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A SEVERE WEATHER CLIMATOLOGY FOR THE NWSO MIDLAND, TEXAS, COUNTY WARNING AREA

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1. Introduction

As a result of National Weather Service (NWS) Modernization and Associated Restructuring, the Midland-Odessa NEXRAD Weather Service Office (hereafter, NWSO Midland) has seen its County Warning Area (CWA) increase to include a large portion of southwest Texas between the Pecos and Rio Grande Rivers, as well as two additional counties to the east (Reagan and Scurry), and one additional county (Eddy) in New Mexico (Figs. 1 and 2). This represents an 80 percent increase in the size of the Midland CWA from the WSO's pre-modernization CWA. Encompassing over 50,000 mi^2, the Midland CWA is now the second largest in the NWS Southern Region. A variety of topographic features and climatic regimes are contained within this CWA, which likely ranks as among the most diverse found in the Southern Region.

Providing severe thunderstorm, tornado, and flash flood warnings continues to be the primary task for the NWSO staff. A severe thunderstorm is defined as a storm that produces wind damage or wind gusts of at least 50 kt, tornadoes, or hail with a diameter of at least 3/4 in. A flash flood is defined as a flood caused by heavy or excessive rainfall within a short period of time, generally less than 6 hours.

Forecasters should be able to recognize climatologically favored times and areas for severe weather within their CWA. For this reason, a local study of NWSO Midland's severe weather climatology was initiated at the same time the new CWA was acquired in October, 1995.

2. Preliminary considerations

a) Population distribution

Population distribution varies considerably among the counties within the CWA (Fig. 2). The United States Census Bureau reported 1990 county populations ranging from 123,620 persons in Ector County to 110 persons in Loving County. The greatest population concentration is within the cities of Odessa and Midland, in Ector and Midland Counties, respectively. The next most populated counties are Eddy and Lea in New Mexico. Generally speaking, population densities within the CWA decrease as one moves south toward the Rio Grande River.

With three national parks and one national forest located in the extreme southern and western portions of the CWA, the number of people in these areas can vary substantially throughout the year. For example, the Big Bend National Park in the extreme southern CWA reported 297,000 visitors in 1995, with the majority visiting in the months of March, November and December (personal communication, National Park Service, Big Bend National Park, 1997). May through August has the fewest number of visitors; significantly, this is the time most severe weather occurs. Reports of severe weather from this far southern area can therefore be especially difficult to obtain. Dissemination of warnings and other information for these areas is also difficult since these National Parks are 150-200 miles from Midland, beyond the effective ranges of Midland's NOAA Weather Radio and WSR-88D.

b) Topography

The new Midland CWA contains especially diverse topography. Mountains in the western CWA result in dramatic elevation changes with distance. Guadalupe Peak, the highest point in Texas at 8751 ft, is located in the far western CWA near the New Mexico border. The lowest elevations of 1800 ft or less are found in the Rio Grande Valley in the far southeast CWA. Generally, elevations increase from southeast to northwest across the CWA.

Another notable topographic feature in the CWA is the Caprock Escarpment (Fig. 1). The escarpment is marked by an abrupt rise in elevation that separates the High Plains of the northwestern CWA from the Low Rolling Plains of the extreme eastern parts of the CWA. It is likely that this escarpment helps create a favorable environment for severe weather (Doswell 1982). Terrain is generally flat on the High Plains, but it becomes more varied toward the canyons near the Rio Grande and east into the Low Rolling Plains.

3. Data

Most data for this study were extracted from the database maintained by the NCEP Storm Prediction Center (SPC) - formerly the National Severe Storms Forecast Center - using the CLIMO program described by Vescio (1995). Severe reports from the years 1955 to 1994 (excluding 1972) were plotted, except for the tornado reports, which are from 1950 to 1994. This same data set, excluding the years 1992 through 1994, was used by a computer program called SVRPLOT (Hart 1993) to plot some of the figures used in this study.

As noted in other severe weather climatology studies, there are many non-meteorological factors that can skew severe weather data (e.g., Hales and Kelly 1985, Hales 1993). Figures 3 and 4 illustrate how the density of significant severe weather reports (i.e., hail at least 1.75 inches in diameter and tornadoes of at least F1 intensity on the Fujita scale) is related to the population densities seen in Fig. 2. Notice the clustering of reports generally north of the Pecos River and in the New Mexico counties of the Midland CWA. The sparsity of reports in the thinly populated counties to the south is also clear. It is very difficult to eliminate such biases, and for this study the data were generally analyzed on a temporal basis. Figures for severe wind, severe hail and tornadoes were plotted by year, month and hour of the day. Variations in hail size and tornado intensity were also noted in some of the figures.

4. Severe weather climatology

a) Yearly trends in severe weather reports

An inspection of the annual distribution of severe weather reports (Figs. 5-8) reveals a general upward trend in the number of severe weather reports through the 1980s into the mid 1990s. This trend can be explained partially by the fact that much of the CWA had a significant increase in population during the 1970s and early 1980s, due to a boom in the local oil industry. As population density increased, public severe weather awareness likely improved due to an increase in NWS outreach programs. Also, reports of severe weather have been more aggressively pursued in recent years thanks to the development of a SKYWARN Spotter program and a severe weather warning verification system.

It is also hypothesized that the data were affected by unusually active severe weather seasons in the El Nino years of the early 1990s (Trenberth and Hoar 1996). In fact, 47 percent of all severe hail reports, 33 percent of all damaging wind reports, and 18 percent of all tornado reports were received from 1990 to 1994.

Other noteworthy trends are apparent in the annual tornado data. Although the number of reported tornadoes has dramatically increased in recent years, a close inspection of Fig. 6 reveals that the proportion of strong or violent tornadoes (F2 or greater on the Fujita scale) has decreased since the 1960s. During the first 15 years of the period (1950-1964), the proportion of all reported tornadoes that were strong or violent was 22 percent, but for the entire period, only 12 percent of the documented tornadoes were given at least a strong rating. This is likely another reflection of increasing population and improved tornado awareness and reporting with time; that is, only the more destructive tornadoes were likely observed and reported in earlier years (Ostby 1993).

Ironically, despite a decreasing proportion of strong or violent tornadoes with time, the only documented violent tornadoes (F4 or F5) during this period occurred in the later years. The most deadly was an F4 tornado that struck Saragosa, Texas on May 22, 1987. Thirty people were killed and 130 were injured. Another F4 tornado struck near the towns of Girvin and Iraan on June 1, 1990. This tornado, known as the Bakersfield Valley tornado, killed two people and injured 21. Fig. 9 illustrates the rarity of violent tornadoes recorded within the CWA.

b) Monthly distributions of severe hail, damaging winds and tornadoes

All severe weather, including tornadoes, is most common during May and June (Fig. 10). With the CWA at a subtropical latitude, the Bermuda High usually develops far enough west to influence the CWA by mid-spring and hold the surface dryline to the lee of the mountains. This maintains deep Gulf moisture through the afternoon and into the evening across most of the CWA. In fact, 66 percent of all tornado events, 66 percent of severe hail events, and 52 percent of damaging wind events occur during May and June (Figs. 11-13).

The most common severe weather event in the Midland CWA is hail, with 1229 events reported during the months of May and June, compared to only 580 damaging wind events during this time.

May is the most active month for severe hail reports (Fig. 12), while June is the most active month for severe wind reports (Fig. 13). This may reflect stronger upper-level dynamics and cooler mid-level temperatures in May, which would aid hail growth. By the end of June, mid-level temperatures increase and the atmosphere becomes dry adiabatic in the lower levels, which sets the stage for more damaging wind events.

It is interesting to note in Fig. 10 that the late summer-early fall "tail" in the severe weather distribution is more pronounced than the late winter-early spring "tail." It is in late summer and early fall that the atmosphere over the CWA loses its strong mid-level capping inversion, homogenous surface features, and weak westerly mid-level flow, and westerly mid-level troughs and associated Pacific cold fronts return to the area, maintaining the ability to generate severe weather.

c) Hourly distributions of severe hail, damaging winds and tornadoes

When all severe weather reports are combined, the hourly distribution (Fig. 14) is remarkably uni-modal. Peak occurrence is centered around 1800 CST, with only a hint of a secondary maximum around sunrise. When the hourly distributions are separated into warm and cool seasons (March through August, and September through February, respectively) some common features are noted. Figures 15-20 all indicate relative maxima in severe weather occurrences near the time of maximum diurnal heating, with most events occurring between 1700 and 2000 CST.

By comparing the vertical scales of the warm and cool season figures, one can see that far more severe weather occurs during the warm season than the cool season. There is a very strong correlation between severe weather occurrence and time of day in the warm season, which leads to the unsurprising conclusion that atmospheric destabilization caused by diurnal heating is a very important ingredient for severe weather in the spring and summer months. Severe weather is most common around 1800 to 1900 CST in the warm season. Cool season data also indicate an afternoon and early evening maximum, but the distribution of severe weather events is somewhat more spread out over the day. This likely reflects more of a dependence on dynamically driven systems for cool season severe weather. For example, the cool season tornado events seen in Fig. 16 support this idea by showing a nearly uniform frequency of tornado occurrence between 1200 and 2200 CST.

5. Severe weather phenomena unique to the Midland CWA and the high plains region

a) Dry microburst wind events

A special type of damaging convective wind found in the High Plains, and consequently part of the CWA, is the dry microburst. A subtropical jet stream usually located near the CWA during the warm season is often able to provide a layer of moisture to the mid or upper levels of the atmosphere. This moist layer aloft, combined with a deep dry adiabatic layer above the surface, sets the stage for high-based thunderstorms. A recent dry microburst study for the CWA using data from 1985 to 1995 (Murdoch 1997) indicates dry microburst storms are most common in the warm season during the late afternoon and early evening hours. This supports the finding in this study that diurnal heating plays a very significant role in warm season severe weather events.

b) Giant hail events

Another notable aspect of the severe weather found in the High Plains of the United States is the relatively high frequency of giant (greater than 2.75 in) hail. This usually occurs when an elevated mixed layer of dry air is advected over the region from the higher Mexican plateaus under mid-level southwesterly flow conditions (Carlson, et al. 1983). When this elevated mixed layer, with its high temperature lapse rates, overlays a relatively shallow surface layer of moist air advected northwest from the Gulf of Mexico, very unstable atmospheric conditions develop that result in strong thunderstorm updrafts capable of producing giant hail. The northwest elevation gradient over the CWA can often result in a dryline, which is a sharp surface moisture gradient separating moist Gulf air from the hot dry air of the interior desert regions. It is well established by other studies (e.g., Rhea 1966) that the dryline is a favored location for thunderstorm development. Many of these storms, most notably the "dryline supercells," are often prodigious giant hail producers.

c) Enhanced storm severity due to local terrain effects

It is noteworthy that the two previously mentioned violent tornadoes in the Midland CWA occurred in roughly the same geographical area. This may be more that just mere coincidence. Szoke and Augustine (1990) and more recently Bosart, et al. (1996) have documented cases where it is believed that complex terrain features may have helped create more favorable environments for severe storm evolution and maintenance.

Figure 1 shows some of the more prominent terrain features in southwest Texas. Note the area located in southwest Reeves County (Fig. 21). This area is bounded on the west by the Davis Mountains and on the south by the Barrilla Mountains. Farther to the southeast are the Glass Mountains. Under southeasterly low-level flow, observations from Fort Stockton, which is located in central Pecos County, have exhibited more easterly winds than other observing sites across West Texas. It is possible that the backing of the low-level winds in this area results from the local terrain orientation. In convective situations, this would generally create a better directional wind shear profile for any storms that do develop, thereby creating larger values of storm-relative environmental helicity. The fact that the town of Saragosa has been virtually destroyed by tornadoes on three separate occasions suggests that local terrain may significantly affect severe weather.

Many times in late May or June when synoptic scale ridging begins to develop over the mountainous terrain of the western United States, the low-level airmass becomes highly unstable over West Texas. At this time it is not uncommon to see 700 mb temperatures in the 10-15 C range, which will cap the convectively unstable atmosphere. Over the higher elevations of southwest Texas, the 700 mb level is part of the boundary layer, where the combination of diabatic heating and the upslope low-level wind component can overcome a significant cap. On numerous occasions, large isolated supercells have developed in this area under these conditions with little more than flat cumulus convection observed over the remainder of West Texas.

6. Other hazardous weather phenomena

Various topographic features contribute to additional weather hazards within the Midland CWA. The mountainous terrain of the western CWA enhances flash flood potential and allows locally strong channelled winds.

a) Flash flooding

Beyond the mostly flat high plains of the northern CWA, increasingly rocky and sloped terrain is found south of the Pecos River, which considerably increases the threat of flash flooding. The far southeastern CWA consists of canyons that have resulted in very significant flash flooding. One notable example occurred on June 11, 1965, when an estimated 15 ft high wall of water inundated the city of Sanderson (Bomar 1995). This city has experienced at least three other major floods since 1935, although a newly built system of dams and levees should make Sanderson less susceptible to flooding in the future.

A survey of Storm Data from the 1980s into the mid-1990s reveals that flash flood fatalities have occurred mostly in the rugged terrain of the southwest CWA. Recent deaths occurred along the Rio Grande near Redford, and in Alpine, which is nestled in the Davis Mountains. This is not the only part of the CWA prone to flash flood deaths. A fatality in 1986 occurred in Upton County a significant distance north of the Pecos River (NOAA 1986).

Within the Midland CWA some of the most rugged terrain around the Pecos River is found in Eddy County, New Mexico. The Guadalupe Mountains in far western Eddy County account for a substantial east-west gradient in the terrain. It is not uncommon for thunderstorms to drop heavy rain some 40 to 50 mi upstream of Eddy County, resulting in flash flooding hours later over 100 mi east of where the rain fell. Rugged and sloped terrain also exists along the southern portion of the Pecos River from near Sheffield south through Langtry. A particularly large flood occurred along the Rio Grande in 1954 as a result of runoff from the Pecos River, resulting in a discharge of over 900,000 cfs at Comstock!

Rocky terrain and numerous small tributaries also make flash flooding possible along the Rio Grande. The most significant threat of flooding along the Rio Grande comes from tropical rains that occur in the Rio Conchos River basin southwest of Presidio, and from reservoir releases that are conducted by Mexican authorities. The chance for flash flood fatalities is increased because the Big Bend National Park is adjacent to the Rio Grande, and hikers, campers and canoers can be numerous at certain times of the year.

b) Channelling of winds through the Guadalupe Pass

A frequent hazardous phenomenon in the Guadalupe Mountains of western Culberson County is the channelling of westerly winds through the Guadalupe Pass, which is oriented in an east-northeast to west-southwest direction. High winds become commonplace through the Guadalupe Pass by early fall, with strengthening westerly flow aloft. Typically, winds through the pass will increase with the tightening of the 700 mb gradient and the passage of an associated mid-level trough. An extreme event occurred in January, 1996, when west winds gusted as high as 128 mph through the pass (NOAA 1996). East winds are also frequently channelled through the pass with the passage of a sufficiently deep cold front.

7. Summary

Severe weather within the county warning area of NWSO Midland shows several distinct trends. Most severe weather occurs during the months of May and June, with a small secondary maximum in hail occurrence noted in September and October. Severe hail events are most common in May, while severe wind events are most common in June. Severe weather showed a strong tendency to occur during the afternoon and early evening hours of the warm season, while the cool season had a more uniform distribution of severe weather occurrence among most hours of the day.

Annual data showed a marked increase in severe weather reports over the past decade. During these later years, a greater proportion of tornado and hail reports were minimally severe (i.e., F0-F1, and 0.75-1.75 in, respectively). Since severe wind events were not similarly categorized, it is not known if a similar trend exists with severe convective wind gusts.

Although it is acknowledged that terrain plays a significant role in the general evolution of weather across the CWA, it also appears that certain geographic areas such as the Caprock, the eastern range of the Davis Mountains, and Guadalupe Pass have an enhanced propensity for severe weather. This suggests that mesoscale terrain features within the CWA may affect the evolution of thunderstorms in some cases.

Variations in terrain also appear to play a role in concentrating flash flood hazards in the southern and western portions of the CWA, where rockier soils and greater variations in topography exist. Relatively flat terrain in the high plains makes flash flooding a less serious problem in the northern CWA.

By studying severe weather and flash flood climatologies, as well as topographic features, for the Midland CWA, one can become better acquainted with the unique forecast problems found within this diverse area. It is hoped that this severe weather climatology provides a general representation of severe weather trends within the local CWA, so that forecast and warning accuracy can continue to improve.

Acknowledgements

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References

Bomar, G. W., 1995: *Texas Weather*. University of Texas Press, pp. 68-69.

Bosart, L.F., Seimon, A., and Bracken, W.E., 1996: Supercells over complex terrain: the Great Barrington tornado of 29 May '95. Preprints, *Conf. on Weather Analysis and* Forecasting, Norfolk, Amer. Meteor. Soc., 391-394.

Carlson, T. N., S. G. Benjamin, G. S. Forbes, and Y.-F. Li, 1983: Elevated mixed layers in the regional severe storm environment: Conceptual model and case studies. *Mon. Wea. Rev.*, **111**, 1453-1473.

Doswell, C. A. III, 1982: The Operational Meteorology of Convective Weather Volume I: Operational Mesoanalysis. *NOAA Tech. Memo. NWS NSSFC-5*, Kansas City, MO., pp. III 61-III 64.

Hales, John E. Jr. and Donald L. Kelly, 1985: The relationship between the collection of severe thunderstorm reports and warning verification. Preprints, *14th Conf. on Severe Local Storms*, Indianapolis, IN, Amer. Meteor. Soc., 13-17.

Hales, John E. Jr., 1993: Biases in the severe thunderstorm data base: ramifications and solutions. Preprints, *13th Conf. Wea. Forecasting and Analysis*, Vienna, VA, Amer. Meteor. Soc., 504-507.

Hart, J. A., 1993: SVRPLOT: A new method of accessing and manipulating the NSSFC severe weather data base. Preprints, *17th Conf. on Severe Local Storms*, St. Louis, Amer. Meteor. Soc., 40-41.

Murdoch, Greg P., 1997: Forecasting Dry Microburst Potential Using the WINDEX. *Southern Region Topics.* SR/SSD 97-6.

National Oceanic and Atmospheric Administration, 1986: *Storm Data.* **28**, No. 10, National Climatic Data Center, Asheville, NC.

National Oceanic and Atmospheric Administration, 1996: *Storm Data.* **38**, No. 1, National Climatic Data Center, Asheville, NC.

Ostby, F. P., 1993: The changing nature of tornado climatology. Preprints, *17th Conf. on Severe Local Storms*, St. Louis, MO, Amer. Meteor. Soc., 1-5.

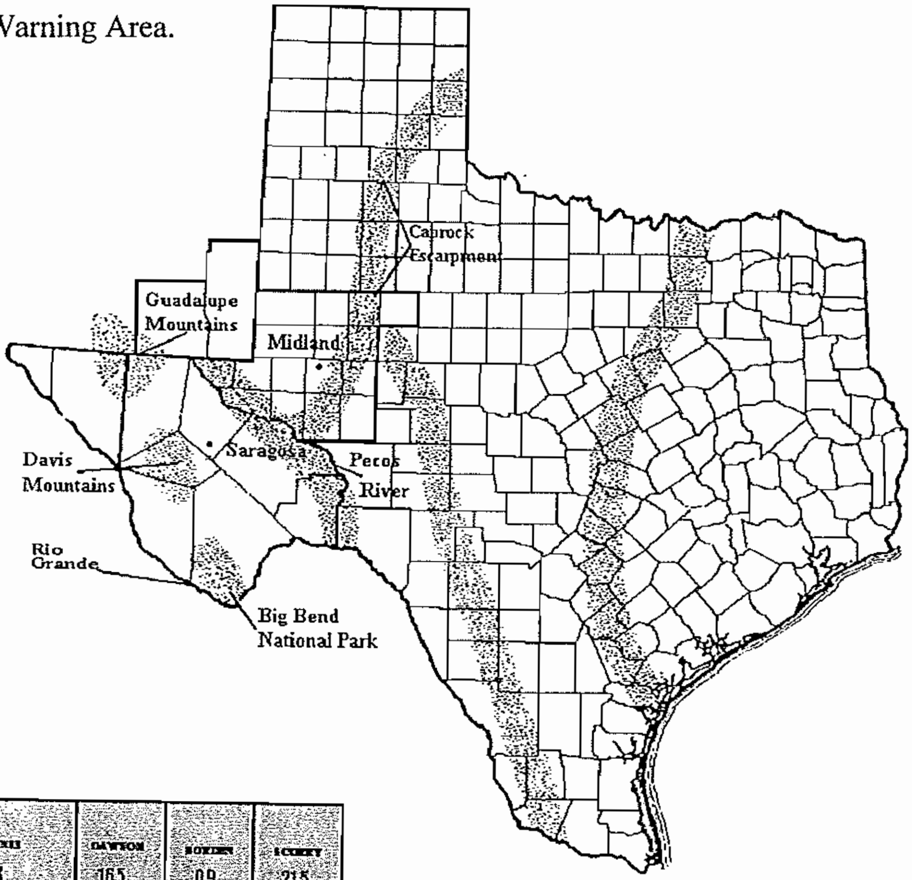
Rhea, J. O., 1966: A study of thunderstorm formation along drylines. *J. Appl. Meteor.*, **5**, 58-63.

Szoke, E.J., and J.A. Augustine, 1990: A decade of tornado occurrence associated with a mesoscale flow feature: The Denver Cyclone. Preprints, *16th Conf. on Severe Local Storms*, Alberta, Canada, Amer. Meteor. Soc., 554-559.

Trenberth, K. E. and Hoar, T. J., 1996: The 1990-1995 El Nino-Southern Oscillation event: Longest on record. *Geophysical Research Letters*, Vol. 23, No. 1, pp 57-60.

Vescio, M. D., 1995: CLIMO: Software to generate severe weather statistics for NWS County Warning Areas. NCEP, Storm Prediction Center, Norman, OK.

Figure 1. Significant geographical features of Midland's County Warning Area.



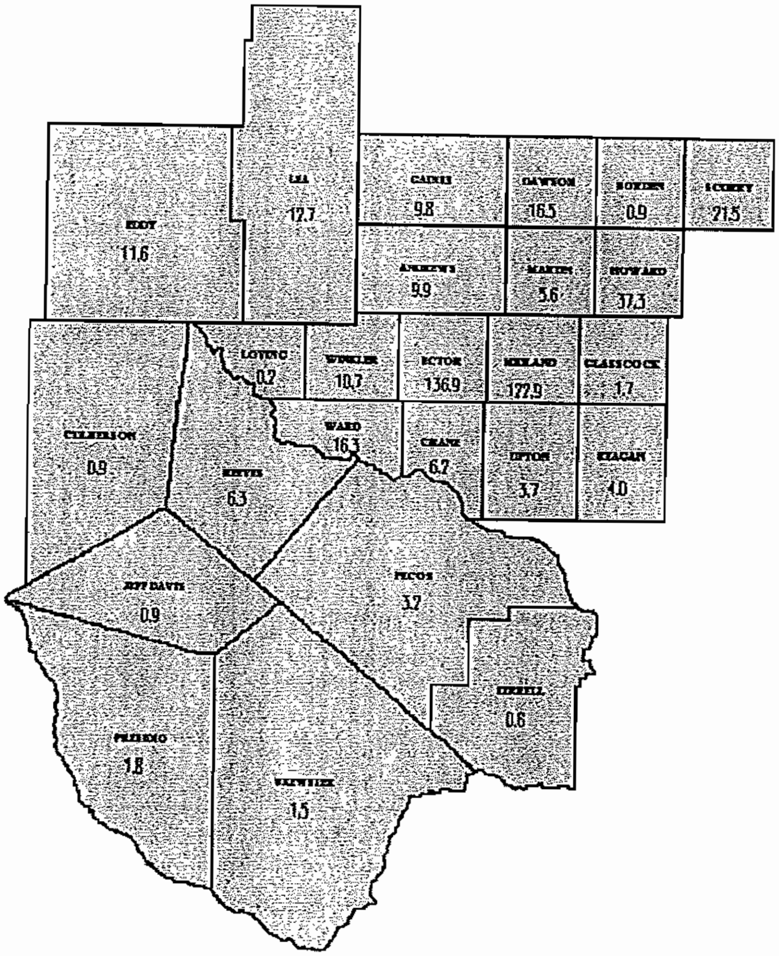


Figure 2. Population density distribution (people/sq. mi.) in Midland's County Warning Area.

Figure 3. Hail reports of 1.75" and greater, 1950 - 1991

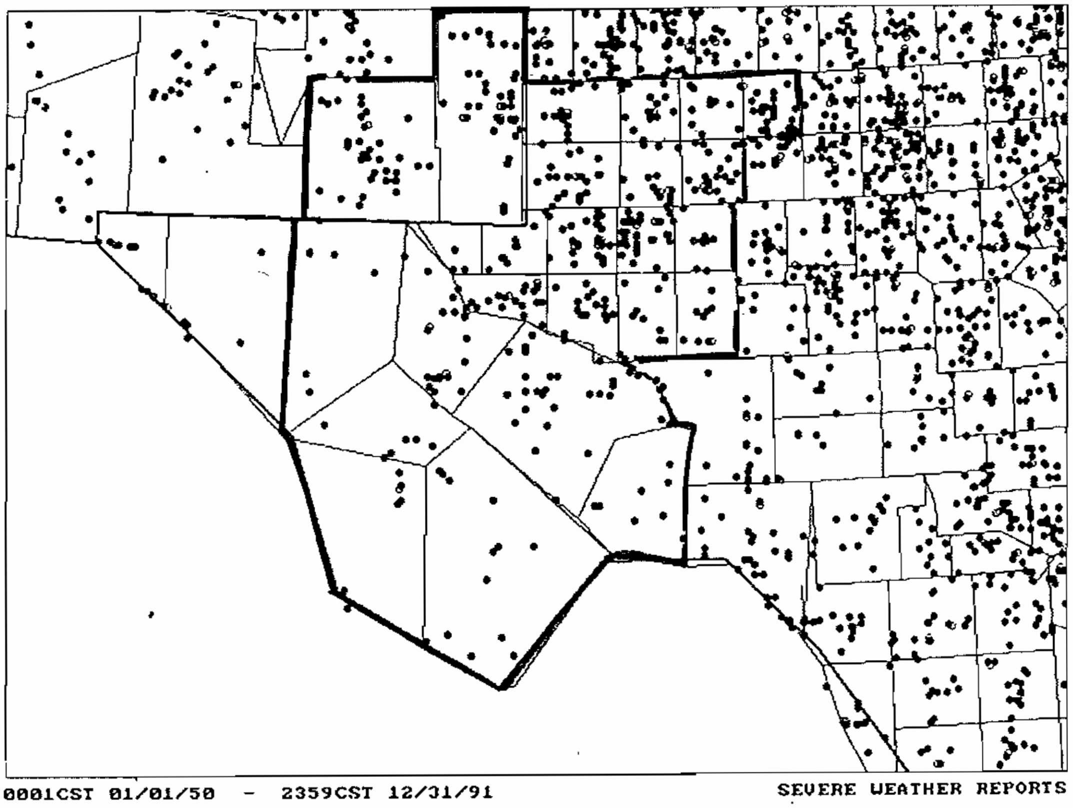


Figure 4. Tornado reports F1 and greater, 1950 - 1991

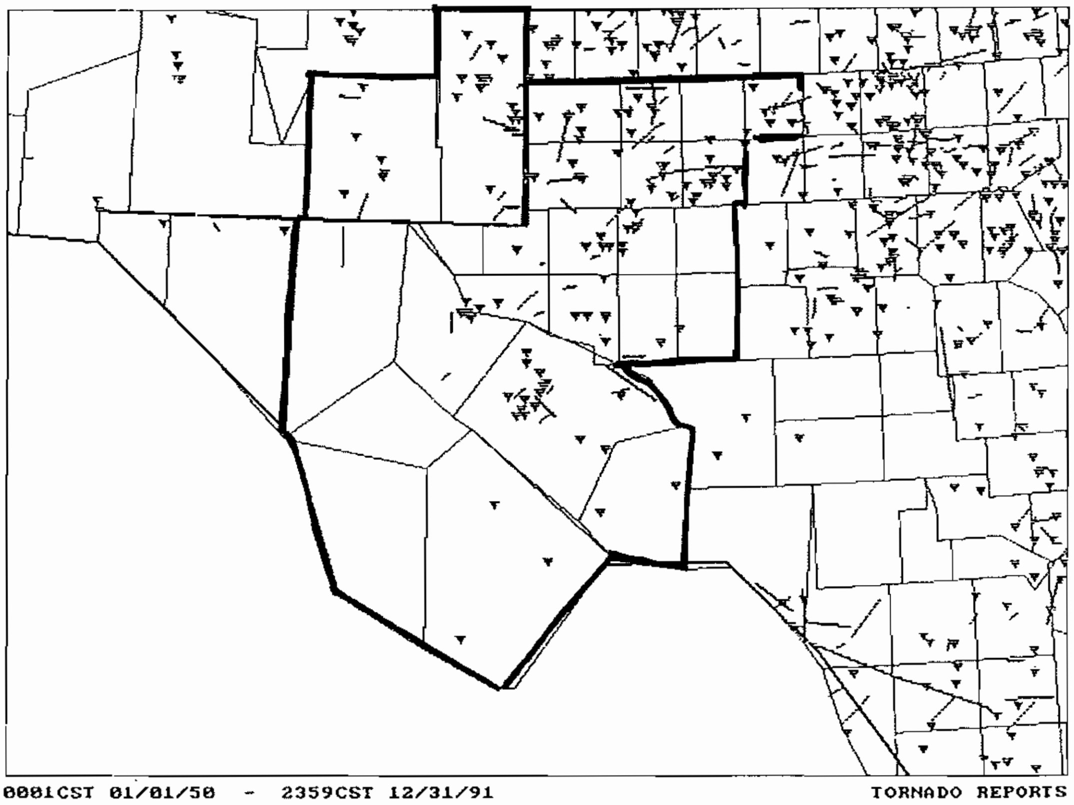
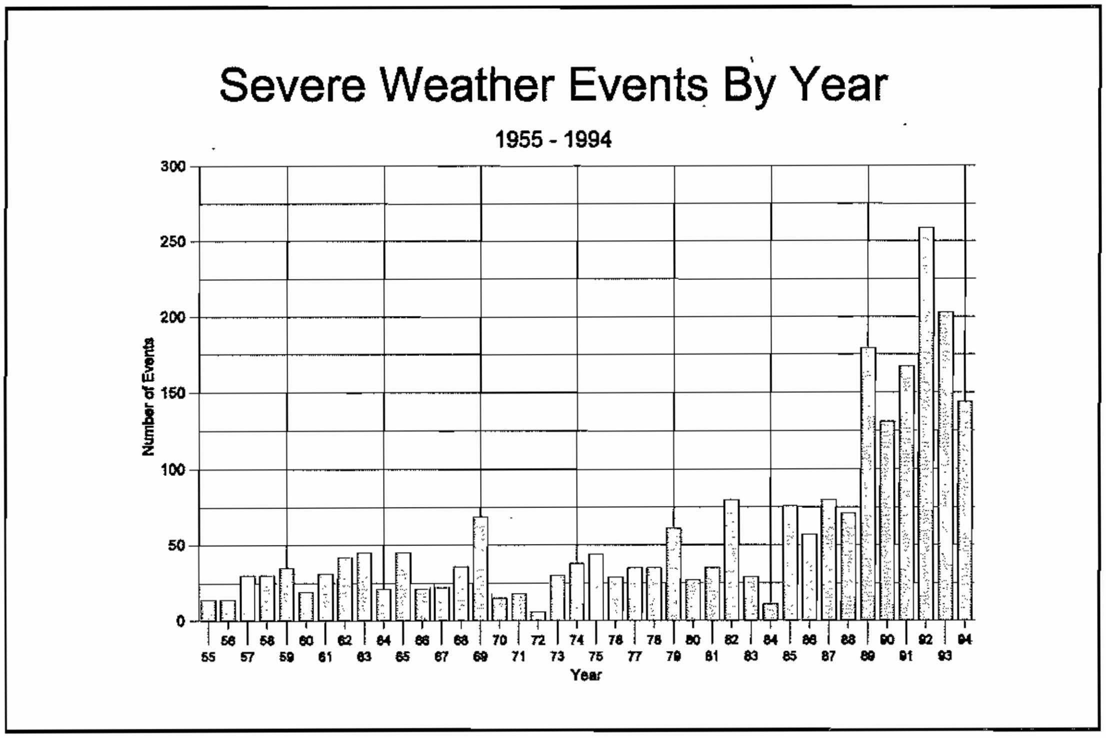


Figure 5



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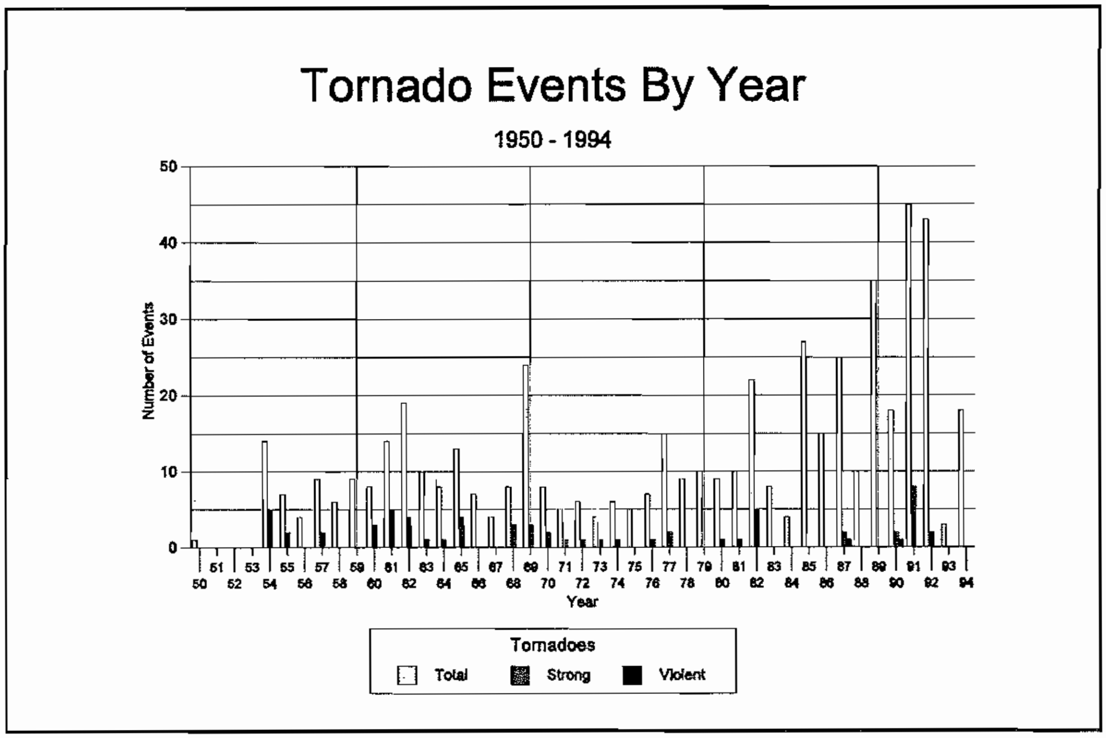

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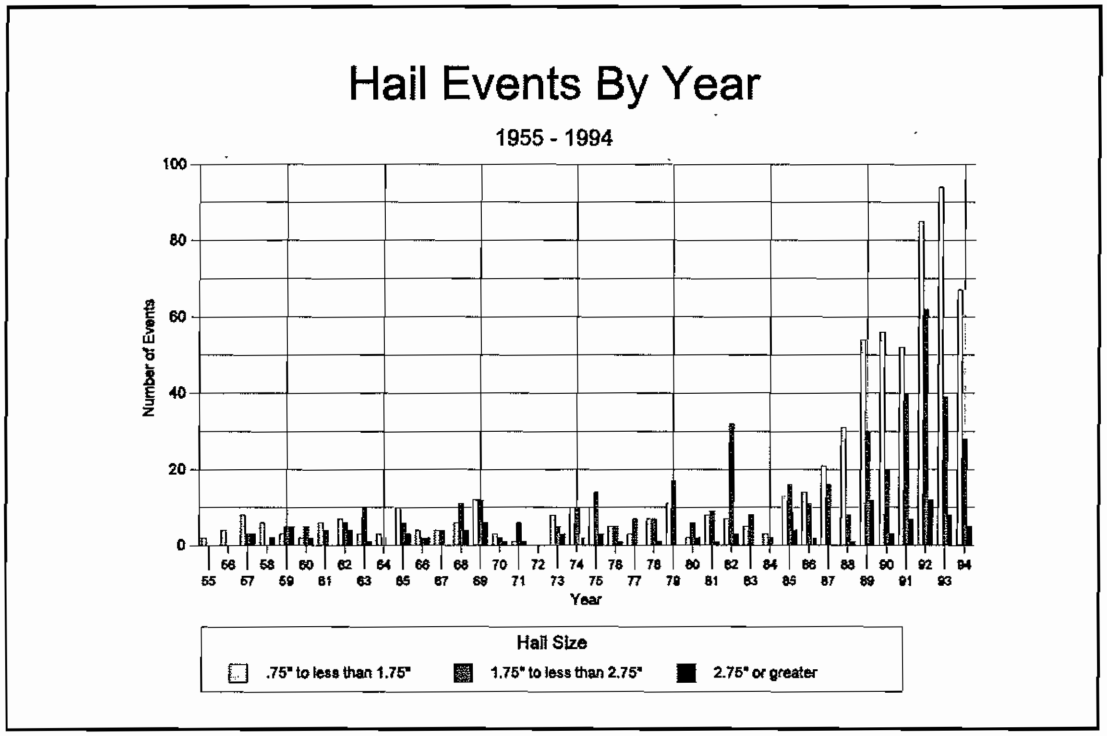

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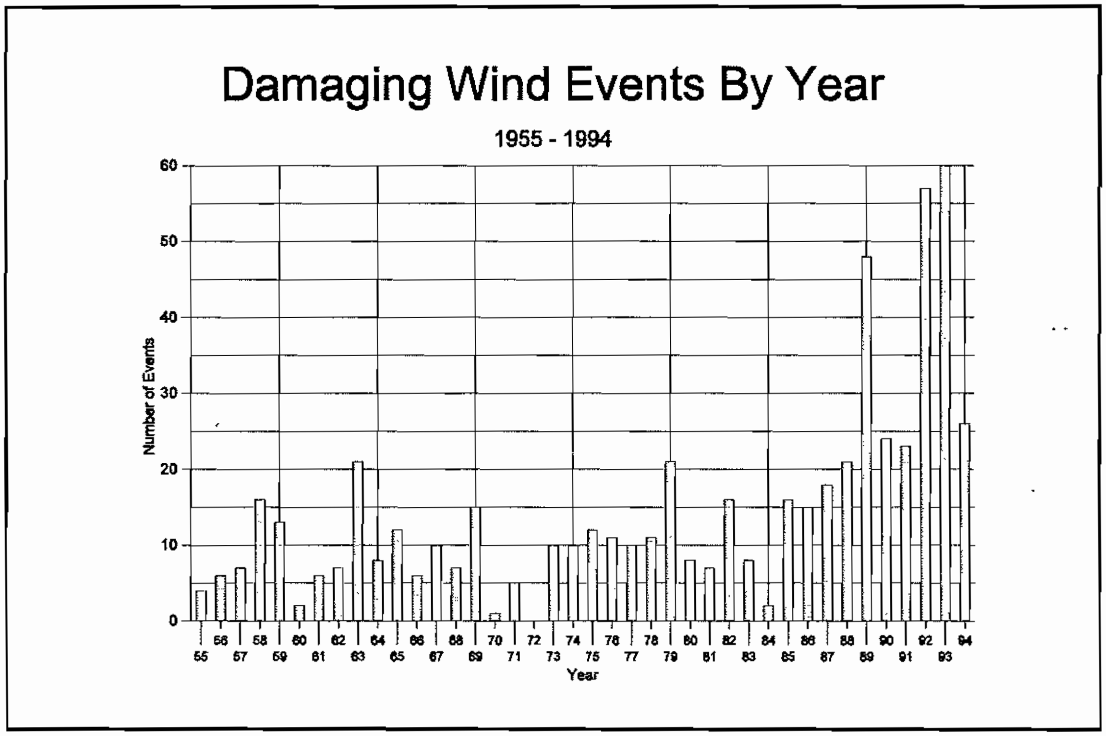

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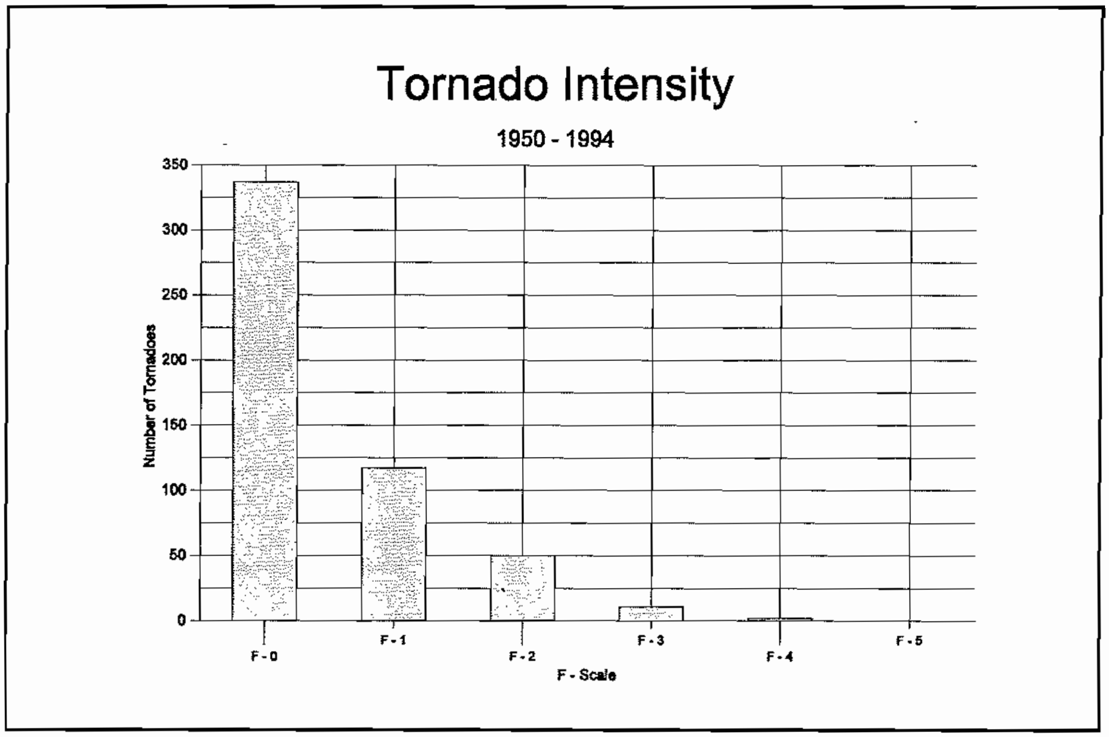


Figure 10

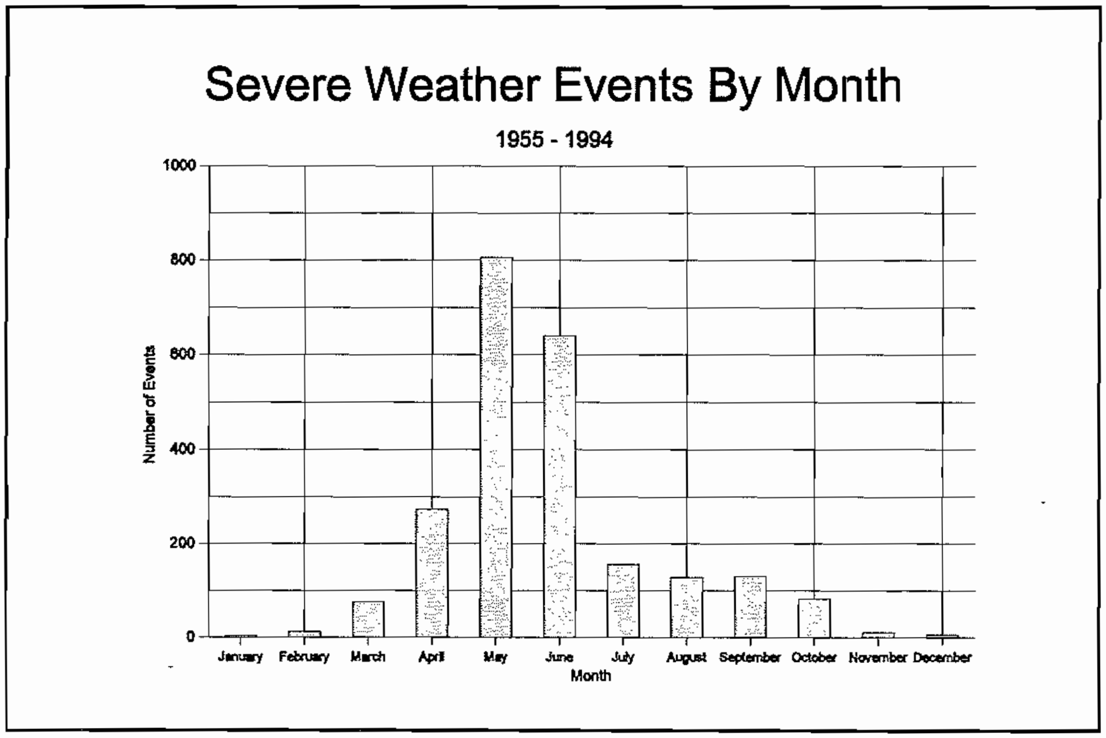


Figure 11

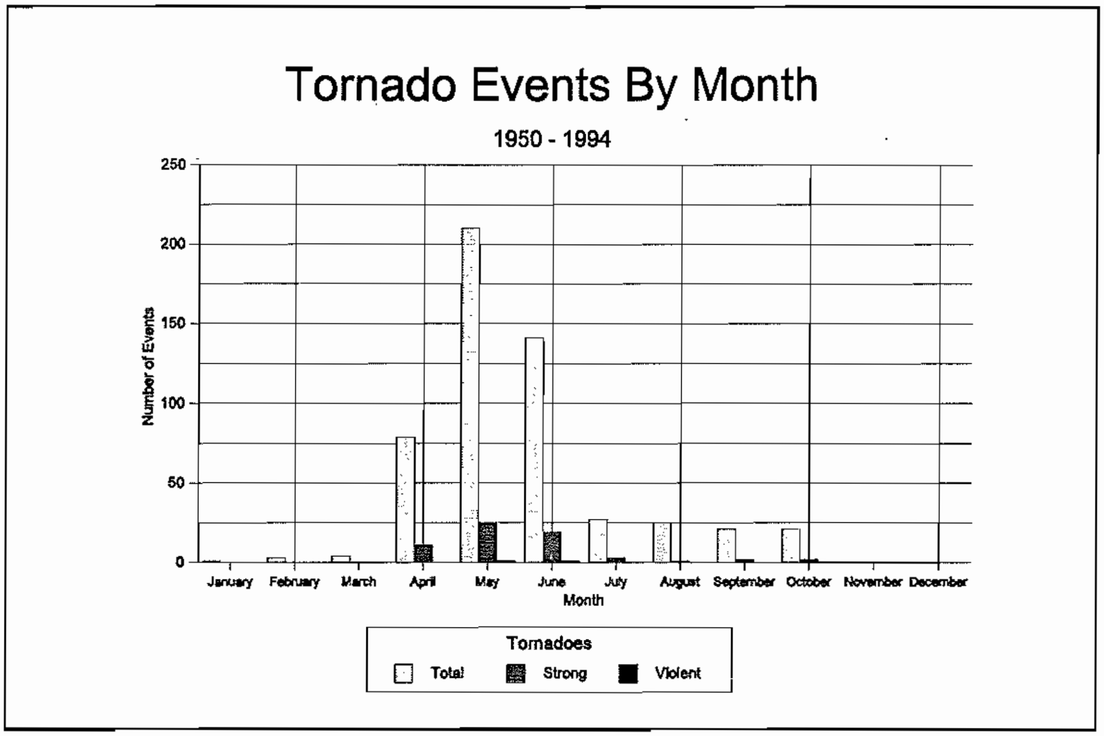
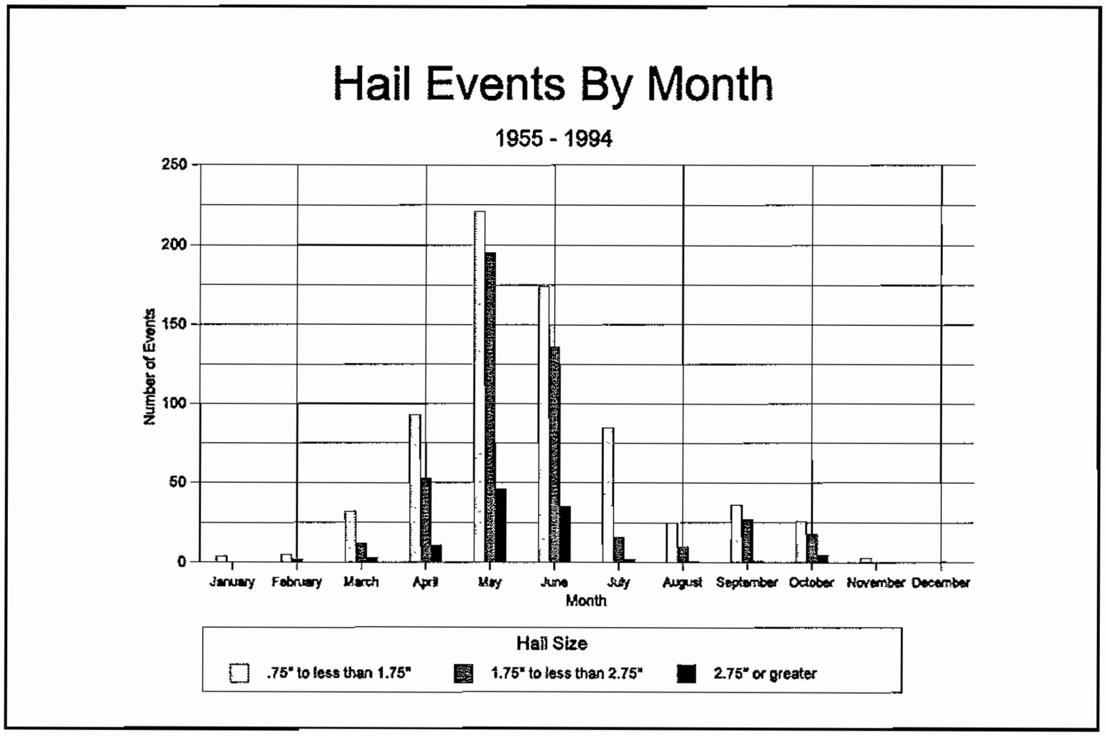


Figure 12



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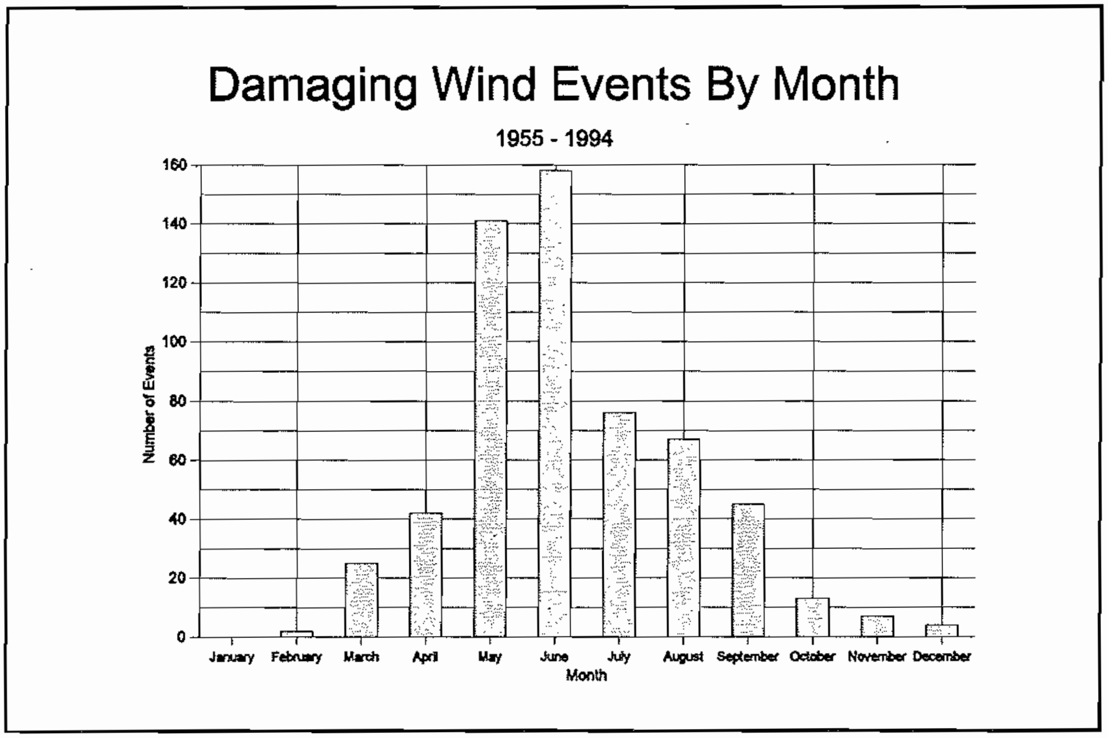

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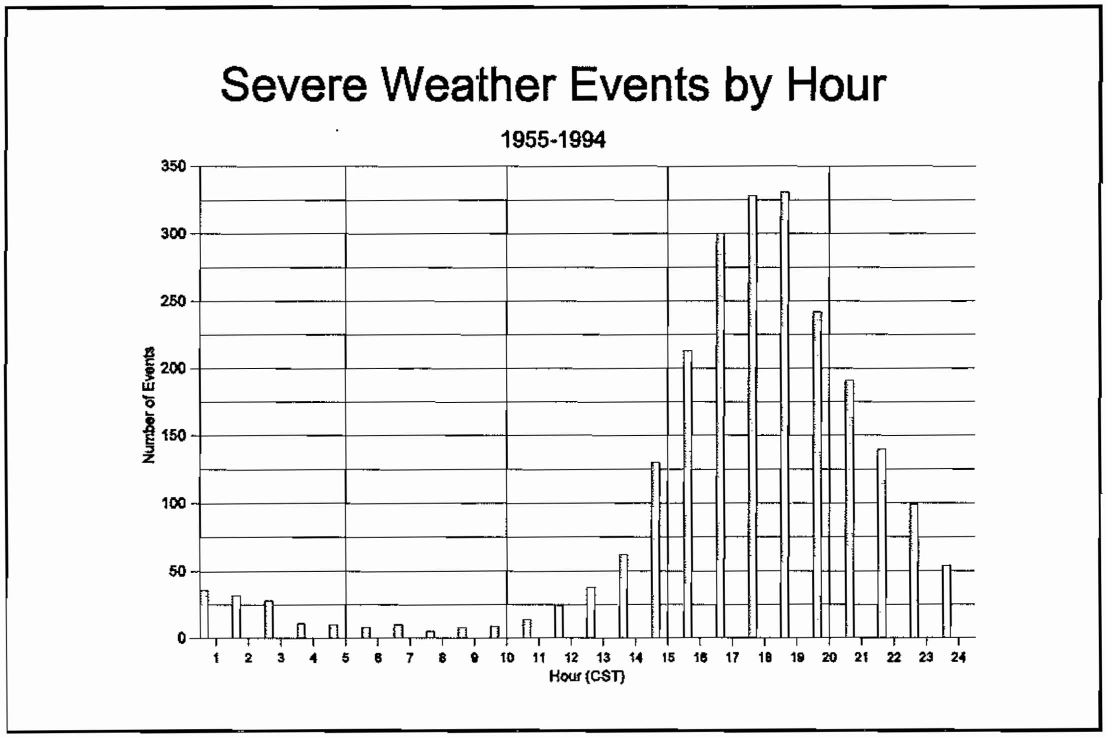


Figure 15

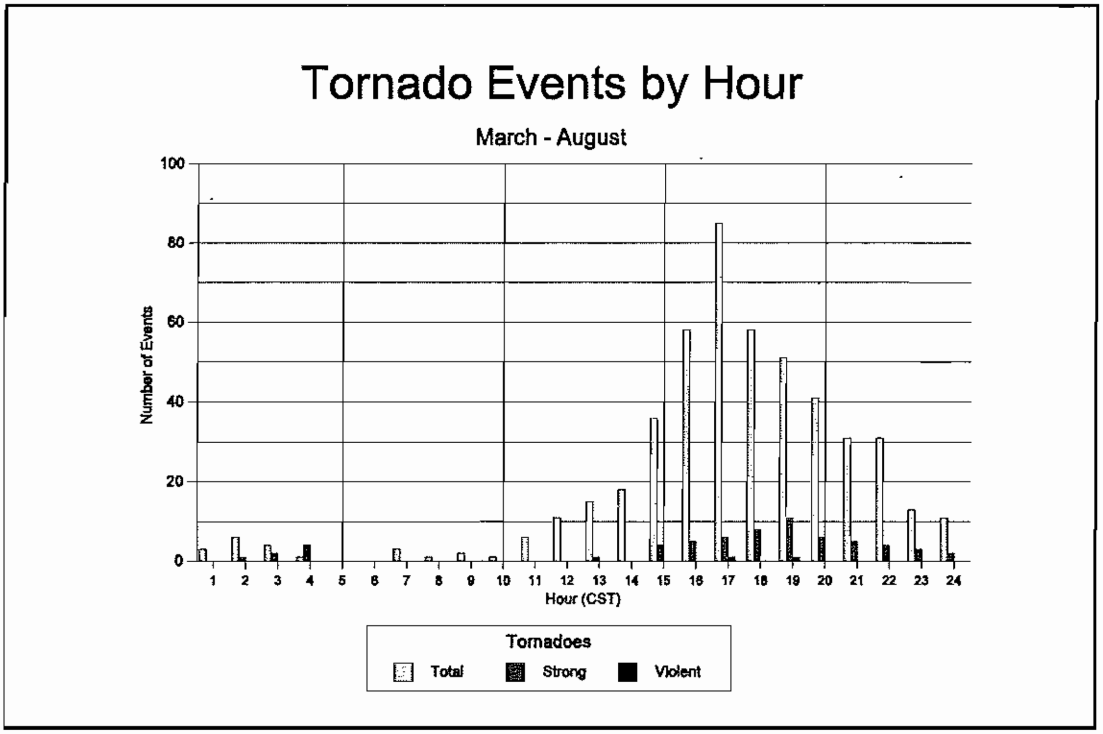


Figure 16

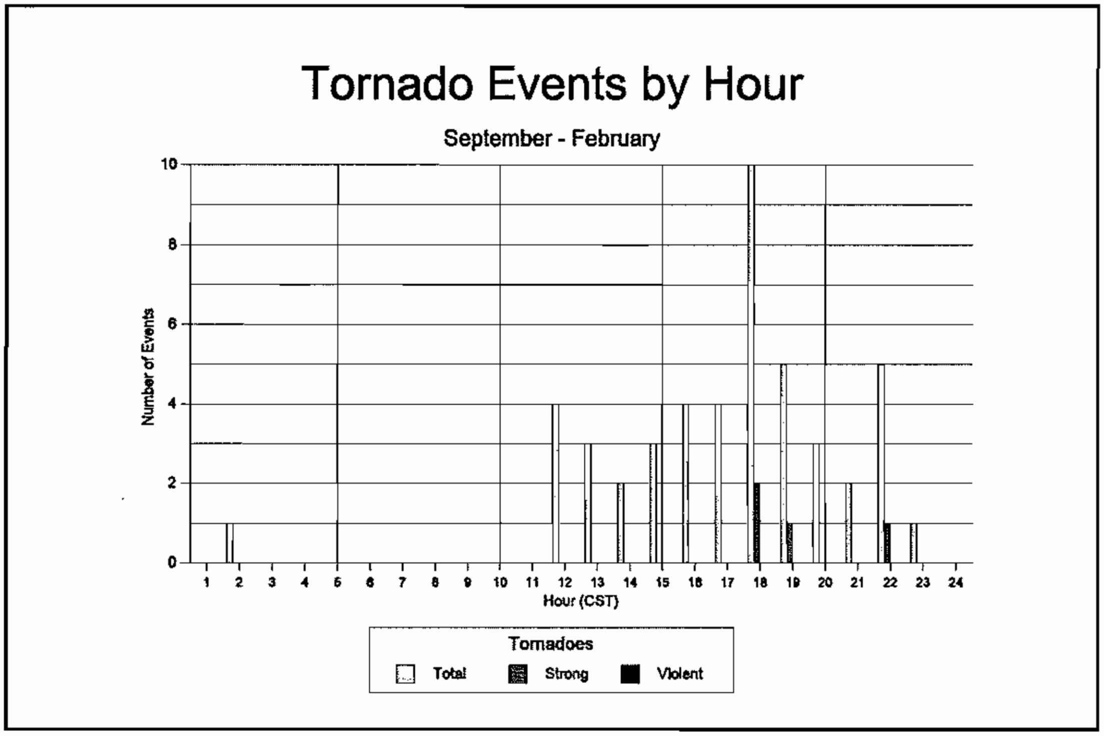
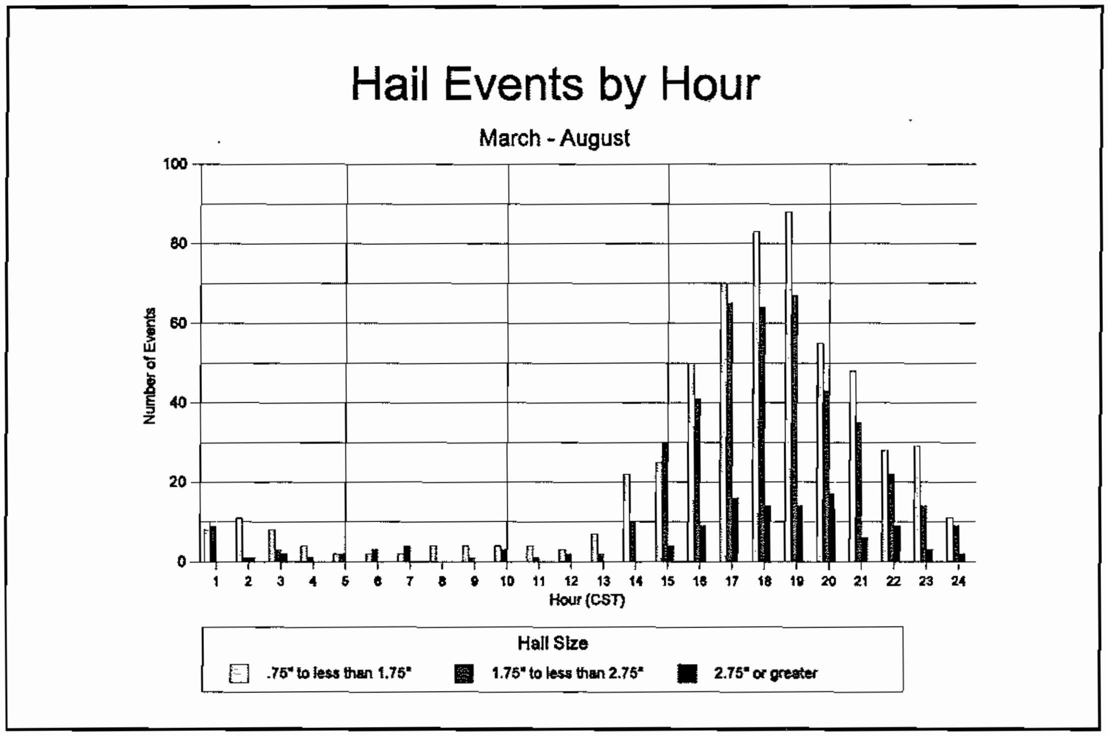


Figure 17



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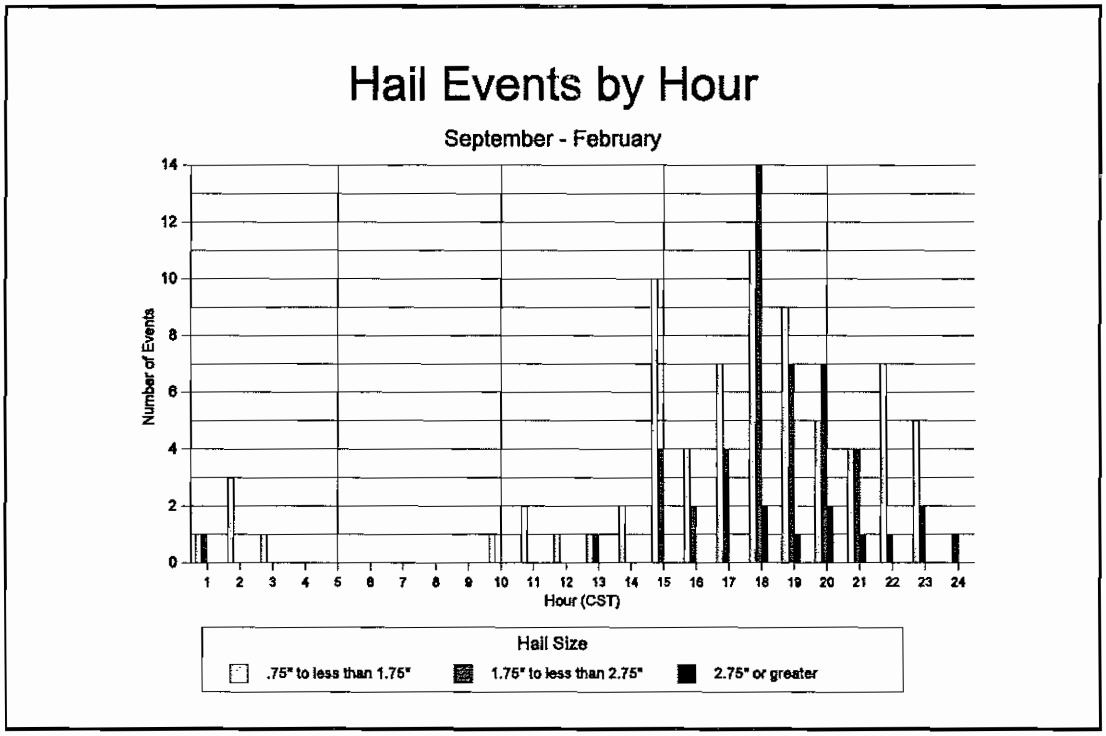
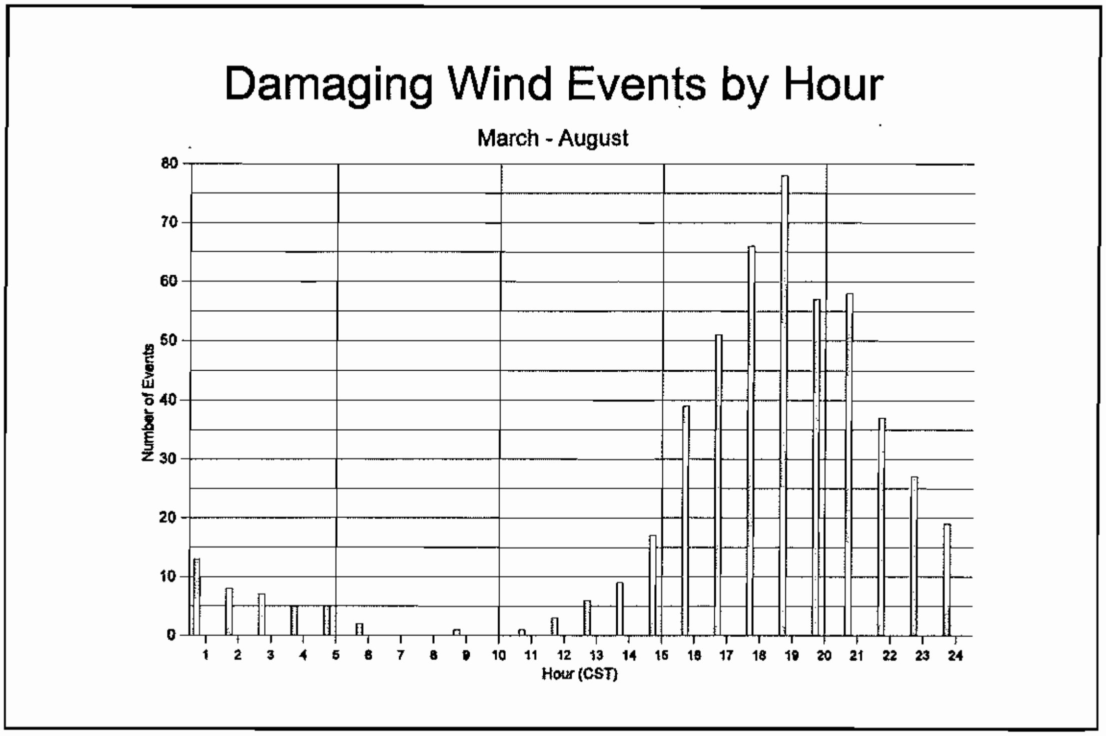


Figure 19



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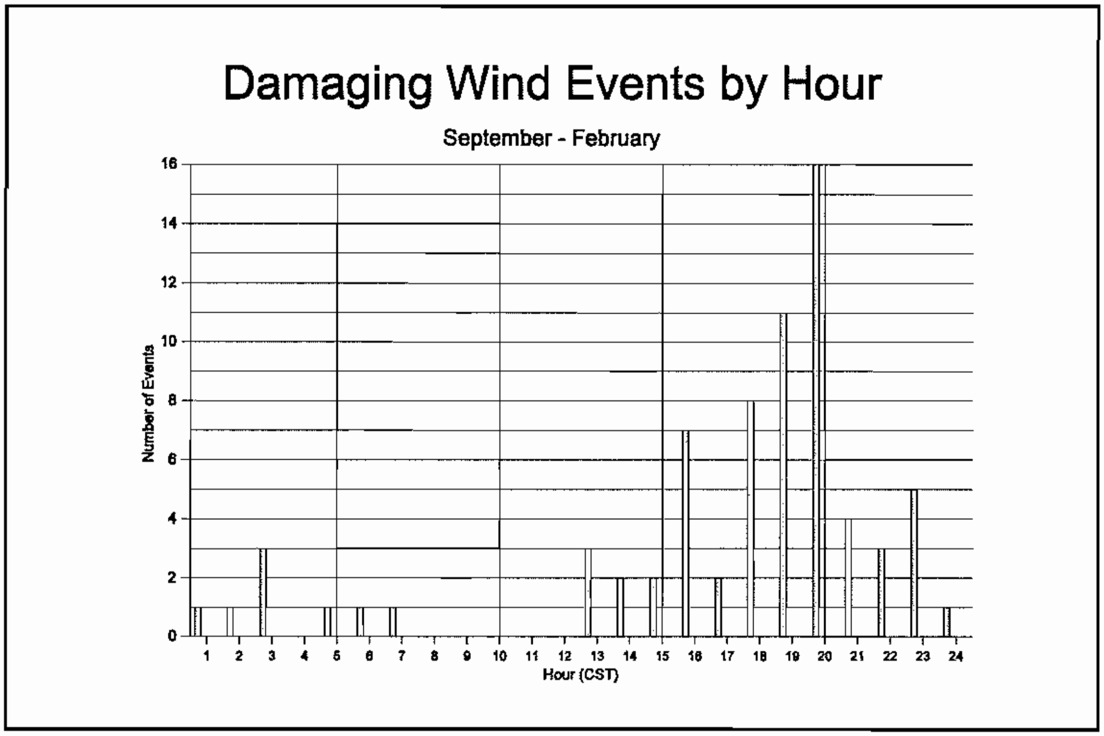

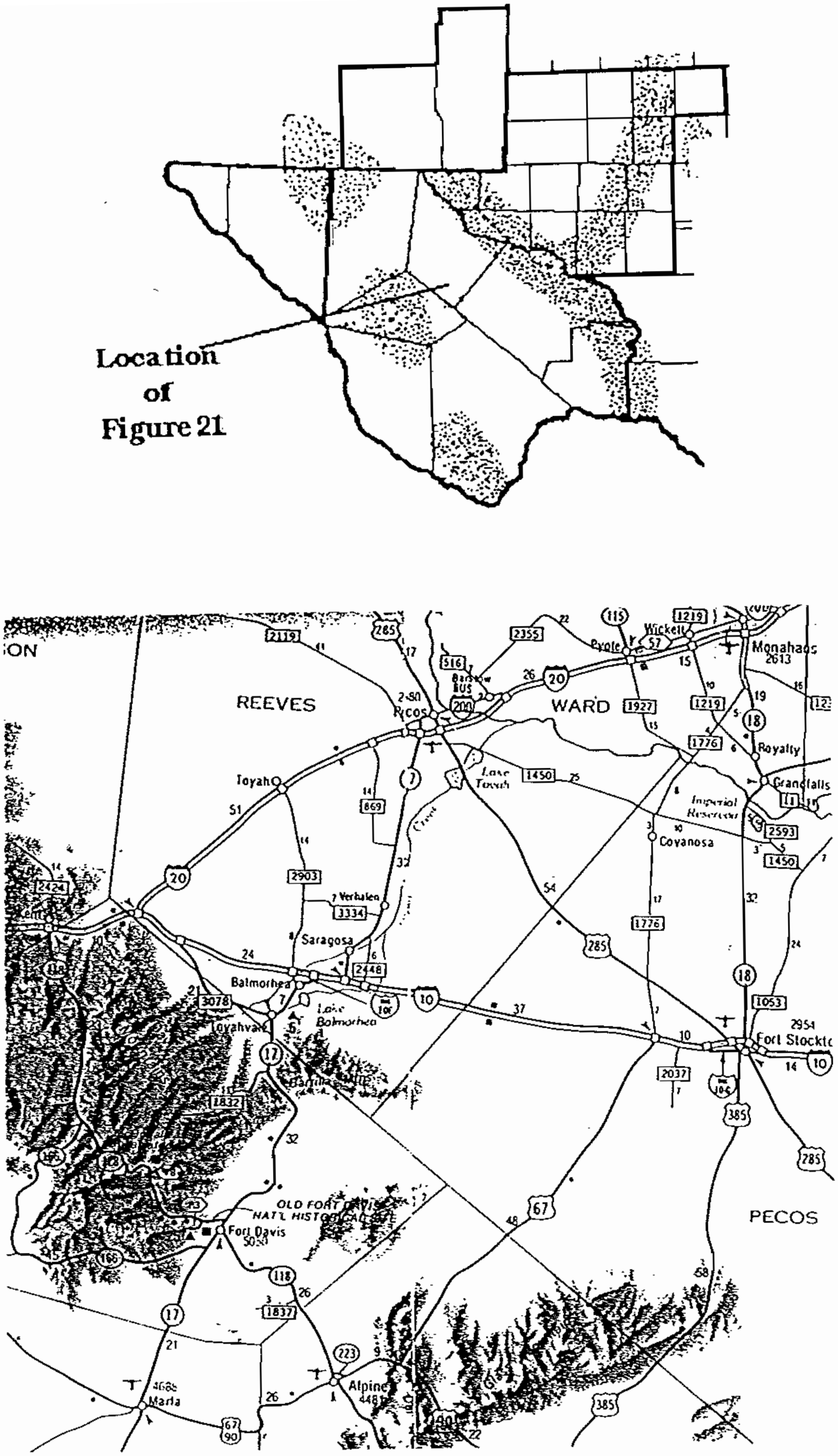

Figure 21. Area hypothesized to have terrain features that enhance low-level storm inflow.