

**Storm Observations and Damage Survey
of the Tornado Outbreak Near
Pampa, Texas on May 19, 1982**

by

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Foreword

The Institute for Disaster Research has studied tornado damage for over a decade. On May 19, 1982 an outbreak of tornadoes was observed and photographed and the damage was surveyed the next day. By combining meteorological observations of the storm with a detailed engineering analysis of the damage, a better understanding of near-ground tornado wind fields was obtained.

The fourth tornado in the sequence was of particular interest since seven prefabricated metal buildings in the Pampa Industrial Park were severely damaged. In addition, this tornado underwent a dramatic transition from a single cell circulation into a multi-vortex circulation during its lifecycle.

Moreover, three tornadoes lasted on the ground over fifteen minutes; two others were anticyclones. The cooperation of the personnel at Halliburton services in coordinating the damage survey of their facilities is gratefully acknowledged.

Funds for the tornado damage documentation effort were provided by the U.S. Nuclear Regulatory Commission Contract No. NRC-04-76-345. Robert F. Abbey Jr. serves as contract monitor on the project.

The cooperation of a number of people and organizations made the collection of this data possible. They include personnel from the Lubbock office of the National Weather Service and Halliburton Services, Inc. in Pampa. Funds for the Intercept Team are provided by the Institute for Disaster Research. The U.S. Nuclear Regulatory Commission supports the study of near ground tornadic wind fields through observation. Additional thanks to Mr. Jim Leonard of Miami, FL, for photographs of the first and third tornadoes. Jennifer Keeney typed the manuscript and scanned in the photos.

Table of Contents

| | |
|-------------------------------------|----|
| Foreward | I |
| Background | 1 |
| Introduction | 1 |
| Tornado Intercept team | 2 |
| Meteorology Summary | 2 |
| Tornado Observations | 4 |
| Storm Damage Investigation Team | 10 |
| Damage Survey of the Second Tornado | 11 |
| Damage survey of the Fourth Tornado | 11 |
| • Warehouse- Admixture Building | 12 |
| • Office Building | 14 |
| • Tool Building | 15 |
| • Shop Building | 16 |
| • Truck Wash Building | 18 |
| Conclusions | 19 |
| References | 19 |

List of Tables

| | |
|--------------------------|------|
| | Page |
| Table 1: Tornado Summary | 20 |

List of Figures

| | |
|---|------|
| Figures | Page |
| Figure 1: Surface sub-synoptic map at 6:00 p.m. | 3 |
| Figure 2: Damage paths of the Pampa tornadoes | 5 |
| Figure 3: The first tornado | 6 |
| Figure 4: Air pressure measurements at first filming location | 6 |
| Figure 5: The second tornado | 7 |
| Figure 6: View of the fourth tornado in the single-cell stage | 8 |
| Figure 7: View of the fourth tornado in the multi-vortex stage | 8 |
| Figure 8: The sixth tornado | 10 |
| Figure 9: View looking north of the remains of a wooden building | 11 |
| Figure 10: Plan view of Halliburton Servies | 12 |
| Figure 11: Remains of the Warehouse-Admixture building | 13 |
| Figure 12: View looking north of Warehouse-Admixture building as rebuilt | 13 |
| Figure 13: Damage to the Office building looking north | 14 |
| Figure 14: View looking northwest of the Office building as rebuilt | 14 |
| Figure 15: The Tool building was the largest building left standing after the tornado | 15 |
| Figure 16: View looking northeast of the Tool building as rebuilt | 16 |
| Figure 17: View looking east of the remains of the Shop building | 17 |
| Figure 18: Example of column anchorage failure in the Shop building | 18 |
| Figure 19: Example of column base plate tearing in the Shop building | 19 |
| Figure 20: View looking east of damaged Truck Wash building | 20 |
| Figure 21: View looking west of Truck Wash building as rebuilt | 21 |

Background

The Institute for Disaster Research has studied tornadoes for more than a decade. One objective of the study is to better understand the characteristics of the near-ground tornado wind field. Two approaches are used. During the spring when tornado occurrence on the Texas Panhandle is very likely, the Tornado Intercept Team at Texas Tech University watches developing weather patterns and attempts to place themselves in safe positions to photograph the life cycle of a tornado as it emerges from a severe thunderstorm. From still photos and movies, the air flow pattern can be identified. A second approach is to observe the patterns of damage and debris after a tornado has occurred. The type of debris and its position after the storm gives an indication of the wind circulation patterns.

Introduction

On the evening of May 19, 1982, an isolated slow moving super cell thunderstorm produced at least eight tornadoes in the Texas Panhandle east of Amarillo. The sequence of tornadoes barely missed the city of Pampa. The Tornado Intercept Team from the Institute for Disaster Research (IDR) was in the field on that day, watching the development of the storm. They observed and photographed the tornadoes as they occurred one after the other. The next day, a damage study team from IDR returned to the area to document the damage and to identify the extent and location of the damage. The situation presented a rare opportunity to combine meteorological observations and instrument data gathered by the tornado intercept team with the information obtained by the damage survey team in order to better understand near ground tornado wind fields.

The objective of the report is to assess the effects of the tornadoes from the two perspectives. In particular, the report focuses on damage produced by the fourth tornado to the Halliburton facility. The mission of the tornado intercept team was to observe and photograph the tornadoes from close range and to gather data regarding temperature, humidity, wind speed, wind direction and atmospheric pressure. Filming locations were marked for future use in photogrammetric analysis of the movies. The damage survey team objectives included: definition of the damage paths, identification of the maximum damage intensity of each tornado using the F-scale (Fujita, 1971) and evaluation of the performance of structures at the Halliburton facility.

The report describes the activities and data collected by the tornado intercept team as well as the data collected by the damage survey team. In the conclusions, the information from the two teams is meshed together to draw appropriate conclusions regarding the impact of this tornado outbreak.

Tornado Intercept Team

A typical tornado chase day begins at the local Weather Office where members of the Tornado Intercept Team assemble to study morning weather maps. A variety of forecast techniques are used to predict potential afternoon tornado activity. Hourly surface changes in temperature, dew point, air pressure and wind are just a few of the parameters which are monitored. Soundings are also plotted and stability indices are calculated.

By early afternoon, if conditions are favorable, a target forecast area, about sixty miles in diameter, is determined based on having the best potential for tornado formation. The team travels to the target area equipped with cameras, tape recorders and meteorological instruments. While en route, team members watch the sky for signs of initial thunderstorm development. If a thunderstorm develops, the team approaches the rain-free portion of the cloud base and watches for development of an organized lowering or wall cloud, which may precede a tornado. When a wall cloud is observed, the team positions itself on the east or southeast side a few miles away. Then, if a tornado develops, this location affords the best

resolution of the tornado's structure on film and assures the best photographic contrast of a light colored tornado against a dark rain-laden background.

On May 19, the best potential for severe storm activity was forecasted to be near Amarillo, Texas, which is located about 125 miles north of Lubbock. The Tornado Intercept Team consisted of two vehicles led by Tim Marshall and Erik Rasmussen. Other members of the team included Roy Britt, Bruce Jensen, Mark Mahey and Bob Yudhin. Shortly after 3 p.m., the team drove northward toward the target areas near Amarillo. During the course of the afternoon, a total of eight tornadoes were observed as they emerged from the super cell system.

Meteorology Summary

A morning surface mesoanalysis showed that the most unstable air for severe weather was located from western Kansas to the Texas Panhandle. The eastern boundary of the unstable air coincided with a prominent moisture axis and wind convergence line from Dodge City, KS, to near Childress, TX. Morning convection had stabilized much of the air mass over central Oklahoma. It was determined that the associated cloudiness should substantially reduce daytime surface heating and limit severe weather in that region. The western boundary of the unstable air was the surface daytime and maximum temperature axis initially located along the Texas and New Mexico borders.

It was forecast that the dry line would move into west Texas and become stationary by mid-day. Therefore the most likely region for the severe weather would be in the eastern panhandle of Texas.

The upper air dynamics were strong for severe weather in the unstable air that day. An 850 mb low, centered in Colorado, prompted a strong low-level jet to advect plenty of moisture from the Gulf of Mexico into the region and also allow warm air advection to occur.

These factors contributed to destabilization of the air mass over the Texas panhandle throughout the day. At 500 mb, an open wave trough with slight negative tilt was dragging southward over Arizona during the morning. This feature would enhance vertical motion and help trigger convection as it approached the Texas panhandle. Mid and upper level jets curved around the bottom of the trough and exited near Albuquerque, NM. These wind maxima would aid in vertical motion and carry thunderstorm anvils downstream.

The morning sounding at Amarillo showed strong turning of the wind (wind shear) below 700 mb which is favorable for severe weather. Total stability was 59 and the SWEAT index at 537 (see Miller, 1972), both exceeding the threshold for tornadoes.

It was decided by the team leaders that convection would most likely begin in western Kansas near the surface low and develop southward into the Texas panhandle by late afternoon with the approach of a short wave trough. Amarillo was chosen as center of the target area where convection would begin.

A surface sub-synoptic map at 6:00 p.m. (CDT) is shown in Figure 1 at the time of the first tornado near Pampa. A well-defined dry line bulge was east of Amarillo with a difference of 26°F in dew point temperature between Amarillo and Pampa. East winds at Pampa resulted in strong moisture convergence for the tornadic thunderstorm just west of the city.

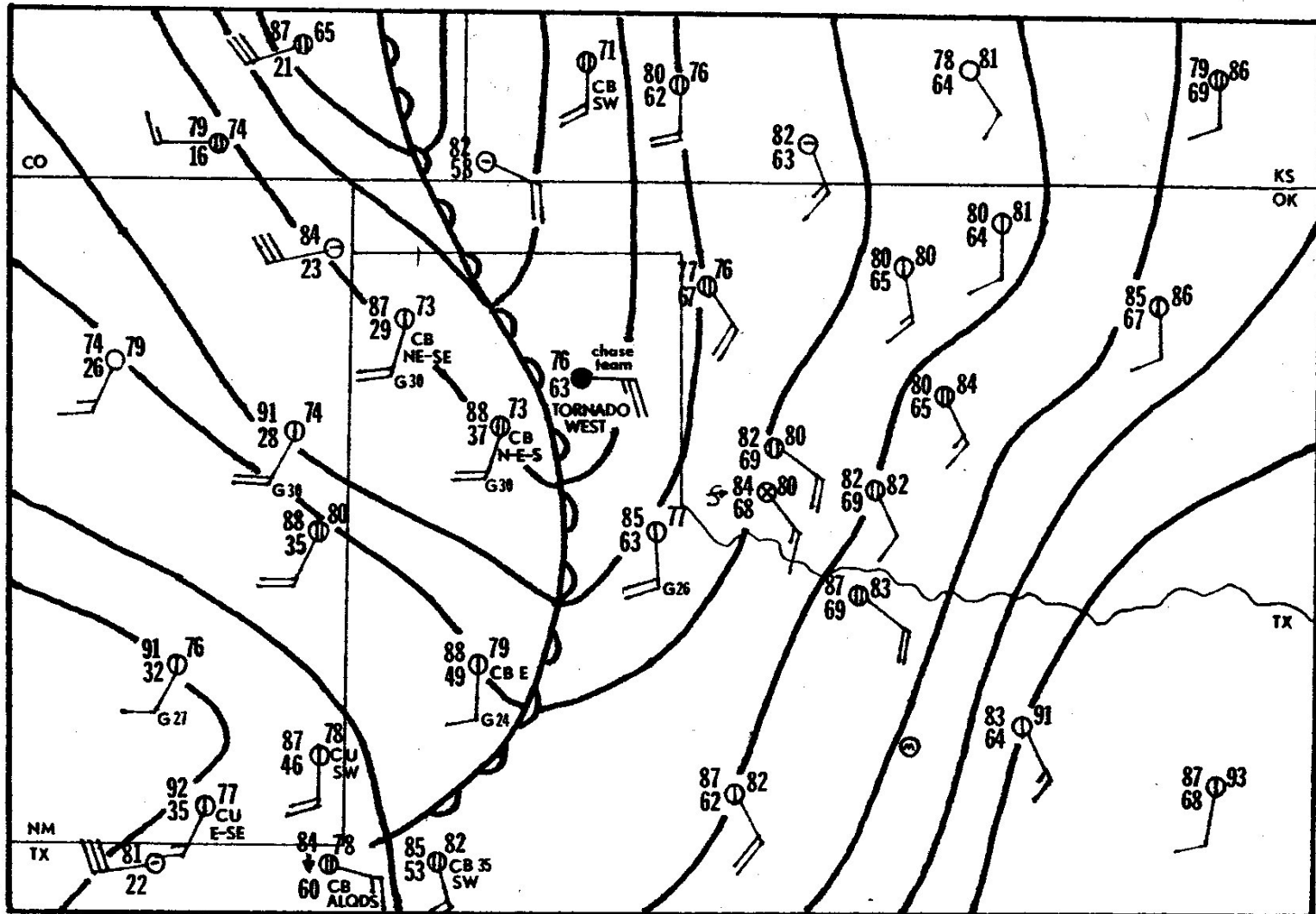


Figure 1. Surface sub-synoptic map at 6:00 p.m. (CDT). For each station, temperatures (°F) are located in the upper left, dew points (°F) in lower left, altimeter pressure (in) in the upper right and the wind speed in kts

Tornado Observations

The locations of the tornado paths and positions of the tornado intercept team are shown in Figure 2. At least eight tornadoes occurred in succession lasting a total of over two hours on the ground. The actual times of tornado touchdown and lifting point are verified from transcribed information from tape recordings. An enlarged view of the damage paths of the second and fourth tornadoes is included since they were responsible for most of the damage.

About 4 p.m., a thunderstorm had developed near Borger and began to move slowly eastward. At that time, the intercept team was near Plainview traveling north toward the storm. The sky was relatively clear with the exception of a cirrus anvil with an overshooting top located on the northern horizon. As the team approached the storm, an extensive rain-free base appeared to the north.

By 5:30 p.m., the team was northeast of Amarillo and observed a violently rotating wall cloud to the north. Moving northeastward, the team observed striations under the rain-free base that were moving rapidly toward the wall cloud. As rotation at cloud base intensified, the team stopped on the east side of Pampa and quickly set up for filming. At 6:00 p.m., the first tornado developed about ten miles west of our location near the town of Skellytown (Figure 3). The tornado was rope-shaped and traveled eastward across ranchland with minimal damage for about two minutes. It was later determined from watching the film motion that the rotation was anticyclonic.

Weather observations taken every few minutes at the first filming location revealed large air pressure fluctuations (Figure 4). A few minutes after the first tornado dissipated, the altimeter pressure increased and became steady until the east edge of the updraft approached. As the perimeter of the updraft passed overhead, the surface winds gusted to 37 mph from the east and the altimeter pressure began falling rapidly. By 6:17 p.m., light rain began falling as the altimeter pressures remained steady.

The storm appeared to go thru a transition stage as another large updraft merged into the storm from the south. Soon, the circulation at cloud base widened and intensified and a large wall cloud emerged. At 6:23 p.m., a laminar funnel protruded from the wall cloud and finally touched ground about four miles west of our location (Figure 5). As the tornado (#2) moved gradually northeastward, it widened into a V-shaped vortex and became obscured by dust.

At 6:25 p.m., the rear flank downdraft passed our location. Winds shifted to light westerly and a pressure jump was observed. The altimeter pressure continued to rise as the tornados began to occlude with the rear flank downdraft.

Throughout the tornado's lifetime, the visible funnel never reached the ground. However, a well-defined dust cloud indicated that strong circulation was present at the surface. At first, the dust cloud was symmetrical with respect to the tornado's axis. Later, as the rear flank downdraft wrapped around the circulation, a dense and sharply defined dust cloud wedge formed at the southern edge of the tornado near the ground whereas on the northern edge, the dust cloud appeared to be carried northward away from the circulation.

As circulation occluded, a third tornado developed along the gust front just north of Pampa. The tornado was embedded in heavy dust and precipitation and gradually moved northward lasting about ten minutes. One of the chase vehicles was on the north side of Pampa and observed strong west winds which blew out a few free standing signs. The other chase vehicle moved eastward and was preparing to photograph the fourth tornado.

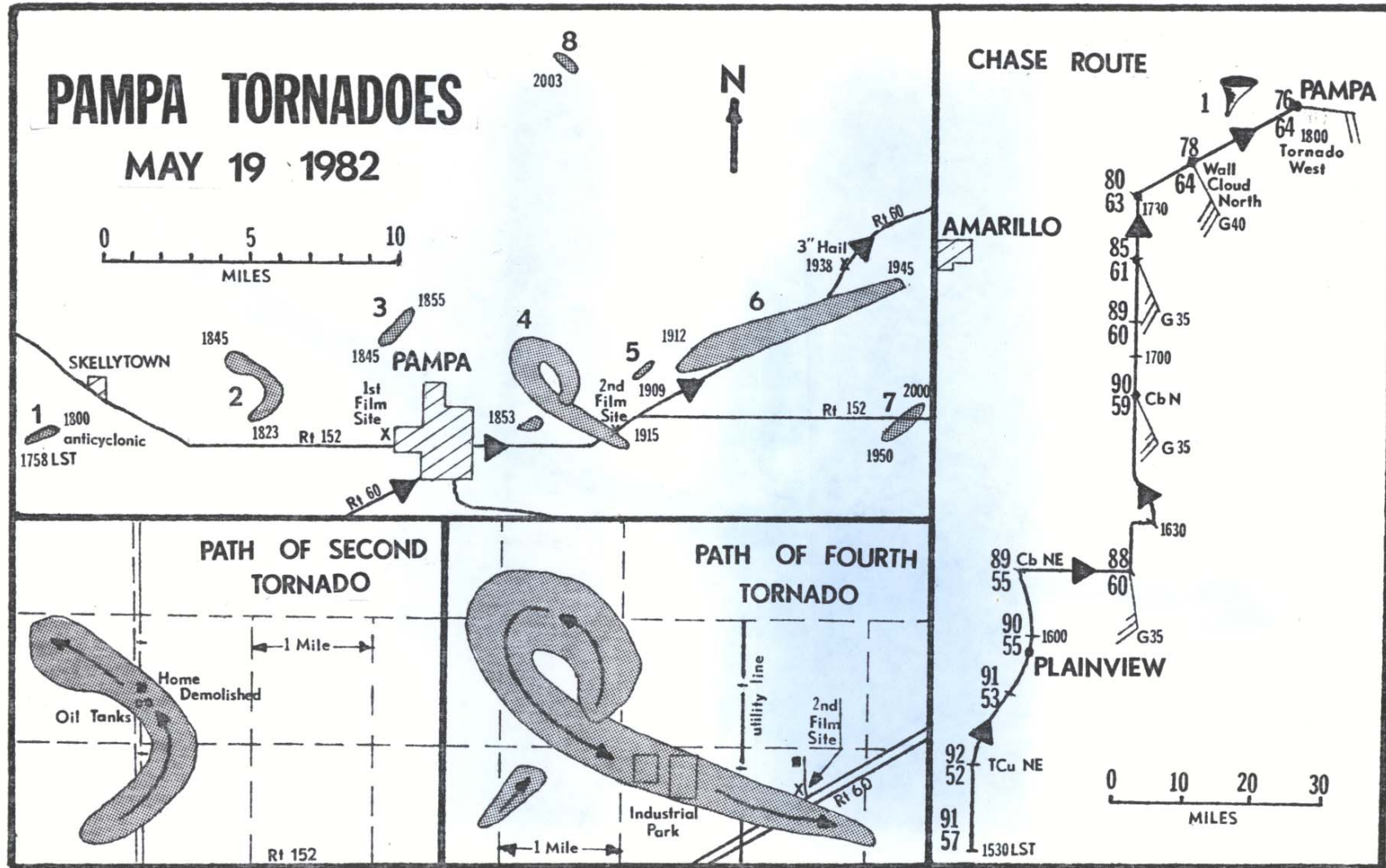


Figure 2. Damage paths of the Pampa Tornadoes. The route of the Intercept Team is shown by arrows. Temperature and dewpoints are in $^{\circ}\text{F}$, wind speed in mph and local time are indicated.



Figure 3 The first tornado touched down near Skellytown and was anticyclonic. (Enlarged sketch from actual photo)

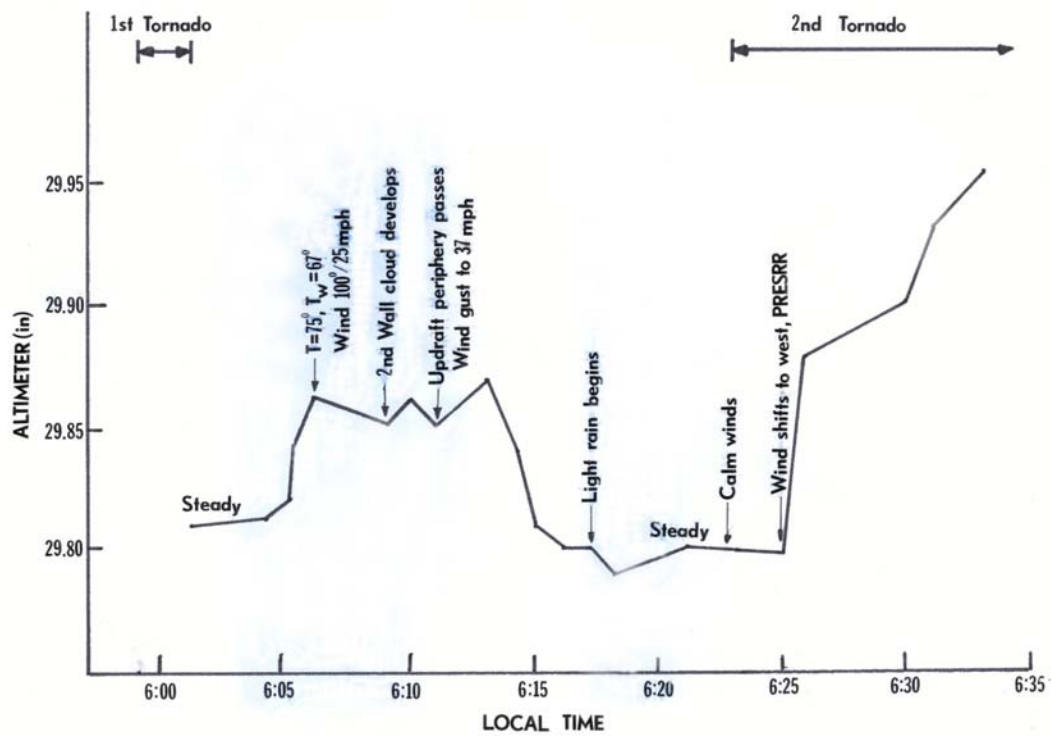


Figure 4. Air pressure measurements at first filming location.



Figure 5. The second tornado developed four miles west of Pampa. Note that the debris cloud is much larger than the condensation funnel.

Soon a fourth circulation developed at cloud base over Pampa and moved eastward. The team followed and set up a second filming location four miles east of Pampa at 6:50 p.m. Within minutes, the fourth tornado developed and touched down two miles west of our location (Figure 6). The single-cell tornado was initially V-shaped and widened rapidly into a cylindrical-shaped vortex. After only a few minutes, the tornado dissipated and the circulation at cloud base widened. Within two minutes a large tornado with three sub-vortices developed a mile northwest of our location (Figure 7). The sub-vortices formed one at a time on the southern periphery of the circulation and moved around to the north-east side where they dissipated. The tornado traveled northward through a plowed field picking up loose soil which changed the tornado to a dark red color. At the same time, an anticyclonic funnel developed overhead and moved northward along the eastern periphery of the updraft.

By 7:05 p.m., the large, cyclonic tornado reversed its direction and moved southeastward toward our location. As a result, the team had to make a fast exit toward the east to avoid the oncoming tornado. A short time later, the tornado struck the Pampa Industrial Park and leveled seven prefabricated metal buildings causing more than three million dollars in damages. This tornado proved to be the costliest one in West Texas this spring. After passing through the Industrial Park, the tornado crossed Rt. 60 and dissipated. The tornado path was a clearly defined loop.

An anticyclonic tornado soon developed to the east of the large cyclonic tornado (not pictured). This tornado appeared to have developed along the eastern periphery of the updraft near the intersection of a low-level cloud band. The cloud band demarcated a boundary of warm, inflow air to the south and rain-cooled air to the north and for the most part it remained essentially stationary. At the base of the anticyclonic tornado, a small debris cloud was observed. The tornado moved eastward damaging some trees and dissipated a few minutes later.



Figure 6. View of the fourth tornado in the single-cell stage just before striking the Pampa Industrial Park. (Photo by Tim Marshall)



Figure 7. View of the fourth tornado two minutes later as it begins the multi-vortex stage. (Photo courtesy of Mr. Roy Britt)

On several occasions that day, anticyclonic funnels were observed developing on the eastern periphery of the updraft. This leads to the conclusion that when a large, cyclonic tornado is formed, anticyclonic tornadoes may simultaneously develop to the east. Similar conditions were observed by authors in the Grand Island, Nebraska, tornado outbreak (Marshall, 1982).

The existence of strong low-level wind convergence along the eastern periphery of the updraft was confirmed in the Pampa storm by the Tornado Intercept Team. On three occasions, as the team moved eastward away from the cyclonic tornado, the wind speed increased from west at 20 mph to near 50 mph as we passed directly underneath the leading edge of the rotating updraft.

By 7:12 p.m., the wind switched to the west as the gust front passed. Soon, visibility became reduced as rain and hail began to fall. Then a dark, ominous wedge-shaped tornado emerged from the heavy precipitation about a mile away (Figure 8). This monstrous-size tornado was nearly a mile wide as it moved northeastward along Rt. 60 across sparsely populated ranchland. Baseball-size hail was encountered as the team drove eastward ahead of the advancing tornado. The tornado stayed on the ground for a half hour before dissipating near Miami, Texas.

Comments on Post Storm-Damage Investigation

A much clearer understanding of the tornadic storm near Pampa was obtained by combining the results of the damage survey with storm observations. The documentation of the storm observations by the Texas Tech Tornado Intercept Team led to an accurate account of the number, time, shape, path length, and path width of the tornadoes which would not have been properly determined by storm damage investigation alone.

Most of the tornadoes occurred in sparsely populated areas so damage to structures was minimal. Only the second, fourth and sixth tornadoes caused enough damage to be accurately assessed by the storm damage investigation team. The conclusions based on damage investigation alone would have led to only three tornadoes, which is the same number of tornadoes listed on the Amarillo storm report.

The times of each tornado from data acquired after-the-fact were also quite inaccurate. Newspaper accounts and public questionnaires were as much as half an hour from the actual times of tornado occurrence. However, Department of Public Safety sources provided more accurate times of occurrence of the three large tornadoes which caused damage. It is important to recognize that the amount of time the tornadoes were on the ground could not be determined from any of the sources. The first, second and fourth tornadoes were photographed by several persons in the Pampa area. Some of these photographs appeared in the local newspaper the next day. Information in the shapes and signs of these three tornadoes were well documented.

Characteristics of the second tornado path were well defined from a ground damage survey. One mile sections of roads, telephone lines and fence rows enable accurate verification of path length and width. However, the characteristics of the rest of the tornado path would have been quite inaccurate by a ground survey alone. For example, the looping path of the fourth tornado would never have been documented. East of Pampa, there are few roads since the Caprock escarpment is encountered. There are few telephone lines and fence rows since the region is primarily rangeland. An aerial damage survey would have revealed similar results. Therefore, the following conclusions would have been made from damage investigation along:

- a) There were at least three large tornadoes which tracked northward.
- b) The time of tornado touchdowns were near 6 p.m., 6:55 p.m. and near 7:30 p.m.

Thus, proper storm observation and film documentation from tornado intercept teams is essential in understanding the storms life cycle and how the damage was caused.



Figure 8. The sixth tornado was nearly a mile wide. This photo was taken looking west about a mile away. (Photo by Tim Marshall)

Storm Damage Investigation Team

The next day, May 20, a storm damage investigation team was sent back to the Pampa area to survey the damage from the previous day's tornadoes. This team also was led by Tim Marshall. He was accompanied by a graduate student and an undergraduate student in Civil Engineering. The objective was this survey team was to:

1. Define the damage paths of the tornadoes
2. Identify maximum damage intensity and assign an appropriate Fujita scale rating
3. Evaluate the performance of any structures affected by the tornadoes.

In particular, the team was interested in the damage to pre-engineered buildings at Halliburton Service Inc.

Most of the tornadoes occurred in sparsely populated areas. Damage to structures was minimal. Only the second, fourth and sixth tornadoes (see Fig. 2) caused damage that was visible on the ground the next day. It is interesting to note that only three tornadoes were confirmed by the Department of Highways and Public Transportation. The other five tornadoes would have gone undetected except for the presence of the two intercept teams.

Damage Survey of the Second Tornado

The damage survey revealed that the tornado traveled only two miles during the twenty-two minutes it was on the ground. The damage path extended northeastward and then curved back towards the northwest where a building was demolished. The entire building was moved more than 100 yards toward the west with debris scattered northwestward (Figure 10). Closer inspection revealed that the building was not anchored to its foundation. Trees in the area were stripped of large branches and telephone poles were snapped off at the ground. Several large oil tanks were damaged by flying debris and covered with mud. Based on damage to the building and the surroundings, the second tornado was rated an F3.



Figure 9. View looking north of the remains of a wooden building which was not anchored to its foundation.

Damage Survey of the Fourth Tornado

The Pampa Industrial Park is located 4 miles east of the city on Rt. 60. On the day of the tornado, Halliburton Services was under construction and about 80 percent completed. The complex consisted of seven pre-fabricated metal buildings which were fully erected (Figure 10). Total cost of the project was near four million dollars.

The tornado traveled across the complex from the northwest to southwest direction. All but two buildings were totally destroyed. Damage at Halliburton Services was carefully documented by photographs and tape recorded comments. A summary of the damage caused to each building is presented here. Based on damage to Halliburton Services and the surrounding area, the damage intensity was rated F3.

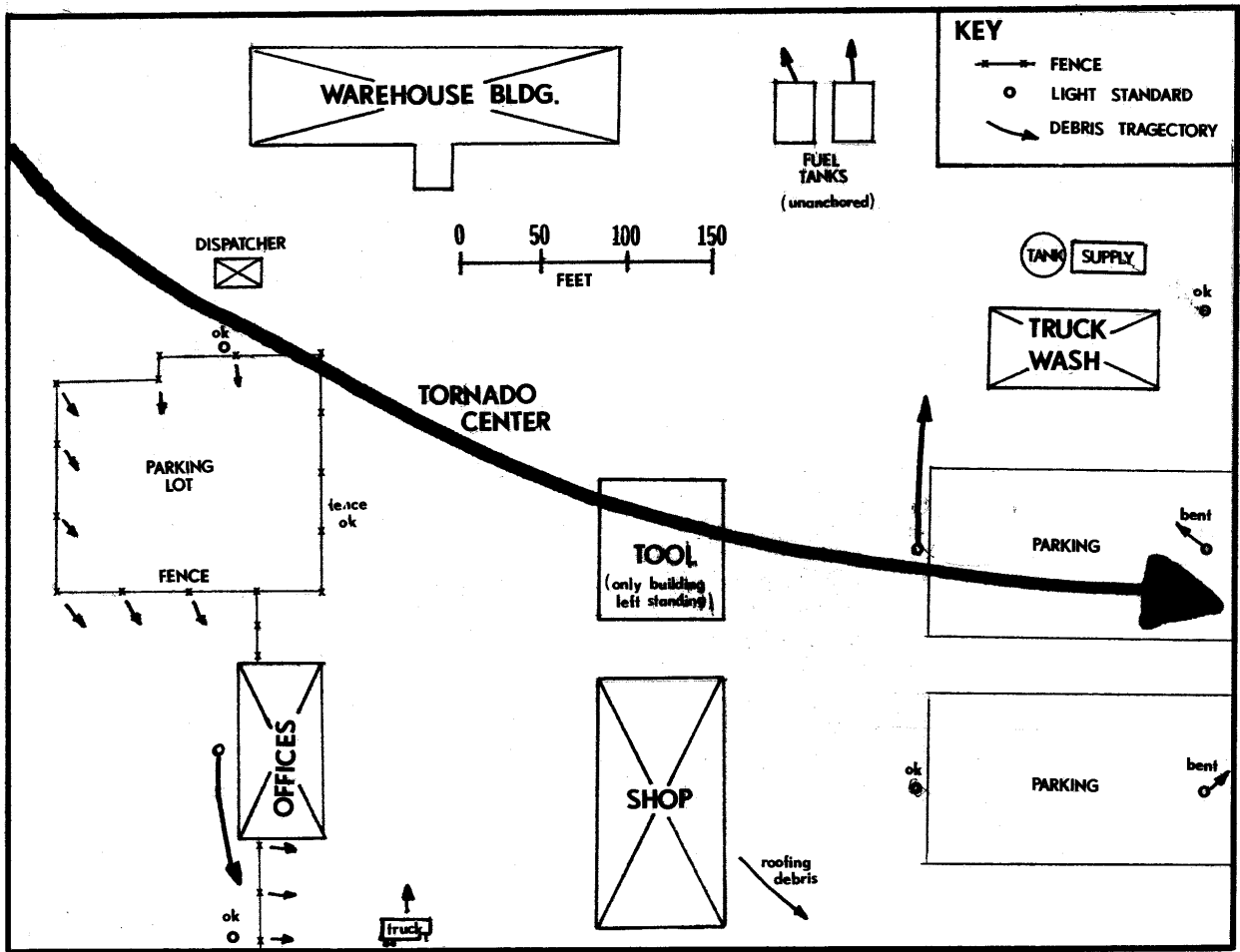


Figure 10. Plan view of the path of Tornado #4 through Halliburton Services.

Warehouse-Admixture Building

The Warehouse-Admixture building was the largest building on the complex. It had a rectangular shape and measured 220' x 60' x 21' tall. Columns were evenly spread at 20' on center. Figure 11 shows all that was left of the building. Block masonry walls were located at the ends of the building and were horizontally reinforced. As the tornado passed, the building appeared to be laterally displaced toward the west. The masonry walls failed and the building collapsed. Figure 12 is a view of the building after it was rebuilt in the same manner as before the tornado.



Figure 11. Remains of the Warehouse-Admixture building which was totally destroyed by the tornado



Figure 12. View looking north of Warehouse-Admixture building as rebuilt.

Office Building

The office building also has a rectangular shape which measures 100' x 50' x 14' tall. Unreinforced face brick veneer was placed on the exterior of the building perimeter. As the tornado passed, the building was laterally displaced toward the south (Figure 13). Columns buckled and the building collapsed. A 30' light standard initially located in front of the building broke off at the base and was transported southward approximately 100 feet. Figure 14 shows the Office building as rebuilt.



Figure 13. Damage to the Office building looking north. Note position of light standard.



Figure 14. View looking northwest of the Office building as rebuilt.

Tool Building

The Tool building was almost square-shaped measuring 80' x 70' x 25' tall. As the tornado approached, the west side of the building became the windward face. Several punctures in the short metal wall resulting from flying debris were noted. The overhead debris on the west side buckled inward allowing the wind to enter the southern portion of the building (Figure 15). Subsequently, the south wall fell outward and the overhead doors on the east side of the building buckled outward. Figure 17 is a view of the Tool building after it was rebuilt.



Figure 15. The Tool building was the largest building left standing after the tornado. View is looking north.



Figure 16. View looking northeast of the Tool building as rebuilt.

Shop Building

The Shop building was a rectangular shape, measuring 160'x 70'x 26' tall. As the tornado passed, the building was laterally displaced toward the east (Figure 17). Seven overhead doors along the west wall buckled inward. It appeared that the beams buckled out of plane as the column anchorages failed.

Two types of column anchorage failures were most common. Either the 7/8 inch diameter anchor bolts were pulled through the 1/4 inch column base plates (Figure 18) or the column base plate tore (Figure 19). Failure of the anchorages in this manner allowed the building to displace eastward and collapse.



Figure 17. View looking east of the remains of the Shop building.



Figure 18. Example of column anchorage failure in the shop building. The anchor bolts pulled through the column base plate as the column was uplifted.



Figure 19. Example of column base plate tearing in the Shop building

Truck Wash Building

The Truck Wash building was rectangular in shape, measuring 100'x 44'x 27' tall. Results of the damage survey show that the building was on the northern side of the tornadic winds. As the tornado passed, the building was displaced northward (Figure 20). An empty tank and supply building which were adjacent to the Truck Wash building had minor damage. A light standard found in front of the building was displaced from approximately 100 feet away. Figure 21 is a view of the Truck Wash building after it was rebuilt.



Figure 20. View looking east of damaged Truck Wash building.



Figure 21. View looking west of Truck Wash building as rebuilt.

Conclusions

At least eight tornadoes occurred from a super cell thunderstorm near Pampa, Texas on May 19, 1982. Most of the tornadoes occurred in open country and damage was minimal. The second and fourth tornadoes were responsible for causing most of the damage.

A summary of tornado characteristics including the F-scale rating is shown in Table 1. Five of the eight tornado paths were surveyed by the Institute of Disaster Research and F-scale ratings were assigned. F-scale ratings of the other three tornadoes were obtained from newspaper accounts of light damage reported.

From the analysis of the damage, it can be conclude that:

1. The highest intensity of damage observed was F-3. Associated wind speeds could have been higher since the tornado struck few buildings.
2. Failure of the prefabricated metal buildings resulted when the beams buckled laterally and the column base plates failed.

From storm observations, it can be concluded that:

1. The first and fifth tornadoes were anticyclonic. This supports the contention that anticyclonic tornadoes do indeed exist.
2. Stronger surface winds were encountered each time the eastern periphery of the updraft passed. More observation is needed to better understand the role of these wind speed maxima in severe storm structure.
3. The rear flank downdraft was an important factor in occluding the updraft which led to the birth and demise of the cyclonic tornadoes.

References

- Fujita, T.T. (1971). *Proposed Characterization of Tornadoes and Hurricanes By Area and Intensity*. SMRP Research Report 91, University of Chicago, 15pp.
- Marshall, T. and McDonald, J.R. (1982). "An engineering analysis of the Grand Island tornadoes," *Preprints, 12th Conference on Severe Local Storms*, San Antonio, TX, 293-296.

Table 1
Tornado Summary

| Tornado Number | Touchdown Time (CDT) | Dissipating Time (CDT) | Path Length (mi) | Path Width | F-Scale Rating |
|----------------|----------------------|------------------------|------------------|------------|----------------|
| 1 | 5:58 | 6:00 | 0.5 | 50 yds | F0 |
| 2 | 6:23 | 6:45 | 2 | 1/3 mi | F3* |
| 3 | 6:45 | 6:55 | 1.5 | 1/3 mi | F2* |
| 4 | 6:53 | 7:15 | 4 | ½ mi | F3* |
| 5 | 7:09 | 7:10 | 0.5 | 20 yds | F0* |
| 6 | 7:12 | 7:45 | 6 | 1 mi | F2* |
| 7 | 7:50 | 8:00 | 1 | 1/3 mi | F1 |
| 8 | 8:03 | 8:04 | 0.25 | 20 yds | F0 |

*Tornado paths surveyed.