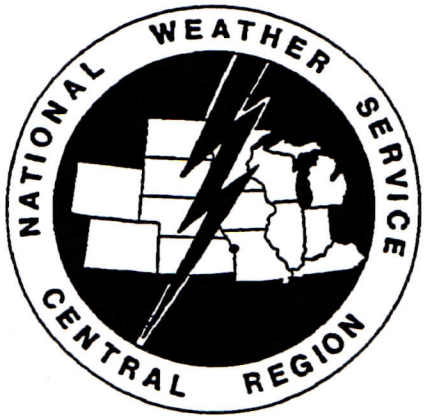
THE WEST LAFAYETTE, INDIANA TORNADO
April 26-27, 1994

National Weather Service Central Region
Richard P. Augulis, Director

November 1994

Front Cover: National Weather Service, Operations Training Facility's classroom at Norman, Oklahoma (circa 1994) where students are taught theoretical and operational aspects of the NWS doppler radar, Weather Surveillance Radar-88D.



Regional Storm Survey Report

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STORM SURVEY TEAM

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LIST OF ACRONYMS

AFOS	Automation of Field Operations and Services
AFSS	Automated Flight Services Station
CMI	Champaign, Illinois
DAU	Data Acquisition Unit
dBZ	Decibels (Radar Reflectivity)
EBS	Emergency Broadcast System
EMA	Emergency Management Agency
EMD	Emergency Management Director
EOC	Emergency Operations Center
FAA	Federal Aviation Administration
FCS	Frame Check Sequence (Error Checking Process)
FEP	Front-end Processor
HMT	Hydrometeorological Technician
HSP	Hard-wired Signal Processor
IND	Indianapolis
KIND	Indianapolis WSR-88D NWS Doppler Radar
KLSX	St. Louis WSR-88D NWS Doppler Radar
kts	Knots
MAWSC	Midwest Agricultural Weather Service Center
mb	Millibar
MIC	Meteorologist-In-Charge
NIDS	NEXRAD Information Dissemination Service
NOAA	National Oceanic and Atmospheric Administration
NSSFC	National Severe Storms Forecast Center

NWR	NOAA Weather Radio
SF	Operational Support Facility
PC	Personal Computer
PSP	Programmable Signal Processor
PUES	Principal Users External System
PUP	Principal User Processor
RDASOT	Radar Data Acquisition System Operability Test
RPG	Radar Product Generator
SOO	Science and Operations Officer
SRWARN	(PC software used to generate NWS warnings)
SVR	Severe Thunderstorm Warning
TOR	Tornado Warning
UCP	Unit Control Position
UGC	Universal Generic Code
UTC	Universal Time Coordinated
VME	VERSO Module Eurobus (communications device between
RPG	and users).
VAD	Velocity Azimuth Display
VWP	VAD Wind Profile
WSFO	Weather Service Forecast Office
WSR-74C	Weather Service Radar-1974 C-Band
WSR-88D	Weather Service Radar-1988 Doppler

EXECUTIVE SUMMARY

THE EVENT

Just before midnight on April 26, 1994, a very strong tornado occurred in Tippecanoe County just west of West Lafayette, Indiana. The tornado produced F3-F4 damage and resulted in 3 fatalities and up to 70 injuries. Property damage estimates are $3.5 million dollars. Sixty-four mobile homes and 11 single-family homes were destroyed; 17 single-family homes, 13 multiple-family homes and 3 businesses received major damage; 24 mobile homes and 7 single-family homes sustained minor damage.

What is believed to be the initial fatality, a 24-year-old male, occurred at the Lafayette Venetian Blind Company. The second fatality, an 11-year-old female, occurred 1 mile from the Venetian Blind Company at the Pine View Farms residential subdivision. The third fatality, the 37 year-old stepfather of the girl, occurred 18-24 hours after the event at a local hospital. Most of the injuries occurred at the Sagamore Village Estates mobile home park which is adjacent to and northeast of Pine View Farms subdivision.

The tornado first touched down at 11:58 p.m. three miles west of West Lafayette, Indiana, and traveled east-northeast between 50 and 60 mph. Based upon an aerial survey by Dr. Ernest Agee, Purdue University, the tornado continued to produce damage along an east-northeast track to the vicinity of the Tippecanoe-Carroll county lines. Damage was not continuous along the 18-mile-long track and became spotty and generally inconsequential after the initial 11 miles of damage, i.e., from touchdown to the vicinity of the I-65 and Indiana Highway 43 intersection. Based upon an estimate of a 55-mph forward speed, the tornado lifted at approximately 12:20 a.m. EST.

Tornado Watch #135, including Tippecanoe County, was issued at 9:49 p.m., April 26 valid until 3:00 a.m., April 27.

The first Tornado Warning for an Indiana County was posted at 10:44 p.m. for eastern portions of Jasper County. Jasper County is located northwest of Tippecanoe County. This warning was based on Doppler-derived rotational velocities which may have been greater than the velocities associated with the storm that later produced the West Lafayette tornado. This storm produced a tornado in Pulaski County, three miles east of the Jasper county line. WSFO Indianapolis (WSFO IND) forecasters were not aware of the tornado in real time, a factor which may have later

influenced actions during the West Lafayette event.

A Severe Thunderstorm Warning was in effect for portions of Warren and Benton counties (immediately west and northwest of Tippecanoe County), until 12:15 a.m. A Severe Thunderstorm Warning was issued for Tippecanoe County at 12:04 a.m. valid until 12:30 a.m. A Tornado Warning was issued for Tippecanoe County at 12:12 a.m. EST valid until 12:45 a.m. The Severe Thunderstorm Warning for Tippecanoe County was based on a mesocyclone signature detected by the non-commissioned Indianapolis WSR-88D Doppler radar (KIND) and storm history. The Tornado Warning was based a telephone report of an observed tornado from the FAA contract weather observer at the Lafayette Airport, subsequent KIND signatures and incoming damage reports.

SERVICES

The National Severe Storms Forecast Center (NSSFC), located in Kansas City, Missouri, has responsibility for providing outlooks and watches for severe thunderstorms and tornadoes for the continental United States. The Convective Outlook issued during the morning of April 26, 1994 indicated a moderate risk of severe thunderstorms for "...today and early tonight..." over an area which included the northern half of Indiana. During the early afternoon, the Convective Outlook was updated and called for a moderate risk of severe thunderstorms for "...the remainder of this afternoon and tonight..." over northern portions of Indiana including Tippecanoe County. NSSFC issued Tornado Watch #135, valid until 3:00 a.m. EST (Indiana does not observe Daylight Savings Time) for a large part of Indiana as well as parts of east-central Illinois and a small part of Ohio. Tornado Watch #135, which included Tippecanoe and adjacent Indiana counties, remained in effect throughout the event.

WSFO IND has warning responsibility for most of central Indiana including Tippecanoe and adjacent Indiana counties. WSFO IND issued 26 Severe Thunderstorm and 2 Tornado Warnings between 9:38 p.m. (4-26) and 2:37 a.m. (4-27). Twenty-four of the 28 warnings (84%) issued by WSFO IND verified.

A Severe Thunderstorm Warning for Tippecanoe County was issued at 12:04 a.m. valid until 12:30 a.m. on April 27. The Severe Thunderstorm Warning was based on WSR-88D Doppler radar imagery. A Tornado Warning was issued for Tippecanoe County at 12:12 a.m. valid until 12:45 a.m. on April 27.

The community preparedness operation developed and nurtured by the coordinated efforts of WSFO IND and the Indiana Emergency Management Agency (EMA) functioned very effectively. At 9:45 p.m., spotter networks were activated across that portion of Indiana affected by Tornado Watch #135. Two amateur radio operators reported to the WSFO to establish a base station. Also at 9:45

p.m., the Emergency Operations Center (EOC), located at the state capitol, was activated and fully staffed.

At 11:58 p.m., a spotter reported the downing of high-capacity, high-power electrical transmission lines west of Lafayette. This information was not forwarded to the WSFO. At virtually the same time, a 911 call to the Tippecanoe County EMA reported windows being blown out of a nearby apartment complex. Based on these reports, Tippecanoe County EMA activated the 24-unit siren system. It is unclear to the Survey Team why this critical storm information was not relayed to WSFO Indianapolis.

At 12:04 a.m., Tippecanoe EMA accessed the local cable television station's all-channel override and succeeded in relaying warning and safety information. At 12:05 a.m. the local cable television broadcast the Severe Thunderstorm Warning issued by the WSFO. At 12:07 a.m. the Severe Thunderstorm Warning for Tippecanoe County was broadcast over NOAA Weather Radio even though the WSFO understood the system to be inoperative. At 12:16 a.m. the Tornado Warning for Tippecanoe County was broadcast via NOAA Weather Radio and shortly thereafter on local cable television.

RADAR IMAGERY AND PERFORMANCE

The Indianapolis WSR-88D Doppler radar (KIND) is not scheduled to be commissioned until the fall of 1994. The KIND WSR-88D functioned within the designed specifications during the event. Based on limited available data to review, the KIND WSR-88D base reflectivity image at 0507 UTC (12:07 a.m. EST) indicated a hook shaped echo (53 dBZ) in northern Tippecanoe County with an associated bow echo (58 dBZ) configuration further south into the county. At the same time, KIND velocity products indicated a thunderstorm-scale mesocyclone with a rotational velocity of 37 kts. The guideline for rotational velocities likely to be associated with tornadic storms is 40 kts or greater at the range of West Lafayette to KIND (55 nm). The only mesocyclone algorithm output that can be verified was 3-D correlated shear at 0527 UTC (12:27 a.m. EST).

The WSR-74C radar located at the Indianapolis Airport displayed the bow echo configuration but no significant overhang, weak echo region or hook-echo signature.

CONCLUSIONS

The Indianapolis WSR-88D Doppler radar operated within the designed specifications throughout the severe weather event. Radar images accurately portrayed the storm structure and provided exceptional guidance to the WSFO meteorologists. The WSFO IND meteorologists issued 28 warnings (Severe Thunderstorm and Tornado) during the event, verifying in excess of 80%.

The cooperative relationship between the WSFO IND staff and the Indiana emergency preparedness community is exemplary. The preparedness community, state and Lafayette County, responded quickly to available storm information from established spotter networks as well as statements and warnings issued by WSFO Indianapolis.

The WSFO IND meteorologists' interpretation of the KIND WSR-88D velocity imagery yielded a mesocyclone rotational velocity of 30-35 kts associated with the West Lafayette storm and 37 kts with the earlier-warned storm in Jasper County.

Survey Team review of the West Lafayette storm indicated a rotational velocity of 37 kts. The OSF-established guideline for a strong mesocyclone is 40 kts or greater. The fact that the Indianapolis meteorologists issued a warning on the Jasper County storm (37 kts rotational velocity) indicates that they did not solely depend upon the OSF guidelines for warning determination.

Considering OSF guidelines, and the thought that the Jasper County storm (greater observed rotational velocities) did not produce a tornado, the decision to warn for severe thunderstorm rather than tornado became a judgment call. The Survey Team has concluded, at least initially, that signature guidelines established for supercell mesocyclones may be higher than guidelines for tornadoes associated with strong lines and bow echo configurations. Some adjustment in guidelines may be necessary for storms in geographical locations outside the Great Plains to account for differences in storm structure and type. It is certain that research-derived warning guidelines must be complemented by other types of input, e.g., spotter reports, antecedent weather observations, etc. Establishment and nurturing of an effective spotter network and an efficient community preparedness team is essential to warning success.

The training and learning process must mature. This maturing process must occur at every level from the OSF to the field site. The OSF should expedite research efforts to establish working guidelines for line and bow echo tornado-producing storm systems. The SOO, with support from the OSF and their Regional Headquarters, should utilize every training opportunity to refine the meteorologists' interpretative skills.

FINDINGS AND RECOMMENDATIONS

FINDING #1:

The rotational velocity of the West Lafayette mesocyclone at 12:07 a.m. EST, 37 kt, was below the 40-kt guideline recommended by the OSF Operations Training Branch for a Tornado Warning without consultation of any other type of input (spotter report, antecedent weather observations, etc.). There is a suggestion that rotational velocities for some storm types that produce tornadoes are less than the current guidelines.

> **RECOMMENDATION:** OSF, with lead from the Applications Branch, should actively pursue analysis of WSR-88D Doppler imagery from all areas of the country as new data are collected in order to assess the guidelines to conditions likely to be seen in different geographical regions. The good judgment of the meteorologist, based upon acquired data integration skills, will allow for the most success in the warning program. This judgment should supersede any predetermined guidelines.

FINDING #2:

The WSFO Indianapolis meteorologists issued a tornado warning for a storm in Jasper County at 10:44 p.m. EST based, in part, on a WSR-88D rotational velocity of 37 kts. Although this storm did eventually produce a tornado, there was no verification to the meteorologists in real time. Operational interpretation of the West Lafayette storm yielded a rotational velocity between 30 and 35 kts.

Actions in response to the Jasper County storm indicate that the Indianapolis meteorologists did not solely rely upon OSF guidelines when formulating their decision to warn.

> **RECOMMENDATION:** It is imperative that meteorologists fully utilize complementary information during a warning scenario. Well-organized and well-trained spotter networks, as well as an efficient community preparedness team is essential for a successful warning program.

FINDING #3:

The Indianapolis WSR-88D was accepted during the summer of 1993. The West Lafayette tornado was the first significant storm event in the Indianapolis CWA since acceptance. The OSF WSR-88D Operator's Training Course is the first step in training that may require a maturing process which is dependent on locality and storm frequency.

RECOMMENDATION: Regional SSDs should seek ways to expedite the maturing process, utilizing the SOO program. As an example, the SOO and the WSR-88D Focal Point should fully utilize every possible hands-on training opportunity, including data collected by other WSR-88D sites having experience with similar severe weather events. This should be a high priority focus of the national SOO program.

FINDING #4:

At the time of the event, WSFO IND was not staffed at the Stage I level. The Hydrometeorological Technician (HMT) staff had been selected but continued to support a split operation, i.e., 24-hour coverage maintained at the IND WSO in addition to WSFO operations. Due to this less-than-optimal staffing scenario, the meteorologists working the event were required to assume some HMT functions, e.g., three NWR consoles, in addition to warning and forecast responsibilities. During this severe weather event, the meteorologists often worked multiple concurrent warnings.

RECOMMENDATION: The value of the HMT staff is crucial to the success of the warning function. Regional Headquarters should make every effort to reach Stage I staffing as soon as possible and eliminate split operational scenarios as soon as possible. In addition to a full complement of HMTs, staffing during significant severe weather scenarios at WSFOs requires a minimum of 5 meteorologists. Each severe weather scenario is unique. Only the severe weather coordinator is in a position to match staffing with warning and forecast demands. However, it is the position of the survey team that two meteorologists should be dedicated to activities associated with PUP interpretation and the decision to warn.

FINDING #5:

WSFO Indianapolis issued a Severe Thunderstorm Warning for portions of Benton and Warren counties valid from 11:41 p.m. until 12:15 a.m. referencing a severe thunderstorm located near Pine Village, Indiana moving northeast at 45 mph. Based upon the information contained in the warning and the WSR-88D storm track algorithm estimate of 55 mph movement at 11:30 p.m., the storm would have entered northwestern portions of Tippecanoe County before midnight. Based on the forward speed of the storm, WSFO IND should have included portions of Tippecanoe County in the 11:41 p.m. Severe Thunderstorm Warning.

RECOMMENDATION: In the preparation of severe weather warnings for convective events, WSFOs should fully consider the storm's forward speed of movement.

FINDING #6:

The FAA contract weather observer at the Lafayette Airport logged "TORNADO" on the 0502 UTC observation and, according to the observer, relayed this information via telephone to the AFSS in Terre Haute. The AFSS sent the observation via established communication circuits. However, the term "FUNNEL CLOUD" was logged in the remarks section of the official observation relayed by the AFSS. A routine station inspection of the Lafayette facility was conducted on March 26, 1992 by Mr. Stephen Mekis, NWS Central Region Headquarters. Item 8 of the subject inspection states that the contract observers noted that there have been times when the AFSS personnel had changed their observations, specifically, moving the weather portion of the observation to the remarks section.

> **RECOMMENDATION:** If required, corrective action should be taken by the Terre Haute AFSS to ensure that contract observations are transcribed as reported by the observer.

FINDING #7:

At 11:58 p.m., a trained spotter reported to the EOC that he had just witnessed the downing of large-capacity high-voltage electrical transmission lines. This event occurred near the beginning of the tornado track. This information was not relayed to the WSFO.

Based upon experience, some forecast offices use the downing of large-capacity high-voltage lines as indicators of tornado--producing thunderstorms.

> **RECOMMENDATION:** Regional Office MSDs should ensure that WSFOs investigate the possibility of establishing a warning communication system with power companies and existing preparedness networks that would provide notice to the WSFO when high-voltage lines are downed by thunderstorms.

FINDING #8:

The National Severe Storms Forecast Center's Severe Weather Outlook for the period in question included a Moderate Risk of severe thunderstorms for the northern half of Indiana including Tippecanoe County. Issuance of a severe weather outlook by the WSFO for their forecast area is optional for NSSFC Moderate Risk areas. WSFO Indianapolis did not issue a severe weather outlook.

> **RECOMMENDATION:** Regional Headquarters should require WSFO-issued severe weather outlooks tailored to the WSFO forecast area for NSSFC Moderate Risk areas.

FINDING #9:

Numerous Special Weather Statements were issued by WSFO IND prior to the onset of convection, reaffirming the threat of severe thunderstorms and the possibility of tornadoes. Severe Thunderstorm Warnings issued by the WSFO reaffirmed the possibility of tornadoes.

> **RECOMMENDATION:** Regional Headquarters should re-emphasize the importance of including the possibility of tornadoes in the text of Severe Thunderstorm Warnings, Severe Weather Statements and Special Weather Statements.

FINDING #10:

The Severe Thunderstorm Warning issued at 12:04 a.m. and the Tornado Warning issued at 12:12 a.m. were coded correctly and technically error-free. Path-casting, i.e., the mention of cities in the path of the storm, was not used by WSFO IND.

> **RECOMMENDATION::** Per established Central Region instructions, path-casting should be used in the text of all warnings.

FINDING #11:

Tornado Watch #135 was posted at 9:45 p.m. EST. The Indiana zone forecasts were promptly updated to reflect the issuance of the Tornado Watch. Within the text of the watched zones, the threat of severe weather was included; rain chances remained at 40%.

> **RECOMMENDATION:** Even though the chances of rain may have remained at 40%, it is the conclusion of the Survey Team that removing the mention of probabilities altogether may have more effectively conveyed the perception of threat.

FINDING #12:

At 11:20 p.m. EST, WSFO Indianapolis determined that NWR station WXK-74, serving Tippecanoe County, was inoperative. Based on established procedures, it was determined that the outage was a telephone line problem. The outage was immediately reported to the telephone company. The WSFO NWR programmer continued to operate the radio as if the NWR system were "up" even though he assumed that the system was "down". It was discovered, well past the event, that radio service had been restored almost immediately and well before the tornado event.

RECOMMENDATION: All NWR offices should learn from this experience and implement the NWR routine in-place at the WSFO IND., i.e., NWR operations should continue uninterrupted even if it is assumed that a NWR problem exists.

FINDING #13: Due to a PUP software hang, the PUP had to be restarted. In the process of rebooting and complicated by the pressures of the weather scenario, initiation of the PUP Archive Level IV was overlooked. Since the KIND WSR-88D was not commissioned and optical disks are in short supply, the Archive III was not operating. For these reasons, there was no on-site archive data available. System status logs were not available as they are auto-purged after approximately 12 hours, dependent on system activity. This situation hampered the storm survey activities and deprived the staff, as well as other staffs, of the opportunity to review the data post-mortem.

RECOMMENDATION: National policies and training procedures should be established to ensure that Archive III data from non-commissioned WSR-88Ds are collected during any severe weather/flash flood watch or warning event. Regional directives and training procedures should be established that ensure the initiation of Archive IV data during any severe weather/flash flood watch or warning event. Further, instructions should be in place to ensure that the status logs are also saved for the event.

FINDING #14: WSFO IND issued a tornado warning for Jasper County effective from 10:44 p.m. until 11:05 p.m. EST on April 26. This tornado warning was based upon KIND WSR-88D rotational velocities which were greater than the observed rotational velocities associated with the West Lafayette tornado. The WSFO did not receive confirmation (feed-back) of a tornado with the Jasper County storm in real-time (spotters). Post-storm surveys found evidence of a F0 tornado in Pulaski County, three miles east of Jasper County. It is the perception of the Survey Team that the WSFO may have calibrated their warning decisions based on the Jasper County warning experience.

RECOMMENDATION: Although calibrating warning actions based upon events of the day may be effective, it is important that meteorologists calibrate on verified events rather than events that do not provide immediate verification, i.e., the lack of immediate feedback does not always mean that the event did not occur.

Chapter III

Data Collection and Communications

A. Surface Observation Networks

The surface observing networks provide basic data for a multiplicity of uses. In general, the networks are divided into two classes: (1) stations that provide data for immediate operational use and for record purposes; and (2) substations that provide data primarily for record purposes. Included in the substation group, class (2), are stations which also report rainfall amounts and river stages for immediate use under certain conditions.

The regular reporting stations in the storm area of West Virginia and Virginia are tabulated in Table I and shown in Figure 4. To describe adequately the phenomena associated with storms the size of the remnants of Camille, the spacing between stations in West Virginia and Virginia should not be more than 65 to 70 miles. A significant gap exists in the area where the storm intensified in West Virginia and Virginia, especially during the night when several of the stations cease reporting.

Some substations record only precipitation data. These substations are distributed around selected watersheds in support of civil and military hydrological projects to provide basic

TABLE I

HOURLY REPORTING STATIONS

WEST-CENTRAL VIRGINIA AND SOUTHERN WEST VIRGINIA

(Precipitation reported every 6 hours)

LOCATION	HOURS OF OPERATION	TRANSMITTED ON	REMARKS
Charlottesville, Va.	24 hrs.	Service A	
Lynchburg, Va.	6 a.m.-Midnight	Service A	Supplementary reports as required by airline Midnight-6 a.m. not transmitted.
Blackstone, Va.	6 a.m.-10 p.m.	Service A	
Roanoke, Va.	24 hrs.	Service A	
Richmond, Va.	24 hrs.	Service A	
Danville, Va.	24 hrs.	Service A	
Pulaski, Va.	7 a.m.-7 p.m.	Service A	Supplementary reports by airline.
Hot Springs, Va.	8 a.m.-9 p.m.	Airline circuit only.	Supplementary reports by airline.
Staunton, Va.	6 a.m.-8 p.m.	Airline circuit only.	Supplementary reports by airline.
Beckley, W. Va.	24 hrs.	Service A	
Charleston, W. Va.	24 hrs.	Service A	
Bluefield, W. Va.	24 hrs.	Service A	
Elkins, W. Va.	5:30 a.m.-9:30 p.m.	Service A	
White Sulpur Springs, W. Va.	7 a.m-6 p.m.	Service A	

northern Illinois but only a few tornado confirmations. Severe Thunderstorm Warnings were first posted by WSFO Indianapolis at 9:38 p.m. EST as the storm system approached the western-most counties of Indiana. During the entire storm event, WSFO Indianapolis issued 26 Severe Thunderstorm Warnings and 2 Tornado Warnings. Initial storm surveys indicate that 24 of the 28 warnings verified (86%).

The severe thunderstorm that produced the West Lafayette tornado formed in association with a squall line which entered Benton and Warren counties of west-central Indiana before midnight. Benton and Warren counties are adjacent and immediately west of Tippecanoe County; a Severe Thunderstorm Warning was in effect from 11:41 p.m. until 12:15 a.m. EST. (Note, Indiana does not observe Daylight Savings Time).

The tornado-producing severe thunderstorm formed a bow-echo configuration on its southern flank as it entered Tippecanoe County. The formation of the bow-echo was accompanied by accelerated forward speed of the storm. The storm's forward movement (at the bow-echo) accelerated from approximately 45 kts to almost 60 kts.

The initial fatality, a 24-year old male, occurred at the Lafayette Venetian Blind Company which is located within the first mile of the storm track. A wall of the heavily damaged building collapsed on the employee who apparently died instantly.

The tornado then moved through the Pine View Farms subdivision and the adjacent Sagamore Village Estates mobile home park. Damage was significant to the subdivision and the mobile home park where the majority of the storm injuries occurred. An 11-year old female, a resident of the subdivision, was the second fatality. Her 37-year old stepfather died 18 to 24 hours later at a local hospital. His wife and 11-year old son also received injuries. The tornado then struck an area two miles north of the Purdue campus, there was no damage to the University. The tornado next moved across U.S. Highway 52, damaging at least four commercial establishments along the track to Interstate Highway 65. The Indiana State Police Post located near I-65 and Indiana Highway 43 received significant damage to a number of patrol vehicles. A 300-foot communications tower at the State Police Post was destroyed.

In addition to the three fatalities, there were as many as 70 tornado-related injuries. A summary of the property damage is shown in Table A.

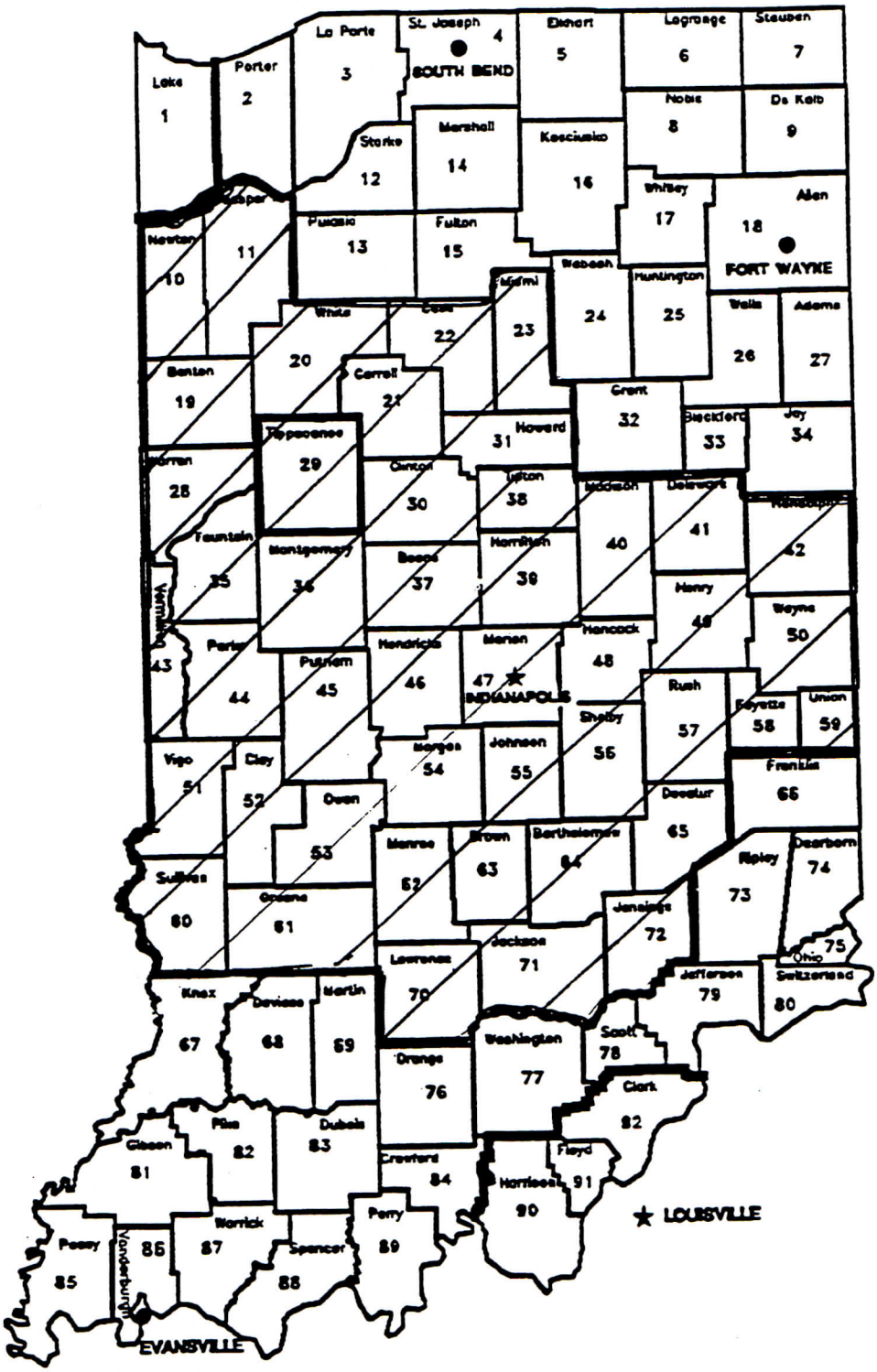
TABLE A

	Single-Family Homes	Mobile Homes	Businesses
Destroyed	11	64	
Major Damage	17	13	3
Minor Damage	7	24	

...TOTAL PROPERTY DAMAGE...$ 3.5 MILLION

INDIANA
ZONE FORECAST BOUNDARIES

IN Zone 1 prepared by WSFO Chicago, IL
IN Zones 2–89 prepared by WSFO Indianapolis, IN
IN Zones 90–92 prepared by WSFO Louisville, KY



★ WEATHER SERVICE FORECAST OFFICE
● WEATHER SERVICE OFFICE

NATIONAL WEATHER SERVICE
CENTRAL REGION

Figure 1.1

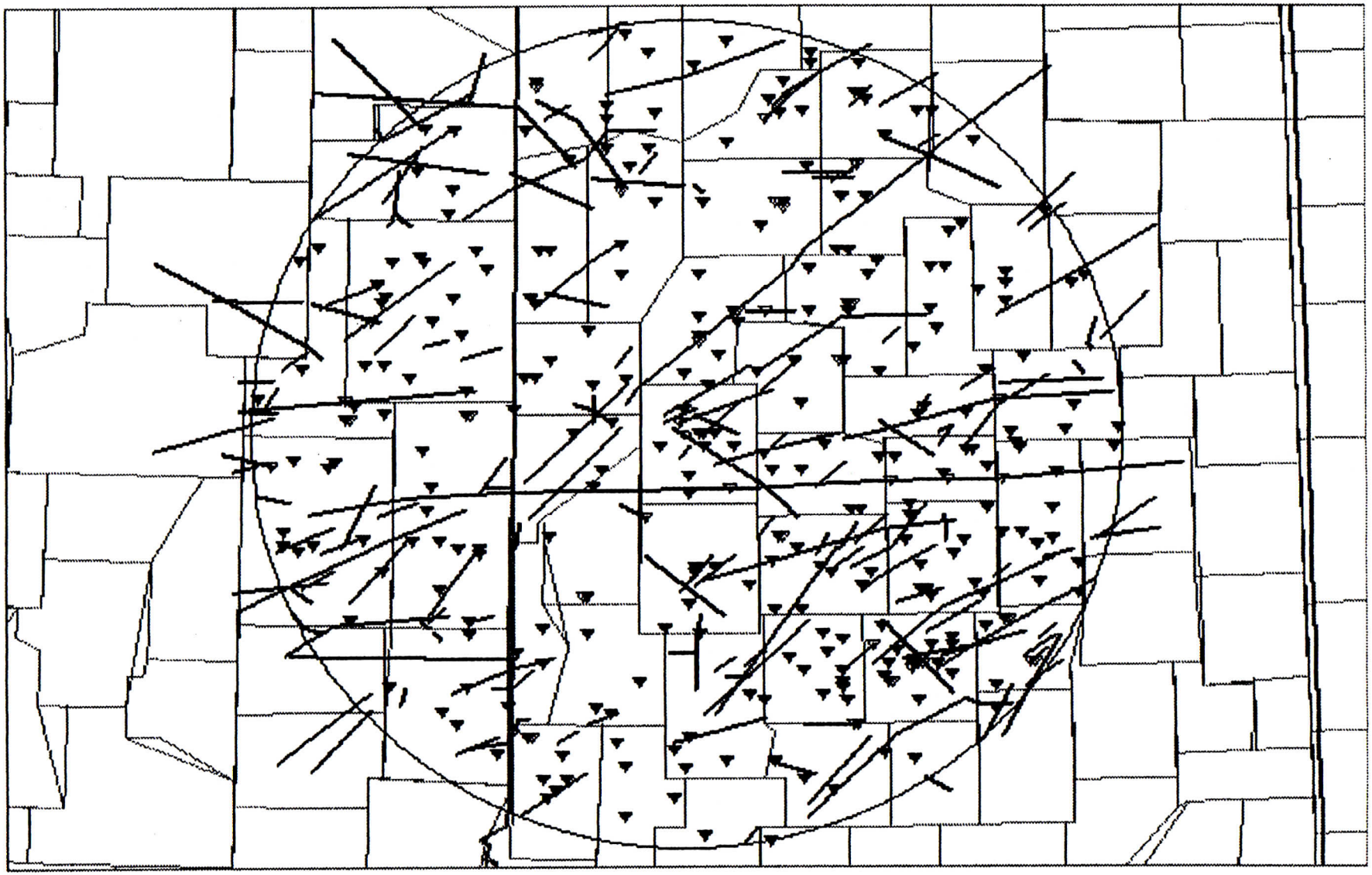


Figure 1.2

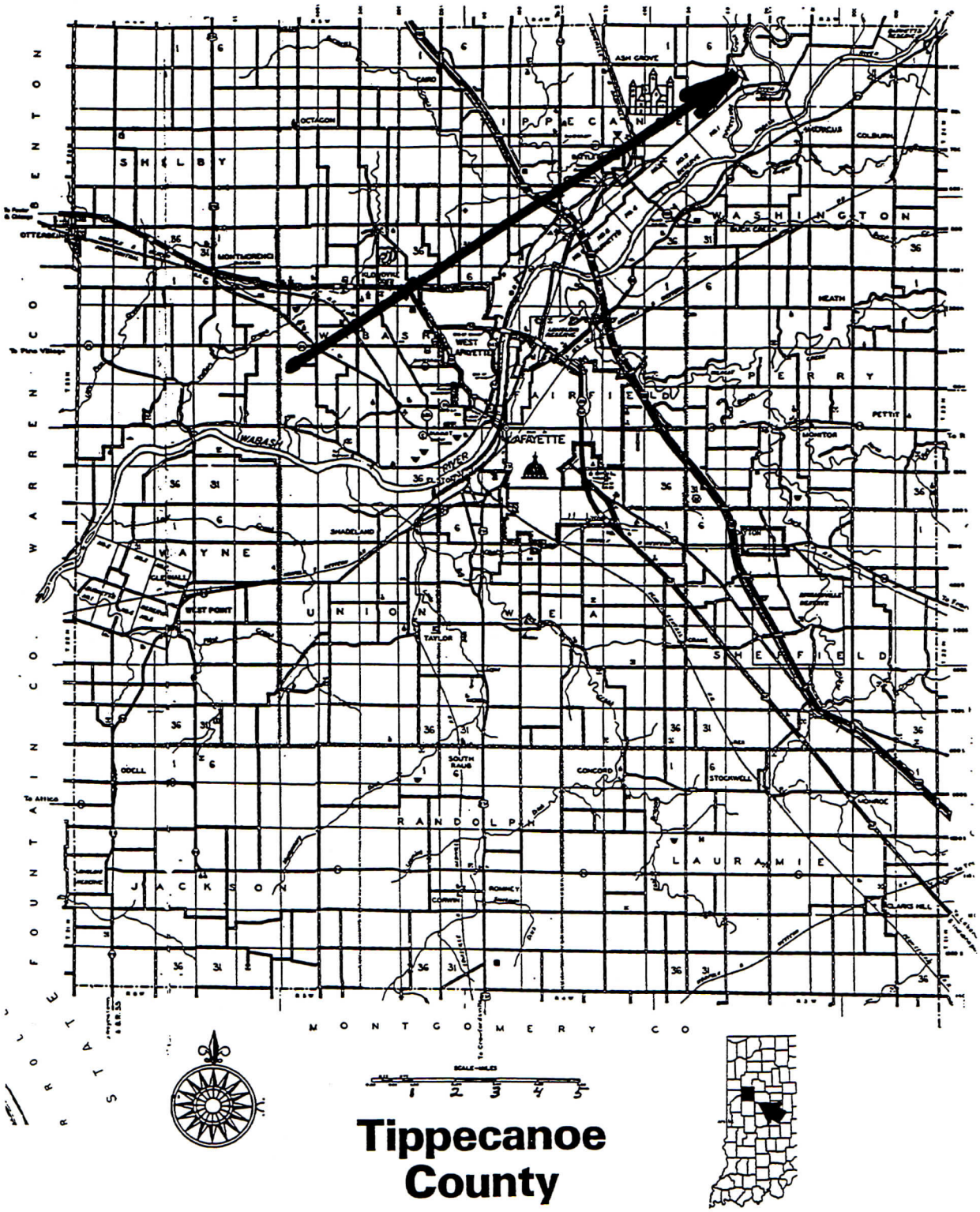

Tippecanoe
County
WARREN CO.
FOUNTAIN CO.
MONTGOMERY CO
BENTON
SHELBY
WASHINGTON
WAYNE
UNION
JACKSON
RANDOLPH
PERRY
SHEFFIELD
LAURAMIE
WABASH
WEST POINT
TAYLOR
SHADELAND
ROMNEY
CONCORD
STOCKWELL
SOUTH RAUB
ODELL
ASH GROVE
WEST LAFAYETTE
LAFAYETTE
MONTMORENCI
OTTERBEIN
OCTAGON
HEATH
PETTIT
MONITOR
SCALE-MILES
1 2 3 4 5

Figure 1.3

Chapter Two

EVENT METEOROLOGY

A deep upper trough existed over the western U.S. on April 26, 1994. A significant shortwave was ejecting from the base of the trough, moving toward the upper Mississippi Valley. In association with the upper trough and a surface cyclone near the Canadian border, there were strong winds at all levels of the troposphere over the middle portion of the country. Wind maxima approaching Indiana at various levels were: 850 mb - 40 kt; 700 mb - 55 kt; 500 mb - 70 kt; and 300 mb - 100 kt. The winds were configured such that wind directions over Indiana veered with height. Thus the vertical shear profile favored long-lived and severe thunderstorms.

During the day on April 26, the strong low-level winds brought considerable amounts of warm and moist air northward into Indiana. Lifted indices were forecast and observed to be as unstable as -6 over the state during the evening.

Numerical model data, viewed at gridpoints using PC-GRIDS, indicated that in association with the approaching shortwave trough there was considerable forcing for rising motion throughout the depth of the troposphere in a band that moved over Indiana during the night of April 26-27. In the favorable environment produced by the shortwave and an advancing cold front, severe thunderstorms formed over Wisconsin, Illinois, Missouri, and further southwest during the afternoon hours. These storms produced a squall line that rapidly moved into Michigan and Indiana by 0500 UTC (12:00 midnight, EST) on April 27.

Not much mesoscale weather data is available. A regional surface map at 03 UTC, (Figure 2.1), does show a secondary surface low in western Illinois and the squall line in eastern Illinois with an associated mesohigh. Note that the low-level moist axis is oriented north/south in western Indiana, right over the Lafayette area. Winds remained southerly and dew points rose to 68°F at the Lafayette Airport reporting site (LAF) between 0300 UTC and tornado time. The Velocity Wind Profile (VWP) from the Indianapolis WSR-88D, (Figure 2.2), indicates details of low-level wind ahead of the squall line in Indiana. A very strong south-southwest low-level jet is present with maximum winds of 60 kts at 4,000 ft MSL. Remembering that surface winds are southerly at about 15 kt, there is significant low-level wind shear.

Given the instability, the strong shear is supportive of the formation of thunderstorms with rotating updrafts. The 60 kt magnitude of the low-level winds also indicates the possibility of strong thunderstorm outflow if the momentum is brought to the surface by storm downdrafts.

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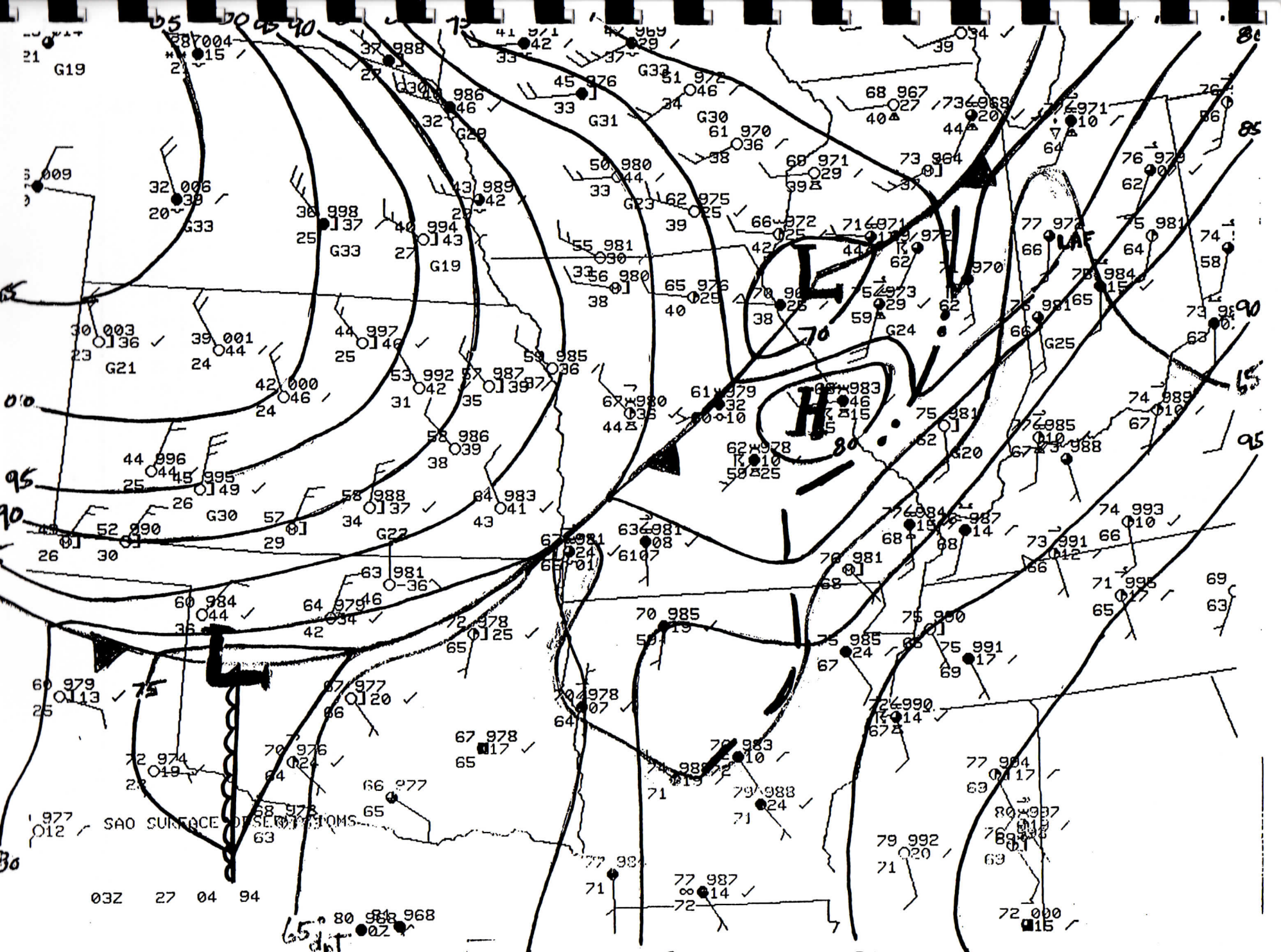
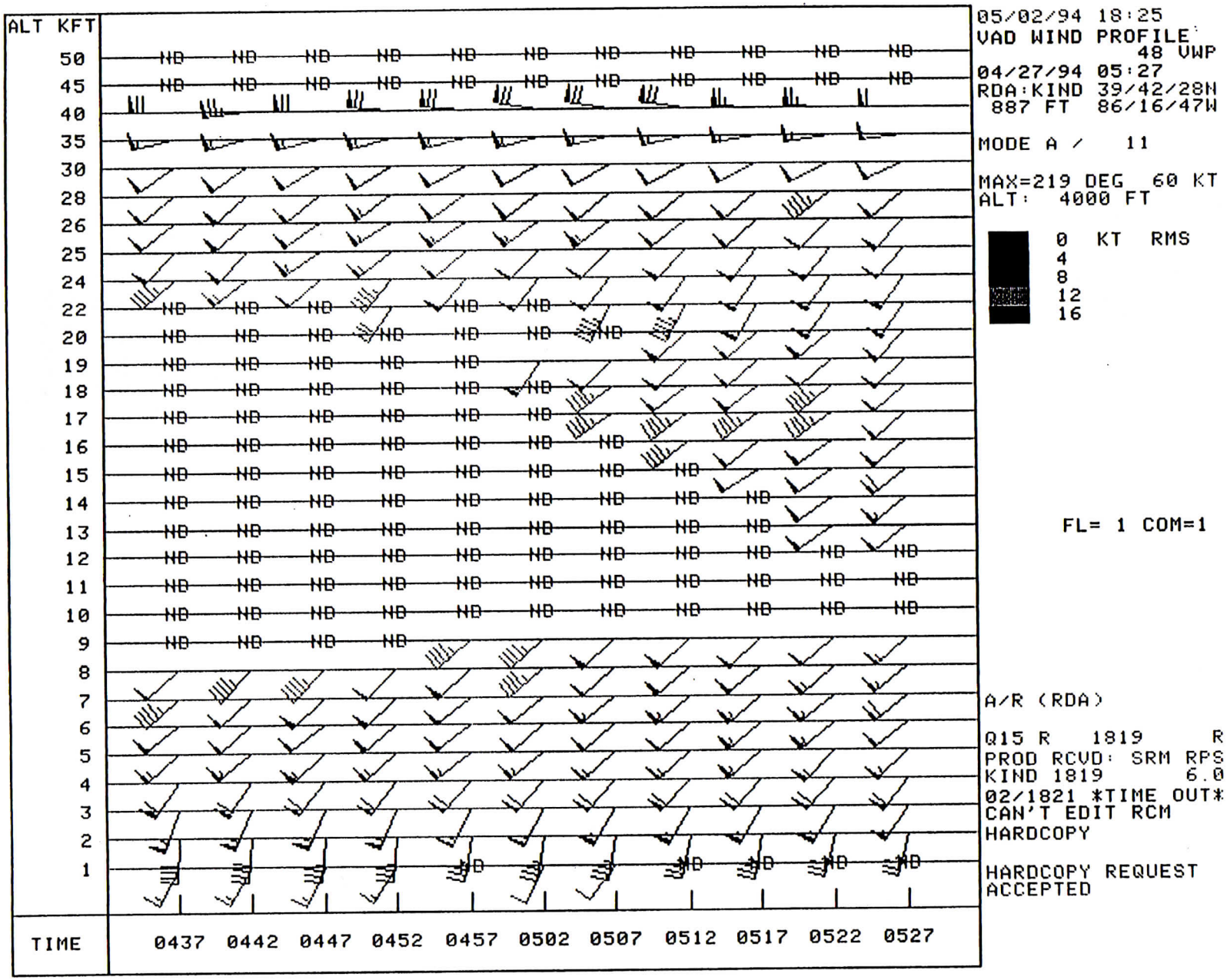


Figure 2.1


ALT KFT
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45
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35
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22
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19
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11
10
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6
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4
3
2
1
ND
TIME
0437 0442 0447 0452 0457 0502 0507 0512 0517 0522 0527
05/02/94 18:25
VAD WIND PROFILE
48 VWP
04/27/94 05:27
RDA:KIND 39/42/28N
887 FT 86/16/47W
MODE A / 11
MAX=219 DEG 60 KT
ALT: 4000 FT
0 KT RMS
4
8
12
16
FL= 1 COM=1
A/R (RDA)
Q15 R 1819 R
PROD RCVD: SRM RPS
KIND 1819 6.0
02/1821 *TIME OUT*
CAN'T EDIT RCM
HARDCOPY
HARDCOPY REQUEST
ACCEPTED

Figure 2.2

Chapter Three

INDIANAPOLIS WSR-88D DOPPLER RADAR (KIND) DATA

ARCHIVE DATA: No data for the tornado were archived at Indianapolis (KIND). Status of KIND archive levels:

1. Level II - Not installed (19 devices for 67 field radars)
2. Level III - Not operating (not required until commissioning, WSFO not yet practicing use)
3. Level IV - Accidentally turned off (had been running prior to a workstation restart at 0342 UTC)

Level IV data from NSSFC for the evening had been saved and were obtained (NSSFC periodically dials into sites experiencing severe weather). For unknown reasons, NSSFC data collection (KIND WSR-88D data) ceased during the critical period near tornado time (0459-0525 UTC). Ron Przybylinski, WSFO LSX, volunteered that the St. Louis WSR-88D (KLSX) had archive IV data, but the site is 150 nm from West Lafayette. As a last resort, NIDS vendors were contacted to see if they might have data. WSI Corporation did have available a limited amount of data:

1. Regional radar summaries (with algorithm attribute overlays for 0430 and 0530 UTC).
2. KIND base reflectivity and base velocity for 0.5° at 0507 UTC.

The base data are not normally available from WSI more than two days after an event because of revolving time-purging archive files, but were available for this event because they had been requested by The Weather Channel (one of their customers) for use on the air. The WSI images were downloaded to a PC, using WSI supplied software, and printed on a color printer.

WSR-88D SIGNATURES: At 0430 UTC (Figure 3.1), there was a line of storms extending from Michigan to southern Illinois. The soon-to-be tornadic storm was one of a pair of large storms in eastern Illinois (northeast of Champaign). Algorithm output indicated a top of 46,400 ft, hail, and a northeastward motion of 48 kt. By 0530 UTC (Figure 3.2), the northeast member of the pair, which had already produced the Lafayette tornado, had a top of 49,200 ft and a northeastward movement of 43 kt. At 0530, NSSFC images (not shown) indicated mesocyclone algorithm output for the Lafayette storm of Three-Dimensional Correlated Shear (strong enough, but not properly configured to be a mesocyclone). KLSX data (lowest height of 30,000 ft based on long range) showed that the southwest member of the storm pair died shortly before 0500 UTC and may have acted to accelerate an outflow boundary northeastward. This would have produced the new echoes (configured in a bow) on the south flank of the tornadic storm as seen on the 0530 UTC regional mosaic. The movement of the boundary from the southwestern storm could have

caused it to interact with the updraft region of the northeastern storm, producing enhanced convergence which might have helped spawn the tornado.

The base data at 0507 UTC (Figure 3.3 and 3.4) are the only velocity data and the only high-resolution images which can be expanded (zoomed) to see detail. The images are centered on a rectangular county (Tippecanoe) with Lafayette in the north-central portion of the county. The reflectivity image shows a hook shape to the echo in northern Tippecanoe County with a bow configuration further south in the county. Spiralling weak echo notches are seen in the leading-edge inflow (northeast of Lafayette) and the rear inflow (southwest of Lafayette). Maximum reflectivities are 53 dBZ with the hook-like feature and 58 dBZ with the bow echo. Perceptions of circulation from the reflectivity data are confirmed by the velocity image. Radial velocities are toward the radar (green/blue) over western Tippecanoe County and away from the radar (orange/red) over northeastern Tippecanoe County. KIND is located two counties to the right and two counties below Tippecanoe County (off the display area). Embedded within the larger circulation signature is a smaller high-shear region (green adjacent to red, noted as "A" in Fig 3.3) which appears to be situated over the northern portion of Lafayette. Based on size (diameter three to four mi), the smaller signature is the thunderstorm-scale mesocyclone and the larger signature is the mesolow (20 mi diameter) forming in association with the bow echo. The rotational velocity of the mesolow is 44 kt and the rotational velocity of the mesocyclone is 37 kt.

Mesocyclone algorithm performance: The sparsity of data precludes a definitive answer. The shears seen at 0507 UTC, if sustained on a higher elevation angle, are sufficient for a detection by the algorithm. The Indianapolis staff, however, does not remember a mesocyclone algorithm detection for the Lafayette storm.

Operator use of velocity data: The sparsity of data again precludes a definite answer. The rotational velocity of the mesocyclone at 0507 UTC (37 kt) is below the 40 kt guideline recommended by the OSF Operations Training Branch for a Tornado Warning without consultation of any other type of input (spotter report, antecedent weather observations, etc.). There is a suggestion that rotational velocities for some storm types that produce tornadoes are less than the current guidelines. The OSF, with lead from the Applications Branch, is actively pursuing analysis of WSR-88D Doppler from all parts of the country as new data are collected in order to better adapt the guidelines to conditions likely to be seen in different local areas. Everyone should remember that it is the data integration skills of the meteorologist operator that will allow for the most success in the NWS warning program.
The good judgement of the warning meteorologist should supersede any predetermined guidelines.

*NOTE: The assistance of WSI Corp., particularly Ms. Maria Pirone, is gratefully acknowledged.

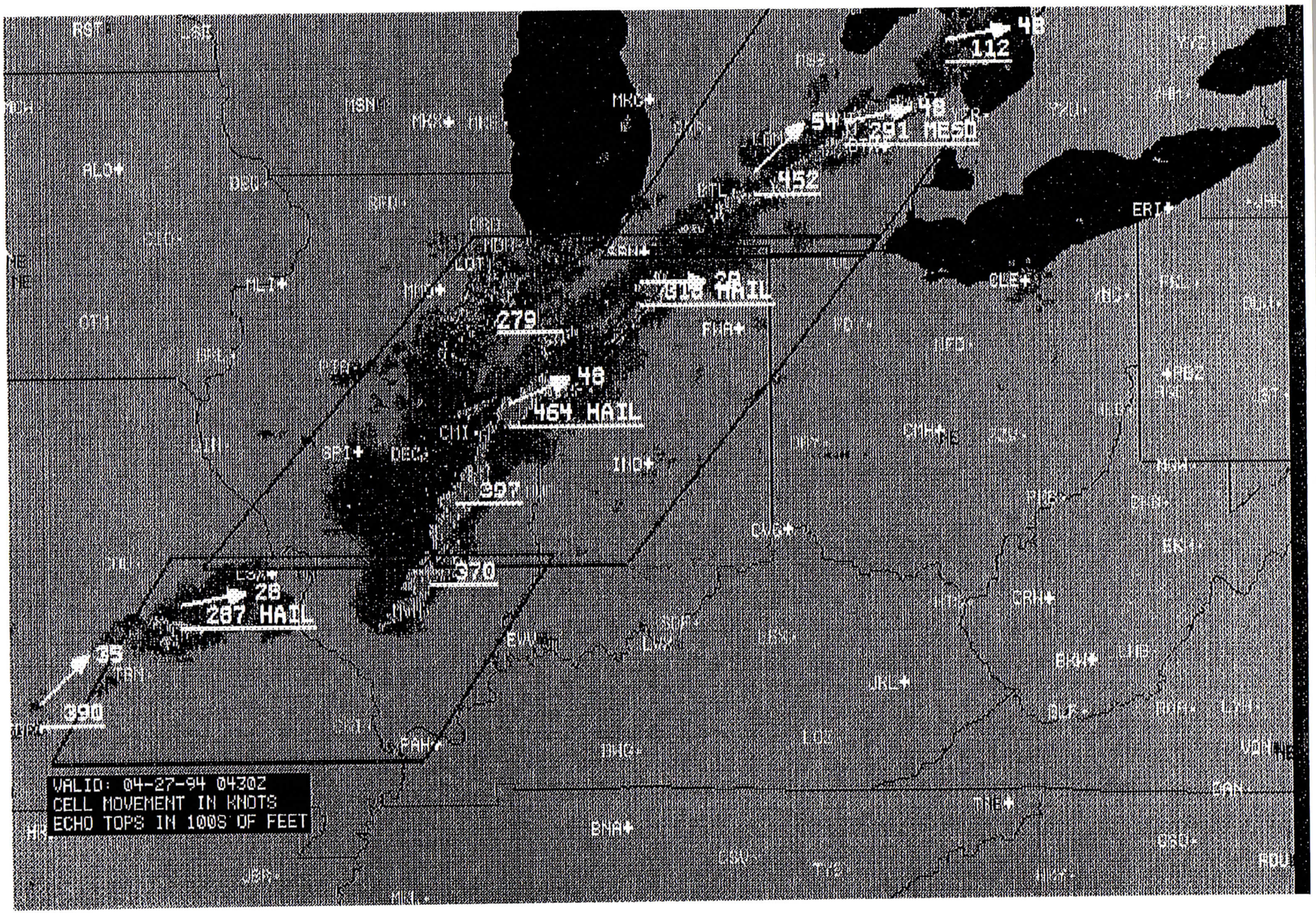
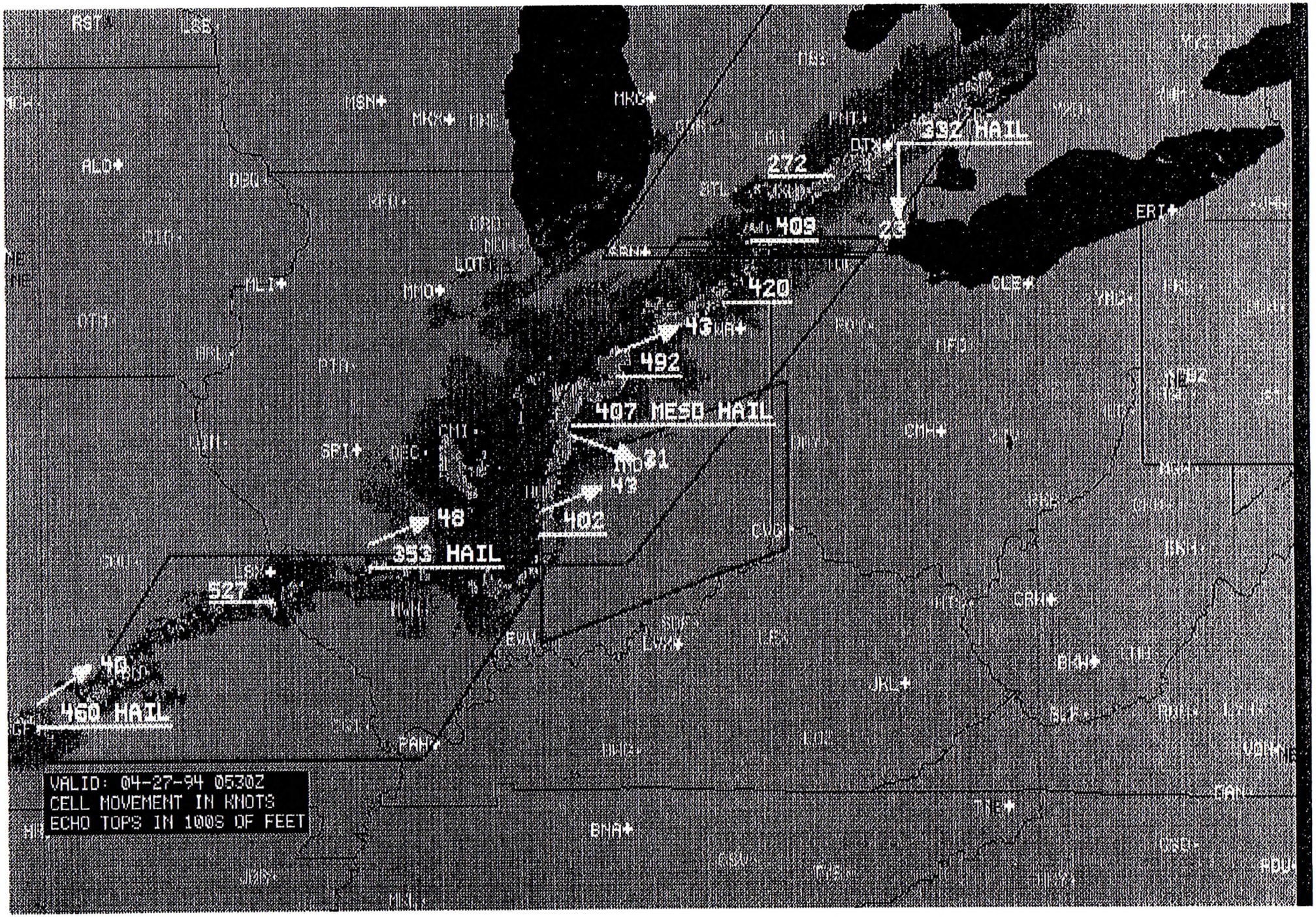

48
112
48
54
291 MESO
452
279
48
464 HAIL
997
970
28
287 HAIL
35
390
VALID: 04-27-94 0430Z
CELL MOVEMENT IN KNOTS
ECHO TOPS IN 100S OF FEET

Figure 3.1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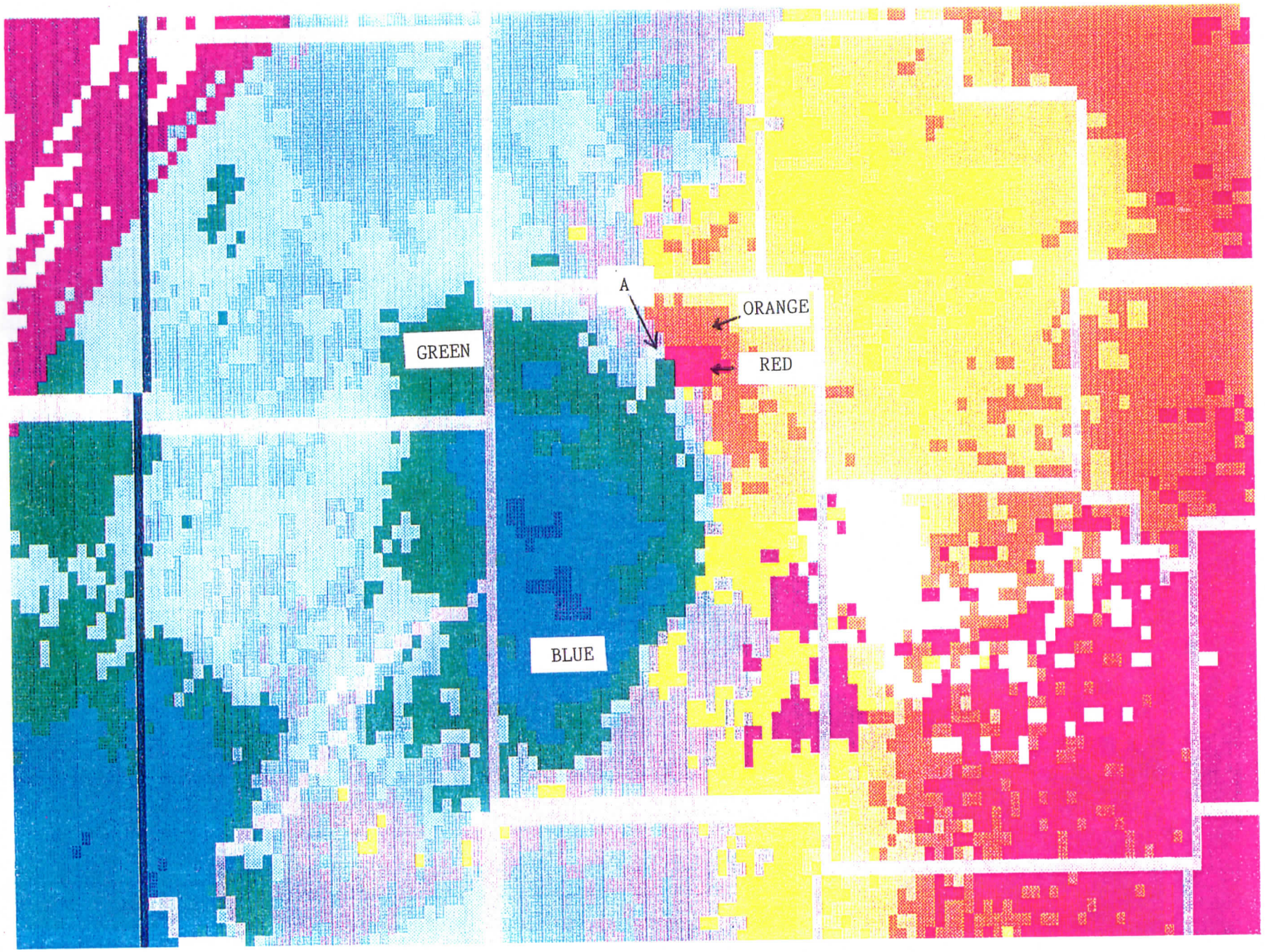
409
23
420
43
492
407 MESO HAIL
21
43
48
402
353 HAIL
527
48
460 HAIL
VALID: 04-27-94 0530Z
CELL MOVEMENT IN KNOTS
ECHO TOPS IN 100S OF FEET

Figure 3.2

WSI DEMONEXRAD IND_VEL1 05:07(05)GMT 27-APR-94



WSI DEMONEXRAD IND_BREF1 05:07(05)GMT 27-APR-94

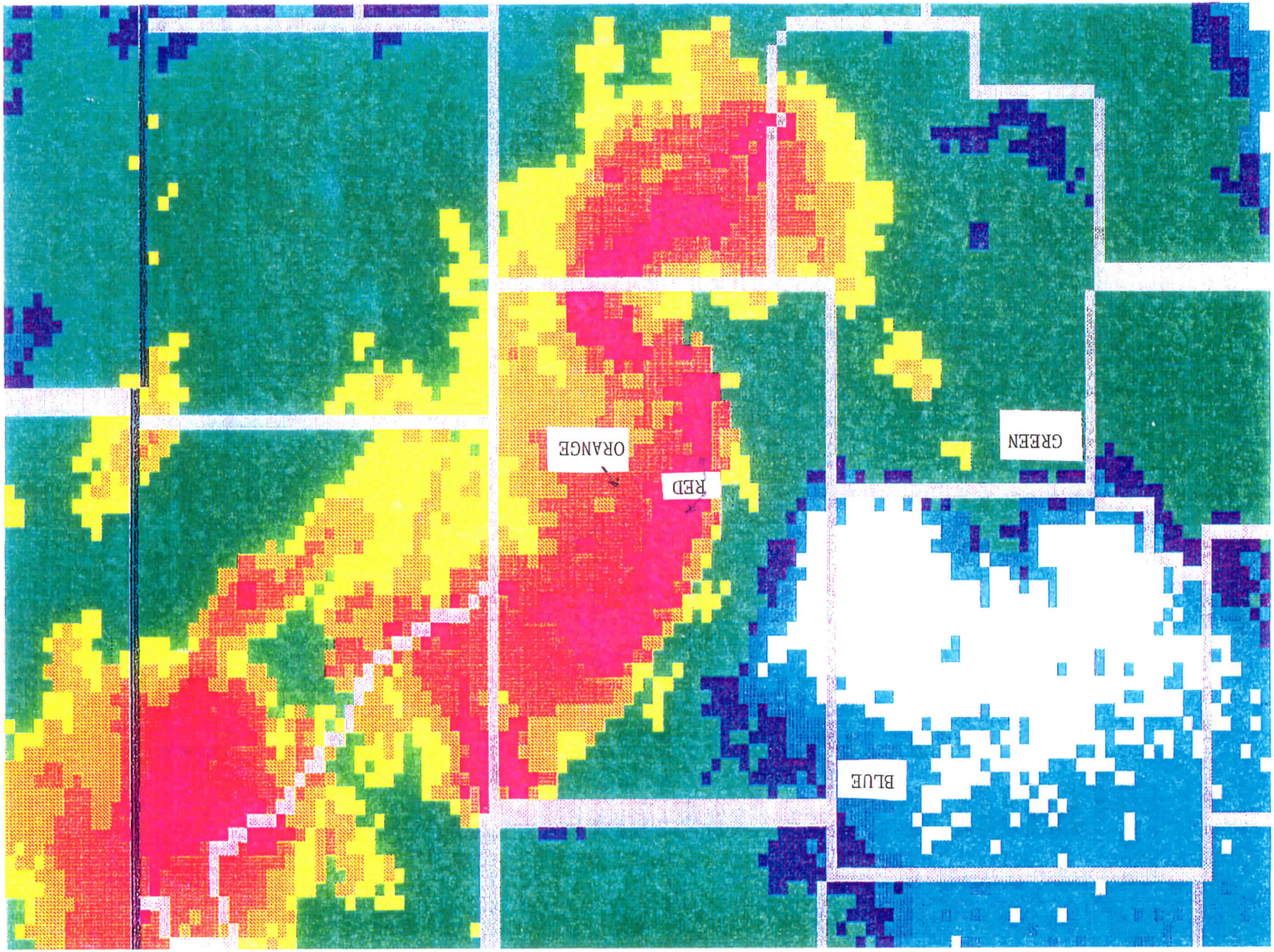


Figure 3.4

Chapter Four

EMERGENCY MANAGEMENT/WSFO READINESS

INDIANAPOLIS WEATHER SERVICE FORECAST OFFICE:

The operational directives, pertaining to severe weather, i.e., Weather Service Operation Manuals, Operations Manual Letters, Regional Operations Manual Letters and Station Duty Manuals were current and readily available to the operational work area. The WSFO's warning operations and communication systems had been fully tested March 16, 1994. A weekly test of the NOAA Weather Radio (NWR) tone alarm for WXK-74 (NWS's Lafayette transmitter) had been conducted successfully the week before the West Lafayette tornado, on April 20, 1994. A severe weather drill, to ensure proficiency in issuing short-fused warnings, had been successfully accomplished by the staff in March of 1994.

Prior to and during the Lafayette tornado event, the Indianapolis Weather Service Forecast Office (WSFO) was staffed by a group of highly trained National Weather Service forecasters. As the severe weather event began during the evening hours of April 26, the staff included the public forecaster, aviation forecaster, warning forecaster, warning coordinator and an additional forecaster assigned to communications functions, i.e., three NWR consoles, NAWAS, telephones, etc. Since the forecast office did not, at that time, have a staff of Hydrometeorological Technicians (HMT), the meteorologists were performing both the task of forecasters and those duties that will normally be assigned to the HMT position. The HMT's duties would have included communications, warning/statement preparation and dissemination, storm verification, Unit Control Position (UCP) functions, etc.

The primary means of data communication, the Automation of Field Operations and Services (AFOS), was fully operational and had the following AFOS products alarmed:

AFOS Product Identifier	Product	AFOS Console
INDTOREVV	Tornado Warning Evansville, IN	A
INDTORFWA	Tornado Warning Fort Wayne, IN	A
INDTORIND	Tornado Warning Indianapolis, IN	C
INDTORSBN	Tornado Warning South Bend, IN	W
INDSVREVV	Severe Thunderstorm Warning Evansville, IN	A
INDSVRFWA	Severe Thunderstorm Warning Fort Wayne, IN	A
INDSVRIND	Severe Thunderstorm Warning Indianapolis, IN	C

INDSVRSBN	Severe Thunderstorm Warning South Bend, IN	W
INDFFWEVV	Flash Flood Warning Evansville, IN	A

AFOS Product Identifier	Product	AFOS Console
INDFFWFWA	Flash Flood Warning Fort Wayne, IN	A
INDFFWIND	Flash Flood Warning Indianapolis, IN	C
INDFFWSBN	Flash Flood Warning South Bend, IN	W
CHITORCHI	Tornado Warning Chicago, IL	W
CHITORSPI	Tornado Warning Springfield, IL	A
CHISVRCHI	Severe Thunderstorm Warning Chicago, IL	W
CHISVRSPI	Severe Thunderstorm Warning Springfield, IL	A
CHISVSCHI	Severe Weather Statement Chicago, IL	B
CHISVSSPI	Severe Weather Statement Springfield, IL	B
CHIFFWCHI	Flash Flood Warning Chicago, IL	W
CHIFFWSPI	Flash Flood Warning Springfield, IL	A

KEY: A - Public AFOS Console
B - Aviation AFOS Console
C - HMT AFOS Console
W - Public and HMT Console

The Chicago and Springfield, Illinois offices have the county warning responsibility for the counties immediately adjacent and west of the WSFO Indianapolis' counties of warning responsibility. These two offices were also at a stage of alert and issuing warnings prior to the West Lafayette tornado.

TIPPECANOE COUNTY:

The Tippecanoe County Emergency Management Director (EMD), had a staff of trained volunteer severe weather spotters on duty the night of the West Lafayette tornado. The spotter training had been provided by WSFO Indianapolis staff members, on March 16, 1994. In the fall of 1993, the Tippecanoe County EMD had attended the WSFO Indianapolis' new facility "Open House", and was briefed on the capabilities of the new WSR-88D equipment. The Indiana State Emergency Management Agency's Emergency Operations Center in Indianapolis, was activated and staffed by trained severe weather and communication technicians at 9:45 p.m. EST on April 26, 1994 when tornado watch number 135 was issued by the National Severe Storms Forecast Center (NSSFC).

The Tippecanoe County Emergency Management Director, after receiving two damage reports, 11:58 to 11:59 p.m. EST, activated the county's 24-siren system, a cable television all-channel override system for public access, and the Emergency Broadcast System at the Common Program Control Station, WAFK AM/FM. The two damage reports were; 1) the downing of high-power electric lines at

a road intersection southwest of Pemerbly Apartments, and 2) the 911 emergency call reporting the breakage of the apartment windows at the Pemerbly Apartments.

Chapter Five

KIND WSR-88D - POST-EVENT ENGINEERING ANALYSIS

Following the April 26-27, 1994 severe weather event, the KIND Doppler radar was tested per technical specifications and appears to have been functioning as specified.

Trouble with the PUES communication line at the RPG was the only problem with the system on April 26-27. The status of this line indicated "Pending" at the UCP applications terminal, and on the AFOS FEP monitor. The line status indicated "Down" due to excessive Frame Check Sequence errors. This communications problem did not affect the operation of the system. Base data information was received at the RPG and the products were generated and transmitted by the RPG. The requested products were received at the associated PUP and at the NIDS Users Systems. Before the severe weather event, the PUP system software hung and the PUP application software required restarting.

The following test procedures were performed at the KIND WSR-88D:

At the RDA, the operation of the receiver and the transmitter were checked using diagnostic tests, reflectivity calibration checks, and electrical measurement checks. Using the RDASOT computer program, diagnostic tests were run for the DAU, the Tower/Utility, the Pedestal, the Programmable Signal Processor (PSP), the Hardwired Signal Processor (HSP), the Receiver, and the Transmitter. All diagnostic tests passed without any problems.

Next, a calibration procedure supplied by the OSF, was used to check the reflectivity levels of the receiver. The receiver calibration values measured an average deviation of -0.9 dB from the expected values, within a specified tolerance of +/- 1 dB. Therefore, the receiver reflectivity is within the specified limits. The preceding procedure will be included in EHB6-510, paragraph 6-6.28 in the next technical manual change.

Finally the power output, the pulse width and shape, and the RF spectrum of the transmitter were measured using steps found in the transmitter alignment procedure. The measurements were found to be within specifications. Also, neither the transmitter status panel, the systems console nor the applications console indicated any errors messages or alarms. The RDA seems to have been functioning as specified in the technical manuals.

At the RPG, the diagnostic tests for the Micro3200 computer, and the VME communications system were run; all diagnostic tests passed as specified.

The self-test for all the wideband and narrowband communication line controllers passed as did the communications line status at the UCP. There were no error messages or alarms at the UCP terminal to indicate a problem with the RPG or the RDA.

At the PUP, the diagnostic test for the Micro3200 computer, the VME communications system, and the graphics processor passed per the technical manual, except for the graphics diagnostic test 14, test 9 and 10. These two tests have software problems within the VME system. Neither the PUP applications terminal or the systems terminal indicated any error messages or alarms.

The KIND WSR-88D seems to have been operating as specified per technical manuals on April 26-27, 1994. Running tests at the RDA, the RPG, and the PUP indicated normal system operation. There were no alarms or error messages to indicate hardware problems with the system.

Problems with the PUP system hanging before the severe weather event seem to be software related. The application program was restarted by rebooting the PUP software. The necessary information to determine the software status was unavailable.

EVENT CHRONOLOGY - Communications

NOTE: Indiana uses EST only.

9:38 PM EST — First Severe Thunderstorm Warning (SVR) is issued by WSFO Indianapolis (IND), Indiana as line of storms enters west-central and northwest Indiana. This warning was issued for Newton County, Indiana valid until 10:30 p.m.

9:45 PM EST — Tornado Watch #135 issued, valid until 3:00 AM EST.

9:45 PM EST — Spotter nets activated, amateur radio operators reported to WSFO Indianapolis to operate equipment. Very little spotter information was relayed to the WSFO directly from Tippecanoe County that evening.

9:45 PM EST — The state EOC, located at the state capitol, was activated with a group of communication officials.

9:49 PM EST — Indiana Areal Outline for Tornado Watch #135 is issued. Tippecanoe County is included.

10:44 PM EST — First Tornado Warning (TOR) is issued by WSFO IND for eastern Jasper County (northwest of Tippecanoe) valid until 11:05 p.m. No reports received. TOR is based on the WSR-88D. WSR-74C operator at IND monitoring storms' progress, apparently no communication was attempted between the WSR-74C operator and WSFO IND staff. Detailed overlay charts were completed by the WSR-74C operator, on a recurring 30-minute basis.

11:20 PM EST — Based on a NWR WXK-74 listener report (of unknown time origin), it was determined by the WSFO IND severe weather coordinator that the NWR was inoperative due to telephone line problems and was formally logged out to the telephone company.

WSFO Indianapolis has a telephone monitoring device that aids in the determination of type of NWR outage, i.e. transmitter versus telephone line problems.

The NWR operator, a forecaster, continued to operate the NWR console as if the system was still fully operational.

11:24 PM EST	The WSR-74C radar operator made his last detailed map overlay. This practice was not continued by the mid shift person. The radar operator did not attempt to contact the WSFO, he assumed that the people operating the WSR-88D had the situation under control as the storms progressed to the northeast from Benton and Warren counties into Tippecanoe County. The WSR-74C radar operator was taking the 0500 UTC surface observation 11:45 - 11:50 PM EST.
11:41 PM EST	Severe Thunderstorm Warning issued for southeast portions of Benton County and northern portions of Warren County. The basis for this warning is the KIND WSR-88D. The warning was in effect until 1215 a.m. EST.
11:58 PM EST	Volunteer spotter reported to the EOC that he has just seen the downing of high-power electrical transmissions lines at an intersection southwest of Pemerbly Apartments.
11:59 PM EST	A public call, 911 to the Tippecanoe County EMA, reported windows being blown out of an apartment at Pemerbly Apartments.
12:00-01 AM	County sirens activated by Tippecanoe County EMA. The county has a system of 24 sirens. Locations of sirens are more than 1.5 miles east and southeast of the initial tornado touchdown and location of the most severe damage as well as where the three deaths occurred.
12:01 AM to 12:04 AM EST	Tippecanoe Emergency Management did access the local cable TV station's (Dimension Cable) all-channel cable override, and relayed emergency message concerning the storm's progress. The EM director also activated the Emergency Broadcast System (EBS) through WAFK AM/FM, EBS Common Program Control Station (CPCS-1) radio station.
12:01 AM	Contract weather observer located at the West Lafayette, Indiana ACTC (airport tower) observes and logs a tornado located northwest of his site with an unknown movement. The observation is telephoned to the AFSS located in Terre Haute, Indiana. The observation transmitted by standard FAA communications system read "Funnel Cloud N LAF TWR".

12:02 AM — A NWS employee, living ¼ mile southeast of the tornado's initial touchdown (near Pemerbly Apts. and the venetian blind factory) does not hear the sirens.

12:00 AM to 12:02 AM — Lafayette Venetian Blind Company is struck, one employee killed. The tornado continues to move to the northeast between 45 and 60 mph.

12:02 AM to 12:04 AM — The tornado moves into the residential subdivision, Pine View Farms. A child is killed during the event, buried in debris of a fully constructed home. There are homes still under construction in the subdivision. An adult injured during the event, in the same residence, died 18 to 24 hours later at a local hospital.

12:02 AM to 12:04 AM — The tornado moves northeast into mobile home park. A report received later from the State Emergency Management Agency (SEMA) stating that approximately 50 people are injured.

12:04 AM — WSR-88D PUP operator decides to issue a Severe Thunderstorm Warning for Tippecanoe County. The storm has already progressed into the center of the county. This warning was based on a combination of information, both the 88D reflectivity and velocity products and the damage report (12:05 a.m. log entry time).

SVR - Quality of Product Comment. SRWARN 6.0 was used to generate the warning. A forecaster, other then the PUP operator generated the warning. The warning was technically encoded correctly, i.e. Universal Generic Code (UGC) and county identification. The basis of the warning described accurately what the warning was based on, yet did not have the "path casting" element that Central Region expects to be included in the warning.

The statement, "A TORNADO WATCH IS ALSO IN EFFECT FOR THE WARNED AREA. REMEMBER SEVERE THUNDERSTORMS CAN AND DO OCCASIONALLY DO PRODUCE TORNADOES WITH LITTLE OR NO ADVANCE WARNING. REMAIN CALM BUT ALERT TO RAPIDLY CHANGING WEATHER CONDITIONS" is included in the text of the warning.

Call to action statement was included.

12:04 AM — Gas station at the intersection of State Highway 43 and Interstate 65 is heavily damaged by high winds.

12:05 AM — WLFI, TV Channel 18, broadcasts the SVR, with supplemental information. This station received the warning initially via its Associated Press wire service. The TV station also monitors NOAA Weather Radio (NWR), yet the NWR broadcast for this warning is not accomplished until 12:07 a.m. EST.

Station is located ¼ mile south of initial tornado touchdown. They recorded 60 mph winds at the TV station's weather instruments. TV station employees did not hear sirens.

12:05 AM — State Police tower, 300 foot and fully guyed, blown down, tower location north of West Lafayette.

12:07 AM — SVR for Tippecanoe County initial broadcast on NWR WXK-74 with the 1050 Hz tone alarm. NOTE, status of the NWR - still believed to be out of service by the WSFO's staff, but NWR operator continues to function as if the NWR was still operative. The Midwest Agricultural Weather Service Center's (MAWSC) Meteorologist in Charge confirmed that the NWR was operational. The TV Channel 18 morning meteorologist also heard the NWR broadcast.

12:12 AM to 12:15 AM — Enhanced bow echo configuration, i.e. comma head development, spurs TOR issuance for Tippecanoe County effective until 12:45 a.m. EST.

TOR - Quality of Product Comment. SRWARN 6.0 was used to generate the warning. A forecaster, other then the PUP operator generated the warning. The warning was technically encoded correctly, i.e. UGC and county identification. The basis of the warning described accurately what the warning was based on, yet did not have the "path casting" element that Central Region expects to be included in the warning.

12:16 AM — NWR WXK-74, Tippecanoe's TOR is broadcast. The NWR transmitter is operative, based upon MAWSC MIC's report.

SEVERE WEATHER WARNINGS ISSUED 4/26-4/27/1994

	TIME	COUNTY	TYPE	VERIFIED WITH	BASIS (R,S,L)
APRIL 26:					
1.	9:38PM-10:30PM	Newton	Severe	hail	R
2.	9:38PM-10:30PM	N. Jasper	Severe	none	R
3.	10:30PM-11:00PM	Newton	Severe	none (pea size hail, 50 mph wind)	R R
4.	10:30PM-11:00PM	Jasper	Severe	Hail, trees down	R
5.	10:44PM-11:05PM	E. Jasper	Tornado	none (F0 tornado Pulaski Co...3E Jasper line)	R
April 27:					
6.	11:36PM-12:15AM	Newton	Severe	none (pea hail)	R
7.	11:41PM-12:15AM	SE Benton	Severe	trees down	R
8.	11:41PM-12:15AM	N. Warren	Severe	trees down	R
9.	12:02AM-12:30AM	Parke	Severe	trees down	R
10.	12:02AM-12:30AM	S.Vermillion	Severe	trees down	R
11.	12:04AM-12:30AM	Tippecanoe	Severe	F3 tornado	R
12.	12:12AM-12:45AM	Tippecanoe	Tornado	F3 tornado	L/R
13.	12:19AM-12:45AM	Carroll	Severe	F3 tornado	R
14.	12:36AM- 1:15AM	E. Vigo	Severe	trees down	R
15.	12:36AM- 1:15AM	E. Sullivan	Severe	trees, power lines down	R
16.	12:40AM- 1:15AM	Clinton	Severe	trees	R
17.	12:47AM- 1:15AM	Greene	Severe	trees, power lines	R
18.	12:47AM- 1:15AM	Clay	Severe	trees down	R

	TIME	COUNTY	TYPE	VERIFIED WITH	BASIS (R,S,L)
19.	12:47AM- 1:15AM	Owen	Severe	F? tornado	R
20.	1:26AM- 2:00AM	Marion	Severe	meas. 68 mph	S
21.	1:41AM- 2:15AM	Hancock	Severe	barn down	R
22.	1:41AM- 2:15AM	N. Shelby	Severe	trees, power lines	R
23.	1:55AM- 2:30AM	Henry	Severe	trees on house, barn	R
24.	1:55AM- 2:30AM	S.Madison	Severe	trees down	R
25.	2:20AM- 3:00AM	Fayette	Severe	trees, power lines	R
26.	2:37AM- 3:15AM	Randolph	Severe	trees down	R
27.	2:37AM- 3:15AM	Union	Severe	trees	R
28.	2:37AM- 3:15AM	Wayne	Severe	trees	R

BASIS...R=RADAR (WSR-88D), S=SPOTTER, L=LAW ENFORCEMENT
COUNTIES WARNED=28; VERIFIED=24...86%

Counties with damage but no warnings....
Hendricks
Johnson
Rush
Pulaski

FUJITA TORNADO INTENSITY SCALE

Category	Definition--Effective
(F0)	Gale tornado (40-72 MPH): Light damage. Some damage to chimneys; break branches off trees; push over shallow-rooted trees; damage sign boards.
(F1)	Moderate tornado (73-112 MPH): Moderate damage. The lower limit is the beginning of hurricane wind speed; peel surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads.
(F2)	Significant tornado (113-157 MPH): Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light-object missiles generated.
(F3)	Severe tornado (158-206 MPH): Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off ground and thrown.
(F4)	Devastating tornado (207-260 MPH): Devastating damage. Well-constructed houses leveled; structure with weak foundation blown off some distance; cars thrown and large missiles generated.
(F5)	Incredible tornado (261-318 MPH): Incredible damage. Strong frame houses lifted off foundations and carried considerable distance to disintegrate; automobile sized missiles fly through the air in excess of 100 yards; trees debarked; incredible phenomena will occur.

Appendix D

SELECTED WARNINGS, STATEMENTS AND FORECASTS
APRIL 26-27,1994

EXHIBIT D1

ZCZC INDSPSIND
TTAA00 KIND 270253
INZALL-270800-

SPECIAL WEATHER STATEMENT
NATIONAL WEATHER SERVICE INDIANAPOLIS IN
950 PM EST TUE APR 26 1993

IN INDIANA A NEW TORNADO WATCH IS IN EFFECT UNTIL 300 AM EST AND INCLUDES THAT PART OF INDIANA...SOUTH OF A LINE FROM ELKHART TO DANVILLE ILLINOIS AND NORTH OF A LINE FROM SULLIVAN TO NASHVILLE TO PORTLAND.

SOME CITIES INCLUDED IN THE NEW TORNADO WATCH ARE...FORT WAYNE...KOKOMO... LAFAYATTE...INDIANAPOLIS AND TERRE HAUTE.

A TORNADO WATCH IS ALSO IN EFFECT NORTH OF A LINE FROM ELKHART TO DANVILLE ILLINOIS UNTIL MIDNIGHT.

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

NNNN

EXHIBIT D2

NNNN
ZCZC INDSVRIND
TTAA00 KIND 270442
INC007-171-270515-

BULLETIN - IMMEDIATE BROADCAST REQUESTED
SEVERE THUNDERSTORM WARNING
NATIONAL WEATHER SERVICE INDIANAPOLIS IN
1141 PM EST TUE APR 26 1994

THE NATIONAL WEATHER SERVICE IN INDIANAPOLIS HAS ISSUED A SEVERE THUNDERSTORM WARNING EFFECTIVE UNTIL 1215 AM EST FOR PEOPLE IN THE FOLLOWING LOCATIONS...

IN NORTHWEST INDIANA

...SOUTHEASTERN BENTON COUNTY

IN WEST CENTRAL INDIANA

...NORTHERN WARREN COUNTY

AT 1140 PM WEATHER RADAR INDICATED SEVERE THUNDERSTORMS IN NORTHERN WARREN COUNTY NEAR PINE VILLAGE...20 MILES WEST OF LAFAYETTE. THESE STORMS ARE MOVING TO THE NORTHEAST AROUND 45 MILES AN HOUR.

A TORNADO WATCH IS ALSO IN EFFECT FOR THE WARNED AREA. REMEMBER SEVERE THUNDERSTORMS CAN AND OCCASIONALLY DO PRODUCE TORNADOES WITH LITTLE OR NO ADVANCE WARNING. REMAIN CALM BUT BE ALERT TO RAPIDLY CHANGING WEATHER CONDITIONS.

EXHIBIT D3

NNNN
ZCZC INDSVRIND
TTAA00 KIND 270504
INC157-270530-

BULLETIN - IMMEDIATE BROADCAST REQUESTED
SEVERE THUNDERSTORM WARNING
NATIONAL WEATHER SERVICE INDIANAPOLIS IN
1204 AM EST WED APR 27 1994

THE NATIONAL WEATHER SERVICE IN INDIANAPOLIS HAS ISSUED A SEVERE THUNDERSTORM WARNING EFFECTIVE UNTIL 1230 AM EST FOR PEOPLE IN THE FOLLOWING LOCATION...

IN WEST CENTRAL INDIANA

...TIPPECANOE COUNTY

AT 1204 AM EST RADAR INDICATED A SEVERE THUNDERSTORM 5 MILES WEST OF LAFAYETTE. THIS STORM WAS MOVING NORTHEAST AT 45 MPH AND HAS PRODUCED STRONG GUSTY WINDS.

A TORNADO WATCH IS ALSO IN EFFECT FOR THE WARNED AREA. REMEMBER SEVERE THUNDERSTORMS CAN AND OCCASIONALLY DO PRODUCE TORNADOES WITH LITTLE OR NO ADVANCE WARNING. REMAIN CALM BUT BE ALERT TO RAPIDLY CHANGING WEATHER CONDITIONS.

SEVERE THUNDERSTORMS PRODUCE DAMAGING WIND IN EXCESS OF 55 MPH...DESTRUCTIVE HAIL...DEADLY LIGHTNING...AND VERY HEAVY RAIN. FOR YOUR PROTECTION MOVE TO AN INTERIOR ROOM ON THE LOWEST FLOOR OF YOUR HOME OR BUSINESS. HEAVY RAINS FLOOD ROADS QUICKLY SO DON'T DRIVE INTO AREAS WHERE WATER COVERS THE ROAD.

ZIMMERMAN

EXHIBIT D4

NNNN
ZCZC INDTORIND
TTAA00 KIND 270513
INC157-270545-

BULLETIN - EBS ACTIVATION REQUESTED
TORNADO WARNING
NATIONAL WEATHER SERVICE INDIANAPOLIS IN
1212 AM EST WED APR 27 1994

THE NATIONAL WEATHER SERVICE IN INDIANAPOLIS HAS ISSUED A
TORNADO WARNING EFFECTIVE UNTIL 1245 AM EST
FOR PEOPLE IN THE FOLLOWING LOCATION...

IN WEST CENTRAL INDIANA

...TIPPECANOE COUNTY

AT 1208 AM EST RADAR INDICATED A POSSIBLE TORNADO NEAR
LAFAYETTE...MOVING NORTHEAST AT 45 MPH. INDIANA STATE POLICE REPORTED
WIND DAMAGE /A DOWNED TOWER/ FROM THIS THUNDERSTORM ON THE NORTH SIDE OF
LAFAYETTE.

IF YOU ARE IN THE PATH OF A TORNADO...THE SAFEST PLACE IS A
BASEMENT. GET UNDER A WORKBENCH OR PIECE OF STURDY FURNITURE.
IF NO BASEMENT IS AVAILABLE...SEEK SHELTER IN AN INTERIOR ROOM
SUCH AS A CLOSET ON THE LOWEST FLOOR. USE BLANKETS...PILLOWS...
OR CUSHIONS TO COVER YOUR BODY. AVOID WINDOWS.

ZIMMERMAN

&

NNNN
ZCZC INDSVRIND
TTAA00 KIND 270521
INC015-270545-

BULLETIN - IMMEDIATE BROADCAST REQUESTED
SEVERE THUNDERSTORM WARNING
NATIONAL WEATHER SERVICE INDIANAPOLIS IN
1219 AM EST WED APR 27 1994

THE NATIONAL WEATHER SERVICE IN INDIANAPOLIS HAS ISSUED A SEVERE THUNDERSTORM WARNING EFFECTIVE UNTIL 1245 AM EST FOR PEOPLE IN THE FOLLOWING LOCATION...

IN NORTH CENTRAL INDIANA

...CARROLL COUNTY

AT 1217 AM EST RADAR INDICATED A SEVERE THUNDERSTORM 10 MILES NORTHEAST OF LAFAYETTE...MOVING NORTHEAST AT 45 MPH. THIS THUNDERSTORM BLEW DOWN THE STATE POLICE TOWER ON THE NORTH SIDE OF LAFAYETTE AND CAUSED A GAS STATION EXPLOSION NEAR SR 43 AND I-65.

THIS THUNDERSTORM WILL MOVE THROUGH THE DELPHI AREA BEFORE 1245 AM EST.

A TORNADO WATCH IS ALSO IN EFFECT FOR THE WARNED AREA. REMEMBER SEVERE THUNDERSTORMS CAN AND OCCASIONALLY DO PRODUCE TORNADOES WITH LITTLE OR NO ADVANCE WARNING. REMAIN CALM BUT BE ALERT TO RAPIDLY CHANGING WEATHER CONDITIONS.

SEVERE THUNDERSTORMS PRODUCE DAMAGING WIND IN EXCESS OF 55 MPH...DESTRUCTIVE HAIL...DEADLY LIGHTNING...AND VERY HEAVY RAIN. FOR YOUR PROTECTION MOVE TO AN INTERIOR ROOM ON THE LOWEST FLOOR OF YOUR HOME OR BUSINESS. HEAVY RAINS FLOOD ROADS QUICKLY SO DON'T DRIVE INTO AREAS WHERE WATER COVERS THE ROAD.

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NNNN
ZCZC INDSVSIND
TTAA00 KIND 270530
INZ020-021-022-029-030-270630-

SEVERE WEATHER STATEMENT
NATIONAL WEATHER SERVICE INDIANAPOLIS IN
1230 AM EST WED APR 27 1994

...TORNADO WARNING IN EFFECT UNTIL 1245 AM EST FOR TIPPECANOE COUNTY...
...SEVERE THUNDERSTORM WARNING IN EFFECT UNTIL 1245 AM EST FOR CARROLL COUNTY...

AT 1225 AM EST A SEVERE THUNDERSTORM WAS LOCATED 10 MILES NORTHEAST OF LAFAYETTE NEAR AMERICUS. THIS THUNDERSTORM WAS MOVING NORTHEAST AT 45 MPH...AND WILL LIKELY PRODUCE DAMAGING WINDS IN THE DELPHI AREA BEFORE 1245 AM EST.

THE PUBLIC REPORTED A TORNADO AT 1215 AM EST NEAR THE INTERSECTION OF SR 43 AND I-65...ON THE NORTH SIDE OF LAFAYETTE.

BY 1245 AM EST THIS THUNDERSTORM WILL BE 10 MILES SOUTHWEST OF LOGANSPORT NEAR BURROWS. PEOPLE IN DELPHI AND CAMDEN SHOULD BE PREPARED FOR A SEVERE THUNDERSTORM WITH DAMAGING WINDS BEFORE 1245 AM EST.

ZIMMERMAN

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NNNN
ZCZC INDZFPIN
TTAA00 KIND 270300 AMD

EXHIBIT D7

INDIANA ZONE FORECASTS...UPDATED
NATIONAL WEATHER SERVICE INDIANAPOLIS IN
959 PM EST TUE APR 26 1994

INZ016-021>024-029>031-035-036-043-270930-
CARROLL-CASS-CLINTON-FOUNTAIN-HOWARD-KOSCIUSKO-MIAMI-MONTGOMERY-
TIPPECANOE-VERMILLION-WABASH-
INCLUDING THE CITIES OF...LOGANSPORT...LAFAYETTE...KOKOMO...
CRAWFORDSVILLE
959 PM EST TUE APR 26 1994

...TORNADO WATCH IN EFFECT UNTIL 3 AM EST...
.TONIGHT...PARTLY CLOUDY WITH A 40 PERCENT CHANCE OF THUNDERSTORMS...
SEVERE STORMS POSSIBLE. BREEZY AND VERY MILD. LOW IN THE LOWER TO MIDDLE
60S. SOUTHWEST WIND 15 TO 25 MPH.
.WEDNESDAY...BECOMING MOSTLY CLOUDY. A 40 PERCENT CHANCE OF
THUNDERSTORMS. HIGH 75 TO 80. SOUTHWEST WIND 10 TO 15 MPH BECOMING
NORTHWEST LATE IN THE AFTERNOON.
.WEDNESDAY NIGHT...CLOUDY WITH A 50 PERCENT CHANCE OF THUNDERSHOWERS.
LOW IN THE UPPER 40S TO LOWER 50S.
.THURSDAY...SHOWERS LIKELY AND MUCH COOLER. HIGH 60 TO 65. CHANCE OF
RAIN 60 PERCENT.

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INZ006>009-017-018-025-270930-
ALLEN-DEKALB-HUNTINGTON-LAGRANGE-NOBLE-STEUBEN-WHITLEY-
INCLUDING THE CITY OF...FORT WAYNE
959 PM EST TUE APR 26 1994

...TORNADO WATCH IN EFFECT UNTIL 3 AM EST...
.TONIGHT...PARTLY CLOUDY WITH A 40 PERCENT CHANCE OF THUNDERSTORMS...
SEVERE STORMS POSSIBLE. BREEZY AND VERY MILD. LOW IN THE LOWER TO MIDDLE
60S. SOUTHWEST WIND 15 TO 25MPH.
.WEDNESDAY...BECOMING MOSTLY CLOUDY. A 40 PERCENT CHANCE OF
THUNDERSTORMS. HIGH 75 TO 80. SOUTHWEST WIND 10 TO 15 MPH BECOMING
NORTHWEST LATE IN THE AFTERNOON.
.WEDNESDAY NIGHT...CLOUDY WITH A 50 PERCENT CHANCE OF THUNDERSHOWERS.
LOW IN THE UPPER 40S TO LOWER 50S.
.THURSDAY...SHOWERS LIKELY AND MUCH COOLER. HIGH IN THE UPPER 50S TO
LOWER 60S. CHANCE OF RAIN 60 PERCENT.

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INZ037>039-044>047-051>055-060>063-270930-
BOONE-BROWN-CLAY-GREENE-HAMILTON-HENDRICKS-JOHNSON-MARION-MONROE-
MORGAN-OWEN-PARKE-PUTNAM-SULLIVAN-TIPTON-VIGO-
INCLUDING THE CITIES OF...INDIANAPOLIS...TERRE HAUTE...BLOOMINGTON
959 PM EST TUE APR 26 1994

...TORNADO WATCH IN EFFECT UNTIL 3 AM EST...
.TONIGHT...PARTLY CLOUDY WITH A 40 PERCENT CHANCE OF THUNDERSTORMS...
SEVERE STORMS POSSIBLE. VERY MILD. LOW IN THE MIDDLE 60S. SOUTHWEST WIND
10 TO 20 MPH.
.WEDNESDAY...BECOMING MOSTLY CLOUDY. A 50 PERCENT CHANCE OF
THUNDERSTORMS. HIGH IN THE UPPER 70S TO LOWER 80S. SOUTHWEST WIND 10 TO
20 MPH.
.WEDNESDAY NIGHT AND THURSDAY...SHOWERS AND THUNDERSTORMS LIKELY.
COOLER. LOW IN THE LOWER TO MIDDLE 50S. HIGH 65 TO 70. CHANCE OF RAIN 60
PERCENT BOTH WEDNESDAY NIGHT AND THURSDAY.