said they made use of CBers and/or HAMs in their net. Only 43% use CBers and/or HAMs in their office for monitoring weather reports, but this practice appears to be on the increase. The number of trained spotters in each state is also highly dependent on its severe weather problem. Of the 29 Forecast Offices queried, the number of spotters trained each year varied from zero to 2,500. In states where the tornado death rate is high, approximately 750 Severe Storm Spotters are trained on the average per year.

2.4 Flash Flood Preparedness

Flash flood preparedness involves Management, the Service Hydrologist, and the Disaster Preparedness Meteorologist at each Forecast Office. They must first identify areas that are prone to flash flooding. Second, they must confer with community officials and make them aware of their vulnerability. Third, they must convince the community leaders that the problem can be alleviated through proper action, planning, and local cooperation. Once the vulnerability has been identified, the community officials made aware of it and their cooperation sought, the Service Hydrologist coordinates with the responsible River Forecast Center and an emergency plan is developed. The plan, frequently referred to as a "Self-Help Scheme", may consist of organizing a team to take frequent readings of rainfall and stream levels in the watershed when heavy rains occur. With this type of plan, the River Forecast Center provides graphs with which a locally trained individual can enter readings and predict downstream levels. If the Service Hydrologist and the River Forecast Center determine that this procedure is not feasible then a flash flood alarm system might be considered; or, a combination of "Self-Help Scheme" and flash flood alarm may be deemed appropriate.

3. THE SEVERE STORM ALERT

The Severe Storm Alert will not be found in official National Weather Service terminology, but it does exist. The Alert is primarily an internal message, but occasionally the synoptic situation may call for public notification. The Severe Storm Alert could be thought of as a routine message if one considers the alerting device to be the Severe Weather Outlook (AC) issued daily by the Severe Local Storms (SELS) forecaster at NSSFC. The AC is transmitted to the field twice a day at 0830Z and 1500Z for the period through 1200Z of the following day. A 1930Z Outlook is also transmitted between February 1 and August 31. These Outlooks are updated as needed and forecast reasoning is included when appropriate. Forecast Offices use the ACs in preparing state, zone, and local forecasts. For example, the forecaster when he finds his area included in the AC may wish to use terminology such as "possible severe thunderstorms" in his text. The AC, however, must be considered a relatively short range alerting device -- good for 12 to 24 hours.

A less formal Severe Storm Alert is also initiated by NSSFC when the potential for an extensive or unusually severe tornado outbreak is anticipated. This alert is usually internal and may be placed into effect up to 48 hours before the event occurs. Normally the SELS forecaster calls the MIC of those Forecast Offices that will be affected.

Once received by the Forecast Office the alerting process is continued by telephoning and coordinating with other Weather Service Offices that have warning responsibility within the state. They in turn notify the Civil Defense, law enforcement agencies, spotter groups, and other local officials. In most instances, if the confidence level is high, the media is advised and the public is informed.

Warning offices take advantage of the alert by testing and checking equipment such as the radar, emergency generator, and communication systems. Management examines the working schedule and determines what staffing will be needed. Standbys are established by carefully considering the experience level of those persons who are scheduled duties in three vital areas: (1) radar observation, (2) communication, and (3) storm warning.

4. THE SEVERE WEATHER WATCH/WARNING

The Severe Weather Watch is also issued by NSSFC. It is usually valid for 6 hours and normally affects a rectangular shaped area of approximately 65,000 square kilometers (25,000 square miles). The Watch may be issued several hours before the watch period begins and it is designed to inform National Weather Service Offices to activate storm spotter groups, to notify civil defense offices, and to advise the public to be prepared to act in case a warning is issued. The general dimensions of the watch area are received at the Forecast Office by teletype. The Forecast Office then outlines the area on a regional map and a redefining statement listing affected counties is disseminated.

4.1 Severe Weather Watch/Warning Dissemination

The Forecast Office has various means of disseminating severe weather information and for mobilizing Severe Storm Spotters. These include:

a. Commercial radio and television
b. NOAA Weather Wire Teletypewriter Service
c. NOAA Weather Radio
d. "Hotline" telephones
e. Sirens
f. National Press wire services
g. Cable television

Since the success of using many of these communication vehicles depends on a mutual effort by the National Weather Service and other agencies, management officials at the Forecast Office are constantly involved in maintaining good working relationships with radio, television, wire services, law enforcement agencies, and the Civil Defense.

One of the most important and rapid means of reaching the public's ear with severe weather information is NOAA Weather Radio (NWR). The VHF-FM frequencies utilized by NWR are 162.40 MHz, 162.475 MHz, and 162.55 MHz. These frequencies are not found on the average home radio now in use. However, a number of radio manufacturers offer special receivers that operate on these frequencies. Some are equipped with an emergency alarm that can be activated from the Forecast Office when a severe weather warning is issued for the listening area. A concerned person who has this type of receiver can, for instance, go to bed at night with his receiver set in a muted mode. If a severe weather warning is issued for his area, a signal transmitted by the Forecast Office will either sound an alarm on his set or automatically turn up the volume to an audible level. The instantaneous warning feature makes NWR especially valuable to schools, hospitals, and public safety agencies. The alarm feature also makes rebroadcast or direct broadcast by radio and television stations possible with little time loss -- a consideration that is so necessary in warning for tornadoes and flash floods.

The effective range of NWR is about 65 km (40 miles). Implementation of the system is less than 60% complete, but it is estimated that by 1979, 90% of the population in the severe local storm belt will be in range of a NOAA Weather Radio broadcast.

5. RADAR AND OTHER STORM DETECTION METHODS

Detection of severe local storms is highly radar dependent and the decision to issue a Severe Weather Warning most often rests with the radar operator. He has been specially trained to identify indicators of potential severe thunderstorms. Some of these indicators are listed below:

a. Hook echo
b. Line echo wave pattern (LEWP)
c. Cell movement 75 km/hr (45 mi/hr)
d. Merging or splitting cells
e. Cells displaying an echo-free vault
f. Cells with hail shafts
g. Intense thunderstorm ahead of instability line
h. Thunderstorm tops near or above the general tropopause level

Since the radar operator is considered to be the key man on the warning team it is highly desirable that the radar operator and the warning forecaster be collocated. Forecast Office MICs are very emphatic on this point. They were asked the question, "Do you feel that the person issuing Severe Weather Warnings from an office with radar has a great advantage over the person trying to issue warnings based on a radar repeater?" They answered:

Yes	No	No Opinion
93%	4%	3%

Some of their remarks include:

a. "Yes, a tremendous one. There is so much that one can do with a radar -- elevate, attenuate, watch for rapid development."
b. "Yes. Have experienced both (methods) and there is no substitute for viewing the real thing and just as important is the direct contact with the operator."
c. "Because of the communication gap it takes longer to issue a warning if radar not on station."
d. "The free exchange of information is severely hampered by the telephone and less than 25% of the radar data is available on WBRR (radar repeater) assuming it is working properly."

Within the severe local storm belt the dependency upon radar can best be illustrated by the MIC's answer to this question: "Approximately what percentage of the time is a Severe Thunderstorm Warning issued based on a radar signature alone?" The answers ranged from 20% to 95% with the median at 70%. The Forecast Office at Oklahoma City conducted a survey of its warnings in 1976 and found that 88% of its Severe Thunderstorm Warnings were based on radar alone.

In direct contrast to the above, the MICs indicated that, in general, the Forecast Office staff had low confidence in the present radar system when it came to detecting tornadoes. They were asked the question, "Approximately what percentage of the time is a Tornado Warning issued based on a radar signature alone?" The answers ranged from zero to 60% with the median approximation 10%. Most warning forecasters are very reluctant to issue a Tornado Warning unless there is positive confirmation. However, even though it is well known that a "hook echo" is sometimes observed when no tornado is present, and vice versa, most warning forecasters do not hesitate to issue a Tornado Warning when this radar signature is observed. With other less definite signatures it is generally felt that spotter confirmation is necessary before a warning is written. With this consideration in mind one might deduce that, of all the Tornado Warnings issued, 10% or less are based on the well noted "hook echo".

It has been stated that radar's primary value is its capability to detect cells with potential to produce severe weather. However, an equally important function is radar's capability to confirm or negate public tornado sightings. False tornado or funnel cloud reports make the warning forecaster's job very difficult indeed. When a Tornado Watch is issued by NSSFC, a nervous public sees many tornadoes that are just not there. The public's conscientious effort to "help" would confuse or even jeopardize the entire warning program if it were not for the manner present day radar is used. The MICs were asked the question, "When your area is under a Tornado Watch do you receive many false reports of tornadoes?" They answered:

Yes	No	No Answer
72%	21%	7%

They were also asked, "What would be your guess as to the ratio of false to actual tornado reports received from the public?" Only 62% of the MICs chose to answer this question but those who did confirmed the magnitude of this problem. Their answers ranged from one false report for 4 confirmed reports to 10 false reports for each confirmed report. The median approximation was two false reports for every one valid tornado.

The MICs responded to this question, "Do you automatically issue a Tornado Warning when one is said to have been reported by the public?" in this manner:

Yes	No	No Answer
* 10%	83%	7%

Therefore, it can be deduced that a public report of a tornado is rarely justification in itself for the issuance of a warning. A warning is only issued if the radar shows that a tornado is possible for the area in which it was reported. This calculated risk is not as dangerous a gamble as it might seem because many false tornadoes are reported in areas totally outside the pattern of intense radar echoes. There is no doubt that some of the false tornado reports received may have been real sightings at one time but are up to an hour old by the time the information reaches the warning office. Considering the life cycle of a tornado it is usually far too late for a warning to have any value by that time.

5.1 Powerline Breaks as a Basis for Tornado Warning

In some instances (Schulz and Smith, 1972) major powerline breaks may serve as a basis for the issuance of a Severe Weather Warning. Power companies maintain a continuous watch for breaks in transmission lines. A knowledge of such breaks when severe weather is occurring is a valuable source of information to the meteorologist who is maintaining a severe weather watch. A radar equipped weather office can also be of aid to the power company that is trying to locate exactly where the break occurred. Consequently, Little Rock and some other Forecast Offices have entered into a formal agreement to exchange information when a major transmission line breaks. Power companies state that their major transmission lines are designed to withstand winds up to 125 mph. Therefore, when severe weather is occurring and a powerline breaks, one can quite confidently assume that a tornado has caused the break. Little Rock has successfully made this assumption on a few occasions and does not hesitate to issue a tornado warning when synoptic conditions are right and a break occurs. This avenue of valuable and potentially life-saving information has not yet been thoroughly tapped by all Forecast Offices. Each warning office should seek a mutual agreement with the local power company and obtain a map showing the location of all major transmission lines.

6. OPERATIONAL ASPECTS AND PROBLEMS

Forecast Offices realize that their credibility is at stake when they issue a warning. Consequently, a concerted effort is made to neither overwarn nor underwarn. However, when the MIC survey asked the question, "Do you think that we tend to issue too many severe weather warnings?", the MICs answered:

Yes	No	No Opinion
59%	27%	14%

Here are some of the comments that were registered:

a. "Yes, especially area warned."
b. "Yes, especially Severe Thunderstorm Warnings."
c. "Yes, recommend criteria for severe thunderstorm be increased."
d. "No, we may include too much area for too long a time, but we have to overwarn at the present 'state of science'."
e. "Yes, too many times people hear a warning and nothing severe occurs."
f. "Yes, this is inherent in the system."
g. "We feel we do not issue too many warnings, but we tend to warn for too large an area."
h. "Yes, we issue too many warnings saturating the EBS (Emergency Broadcast System) and allowing the public to think 'Oh, it's just another warning'."

From reading all the comments it was not difficult to detect a note of frustration. It is known that too many warnings are issued and for too large an area, but the Forecast Office realizes that the public will tolerate a certain amount of overwarning. Warnings only have to be right occasionally for the program to be effective.

Public opinion dictates that we continually strive to improve our watch/warning program. There is no doubt that the Weather Service's efforts in disaster preparedness and in the watch/warning program have been dramatically effective in saving lives, but what further improvements can be made? Since it has been established that overwarning is a problem, how can it be solved? It has often been suggested that our overwarning problem is really confined to issuing too many Severe Thunderstorm Warnings. Some advocate abolishing Severe Thunderstorm Warnings altogether by replacing such warnings

* Includes those who answered "rarely"

with Severe Weather Statements. Therefore, the MICs were asked the question, "What would be the effect on the warning program if Severe Thunderstorm Warnings as we know them today were abolished?" They answered:

Improve Effectiveness	Reduce Effectiveness	No Opinion
17%	62%	21%

Here is a sample of comments from MICs who thought eliminating Severe Thunderstorm Warnings was a good idea.:

a. "Eliminating the Severe Thunderstorm Warning would improve our credibility."
b. "The word 'thunderstorm' in the forecast is warning enough."
c. "Perhaps it would be better not to issue Warnings but to issue Severe Thunderstorm Watches only."

Here are some comments from MICs who thought elimination of Severe Thunderstorm Warnings would not be a good idea:

a. "A Severe Thunderstorm Warning is a pre-alert to a possible tornado."
b. "More tornadoes occur during Severe Thunderstorm Warnings than during Tornado Warnings."
c. "Severe Thunderstorm Warnings sensitize the public to severe weather and make them keep an 'eye on the weather'."
d. "This (abolishing Severe Thunderstorm Warnings) would seriously cripple the public service now performed."
e. "There is less public criticism about lack of warning when a Severe Thunderstorm Warning is issued and a tornado develops at a later stage and a warning is not issued."
f. "The elimination of Severe Thunderstorm Warnings would probably result in an increase in the number of Tornado Warnings in marginal situation."

In summary to this question, the majority feel that the elimination of the Severe Thunderstorm Warning would reduce the effectiveness of the warning program, but the number of warnings should still be reduced. If they are not reduced the public will lose their sensitivity to them. Since many of the MICs indicate that Severe Thunderstorm Warnings act as a "pre-alert" to a possible tornado, perhaps they are trying to say that Severe Thunderstorm Warnings should only be issued for those cells which have the potential to produce a tornado, if that determination can be made. A warning forecaster operating with this precept would more than likely substantially reduce the number of Severe Thunderstorm Warnings he issues. If this concept was adopted then its success would depend on the warning forecaster's ability to judge cell potential in the synoptic environment. Does he need more help in making this judgment?

With this idea in mind, this question was placed before the MIC survey, "Since we all know that some Tornado Watches verify better than others, do you think that the SELS forecaster should give the field some internal sign of his confidence or the "hotness" of the box -- a sort of 'Perspiration Index'? Wouldn't this index if it were adopted, give us -- and perhaps even more so WSOs -- the type of warning attitude to adopt for the particular situation?" The MICs answered:

Yes	No
52%	48%

Some of their remarks not in favor include:

a. "Low index might lead to complacency."
b. "Adoption at this suggestion would serve no useful purpose."
c. "No, the SELS forecaster has passed his threshold value when he decides to issue a Watch."
d. "Absolutely not! Our guard would not be up all the time. Most of us are experienced enough to know when we are in a "hot box" anyway."

Here are some remarks in favor of a 'Perspiration Index':

a. "This (Perspiration Index) would lend to greater credibility and accountability by SELS."
b. "I think the idea has merit. Suspect about three levels might be all a SELS forecaster might distinguish."
c. "Its worth a try. Suggest only three categories be used."
d. "Yes, if SELS has this capability."
e. "Good idea, but must be developed cautiously."
f. "Staff in full agreement with this."

As one can see this suggestion was received lukewarmly. Some found it to be an affront to their professionalism; but, in a majority of instances, the MICs thought the idea had some merit. However, the skill of the SELS forecaster in categorizing Watches was questioned. A test of the SELS forecaster's capability would be necessary before this suggestion could be adopted.

6.1 Operational Stress During a Severe Weather Outbreak

Severe weather may only last for a few hours but there are other times when the warning office must be on its guard for 12, 16, 24 hours or even days at a time. How do people stand up to the stress generated by long sieges in a Watch situation? Most of the MICs polled believe that people rise to the occasion and can work effectively for long periods if need be. However, they were asked the question, "When your office has a long siege of continuous severe weather, do you notice any signs of battle fatigue?" The MICs answered:

Yes	No
90%	10%

Some of the remarks concerning this question pointed to the importance of knowing your staff. Management must judge each individual's ability to cope with severe weather stress. Some seem to thrive on it while others seem to lose their effectiveness in a relatively short period of time. The ability to handle stress may also be dependent on job interest or proficiency. For instance, a person might feel more stress issuing warnings and statements if his real interest was in operating the radar. It is recognized that, even though stress thresholds vary, individuals may not be able to identify the point when they begin to lose their effectiveness. For example, a warning forecaster may begin to lose his sense of immediacy after issuing 10, 20, or 30 warnings -- especially if little damage has occurred. He may decide to ignore a cell on the radar for which he previously would have not hesitated to warn. This cell might produce the devastating tornado. Regardless of differences in the individual's job proficiency, it was generally recommended that jobs be rotated if possible. The survey asked the question, "How long do you think one man can effectively operate the radar in such times (long sieges of continuous severe weather)?" The answers received ranged from 1 hour to 12 hours, but the median, and most common estimate, was 4 hours.

6.2 Further Comments on the Flash Flood Preparedness/Watch/Warning Program

The Flash Flood Preparedness/Watch/Warning Program is a topic that receives a considerable amount of self-criticism. In general, operational meteorologists/hydrologists are not particularly satisfied with their adequacy in achieving their objectives of preventing injuries and loss of life and in minimizing damage to property when flash floods occur. The record in issuing timely Flash Flood Watches/Warnings has many blemishes. Among the more recent ones are the flash floods which occurred at Black Hills-Rapid City, South Dakota, June 9-10, 1972, (Geological Survey and NOAA 1975); Enid, Oklahoma, October 10, 1973 (Merritt, Wilk, and Weible, 1974); and Big Thompson Canyon, Colorado, July 31-August 1, 1976 (NOAA, 1976). The report on the latter points not to inattentiveness on the part of the forecaster involved but rather attests to the "gaps in our knowledge and understanding of mesoscale meteorology." The MICs were asked this question: "What do you think our overall skill is in forecasting abnormally heavy rain?" They responded:

Good	Fair	Poor	No Opinion
3%	21%	52%	24%

One can see from the results that there is no question as to where we stand.

How do we improve the situation? There is evidence that our watch/warning program for severe thunderstorms and tornadoes -- though it could be improved -- does achieve the objective of saving lives. Mogil and Groper (1977) state that for the period January-March 1976 "75% of the tornado-related fatalities were in severe weather watch areas with an average lead time, from watch issuance, of 2 hours and 32 minutes". The statistics for how we stand on flash flood-related fatalities are unknown, but it is known that few of the disastrous flash floods occurred with a timely flash flood watch/warning in effect. Since some success has been achieved in giving the public advance notice of when and where tornadoes will occur, why could not a similar program be adopted for predicting when and where abnormally heavy rain will occur? The MICs were asked: "Do you think the NWS could issue better forecasts and warnings for abnormally heavy rain if it adopted a policy similar to the one we use for severe weather? For example, have the SELS unit or the QPF unit issue Flash Flood or Heavy Rain Watches?" The MICs answered:

Yes	No	No Opinion
31%	48%	21%

Here are some comments in favor of such a unit:

a. "I think they would do a better job. Their expertise is more on the scale of the flash flood event."
b. "Would improve coordination between states and somewhat simplify the problems for WSFOs."
c. "This would free forecasters from the time consuming task of issuing and coordinating Flash Flood Watches."
d. "Worth a try. Should be tested internally before becoming operational for the public."

These are some of the comments opposing centralizing Flash Flood Watch responsibility:

a. "Neither SELS nor the QPF unit have staffing for the type of mesoscale forecasting needed."
b. "Local forecasters' knowledge of his state terrain should give him a positive edge over a national unit."
c. "QPF Heavy Snow Forecast not too great, and Heavy Rain Watch would verify about the same."
d. "On the basis of what we're seeing coming from SELS and QPF now we're better off with what we're doing."

Apparently the idea of establishing a national unit with flash flood forecast responsibility is not distasteful to the MICs, but there is more a feeling that the program would not operate as effectively as it does now.

Most MICs agree that aggressive preparedness for abnormally heavy rain and accompanying flash flood event would pay better dividends at this state of the science. However, aggressive preparedness is easier said than done. A flash flood is a relatively rare event. Some areas are more prone than others, but we are speaking in terms of one flash flood event every 10, 20, or 50 years. After a flash flood has occurred, it is relatively simple to interest a community in a flash flood plan designed to buy time for precautionary measures to be taken the next time abnormally heavy rain occurs. But, if one tries to stimulate interest in a vulnerable community, five years after the last flash flood, one often runs into a wall of complacency -- especially if the plan calls for the expenditure of local time and money. This complacency is an obstacle we must find ways of overcoming.

7. EXPECTED FUTURE IMPROVEMENTS

Three significant improvements in the Severe Weather Watch/Warning Program are foreseen for the future. The first, NOAA Weather Radio, is near-term and its advantages have already been discussed. The second is also near-term. It is a highly sophisticated communications system called AFOS (Automation of Field Operations and Services). Installation of AFOS will begin this year and will be complete by 1980. This system will feature high speed data handling and display capabilities by on-site minicomputers linked together in a nationwide network. Features such as preformated message composition, computer-generated voice and elimination of the need for tape cutting, which is a part of today's teletype system, will allow warning messages to reach the public's ear in about 3 minutes, or about half the time it takes today. The impact of this improvement in warning capability should be a significant reduction in lives lost. Today a tornado moving at 60 mph will cover a distance of 6 miles before a National Weather Service Tornado Warning will be heard by the public. A post-AFOS tornado moving at the same rate will have moved only 3 miles before the citizenry hears the official warning.

Another AFOS feature that should make a significant improvement in our flash flood warning capability is automatic monitoring. The minicomputer can be programed to constantly monitor rain gages or digitized radar and/or satellite rainfall estimates. When the rainfall, or estimates thereof, approach the Flash Flood Index for a certain area an alarm will sound notifying the warning forecaster. In all likelihood, the minicomputer will be programed to write the Flash Flood Warning for the appropriate area. If the forecaster agrees that this warning is necessary he will press a button on the console and the warning will reach the public in a few minutes.

The final area of improvement that is 5 to 10 years off, will be the sophistication and implementation of Doppler radar (NOAA, 1977). Doppler radar differs from conventional radar by its ability to monitor both the intensity and motion of precipitation. It is hoped that the precursor of a tornado -- cyclonic circulation within the thunderstorm -- can be detected by Doppler radar up to 30 minutes before the funnel touches the ground.

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AMATEUR RADIO AND THE NATIONAL WEATHER SERVICE

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There has been great emphasis in recent years on development of equipment for positive identification of tornadoes and determining their position. The NOAA Severe Storms Laboratory is currently heavily involved in the effort and it is likely we shall in time see such a tool in operational service. However, the realities of today and the near future are that in most tornado cases the initial warning is issued as a result of a tornado sighting reported by a responsible observer rather than as a result of a detection device. Further, the likelihood is that property damage and possibly loss of life will occur before the first warning is issued. The tornado warning service remains dependent on the input from a trained storm spotter for its ability to provide adequate, short-term warnings to the public. This is despite ever increasing understanding of severe weather and advancing technology and the greater confidence Weather Service personnel have in issuing tornado warnings on the basis of radar indications.

Over the last 5 years the Weather Service has strongly encouraged the formation of storm spotter networks and this has been publicized widely under the SKYWARN label. Of course, spotter networks are really an old idea continuously being burnished and improved. For example, the spotter network for Kansas City in the very early 1940's consisted of telephone operators in small towns to the west and southwest of Kansas City. They were selected because they had immediate access to communications to the Weather Service and could break into busy circuits with emergency information. Through the ensuing years experience has shown there are 3 essential ingredients to a successful spotter network: Reliable and fast communications (preferably radio), spotter training, and a continuing sense of responsibility and dedication on the part of the cooperators. These characteristics have been amply demonstrated in the fine results achieved using state police, other law enforcement and public safety officials in the spotter programs.

The Weather Service Southern Region has made a special effort in the last year to develop supplemental storm spotter networks using the Amateur Radio Service. This decision was made because of the history of successful operation of spotter networks manned by amateur radio operators at several locations. At Waco, Texas the spotter network has operated effectively for 8 consecutive years; at Tulsa, the amateur operated spotter network has a history of successful operation for more than a decade.

The Amateur Radio Service is authorized by the Federal Communications Commission for the purpose of providing a means for persons to conduct radio experiments, for development of a reservoir of communications skills in the national interest, to provide emergency communications capabilities at times of major disaster, and to encourage international good will. Amateur radio operators are strictly prohibited from receiving any form of compensation for communications services, which must remain non-commercial in nature. There are more than 300,000 licensed amateur radio operators in the nation, each having been required to demonstrate technical knowledge, communications procedure skills and International Morse Code proficiency commensurate with the operating privileges granted in the license. Collectively, they may be viewed as a group aware that continuation of their hobby depends on the value of the Amateur Radio Service to the nation. Historically they have given freely of their personal time and made their equipment available to meet almost every imaginable emergency communications need.

Experience has shown that the amateur 2-meter band (specifically 144-148 mHz) is best suited to storm spotter communications because of propogation conditions and because of the relatively large percentage of operators with equipment for this band. It provides reliable and relatively noise-free communication over distances of 10 to 30 miles.

The feasibility of spotter networks manned by radio amateurs was enhanced very significantly after the Federal Communications Commission authorized automatic repeater stations in the Amateur Radio Service. In practically every city of 100,000 or so the amateurs will be found to have one or more repeater stations, usually on the 2-meter band. Typically these are located to provide for a high antenna location. Amateur transmissions are received by the repeater and automatically re-transmitted on an adjacent channel. The favorable antenna location for these essentially line of sight transmissions and the customarily higher power of the repeater stations usually extend the communications range to as much as 100 miles. Because the repeater stations are financed, installed, maintained and controlled by the amateurs the combined capability of perhaps hundreds of amateur fixed location and mobile stations and the repeater represents a ready-made opportunity to use an existing volunteer communications service and the organization's manpower resources to operate a successful spotter network.

The spotter network for the Fort Worth-Dallas area is described here because it is representative of networks in other areas, although it may differ in detail. There the network includes several hundred operators in the home counties of Tarrant and Dallas as well as associated groups in adjacent counties. Spotters in Tarrant and Dallas counties were organized largely through the efforts of Civil Defense. Special regulations of the Federal Communications Commission recognize the Radio Amateur Civil Emergency Service (RACES). It is intended to provide Civil Defense-related communications services during civil emergencies and authority for its formation and direction rests with Civil Defense.

The RACES spotter network is activated by Civil Defense on advice from the Weather Service. Each of the participating operators is furnished a map of the metropolitan area gridded in 3 mile by 3 mile squares for location identification purposes. A Net Control Station in Civil Defense Headquarters directs the operations and maintains circuit discipline. A Monitor Post established at the Weather Service Forecast Office is manned as needed. Antennas and suitable power sources are permanently installed; volunteer operators furnish the radio transmitting and receiving equipment. The prime function of the Monitor Post is to maintain a buffer between the network operations and the NWS persons responsible for making warning decisions. The Monitor Post screens incoming reports, relays pertinent information to the Weather Service warning position; accepts and forwards Weather Service requests for information from certain areas. All communication is on the 2-meter band via an automatic repeater station. All spotters are expected to have completed a spotter training course sponsored by Civil Defense in cooperation with the Weather Service in order to be recognized as a participant. In adjacent counties amateur radio operators not under the RACES organization also serve as spotters and have established radio communications channels to feed their information into the system.

The Fort Worth-Dallas RACES spotter network is relatively new but its performance was well documented in the Dallas Tornado of May 26, 1976. The Meteorologist in Charge credits these spotters with providing the on-the-scene observations which made it possible for the Weather Service to give 30 minute advance warning to Dallas as well as frequent and detailed up-dated accounts of the tornado's progress.

Although the principal use of the Amateur Radio Service in the Southern Region has been in support of storm spotting, it is significant that radio amateurs also continue to support the flash flood warning program of the Weather Service. An example is San Antonio, Texas, where several creeks run through the city and have numerous low-water crossings. These conditions have been the cause of considerable damage from time to time and occasional loss of life as a result of vehicles being caught in rising waters in the normally dry crossings. For many years an amateur radio organization at San Antonio has assisted the Weather Service in its flood warning work. By prearrangement, mobile operators are dispatched by net control to designated points along the creeks and low water crossings. From there the operators report frequently on water level and cumulative rainfall to help the Weather Service to continually up-date its warnings. An amateur operating position is set up permanently in the Weather Service Forecast Office so it may be activated on very short notice. All communications is on the 2-meter band using an automatic repeater station to extend range.

Other management regions of the Weather Service have reported similar experiences with the Amateur Radio Service. The Central Region has been successful in using the West Nebraska Weather Net to provide visual observations from a number of remote locations in the sparsely populated western part of the state. This has been particularly helpful in incipient blizzard situations.

Because of the excellent results achieved by the Amateur Radio Service, the Southern Region has undertaken a program to enlist the aid of amateur radio organizations in most of the larger cities in the Region presently without such help in support of the storm and flash flood warning service. One of the difficulties in getting started was a lack of understanding by the amateur operators of the basic mission of the Weather Service and its operations. It was difficult to explain to local radio clubs how their participation would contribute, why their help was desired but also that some limitations would have to be imposed to prevent the effort from becoming counter-productive. Similarly, not all Weather Service officials seeking to recruit the Amateur Radio Service understood the purpose of amateur radio. Following this, the decision was made to prepare a booklet specifically addressing the matter of how the Weather Service and the Amateur Radio Service could work together for the public benefit. This booklet has now been distributed widely for use as a general reference. Copies are available without charge to all interested persons and groups by addressing the National Weather Service Regional Headquarters at Fort Worth, Texas.

There are 59 Weather Service offices in the Southern Region which have county warning responsibility for severe weather and flash flooding. At the beginning of 1976, 5 of these offices had organized amateur groups supporting their work as spotters and observers. At this time an additional 4 networks have been established or in the process of being organized and several have already demonstrated their ability to perform. It is estimated that an additional 25 or so locations have high potential for development of spotter or other warning related networks operated by radio amateurs.

Revisions of remarks made by the senior author at the Tenth AMS Conference on Severe Local Storms(Omaha, Nebraska-October, 1977).

SOME VIEWS ON THE WARNING PROBLEM IN DISASTERS AS SUGGESTED BY SOCIOLOGICAL RESEARCH

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Research is not important because it finds that certain things are so, that the evidence supports commonly held views, but rather because it establishes that certain things are not so, are different from what is widely believed, and advances new ways of looking at problems. Much of the research into disasters by social and behavioral scientists has pointed out many mythological beliefs about disaster behavior and has indicated new ways of thinking about the phenomena being studied. Therefore, in the following remarks we want to set forth, in a very selective fashion, what sociological research has established about misconceptions as to disaster warnings and what such studies suggest as to untraditional ways of looking at the problem.

There is a tendency to think of disaster warnings in technological and/or mechanical terms, such as radio or siren soundings. But these devices are <u>means</u> of communication, at best. Their activation, use and functions are determined by the behavior of people and the actions of organizations. As such, warning should be thought of primarily as involving psychological functions and social structures. Viewed this way, warning can be seen as a <u>process</u> that is a product of social organization.

This view of warning is quite different from one that suggests that warning can be equated with information about a disaster agent. Viewing warning as a complex process and product means seeing it as involving all of the components, relationships and factors which effect:

(1) the determination and estimation of danger;

(2) the formulation and transmission of warning messages about this danger; and

(3) the way people interpret and act upon these messages.

<u>The Establishment of Threats Requiring Warning</u>

Some of the complexities involved can be seen in the collection, collation and evaluation of threat data. Before a warning message can be issued, information about the danger must be obtained, pulled together and judged. This is not purely a technical matter or a simple linear flow of information. Look at what is involved in the collection of threat data.

First, information about danger cues primarily is gathered by organizations rather than by individuals. This is more than a play upon words. Organizations process information differently from the way persons do.

Second, many different groups are involved, in varying degrees, in obtaining this information. It is a multi-group process.

Third, not all social entities taking part in the collection of threat information are equally active in seeking cues or monitoring danger signs. Put in other words, there is a considerable difference in the involvement of groups in looking for threat data.

Fourth, there are also marked differences in organizational ability to detect and understand danger cues. Some organizations are "smarter" than others.

Fifth, even active agencies operating in intelligent fashion often do not cover the full range of potential danger cues. Conversly, they pay little attention to cues or indicators of trouble outside of their organizational domain or responsibility.

What we have just noted is merely a surface glance at the complexity involved solely in the collection of threat data. It would be possible to illustrate similar complexity in the collation and the evaluation of danger cues.

The emphasis here is on the complexity of the process and product solely involved in the determination and estimation of danger, which is only part of all that is involved.

We stress this to make the point that all sorts of things can go wrong in the collection, collation and evaluation of threat data. Whatever technology might be employed--computers, radar or what have you--it can be no better than the organizational flaws and failures that are a mark of groups in the same way that human errors and mistakes are a characteristic of human beings. If there are problems in disaster warnings, it should be recognized that the source of the problems may be as much in the providers or the sources of the warnings as it is in the recipients of these warnings. Particularly in the disaster warning area, there is a strong tendency to see problems as residing primarily in the public at large, the recipients of the warning messages. A more balanced perspective recognizes that the providers of warnings, the agencies determining and estimating danger, have their own problems which, if not solved properly, making problems in the delivering and receiving of warning messages relatively unimportant.

The Dissemination of Warning Messages

There is often a tendency for organization officials to delay warning messages for many disaster agents because they feel that the "public" cannot deal with them effectively and will respond in irrational ways. Most research shows that irrational behavior under stress, even extreme stress, is a very rare phenomena. It is much better to assume that the vast majority of people will respond reasonably to intelligent and intelligible warning messages.

The major action needed to insure the effectiveness of warning messages is to make certain that information will be provided that will lead to adaptive behavior. Some disaster messages, intended to warn people about dangers, contain only information of threat and no suggestions for adaptive behavior. That is not a warning message. At best, it is merely an alert that something may be wrong, but it generally will not lead to action. And it is action, i.e., responsive behavior, that should be the intent or objective of any warning message, rather than solely a sensitization that something might be wrong.

Research suggests that an adequate warning message is one which gradually prepares for action by (a) providing various and multiple cues which are convincing about threat and at the same time (b) presenting possible alternative actions to be considered that would be adaptive and convenient. While too many cues can confuse recipients of messages, cues that reinforce one another can help convey the idea that there is real danger. The presentation of alternative courses of action makes it more likely that a recipient will find one convenient to follow.

In American society the general assumption has been to utilize more impersonal and individualistic means to disseminate warnings, such as radio, to alert the "public." On the other hand, little attention has been given to the utilization of channels of communication that already exist within particular social groups. For example, most organizations, whether they be schools, factories, offices or businesses, have everyday means and channels for communicating with their own members. In addition, most organizations are part of everyday interorganizational networks. The vast majority of people and groups are tied, in a routine way, with many other people and groups. Much more could be done to take advantage of such additional channels of communication and multiple linkages for dissemination of warnings than has been done in the past.

There is a need for some creative thinking along this line instead of continually following the old, and in many respects incorrect, model which posits a major disseminator; e.g., a key radio station broadcasting to the isolated masses in the community. Ways ought to be explored to take advantage of everyday behaviors, rather than to try to force persons to act in "unnatural" ways; i.e., contrary to routine habits and impulses. For example, the "public" is frequently urged not to use some channels of communications at times of collective trouble, such as the telephone. Such admonitions, all the evidence indicates, are useless. People will use the phone since that is a normal, everyday habit. Instead of trying to stop the impossible, people calling one another at times of community stress, ways ought to be found to take advantage of such calls so as to improve the dissemination of warning messages. This is not a usual way of thinking about the problem, but if present ways of doing things are unsatisfactory, new ways should be sought, no matter how unorthodox they may appear at first glance.

Furthermore, warnings cannot be seen as a simple technical message issued by a creditable organization to a responsive public. Just as organizations must deal with the possible consequences of information they issue, the population also has to consider the consequences of attending to the danger cues and following suggested courses of action. At one level, the assessment process is not that different, be it by distributors of warning messages or recipients of them. In both cases, the parties involved must make assessments of the possible consequences if they do or do not accept certain cues and attempt certain actions.

There is an implication here that the fear, held by those responsible for the issuance and distribution of warnings, that the public cannot deal with threat comes true because of the willingness of those in command to share the evaluation process with those to be warned. Groups involved in warnings should open to the public their processes and ways of judging cues and arriving at decisions. In general, more trust is placed in those statements for which there is understanding of the decision behind them than in flat edicts which seem to come from nowhere. Similarily, warning messages are more likely to be accepted if the process leading up to them is more clearly understood by those towards whom the warning message is directed.

Response to Warnings

The most studied aspect of the warning problem has been the response to them. We can only touch on three points in our brief comments.

Warning messages are often not received by their intended audience or are received by an unintended audience. This is particularly true when impersonal and non-specific channels of communication, such as radio, are used. Mass media exposure varies tremendously in terms of day, time and season. Different channels have different audiences. For example, different radio stations in the same community may have almost no overlap of audiences, reaching sharply different segments of the community. This is not an insignificant fact, given the potential victim populations have differential probabilities of being impacted because of the kind of housing they have (e.g. mobile homes), the particular topographical features of the neighborhood in which they live (e.g. flood plains), or their easy access to understandable information (e.g. non-English speaking groups). It is remarkable that whole subpopulations of a community can "miss" compared with the exposure others get to the same words, be the message warning or other community relevant information. Stated another way, there is not a "public" out there ready to be warned, but a variety of different groups with different probabilities being tuned in to any general community directed message. Differential exposure to disaster warnings almost insures differences in responses.

Even if warning messages are clear and specific and are conveyed through multiple channels, this does not guarantee that the message will be received by the "public" in the same way that the officials intended in issuing the warning. Let us cite just one complicating factor. Some communities have had considerable prior disaster experience; cues and warnings are interpreted differently to such communities than they would be in one without previous experience. Warnings are always issued in supportive or denying contexts, never in neutral settings. Response is, therefore, not solely to the warning message per se, but to that information as it is perceived in a particular historical background. A warning message never simply goes "out there"; it reaches particular communities containing subpopulations with different learned ways of reacting in and responding to threats. Response patterns are as much a function of the background of the warned group as they are of the warning message itself. Thus, there can be huge discrepancies in the response intended by the warning message and the actual response which is evoked.

Finally, responses to warnings are only effective if they lead to preventive, protective or ameliorative actions. The probability of this occurring is dependent on many factors. However, as a general principle, the more desired response to the warning message is in line with everyday behaviors, the more likely it is to occur. This is another way of restating an old DRC principle; that is, it is by far more effective to adjust-disaster plans to people than to try to force people to follow prescribed plans which mandate or require unusual or non-routine behaviors. The relevance of prior and exercised planning to achieve this, is of course, obvious.

These remarks hardly exhaust all that could be said. For instance, little thought is given to the nature and the form of later time warnings that are often needed after the initial alert. Disaster impact frequently generates a series of continuing and secondary threats that may exist for a long time after the initial warning message. Likewise, almost no attention has been given to harmonizing the issuance of warning messages with the "social time" of the community. By social time is meant the customary rhythms which exist within a community; for example, school, work, shift, etc., times.

In conclusion, it is necessary to emphasize that warning is more than a message; it is a complex process involving many organizations and individuals. Furthermore, the warning process always occurs in an on-going social situation and not in a neutral context. Finally, it is better to adjust plans to people than to try to force people to follow plans. If such things are kept in mind, the effectiveness and efficiency of the warning process can be improved.

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CORRECTING FOR THE HUMAN FACTOR IN TORNADO WARNINGS

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Tornadoes, like flash floods, fit the category of natural hazards which strike quickly such that the warning period is short and there is little time for people to respond to warnings. Mogil and Groper report findings for the period January-March 1976 which indicate an average lead time from watch issuance of two hours and thirty-two minutes; eighty-two percent of the fatalities were in valid severe weather warning areas with an average lead time of thirty minutes (Mogil and Groper, 1977, p. 326).

In areas which have repeated threats of tornadoes, communities may develop fairly routine responses with more organized warning proceudres (Eliot, 1932; Moore, 1964). Protective measures are related more to the saving of lives and movable property; little can be done to minimize major property damage. Tornado warning systems can be termed "dramatic event warning systems" which are established to save lives and movable property and to reduce injuries and social disruption.

Effectiveness of warning systems is based in part on degree of predictability of the event. Tornadoes, unlike earthquakes or landslides, can be predicted to some degree. In general, "the more accurate the prediction as to the location of the threat, the more effective the response may be by the population affected." (McLuckie, 1970, p. 11).

Warning systems, however, involve more than the ability to forecast a tornado successfully and to broadcast the message to the threatened population. A properly integrated warning system includes both technological and social components of warning and warning response. The system performs the basic functions of: 1) evaluation of the threat; 2) dissemination of the warnings; and 3) response to the warnings. Various groups and persons perform each function. Related social processes comprise each function, which is divided into the two basic subsystems of any warning system: 1) the evaluation -dissemination subsystem, and 2) the response subsystem. These ideas are illustrated in Figure 1.

The evaluation function of the first subsystem includes tornado detection, data gathering and collation, interpretation of data, and decision to warn. The dissemination function involves decisions on content of the warning message and on how to make the information available.

What factors explain differences in warnings issued from the evaluation-dissemination subsystem? Three central elements which explain how warnings are issued are: 1) the experience of community and agency officials in warning roles; 2) the pre-tornado structure and organization of warning-related community agencies; and 3) the nature of actual disaster-related communication between warning-related organizations (Mileti, 1975, p. 16).

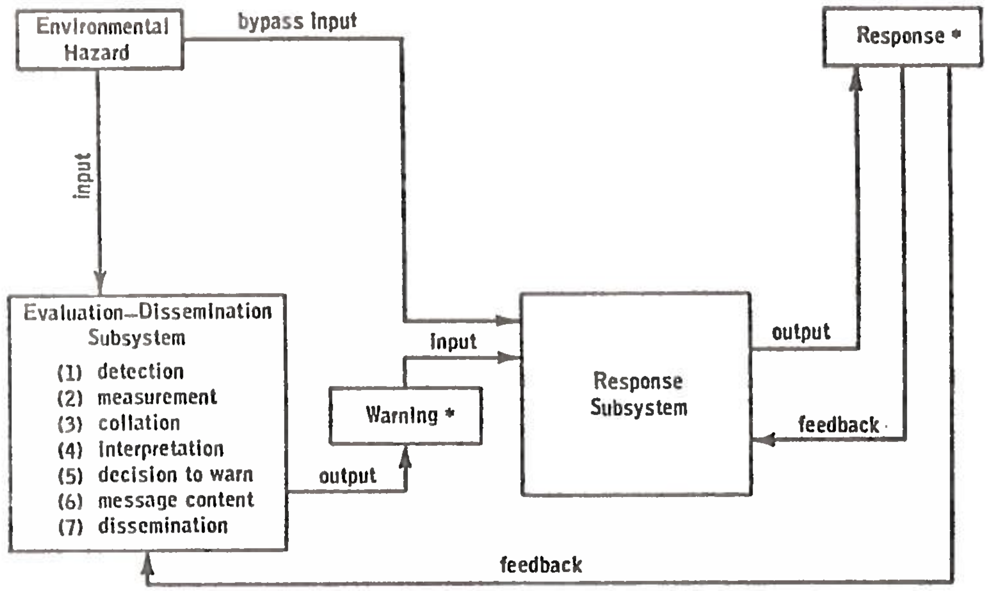
Communication is a key variable. The capacity of an organization for communication determines to a large extent the likelihood of its participation in the warning process. Ambiguity or clarity of communication and speed of interorganizational communication are highly related to issuance of warnings.

The dissemination of warnings becomes relevant only in the context of individual, organizational, and community response. The response subsystem includes social system variables which can be classified as sociological, psychological, and social-psychological. Response is the adoption of protective behavior by the individuals, small groups, organizations, and community as a whole. Interpretations of the warning by those who respond precede actual behavior. The effectiveness of a tornado warning is measured by the degree to which protective response occurs among the threatened persons.

The evaluation-dissemination and response subsystems operate within a feed-

FIGURE 1

SYSTEMS MODEL OF A WARNING SYSTEM



* Major dependent variables in the system.

back relationship. Response to warnings (internal feedback) or environmental cues can serve as input to the evaluation -dissemination subsystem. The feedback consists of "information about the... actions of recipients to the issuers of warning messages," and leads to "new warnings, if possible and desirable, corrected in terms of responses to the first warning messages" (Williams, 1964, p. 83).

<u>Why are tornado warnings effective when they work?</u>

Barton reports that communities and groups which have experienced disaster cope better than do those which have not (Barton, 1970, 142). Prior experience with tornadoes may result in learning better evaluation and dissemination techniques as well as general expansion of emergency services. Group culture may emerge which produces norms and attitudes more appropriate to dealing with the problems of community preparedness and adequacy of warnings. Mogil and Groper report that Jonesboro, Arkansas had no preparedness at the time of its 1968 tornado with regard to NOAA Weather Wire Service, radio and television dissemination of watches and warnings, spotter networks, educational programs, emergency operations center, or disaster drill procedures. By the time of its 1973 tornado all of these capacities were available (Mogil and Groper, 1977, p. 320).

A look at effects of the tornadoes at Jonesboro shows that in 1973 deaths, injuries, and hospitalization had been greatly reduced although damage had increased by 625 percent.

Key factors in securing appropriate response to the tornado warning include: 1) adequate communication of the threat, 2) confirmation of the warning, 3) belief in the warning; and 4) how what people hear stimulates them to react.

Warnings are likely to be believed: 1) if they come from official sources, 2) if there is consistency among messages; 3) if there are repeated messages; 4) if the message is delivered in a personal manner; 5) if changes in the physical environment support the threat message; 6) if others are behaving as if they believe the warning; 7) if the receiver of the message senses certainty in the sender; and 8) if responses to questions by official sources are credible.

Belief in the tornado warning is essential to taking protective action, but even if one believes in the presence of danger one may fail to take adaptive action if the message content is misunderstood. Willingness to take protective action is related to: 1) past tornado experience; 2) perceived location of impact; 3) family discussion; 4) age of respondent (older people are less willing to act); and 5) face-to-face contact with officials (Mileti, 1975, pp. 21-22).

Why are tornado warnings ineffective when they don't work?

Why do some communities have elaborate warning systems while others have none? Why do warning systems work well in some instances and in others fail miserably? These simple questions have complex answers; the answers deal with warning system constraints.

There are two major kinds of constraints: 1) those which retard the development and adoption of warning systems at local levels, and 2) those which reduce the effectiveness of warning systems when they are put into operation.

Perhaps the strongest constraint to the development and adoption of warning systems at local levels is that they deal with infrequent events. Consequently, communities give a low priority to establishment and maintenance of any warning system in light of more pressing and immediate everyday needs for tax dollar expenditures.

This constraint reduces effectiveness of the warning system. Poor communication exists between evaluators and disseminators of information. Public warning dissemination may proceed without enough knowledge or training in the appropriate content and delivery of public warnings. "The result is often an inadequately warned public and needless deaths and injuries" (Mileti, 1975, p. 15).

Other constraints which reduce effectiveness of warning systems are: 1) technical problems in making an accurate assessment and prediction of the event; 2) getting that information to public warning disseminators; 3) inadequate community preparedness or organization, and 4) public warning disseminators not knowing how and what information should be dispersed in light of the varied sociological, social-psychological and psychological factors which affect and even determine what one will do in response to a warning.

Let us look briefly at features of tornado warning and response in the light of these constraints.

Various technical problems exist in forecasting tornadoes because of the suddenness of the event, its short duration, extreme variability in the strike pattern, level of disruption or knowledge of the danger and extent of the weather observing system. Kessler points out that "the weather observing system we now have...limit(s) us to indicating the probability of thunderstorms and accompanying tornadoes in regions much larger than the storms" (Kessler, 1970, p. 927).

The National Weather Service relies on radar (some equipment is outdated), weather satellites, electronic tornado detectors or sensors, and actual sightings by professional and volunteer spotters (Mileti, 1975, p. 35). The National Warning System is a telephone-operated hotline connecting Civil Defense Warning Points within each earning area. The NOAA Weather Wire Service includes generally only larger cities. It is a system which is highly dependent on information fed into it, and is more likely to have data for long track tornadoes than for more localized ones. Information is generally transmitted to commercial FM and AM radio and television stations. Warnings are usually transmitted by them without explicit instructions on appropriate public response.

Dispersion of information to the public occurs within the evaluation-dissemination subsystem. The processes of detection, measurement, collation, and interpretation occur in organizations such as the National Weather Service. They then pass threat information to emergency groups of the affected community who then make the warnings public. Organizations concerned with evaluation and those concerned with dissemination of public warnings often experience interorganizational difficulties. Dissemination of adequate warning to the public has also been shown to be problematic. Predictions and forecasts of danger are pointless without an adequate vehicle for informing the families and individuals who comprise the community.

Even with warnings, a community may remain unprepared or unwilling to take protective measures. One well-documented feature of human response to warning systems (Fritz, 1961, p. 664) is that people do not overreact with mass panic or when the warning is taken too seriously.

Prior experience with tornadoes may cause those charged with the responsibility to issue warnings to develop a reduced sense of urgency and adequacy of response, although positive effects are also possible from such experience. A typical problem for communities with established warning systems is that such systems may deteriorate after prolonged disuse. There is thus a danger of impaired communication of warning and feedback with too-frequent or too-infrequent use of warnings.

It should be noted that response is not dependent purely on formal warnings, but is affected by other factors, such as interpretations of likelihood of danger from the tornado, e.g. observation of the skies, rain advice or comment from friends, neighbors or relatives. Not all warnings are official. The link between the tornado and the response subsystem is called "bypass input" in Figure 1; the linkage of persons in the response subsystem is "internal feedback." Monitoring of such feedback in order to improve effectiveness of warning systems rarely occurs. Knowledge when it is acquired through this feedback process "may and does result in changes in official warning systems and in other systems involved in the presumed effectiveness or ineffectiveness of the warning" (Williams, 1964, p. 96).

The great variability among people makes more difficult the task of disseminators of tornado warning information. There are three simple but important features of people's response to warnings: 1) though people may listen to the same warning, each hears something different; 2) people respond on the basis of how what they hear stimulates them to behave; and 3) people are stimulated differently depending on who they are, whom they are with, or who and what they see (Mileti, 1975, p. 43).

In addition, response to warning is mediated by the variables of warning confirmation (the process whereby the recipient of a warning seeks additional information beyond the original warning) and warning belief (definition of the situation as threat or otherwise).

Costs and benefits of upgrading effectiveness of warnings

Warning systems crosscut political levels and hazard types. Agency costs for one hazard, especially weather-related hazards, are often inseparable from larger hazard groupings. One estimate of the national cost of warning systems for groups and agencies involved in the three basic functions of warning systems (evaluation, dissemination, response) is in excess of $140 million annually.

Given the frequency of tornadoes in the nation, the loss of life is relatively small. For the period 1960-1970 the average death rate each year attributed to tornadoes was 101. For the same period, there were only 0.137 deaths per observed tornado. "In yearly averages the 'loss of life' criterion for tornadoes is a weak rationalization for additional monies being spent on warning research...The same conclusion may be reached for tornadoes in reference to average loss of property" (Mileti, 1975, p. 84). It is unlikely that improved warning systems would reduce building losses significantly.

Warning systems do mobilize parts of community, relevant emergency groups and organizations for response to disaster, saving lives, reducing injuries, and saving some movable property. They also maintain a community level awareness of tornado danger and openness to consideration of other possible adjustments. Communities must determine whether or not these benefits outweigh the disadvantages of reappropriating tax dollars in the direction of enhanced warning system capabilities.

Some steps to consider options in light of other national warning system priorities

Warning systems rely on communication for effectiveness. Effectiveness decreases over time partly because of the limited interaction among parts of the system between threats of tornado activity. Interagency and interorganization communications must be increased in specificity, consistency, clarity, and speed. Integration of tornado warning systems with all-purpose emergency systems and establishing direct communication lines (such as telephone hotlines) with forecasting and dissemination agencies could be achieved. By altering existing routine interaction patterns among agencies or establishing low-vulnerability communication links present systems could be upgraded.

Guidelines should be developed for when, how, and what messages will be released to the public. The content of such messages should be prepared in terms of features which promote adaptive response of recipients of the warning. Warnings, should be consistent in content to facilitate people's ability to confirm warnings.

A tornado warning should include preformulated message statements concerning appropriate protective response. Insofar as it is possible specific danger points should be identified.

Messages should be dispersed by means other than the mass media to encourage protective action by those more likely to be motivated by the personal delivery of messages or by official statements, e.g. to the elderly. Where the media are used, guidelines should include "fail-safe communications with evaluative agencies, checking of equipment against malfunction, practice exercises at the beginning of the tornado season, training of announcers to handle all types of warning messages, repetition of messages, and delivery which is as personal as possible. Specific directions on protective action to be taken should be given. All information should be as specific and current as possible.

Provision should be made within the situation for improvement of the feedback process from the response subsystem to the evaluation-dissemination component. Anderson suggests the importance of information on: 1) how effectively responsible organizations performed during the disaster; 2) response of the general public; 3) shortcomings in response; and 4) recommendations for improvement (Anderson, 1969, p. 102).

Tornado warning effectiveness is both constrained and enhanced by people factors. To the degree that communication and feedback operate to maximize the process of evaluation-dissemination-response warnings will achieve their purposes of saving lives and property.

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