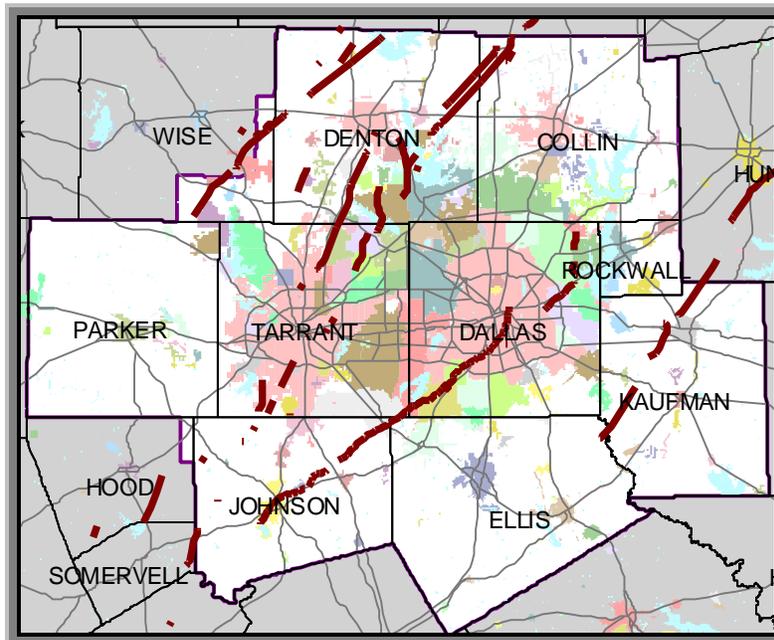


Tornado Damage Risk Assessment Dallas-Fort Worth Metroplex

A Regional Exercise in Demographic,
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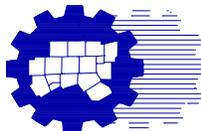
Scenario One

Tornado Outbreak Data
Centered at $-96.93, 32.89$



All figures included in this summary are estimates based upon the best information available at the time of the study. A variety of other variables can be incorporated into future studies or come into play during a real event of this magnitude.

Last Update: January 9, 2001



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Data Analysis and Geographic Information System Data Compilation

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Special Thanks for Data Contributions and Suggestions

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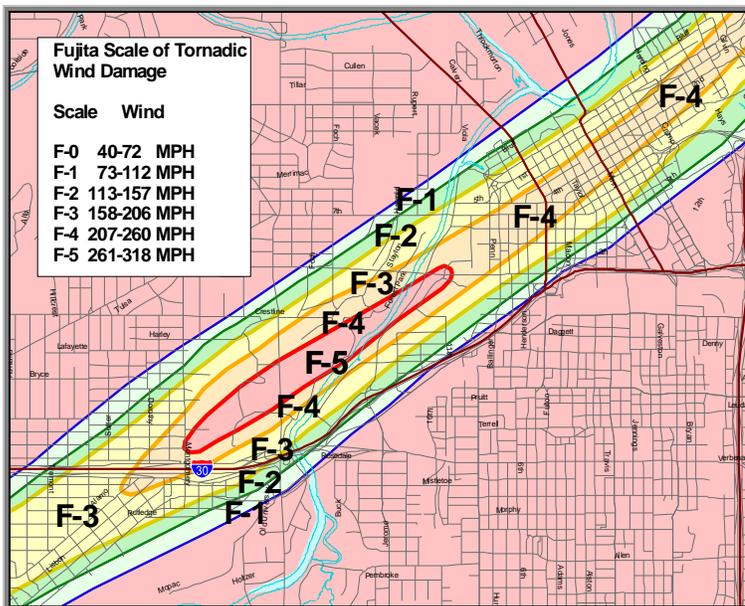
Study Overview

This study features the use of digitally mapped tornado path information from a real tornado outbreak laid atop Dallas-Fort Worth urban and demographic data. Modern computer technology can help estimate the magnitude that the tasks of warning, rescue, and recovery would require. If we make the very likely assumption that *Dallas-Fort Worth would see comparable damage in the same portions of the tornadoes that caused damage in Oklahoma*, we can then model this same event across the Dallas-Fort Worth Metroplex and assess how susceptible the area is to large tornado damage potential.

Five (5) separate distributions (scenarios) of the same Oklahoma tornado paths are modeled with the output including:

- The number of structures in the path
- Potential dollar damages to structures and contents
- Residents living in the path
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- Estimated roadway miles and vehicles travelling in the path

The goal is to stress the importance of planning and preparation for the day when this type of event does occur in Dallas-Fort Worth. A tornadic outbreak like the one in Oklahoma would cover an amazing amount of North Central Texas territory, and this study will help quantify that which would be in the way of the storms themselves.



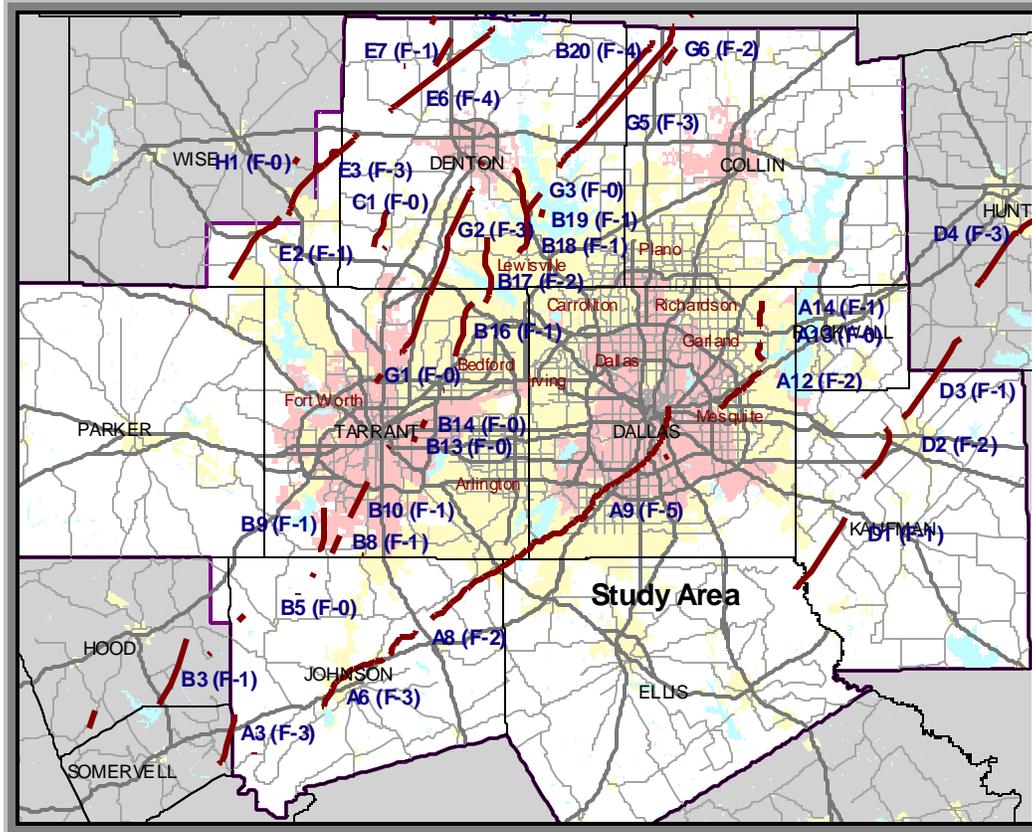
The Tornadoes used in this analysis were mapped using a distinct delineation of the Fujita Scale (F-Scale) damage regions as they occurred in Oklahoma. The F-Scale corresponds to the magnitude of damage occurring to structures.

This document focuses on scenario one of the study. For more information about study

methodology, data, and procedures, please refer to the [study summary](#) document.



Scenario One



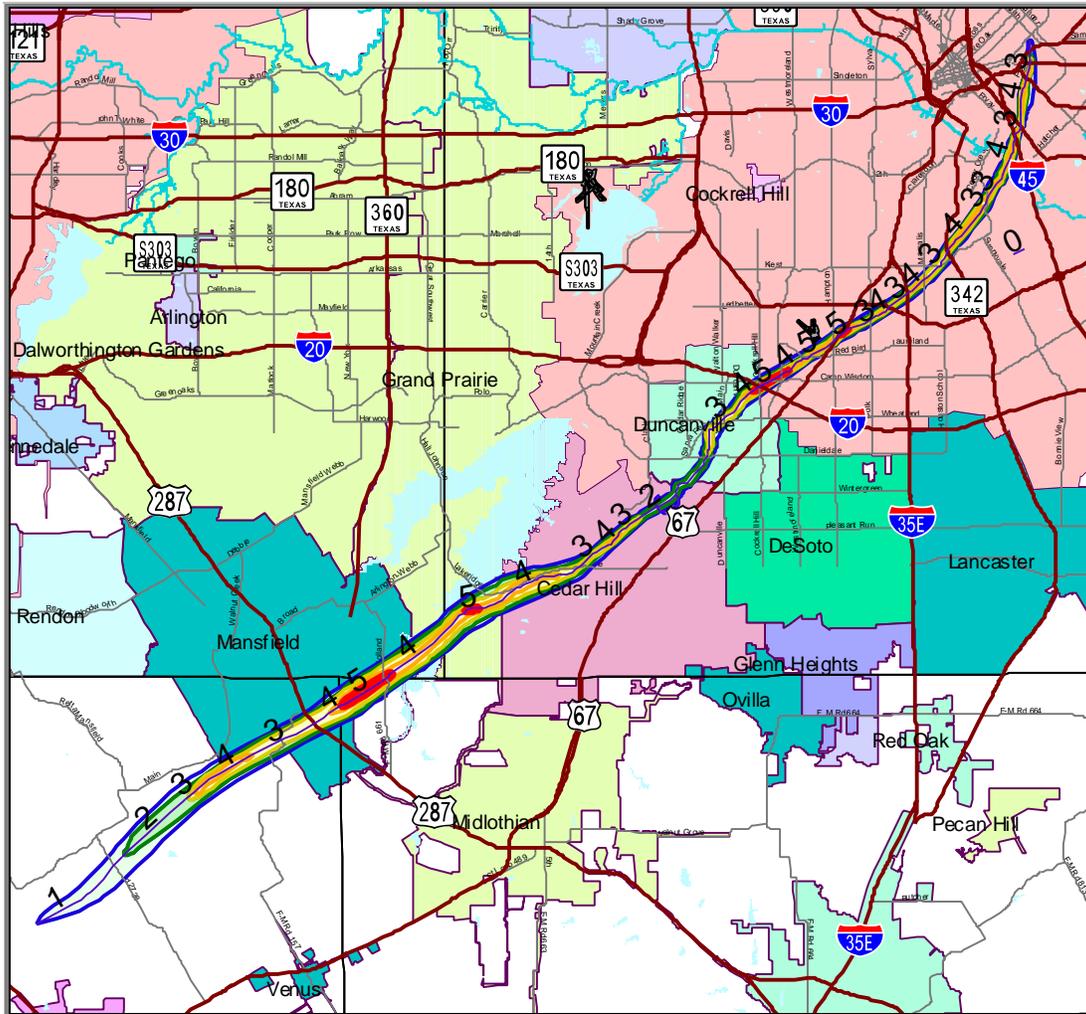
Scenario one centers the entire outbreak of tornadoes at -96.93,32.89 (long/lat decimal degrees). This positioning brings the big tornado “A9” up from the southwest through southwest Dallas County. The northern-most tornadoes have significant paths through Denton County. Most of the land that is impacted in this scenario is classified as vacant, but the pockets of residential and commercial land contain property values exceeding \$1.6 billion. The big tornado’s parent system begins in Somervell County and moves up across Cleburne into Dallas County. This tornado outbreak produces the 4th highest potential property losses from damage of the five scenario outbreaks.

Scenario 1 –Summary of Structures in Path

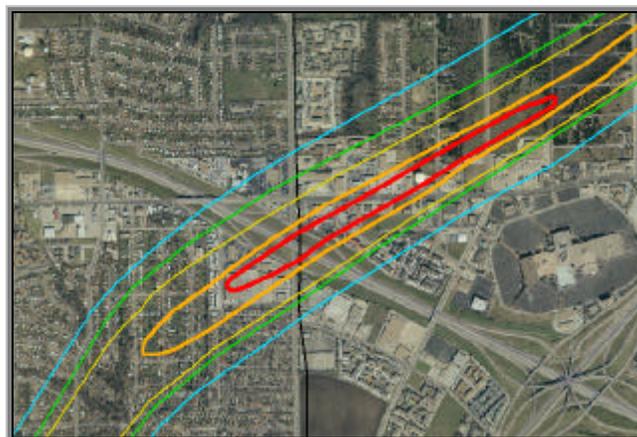
Fujita Scale Contour	Structures Impacted	Property Value in Path	Potential Property Losses
0	1071	\$112,724,707	\$5,621,728
1	7376	\$668,453,041	\$55,143,721
2	3437	\$362,933,244	\$273,588,297
3	3440	\$304,699,713	\$295,004,708
4	1653	\$168,756,784	\$168,756,784
5	93	\$13,045,893	\$13,045,893
Total	17070	\$1,630,613,000	\$811,000,000



Tornado Damage Risk Assessment – Dallas-Fort Worth



Above: Path of the big tornado “A9”(Moore, OK) across the southern metroplex. Bold numbers along the path indicate the F-Scale rating given to the same portion of the tornado in Oklahoma.



Aerial Image Maps Courtesy of VARGIS LLC

Above: Tornado “A9” path across Interstate-20 in south Dallas County. Velocities of this model path alignment reach F-5 and present the largest traffic threat of the scenario.



Major Land Uses in Tornado Paths

The largest number of tornado damage paths cross the North Central Texas study area in Scenario One. Most of the land located in the damage paths is classified as vacant. The structural damage from all of the tornadoes can be credited to less than 20% of their path.

Land Use Category	Impacted Acres	Maximum Fujita Scale	Impacted Square Miles	Percent of Total Area in Tornado Paths
Vacant	32438.08	5	50.68	78.13%
Single Family	3827.49	5	5.98	9.22%
Water	1859.33	4	2.90	4.48%
Parks & Recreation	1200.96	4	1.88	2.89%
Retail	434.48	5	0.68	1.05%
Institutional	275.20	5	0.43	0.66%
Mobile Home Parks	262.83	4	0.41	0.63%
Industrial	239.48	4	0.37	0.58%
Multi-family	181.51	4	0.28	0.44%
Airport	103.99	4	0.16	0.25%
Office	16.30	4	0.03	0.04%
Landfill	9.18	1	0.01	0.02%

Major Land Uses in the Path of Tornado “A9” (Moore,OK)

Land Use Category	Impacted Acres	Maximum Fujita Scale	Impacted Square Miles	Percent of Total Area in Tornado “A9” Path
Vacant	7479.06	5	11.68	61.11%
Single Family	1806.33	5	2.82	14.76%
Water	786.49	4	1.23	6.43%
Parks & Recreation	746.45	4	1.17	6.10%
Retail	283.16	5	0.44	2.31%
Institutional	178.50	5	0.28	1.46%
Mobile Home Parks	175.35	4	0.27	1.43%
Industrial	170.14	4	0.27	1.39%
Multi-family	128.87	4	0.20	1.05%
Airport	65.47	4	0.10	0.53%
Office	11.43	4	0.02	0.09%

Detailed Structure Summary

The table below provides structure damage estimates for all of the tornado paths. Damages are calculated based on appraisal data and the Fujita Scale contour the structure is located in.

Type	Total in Path	Property Value in Path	Potential Property Losses
Single Family Homes	11944	\$1,232,998,903	\$643,821,260
Apartment Units	3728	\$83,528,277	\$32,652,392
Mobile Homes	818	\$18,946,847	\$6,233,035
Commercial Properties	505	\$249,161,535	\$96,426,015
Industrial Structures	64	\$45,977,820	\$32,028,440



Residents and Employees in Path

The table below provides an estimate of the number of persons occupying the structures in the path of the tornadoes. Numbers are based upon city data for household size, occupancy rates, major employer locations, and traffic survey zone employment data.

Category	Total Persons	Persons in F-2 or Greater Contour	Persons in F-4 or F-5 Contour
Residents at Home	34644	14178	4296
Employees at Work	10423	5722	1156

Estimated Number of Persons Occupying Residential Structures In the Path of Tornadoes

Fujita Scale Contour	Persons in Homes	Persons in Apartments	Persons in Mobile Homes
0	1997	315	290
1	13249	3297	1318
2	7295	1212	101
3	7163	1249	27
4	3405	590	60
5	240	0	0
Total	26185	6663	1796

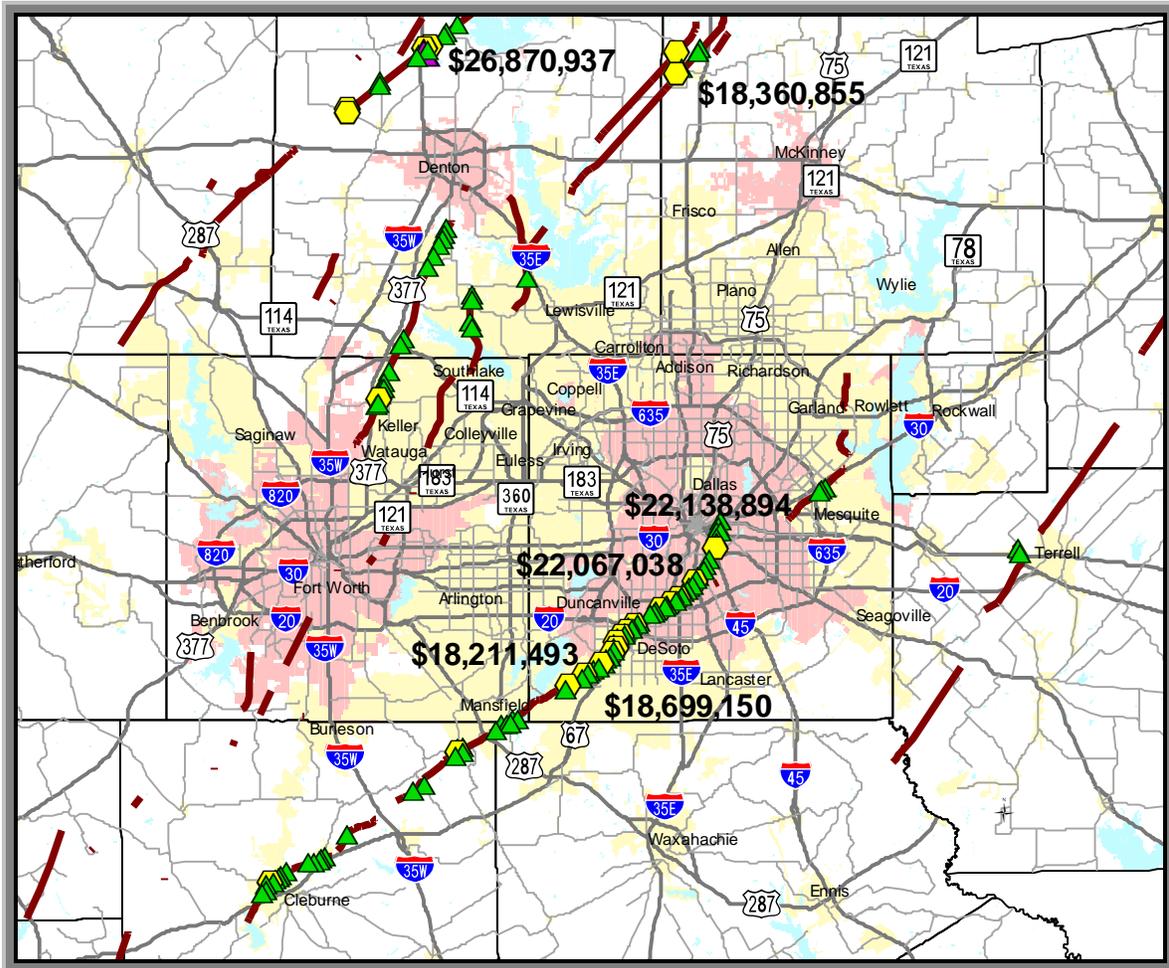
Largest Potential Losses by City

City	Structures	Property Value in Path	Potential Property Losses	Maximum Fujita Scale	Employees in Path	Residents in Path
Dallas	5944	\$333,652,222	\$191,311,251	5	6322	12687
County Land or Undefined	2778	\$309,085,562	\$179,825,950	5	764	7082
Duncanville	1705	\$170,337,372	\$106,357,865	5	1065	4536
Cedar Hill	787	\$118,237,561	\$76,107,321	4	58	2295
Sanger	946	\$108,935,034	\$69,086,396	4	127	2549
Cleburne	814	\$114,405,328	\$47,187,308	3	521	2024
Keller	397	\$51,844,101	\$31,854,750	3	75	1132
Mansfield	238	\$30,915,247	\$26,628,331	5	8	696
Mesquite	668	\$91,500,772	\$18,927,655	2	670	1850
Flower Mound	301	\$33,424,503	\$10,036,393	2	9	844
Trophy Club	96	\$13,741,749	\$8,414,326	3	45	256
Keene	204	\$17,675,095	\$7,872,813	3	70	541

Other Features Impacted

Category	Total Number	Number in F-2 or Greater Contour	Number in F-4 or F-5 Contour
Schools	9	3	1
Miles of Roads	294.91	155.80	34.34
Miles of Railroads	10.52	6.02	2.7
Major Electrical Utility Lines Intersected by the Centerline of a Tornado	34	20	10

Tornado Damage Risk Assessment – Dallas-Fort Worth



Legend	
Structural Damage Estimates in Dollars	
▲	\$1,000,000 - \$10,000,000
⬡	\$10,000,000 - \$25,000,000
▲	\$25,000,000 - \$75,000,000
●	> \$75,000,000

Above: The most significant damage areas as calculated for scenario one. Displayed points represent small area locations with total damages exceeding \$1,000,000. The small areas are no larger than .2 square miles and exist entirely within the tornado path. A few of the larger damage total dollar values are displayed on the map. Their positioning has been generalized for the scale of mapping.

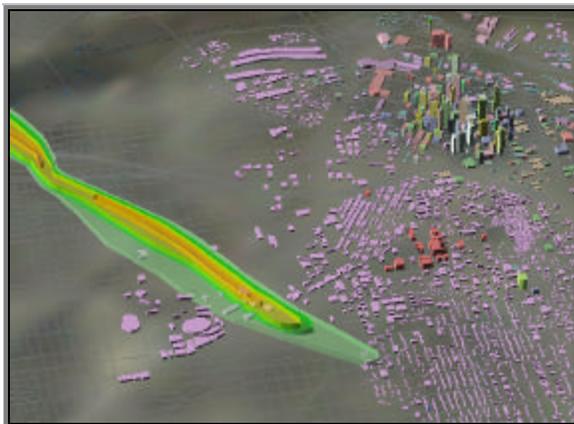
Percentage of City Current Single Family Housing Units Destroyed By Tornadoes

The table below describes the inventory of single family houses currently existing in several North Central Texas cities, and compares that to the number that would have been destroyed in scenario one. The city of Sanger in Denton County would have been hit significantly by one of the northern F-4 tornadoes in the group – and the path would have taken the storm across significant single-family housing neighborhoods in the southeastern portion of the city. If Sanger's housing received similar damage that the houses in Oklahoma experienced in that path, an amazing 34 percent of the city's single-family housing inventory would likely have been destroyed. There were multiple strong tornadoes in the Oklahoma outbreak, and the alignment of scenario one would have brought numerous of the northern tornadoes far enough south to have long damage paths in the region.

City	Houses Destroyed (F2 or Greater Contour)	Estimated Number of Current Single Family Units in 1999	Percent Destroyed
Sanger	531	1554	34.2%
Duncanville	974	10838	8.9%
Cedar Hill	527	9141	5.7%
Roanoke	31	594	5.3%
Cleburne	371	7958	4.6%
Celina	30	655	4.5%
Keller	250	7868	3.1%
Argyle	22	717	3.0%
Trophy Club	60	2033	2.9%
Mansfield	206	7568	2.7%
Double Oak	10	686	1.5%
Dallas	1943	227914	0.8%
Flower Mound	86	14946	0.5%



Above: Path of tornado “E6” through Sanger in Denton County. Colored city polygons represent variations in land use categories.

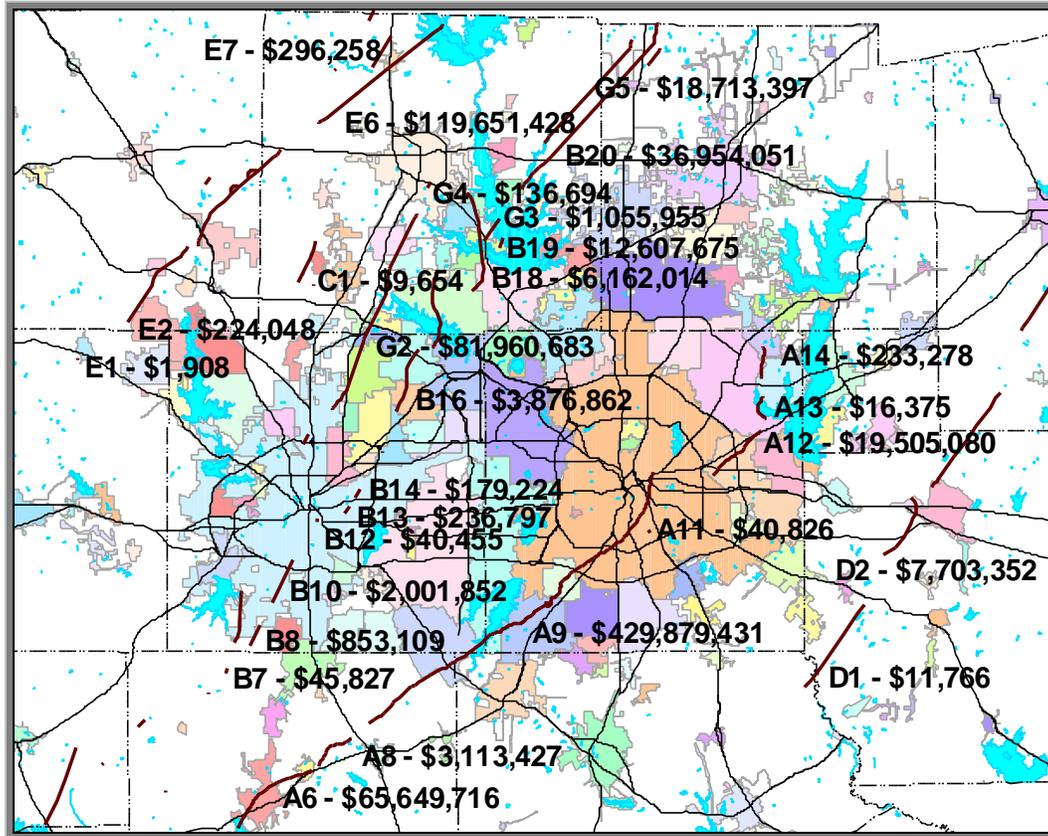


Above: Path of tornado “A9” just southeast of Downtown Dallas. Select buildings are mapped and displayed in relationship to the tornado path. The tornado terminates its F-4 damage path at Fair Park.

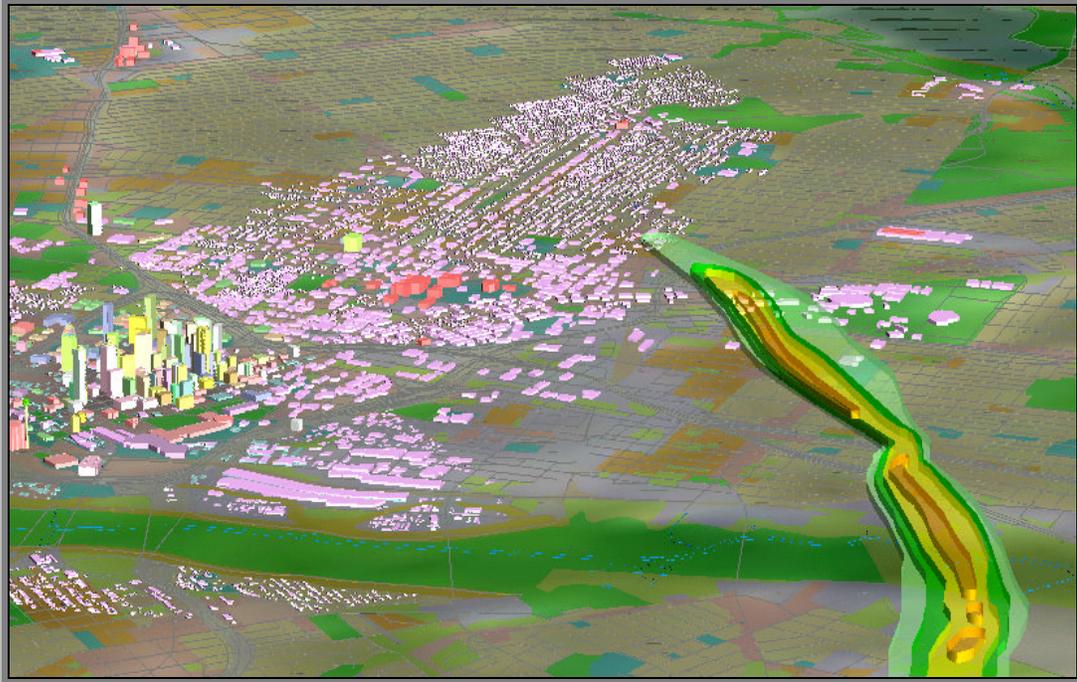
Population Threat and Losses by Tornado

In scenario one, the big tornado “A9”, produces its lowest threat of the five scenarios. Despite this “lesser” impact from the big tornado, the scenario still produces over \$800 million of potential property losses. This is due to the fact that ten (10) separate tornadoes each produce over \$10 million of potential property losses. The tornado “E6” is significant at over \$119 million.

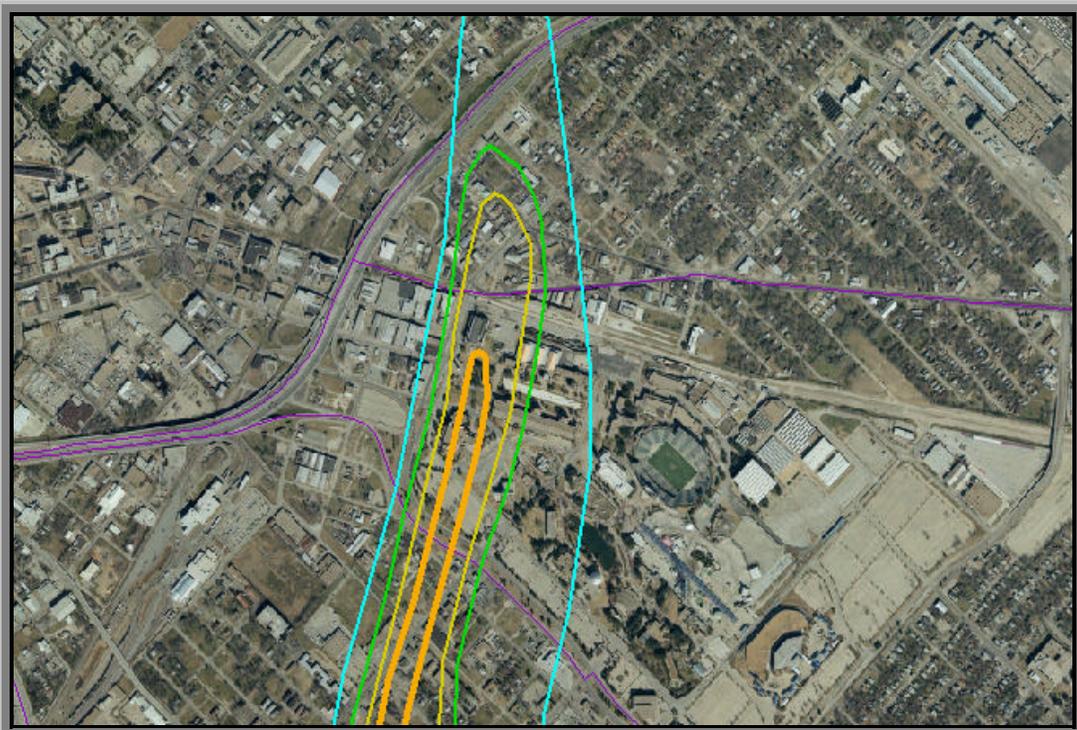
Tornado	Maximum Fujita	Residents in Path	Impacted Structures	Property Value in Path	Potential Property Losses
A9	5	22360	9582	\$716,276,651	\$429,879,431
E6	4	4130	1543	\$186,154,744	\$119,651,428
G2	3	2810	1022	\$133,321,694	\$81,960,683
A6	3	3013	1245	\$151,802,072	\$65,649,716
B20	4	699	265	\$48,982,847	\$36,954,051
A12	2	2319	889	\$99,653,144	\$19,505,080
G5	3	371	138	\$24,656,726	\$18,713,397
B19	2	788	261	\$35,555,605	\$12,607,675
D2	2	405	161	\$14,509,387	\$7,703,352
B18	1	1898	683	\$77,339,683	\$6,162,014
B16	1	587	182	\$49,341,881	\$3,876,862
A8	2	203	79	\$7,618,807	\$3,113,427
B10	1	754	372	\$26,436,540	\$2,001,852



Above: Potential Structural Damage Losses by Tornado for Scenario One.

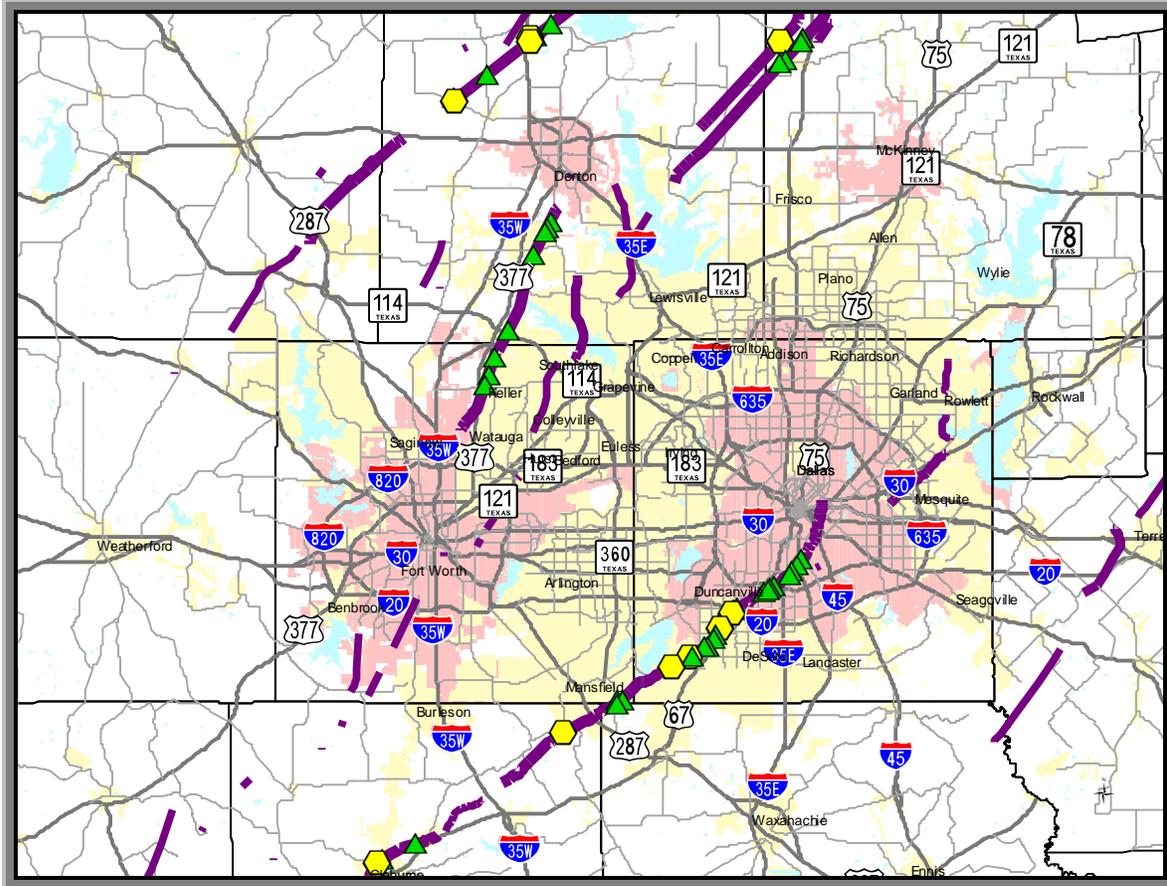


Above: 3-D Enhanced path of tornado "A9" across Dallas County. The downtown Dallas skyline is visible to the left center. The view is to the north-northeast.



Above: Aerial view of tornado path "A9" across northwestern portions of Fair Park. The tornado is nearing the end of its life span, but it is still several blocks wide with significant F-4 damage potential.

Tornado Damage Risk Assessment – Dallas-Fort Worth



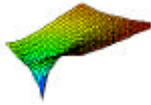
Above: Areas of estimated damages to single family homes and apartment units exceeding \$5 million. Dollar values are a function of the number of structures, their appraised value and the magnitude of wind velocities at their location.

Estimated Traffic in the Path of Tornadoes

Traffic figures for vehicles in the path of the tornadoes are based on NCTCOG transportation modeling for major thoroughfares through the region. The data is an estimate of road volumes and capacities across more than 21,000 links throughout the metroplex, many of them calibrated to actual traffic count data. The models include estimates for freeways, arterials, and collectors, but do not include local residential streets. The numbers for scenario one are derived from those modeling numbers. For scenario one, we are estimating the number of cars that, as a function of volume, speed, time, and distance, should be located on the actual roadway pavement in the tornado's path at the time the tornado overtakes the route. **Hourly traffic** numbers provide an estimate of how many cars would actually cross the path during the hour of the tornado's primary impact. **Vehicles trapped** numbers are estimates of how many vehicles should theoretically be on the roadway in the tornado path when the tornado strikes (under varying traffic levels).

Hourly Vehicles on Routes Crossed by Tornadoes	Vehicles Located in Tornado Paths at Normal Roadway Vehicle Volumes	Vehicles Trapped in Tornado Paths if Roadways all Backed Up
*104697	*635	44635

- Estimated based on daily modeling totals and hourly multipliers

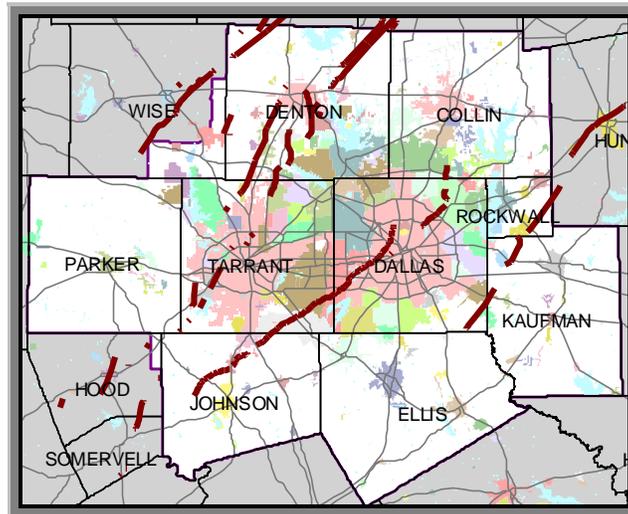


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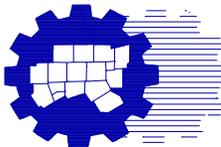
Scenario Two

Tornado Outbreak Data
Centered at $-97.00, 32.95$



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Last Update: January 9, 2001



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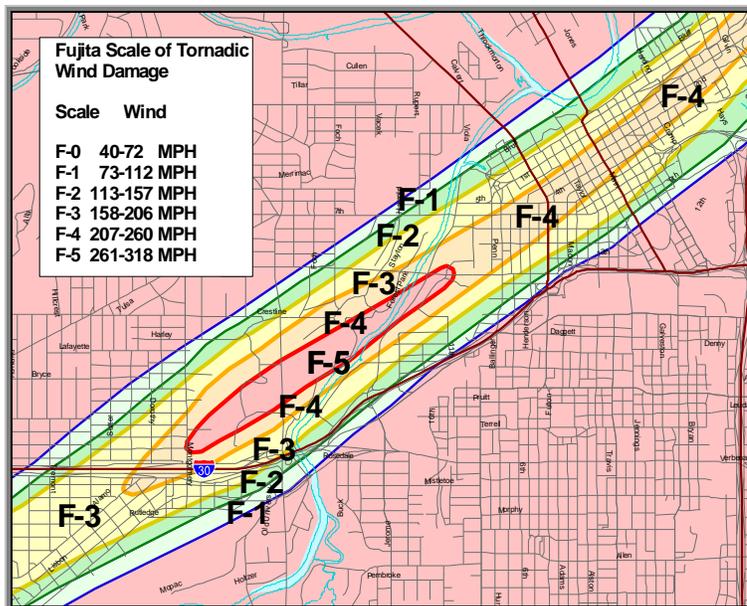
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Five (5) separate distributions (scenarios) of the same Oklahoma tornado paths are modeled with the output including:

- The number of structures in the path
- Potential dollar damages to structures and contents
- Residents living in the path
- Employees working in the path
- Utility lines in the path
- The distribution of land use in the path
- Estimated roadway miles and vehicles travelling in the path

The goal is to stress the importance of planning and preparation for the day when this type of event does occur in Dallas-Fort Worth. A tornadic outbreak like the one in Oklahoma would cover an amazing amount of North Central Texas territory, and this study will help quantify that which would be in the way of the storms themselves.



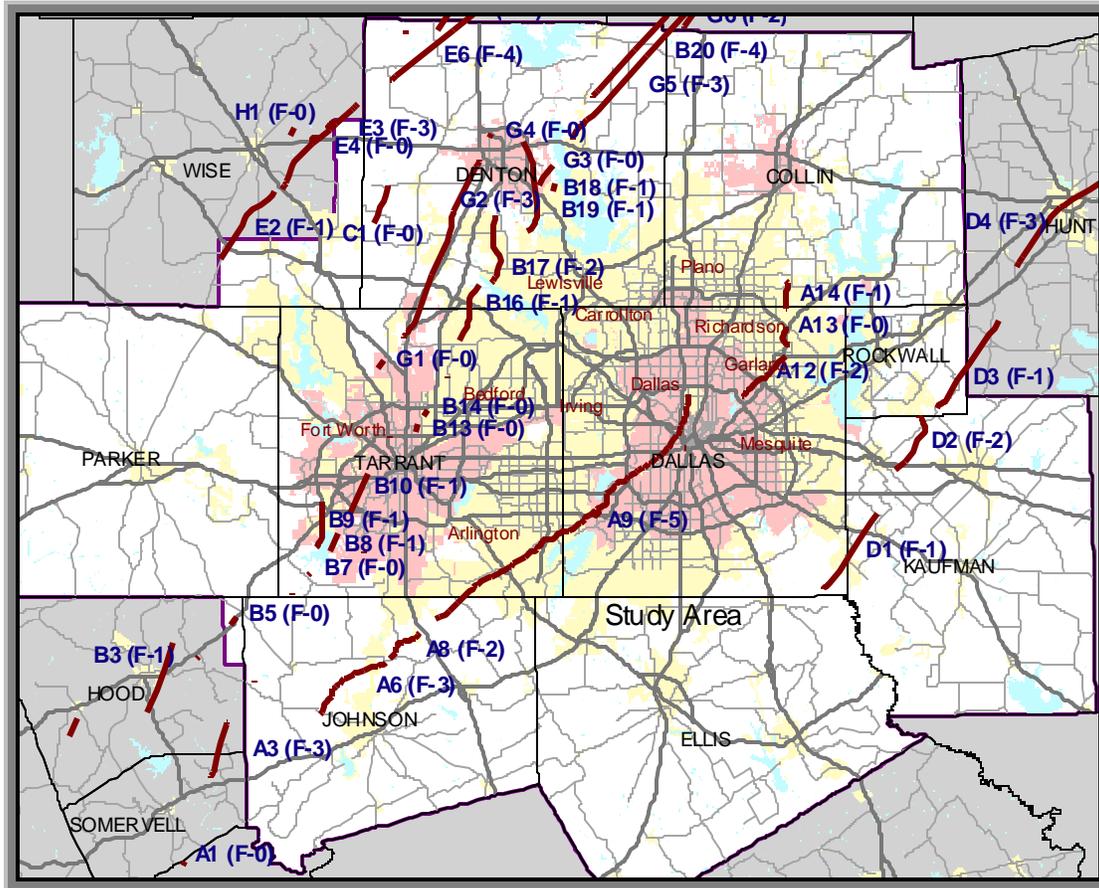
The Tornadoes used in this analysis were mapped using a distinct delineation of the Fujita Scale (F-Scale) damage regions as they occurred in Oklahoma. The F-Scale corresponds to the magnitude of damage occurring to structures.

This document focuses on scenario two of the study. For more information about study

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Scenario Two



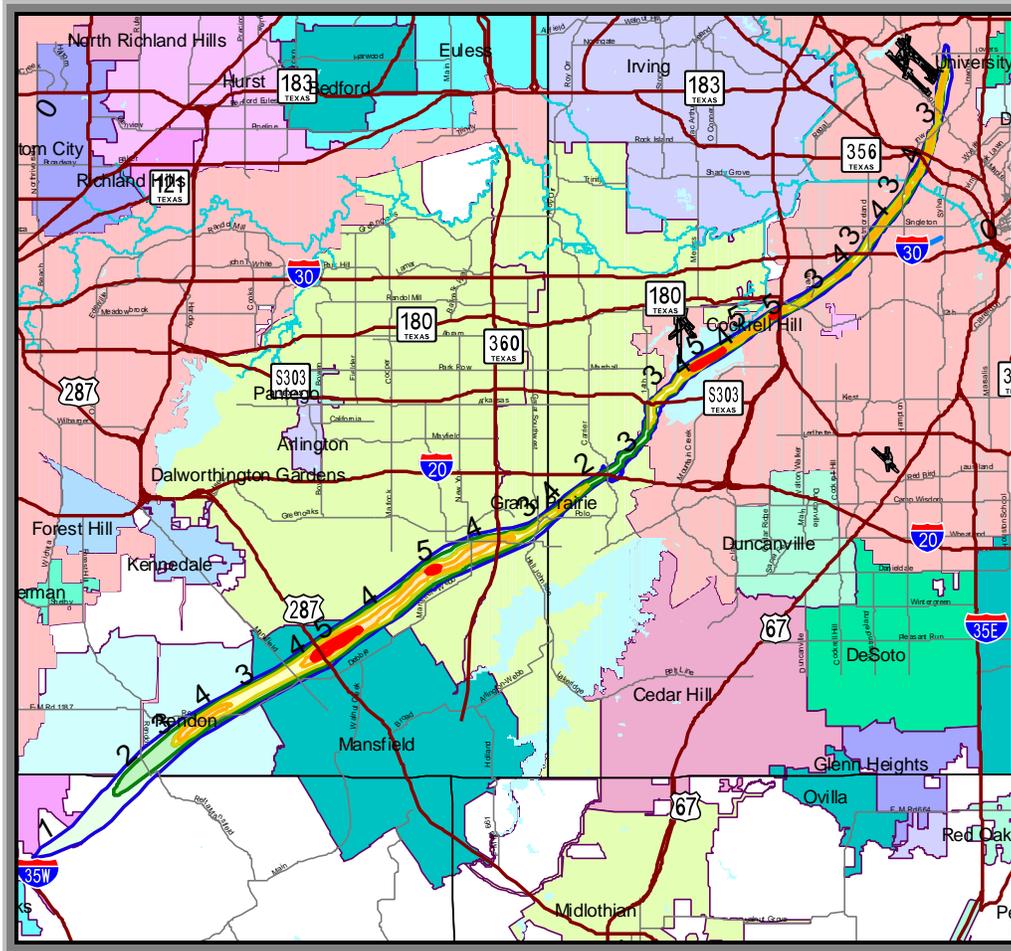
Scenario two centers the entire outbreak of tornadoes at -97.00,32.95 (long/lat decimal degrees). This positioning starts the big tornado “A9” near Interstate 35W in northern Johnson County. Following the precise path direction that it did in Oklahoma, the storm moves through northwest Mansfield, through southern Grand Prairie, across Interstate 20, and northeast into Dallas. This alignment of paths produces the lowest damage estimates of the five scenarios, but the damages still approach \$800 million. Arlington, Grand Prairie, Mansfield, and Dallas could each lose over 500 single family homes.

Scenario 2 – Summary of Structures in Path

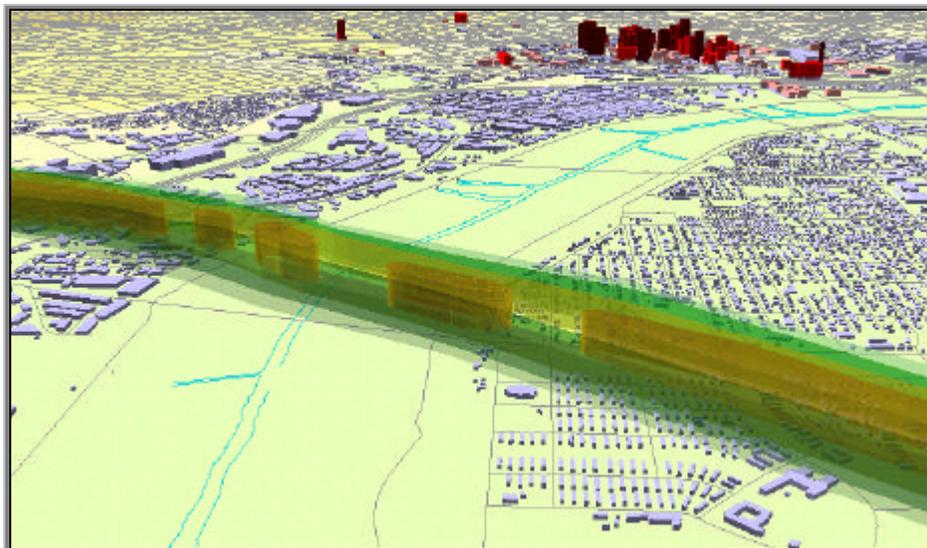
Fujita Scale Contour	Structures Impacted	Property Value in Path	Potential Property Losses
0	559	\$49,202,987	\$2,333,068
1	6171	\$756,795,476	\$60,115,664
2	3393	\$414,459,618	\$309,800,222
3	2632	\$277,734,269	\$263,551,342
4	1566	\$147,500,912	\$147,500,912
5	39	\$6,570,143	\$6,570,143
Total	14363	\$1,652,263,000	\$790,000,000



Tornado Damage Risk Assessment – Dallas-Fort Worth



Above: Path of the large tornado "A9" through Tarrant and Dallas Counties. Bold numbers along the path indicate the F-Scale rating given to the same portion of the tornado in Oklahoma.



Above: Three-dimensional computer rendering of tornado "A9" path crossing the Trinity River northwest of downtown Dallas and entering the Stemmons industrial district.



Major Land Uses in All Tornado Paths

Like scenario one, nearly 80% of the tornado paths in scenario two would be made up of vacant land. The damage from the tornadoes can be attributed to less than 20% of their paths. Denton County is extremely active in this scenario, but the slight adjustment of the paths to the northwest spares many communities from the direct hits that occurred in scenario one.

Land Use Category	Impacted Acres	Maximum Fujita Scale	Impacted Square Miles	Percent of Total Area in Tornado Paths
Vacant	27487.24	5	42.94	79.95%
Single Family	2853.82	5	4.46	8.30%
Water	720.60	5	1.13	2.10%
Industrial	683.87	4	1.07	1.99%
Parks & Recreation	676.31	4	1.06	1.97%
Mobile Home Parks	315.81	4	0.49	0.92%
Retail	285.74	5	0.45	0.83%
Institutional	235.29	4	0.37	0.68%
Multi-family	175.78	4	0.27	0.51%
Airport	157.08	4	0.25	0.46%
Office	36.94	4	0.06	0.11%

Major Land Uses in the Path of Tornado “A9” (Moore,OK)

Land Use Category	Impacted Acres	Maximum Fujita Scale	Impacted Square Miles	Percent of Total Area in Tornado “A9” Path
Vacant	7441.65	5	11.63	60.81%
Single Family	1961.76	5	3.06	16.03%
Water	654.59	5	1.02	5.35%
Industrial	529.04	4	0.83	4.32%
Parks & Recreation	466.67	4	0.73	3.81%
Retail	190.92	5	0.30	1.56%
Institutional	174.13	4	0.27	1.42%
Mobile Home Parks	153.21	4	0.24	1.25%
Multi-family	147.75	4	0.23	1.21%
Airport	36.82	4	0.06	0.30%
Office	33.97	4	0.05	0.28%

Detailed Structure Summary

The table below provides structure damage estimates for all of the tornado paths. Damages are calculated based on appraisal data and the Fujita Scale contour in which the structure is located.

Type	Total in Path	Property Value in Path	Potential Losses
Single Family Homes	8790	\$1,043,387,374	\$499,778,737
Apartment Units	3900	\$166,885,696	\$92,655,150
Mobile Homes	1214	\$19,587,208	\$14,326,747
Commercial Properties	361	\$286,711,473	\$139,740,610
Industrial Structures	85	\$86,488,667	\$43,370,106



Residents and Employees in Path

The table below provides an estimate of the number of persons occupying the structures in the path of the tornadoes. Numbers are based upon city data for household size, occupancy rates, major employer locations, and traffic survey zone employment data.

Category	Total Persons	Persons in F-2 or Greater Contour	Persons in F-4 or F-5 Contour
Residents at Home	34030	17706	3469
Employees at Work	19131	10062	2103

Estimated Number of Persons Occupying Residential Structures In the Path of Tornadoes

Fujita Scale Contour	Persons in Homes	Persons in Apartments	Persons in Mobile Homes
0	882	86	356
1	11691	2392	917
2	5940	1676	526
3	4091	1477	529
4	1819	1202	342
5	104	0	0
Total	24527	6833	2670

Largest Damages by City

City	Structures in Path	Property Value in Path	Potential Losses	Maximum Fujita Scale	Employees in Path	Residents in Path
Dallas	4813	\$448,738,666	\$249,575,752	5	12957	9354
Mansfield	836	\$200,291,677	\$122,641,370	5	579	2368
Rendon	1191	\$175,637,202	\$102,234,975	4	157	3145
Grand Prairie	1921	\$181,753,763	\$96,111,457	4	148	5098
Arlington	1260	\$134,394,102	\$75,921,563	5	271	3192
County Land or Undefined	1825	\$189,908,589	\$58,374,655	4	278	4633
Krugerville	623	\$65,122,069	\$52,547,411	4	38	1676
Fort Worth	388	\$41,851,518	\$6,682,848	3	2687	934
Aubrey	72	\$12,544,270	\$5,697,519	4	164	129
Burleson	505	\$47,352,218	\$4,468,870	1	1	1415
Denton	421	\$52,225,749	\$4,184,262	1	949	771

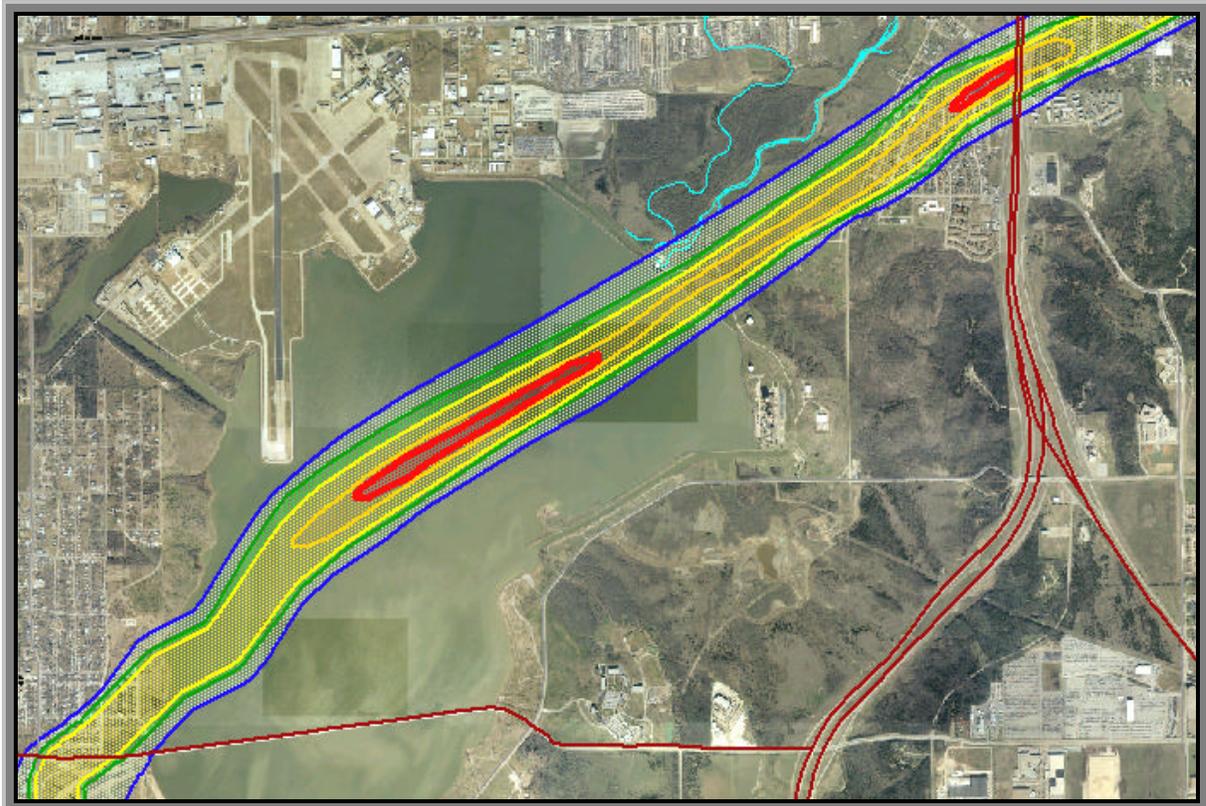
Other Features In Path

Category	Total Number	Number in F-2 or Greater Contour	Number in F-4 or F-5 Contour
Schools	11	5	5
Miles of Roads	270.11	144.05	28.13
Miles of Railroads	24.70	14.26	1.61
Major Electrical Utility Lines Intersected by Centerline of Tornado	44	27	12

Percentage of City Current Single Family Housing Units Destroyed By Tornadoes

The table below describes the inventory of single family houses currently existing in several North Central Texas cities, and compares that to the number that would likely have been destroyed in scenario three. The City of Mansfield would experience the largest percentage loss in this scenario. Grand Prairie also would experience a significant loss of property.

CITYNAME	Houses Destroyed (F2 or Greater Contour)	Estimated Number of Current Single Family Units in 1999	Percent Destroyed
Mansfield	558	7568	7.38
Haslet	25	378	6.74
Aubrey	27	406	6.73
Grand Prairie	807	29854	2.70
Argyle	11	717	1.58
Arlington	505	75920	0.67
Dallas	699	227914	0.31
Joshua	3	1426	0.28
Flower Mound	14	14946	0.10
Fort Worth	36	133889	0.03



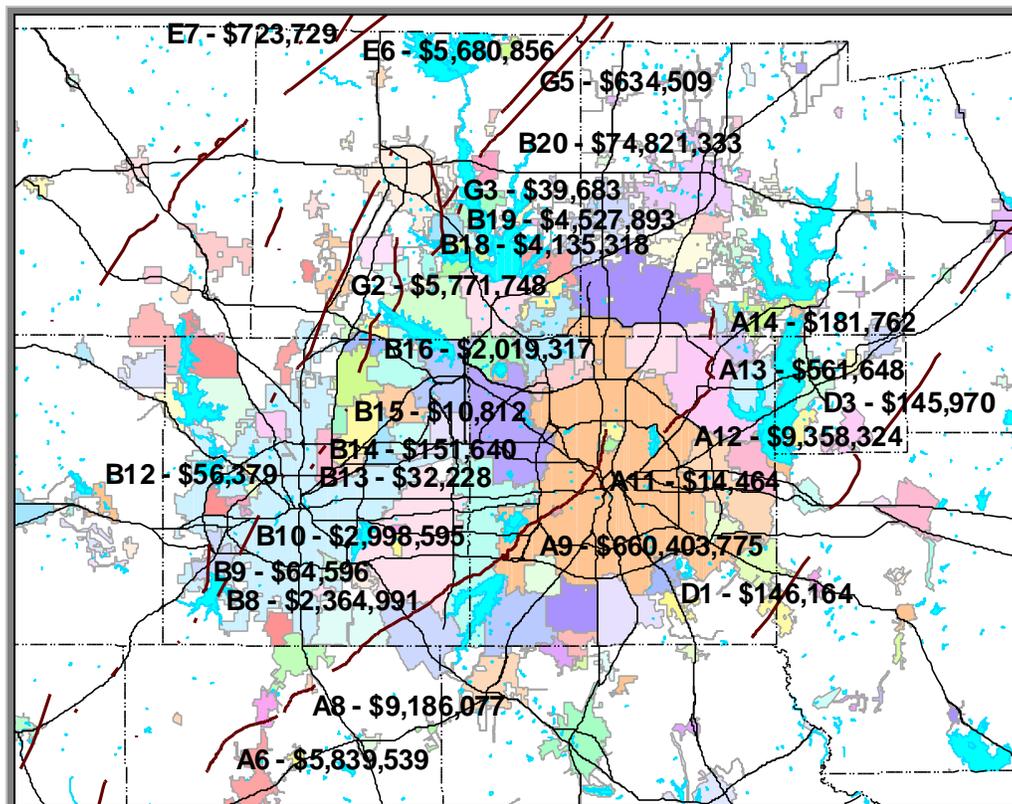
Aerial Image Maps Courtesy of VARGIS LLC

Above: *Midway along the path of tornado “A9”.* This tornado would unleash some of its most intense strength over the open waters of Mountain Creek Lake. The damage path narrowly misses the former Naval Air Station, but does return to shore to produce large damage totals.

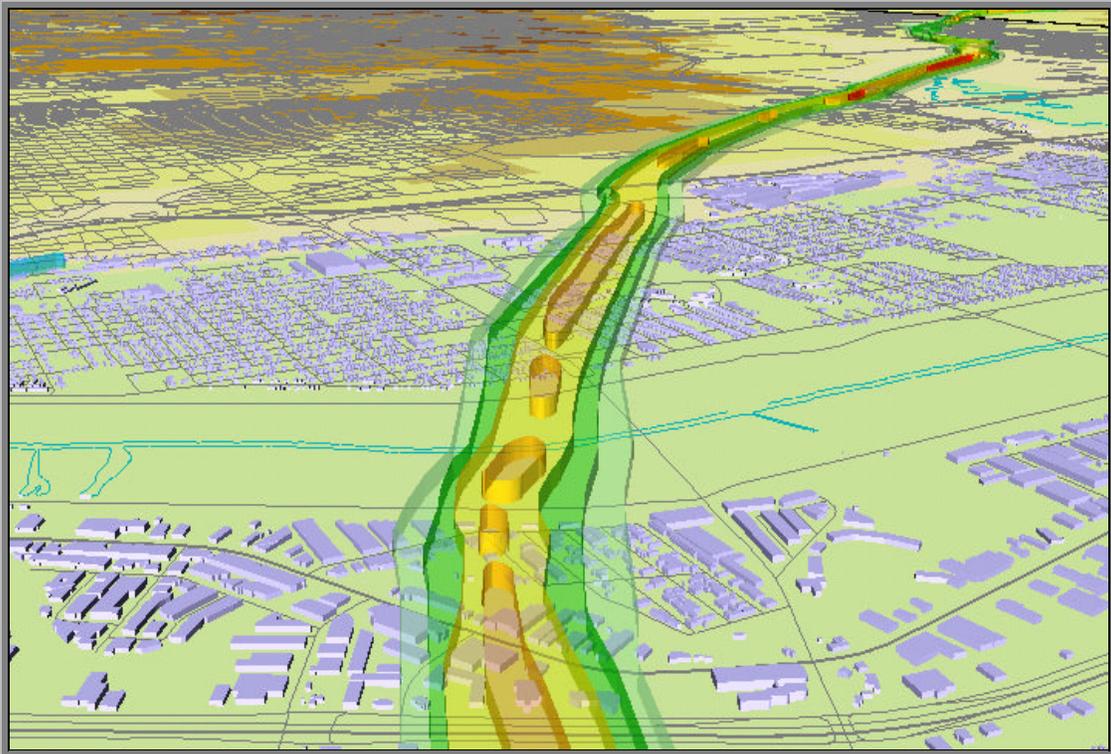
Population Threat and Losses by Tornado

In scenario two, the big tornado “A9” would produce the largest threat. Tornado “B20” would impact nearly \$100 million of property in Denton County – much of it in F-4 contours. Tornado “E6” threatens F-4 damage like it did in scenario one, but its slight shift to the north and west dramatically reduces its potential losses. None the less, it still impacts 367 structures.

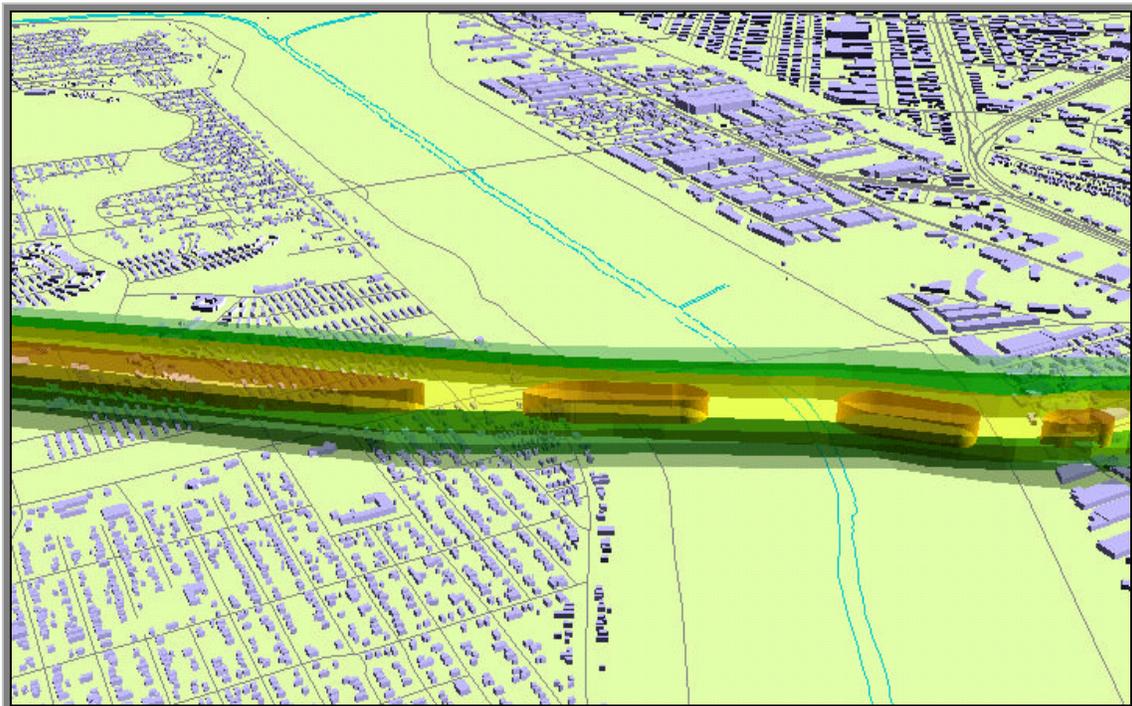
Tornado	Maximum Fujita Scale	Residents in the Path	Structures Impacted	Property Value in Path	Potential Losses
A9	5	25019	10555	\$1,202,475,446	\$660,403,775
B20	4	2267	877	\$99,443,467	\$74,821,333
A12	2	1721	774	\$82,408,692	\$9,358,324
A8	2	455	171	\$21,874,120	\$9,186,077
A6	3	261	99	\$9,817,269	\$5,839,539
G2	3	188	65	\$7,405,818	\$5,771,748
E6	4	771	367	\$6,564,932	\$5,680,856
B19	2	157	62	\$9,453,333	\$4,527,893
B18	1	723	394	\$52,053,559	\$4,135,318
B10	1	558	234	\$39,818,038	\$2,998,595
B8	1	473	174	\$30,099,871	\$2,364,991
B16	1	375	147	\$25,350,963	\$2,019,317



Above: Potential Losses from Structural damages by tornado for Scenario Two.

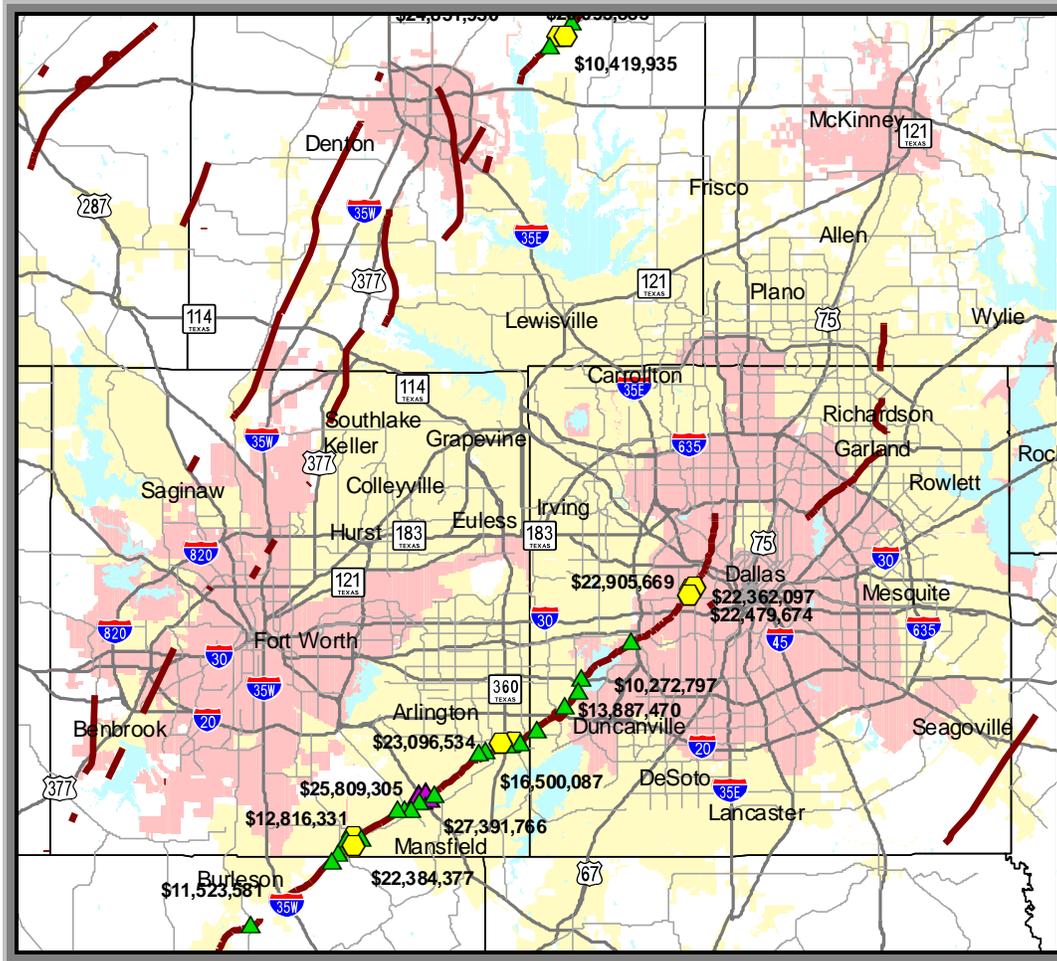


Tornado path enhanced in 3-Dimensional computer model of Trinity River Corridor near the Stemmons Industrial District. The tornado path is slimmer than earlier in its life cycle, but the tornado is still capable of F-4 damage.





Tornado Damage Risk Assessment – Dallas-Fort Worth



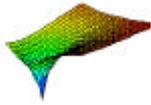
Above: Areas of estimated damages to single family homes and apartment units exceeding \$5 million. The estimation is a function of tornado strength, width, and structure appraisal data.

Estimated Traffic in the Path of Tornadoes

Traffic figures for vehicles in the path of the tornadoes are based on NCTCOG transportation modeling for major thoroughfares through the region. The data is an estimate of road volumes and capacities across more than 21,000 links throughout the metroplex, many of them calibrated to actual traffic count data. The models include estimates for freeways, arterials, and collectors, but do not include local residential streets. The numbers for scenario two are derived from those modeling numbers. For scenario two, we are estimating the number of cars that, as a function of volume, speed, time, and distance, should be located on the actual roadway pavement in the tornado's path at the time the tornado overtakes the route. **Hourly traffic** numbers provide an estimate of how many cars would actually cross the path during the hour of the tornado's primary impact. **Vehicles trapped** numbers are estimates of how many vehicles should theoretically be on the roadway in the tornado path when the tornado strikes (under varying traffic levels).

Hourly Vehicles on Routes Crossed by Tornadoes	Vehicles Trapped in Tornado Paths at Normal Roadway Vehicle Volumes	Vehicles Trapped in Tornado Paths if Roadways all Backed Up
*101970	*643	39329

* Estimated based on daily modeling totals and hourly multipliers

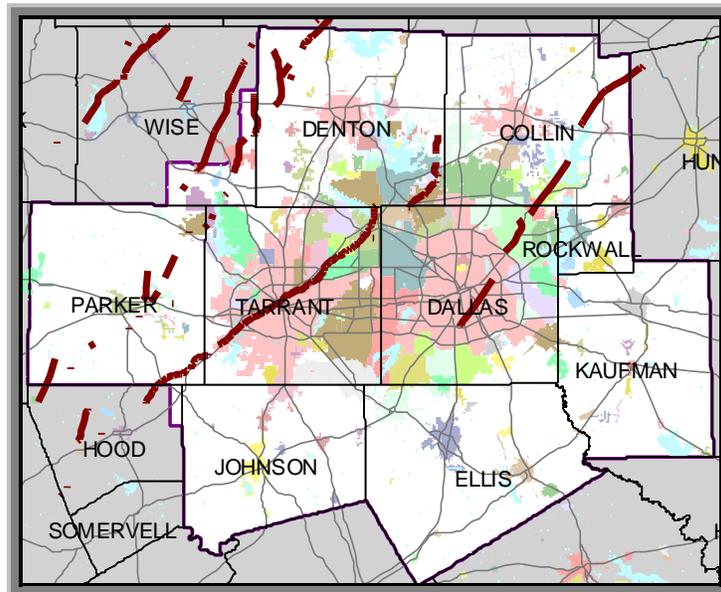


Tornado Damage Risk Assessment Dallas-Fort Worth Metroplex

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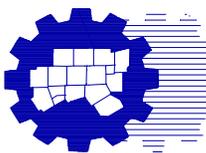
Scenario Three

Tornado Outbreak Data
Centered at $-97.21, 33.09$



All figures included in this summary are estimates based upon the best information available at the time of the study. A variety of other variables can be incorporated into future studies or come into play during a real event of this magnitude.

Last Update: January 11, 2001



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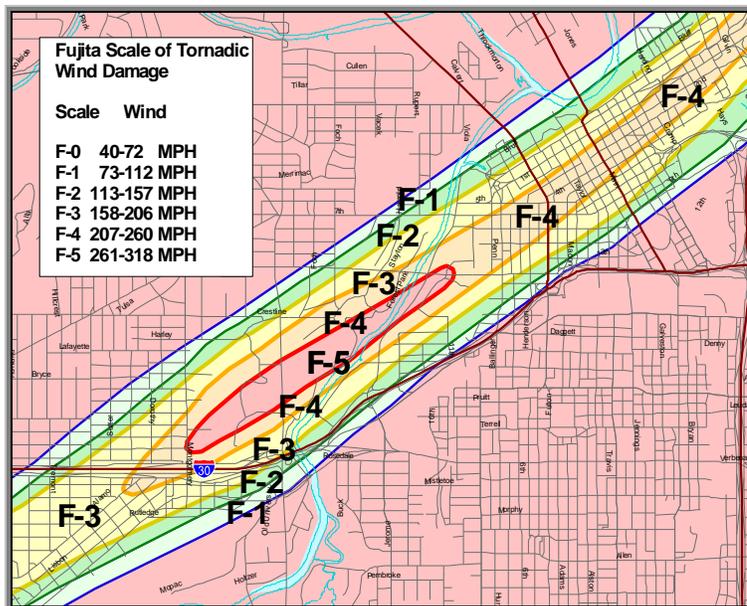
Study Overview

This study features the use of digitally mapped tornado path information from a real tornado outbreak laid atop Dallas-Fort Worth urban and demographic data. Modern computer technology can help estimate the magnitude that the tasks of warning, rescue, and recovery would require. If we make the very likely assumption that *Dallas-Fort Worth would see comparable damage in the same portions of the tornadoes that caused damage in Oklahoma*, we can then model this same event across the Dallas-Fort Worth Metroplex and assess how susceptible the area is to large tornado damage potential.

Five (5) separate distributions (scenarios) of the same Oklahoma tornado paths are modeled with the output including:

- The number of structures in the path
- Potential dollar damages to structures and contents
- Residents living in the path
- Employees working in the path
- Utility lines in the path
- The distribution of land use in the path
- Estimated roadway miles and vehicles travelling in the path

The goal is to stress the importance of planning and preparation for the day when this type of event does occur in Dallas-Fort Worth. A tornadic outbreak like the one in Oklahoma would cover an amazing amount of North Central Texas territory, and this study will help quantify that which would be in the way of the storms themselves.



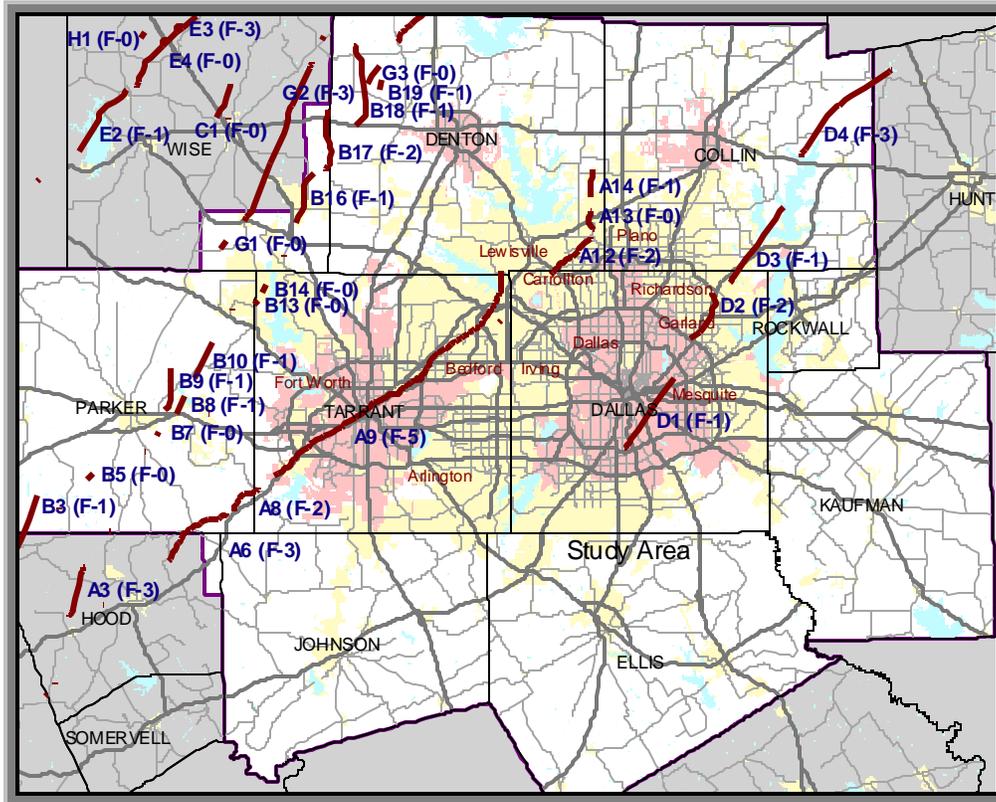
The Tornadoes used in this analysis were mapped using a distinct delineation of the Fujita Scale (F-Scale) damage regions as they occurred in Oklahoma. The F-Scale corresponds to the magnitude of damage occurring to structures.

This document focuses on scenario three of the study. For more information about study

methodology, data, and procedures, please refer to the [study summary](#) document.



Scenario Three

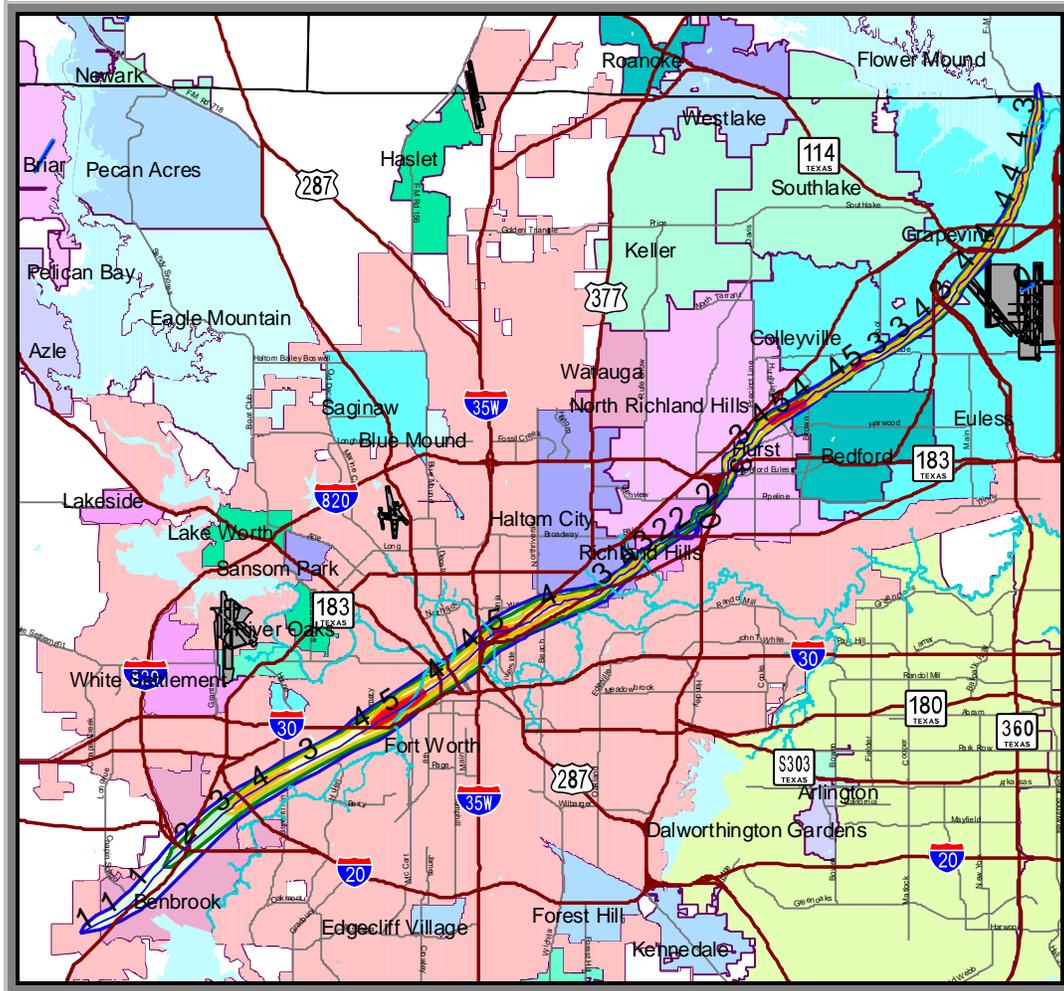


Scenario three centers the entire outbreak of tornadoes at -97.21,33.09 (long/lat decimal degrees). This positioning starts the big tornado “A9” near Lake Benbrook. Following the precise path direction that it did in Oklahoma, the storm moves directly through downtown Fort Worth, Haltom City, Richland Hills, Hurst, Colleyville, Bedford and up to the Dam at Lake Grapevine. This is the first multi-billion dollar damage event of the five scenarios. Approximately \$4 billion of property would lie in the path of these tornadoes. Tornado D1 produces a 9 mile path through southeast Dallas, but with F-1 winds and a small 30 yard width. Meanwhile, tornado D2 (F-2), with a 250 yard width, causes \$50 million of damage in Garland.

Scenario 3 – Summary of Structures in Path

Fujita Scale Contour	Structures Impacted	Property Value in Path	Potential Property Losses
0	57	\$8,183,370	\$401,653
1	8148	\$1,073,874,165	\$82,239,941
2	6447	\$1,014,789,747	\$668,175,650
3	7120	\$1,471,786,655	\$1,281,121,012
4	1588	\$601,097,140	\$601,097,140
5	118	\$19,262,130	\$19,262,130
Total	23380	\$4,188,993,000	\$2,652,000,000

Tornado Damage Risk Assessment – Dallas-Fort Worth



Above: Path of the large tornado "A9" through Tarrant County. Bold numbers along the path indicate the maximum F-Scale rating at that location.



Aerial Image Maps Courtesy of VARGIS LLC
Above: Aerial image of tornado "A9" path over downtown Fort Worth.



Major Land Uses in All Tornado Paths

Nearly 80% of the tornado paths in scenario one were made up of vacant land, but scenario three sees a dramatic increase in other land uses, particularly single family. For the first time in the study, the path of the big tornado “A9” hits more developed land than vacant land. Quite simply, this translates to a large number of destroyed structures, big dollar totals, and residents at risk.

Land Use Category	Impacted Acres	Maximum Fujita Scale	Impacted Square Miles	Percent of Total Area in Tornado Paths
Vacant	11549.52	5	18.04	51.26%
Single Family	4741.62	5	7.41	21.04%
Parks & Recreation	1278.93	5	2.00	5.68%
Industrial	955.45	5	1.49	4.24%
Retail	864.12	5	1.35	3.84%
Institutional	579.34	5	0.91	2.57%
Water	550.35	4	0.86	2.44%
Multi-family	283.20	4	0.44	1.26%
Office	267.01	4	0.42	1.19%
Airport	141.44	4	0.22	0.63%
Mobile Home Parks	4.94	3	0.01	0.02%

Major Land Uses in the Path of Tornado “A9” (Moore,OK)

Land Use Category	Impacted Acres	Maximum Fujita Scale	Impacted Square Miles	Percent of Total Area in Tornado “A9” Path
Single Family	4075.10	5	6.37	33.30%
Vacant	2850.96	5	4.45	23.30%
Parks & Recreation	1225.96	5	1.92	10.02%
Industrial	853.83	5	1.33	6.98%
Retail	763.05	5	1.19	6.23%
Institutional	558.69	5	0.87	4.57%
Multi-family	268.41	4	0.42	2.19%
Office	266.37	4	0.42	2.18%
Airport	134.00	4	0.21	1.09%
Parking	127.53	4	0.20	1.04%
Water	11.23	4	0.02	0.09%
Mobile Home Parks	4.66	3	0.01	0.04%

Detailed Structure Summary

The table below provides structure damage estimates for all of the tornado paths. Damages are calculated based on appraisal data and the Fujita Scale category at the structure location.

Type	Total in Path	Property Value in Path	Potential Losses
Single Family Homes	14480	\$1,311,323,302	\$753,579,000.00
Apartment Units	6200	\$237,749,649	\$172,914,000.00
Mobile Homes	31	\$488,506	\$267,313.00
Commercial Properties	1408	\$2,204,693,573	\$1,464,295,345.00
Industrial Structures	478	\$434,738,177	\$261,241,264.00



Residents and Employees in Path

The table below provides an estimate of the number of persons occupying the structures in the path of the tornadoes. Numbers are based upon city data for household size, occupancy rates, major employer locations, and traffic survey zone employment data.

Category	Total Persons	Persons in F-2 or Greater Contour	Persons in F-4 or F-5 Contour
Residents at Home	51312	33378	3845
Employees at Work	64636	52242	11287

Estimated Number of Persons Occupying Residential Structures In the Path of Tornadoes

Fujita Scale Contour	Persons in Homes	Persons in Apartments	Persons in Mobile Homes
0	142	0	0
1	14721	3033	47
2	10614	3850	23
3	10532	4785	0
4	2926	351	0
5	284	0	0
Total	39222	12020	70

Largest Damages by City

City	Structures in Path	Property Value in Path	Potential Losses	Maximum Fujita Scale	Employees in Path	Residents in Path
Fort Worth	12000	\$2,523,611,447	\$1,807,391,422	5	51903	25050
Colleyville	927	\$324,577,041	\$170,072,599	5	195	2839
Hurst	954	\$266,282,468	\$167,498,093	5	3523	2197
Haltom City	1486	\$244,415,002	\$160,702,344	4	3800	2962
North Richland	1552	\$125,541,221	\$71,140,903	3	853	2991
Benbrook	1533	\$240,307,563	\$67,365,319	3	1472	3497
Grapevine	533	\$114,109,996	\$66,571,773	4	456	1259
Garland	1637	\$110,455,032	\$49,419,783	2	1423	4381
Richland Hills	1316	\$89,423,870	\$45,620,244	3	719	2900
Bedford	333	\$50,312,742	\$30,862,305	5	16	951
Carrollton	200	\$24,822,121	\$6,375,179	2	49	518

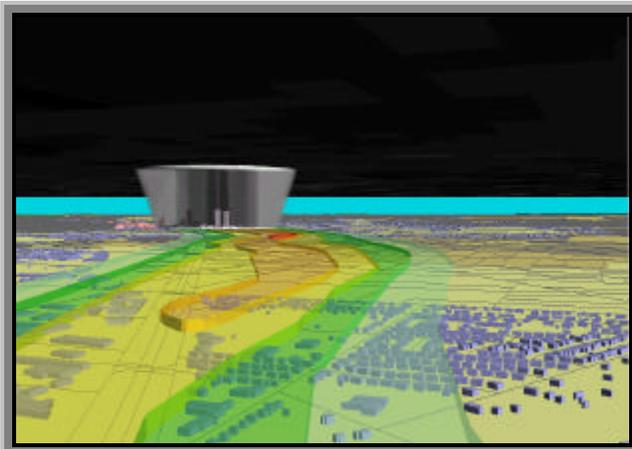
Other Features Impacted

Category	Total Number	Number in F-2 or Greater Contour	Number in F-4 or F-5 Contour
Schools	13	8	1
Miles of Roads	400.30	265.21	45.22
Miles of Railroads	20.39	10.12	2.35
Major Electrical Utility Lines Intersected by Centerline of Tornado	40	22	6

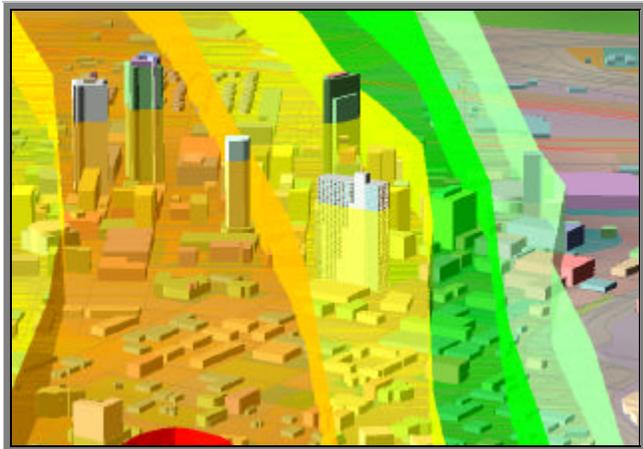
Percentage of City Current Single Family Housing Units Destroyed By Tornadoes

The table below describes the inventory of single family houses currently existing in several North Central Texas cities, and compares that to the number that would have been destroyed in scenario three. The Cities of Richland Hills, Colleyville and Haltom City see major impacts to their housing inventory from this scenario. Over 5500 houses are destroyed in Fort Worth.

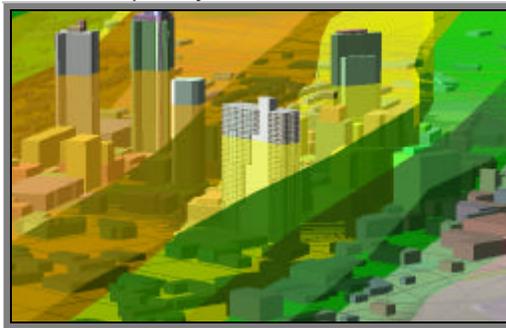
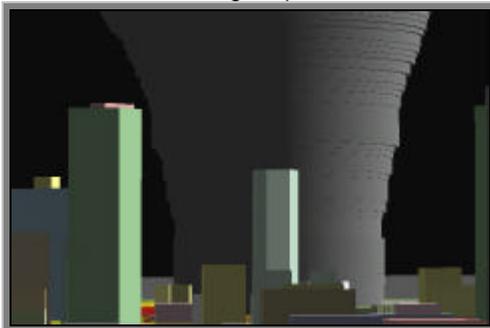
CITYNAME	Houses Destroyed (F2 or Greater Contour)	Estimated Number of Current Single Family Units in 1999	Percent Destroyed
Richland Hills	426	2730	15.61%
Colleyville	575	6174	9.33%
Haltom City	683	10093	6.78%
Fort Worth	5554	133889	4.15%
Hurst	370	10009	3.70%
Grapevine	253	10044	2.53%
Bedford	205	12106	1.70%
Garland	779	56221	1.39%
Benbrook	21	6386	0.34%
Carrollton	49	27059	0.18%



Computer Models of tornado “A9”, wide enough at this point to encompass the entire width of Downtown Fort Worth. This tornado would also destroy over 5000 homes along its path.



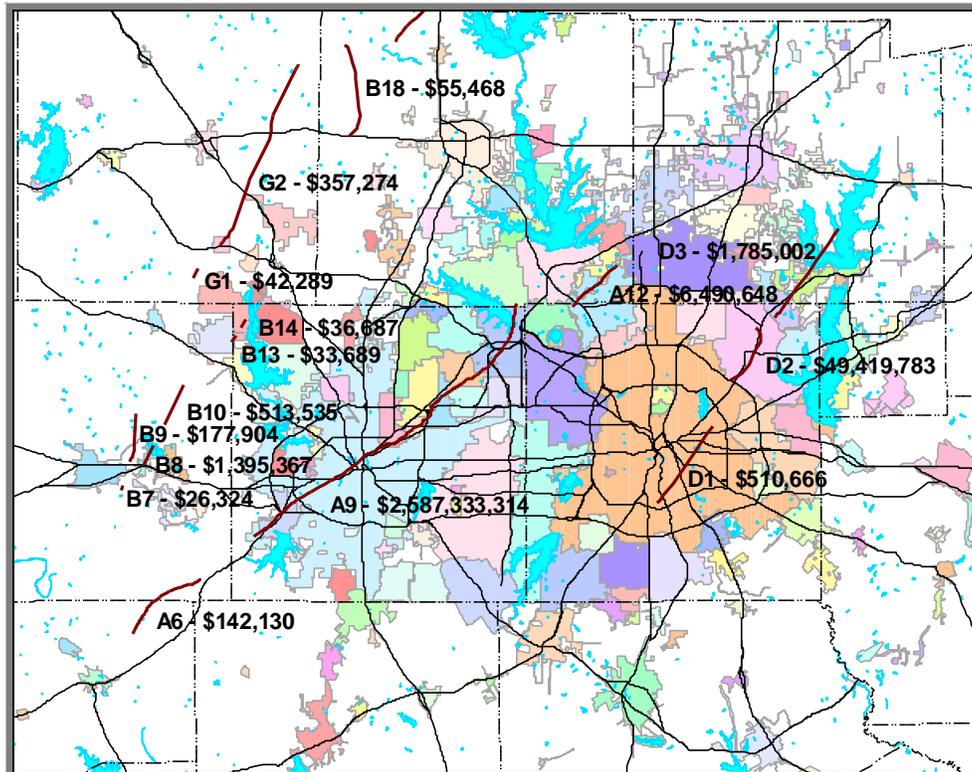
Above: Tornado “A9” path enhanced vertically to emphasize Fujita-Scale contour lines, The largest glass office-buildings in Fort Worth would be completely within F-3 and F-4 wind areas.



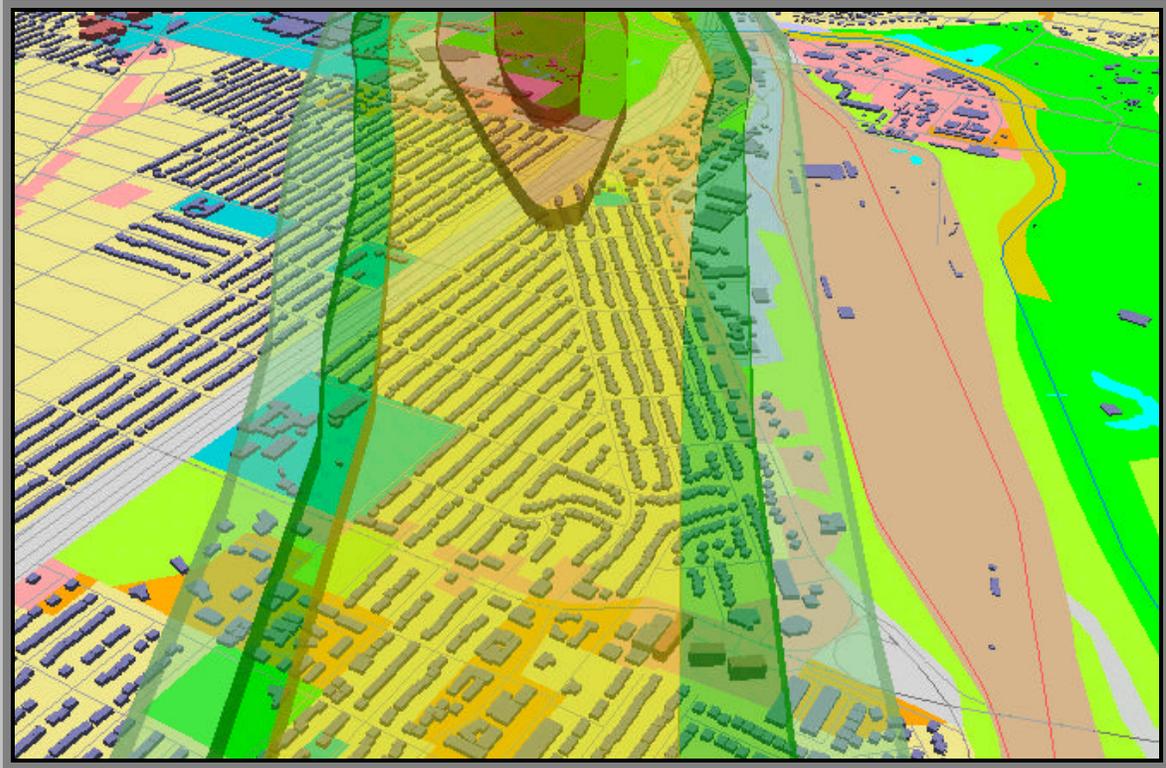
Population Threat and Losses by Tornado

In scenario three, the big tornado “A9”, impacts a huge amount of property. This is a true nightmare of a tornado strike, with nearly \$2.6 billion of losses attributed to this one tornado. The impact of tornado D2 is significant in northeast Dallas County. Many of the northern tornadoes in this outbreak slide above the study area and do not provide much data.

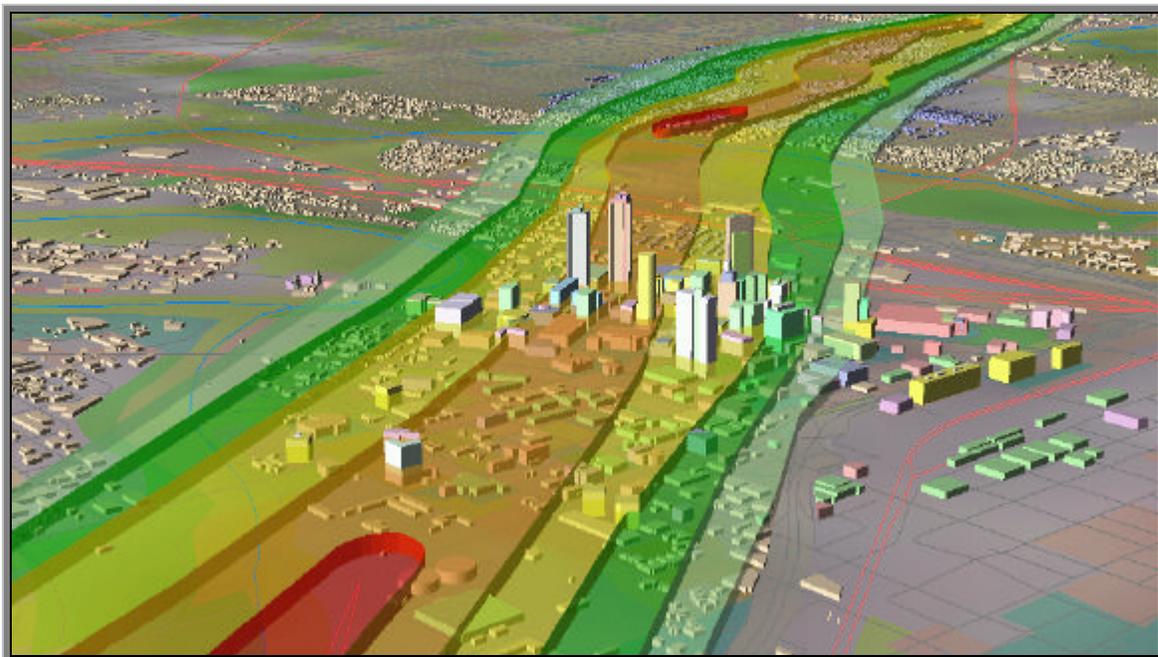
Tornado	Maximum Fujita Scale	Residents in the Path	Structures Impacted	Property Value in Path	Potential Losses
A9	5	44649	20360	\$3,978,691,841	\$2,587,333,313
D2	2	4381	1637	\$110,455,032	\$49,419,783
A12	2	531	205	\$25,630,718	\$6,490,647
B20	2	184	68	\$8,137,951	\$3,977,458
D3	1	481	170	\$22,860,580	\$1,785,001
B8	1	279	121	\$17,908,842	\$1,395,367
B10	1	146	54	\$6,456,827	\$513,534
D1	1	439	176	\$6,535,897	\$510,666
G2	2	69	30	\$5,634,132	\$357,273
B9	1	51	19	\$2,264,227	\$177,903
A6	2	20	8	\$985,666	\$142,129
B18	1	15	6	\$705,954	\$55,467



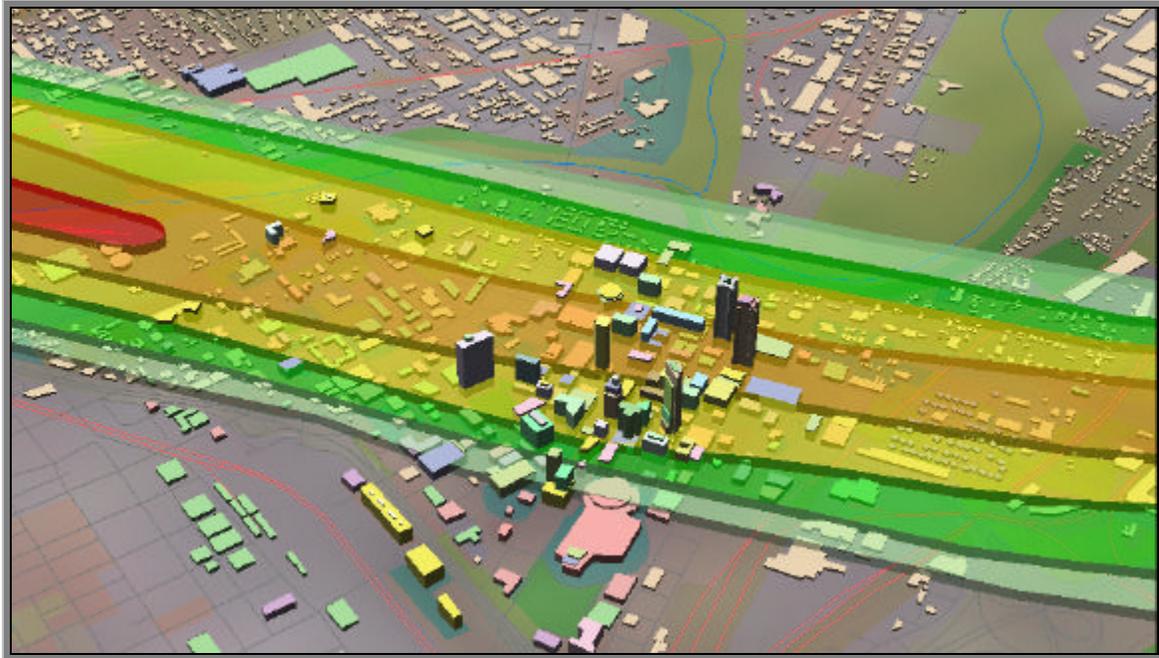
Above: Structural damage estimates by tornado for Scenario Three



Above: *Building structures in the path of Tornado "A9" just southwest of Downtown Fort Worth. Nearly 21,000 structures would be in the path of this tornado alone.*



Above: *Computer Model of path of Tornado "A9" passing through downtown Fort Worth. Over 90% of downtown structures would be impacted in this scenario.*



Above: Computer Model of path of Tornado "A9" passing through downtown Fort Worth. The appraised value of structures in the downtown area total around \$1 Billion. There are over 50,000 jobs in the area as well.

Estimated Traffic in the Path of Tornadoes

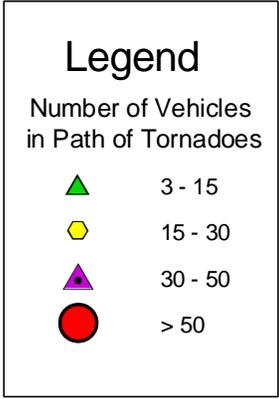
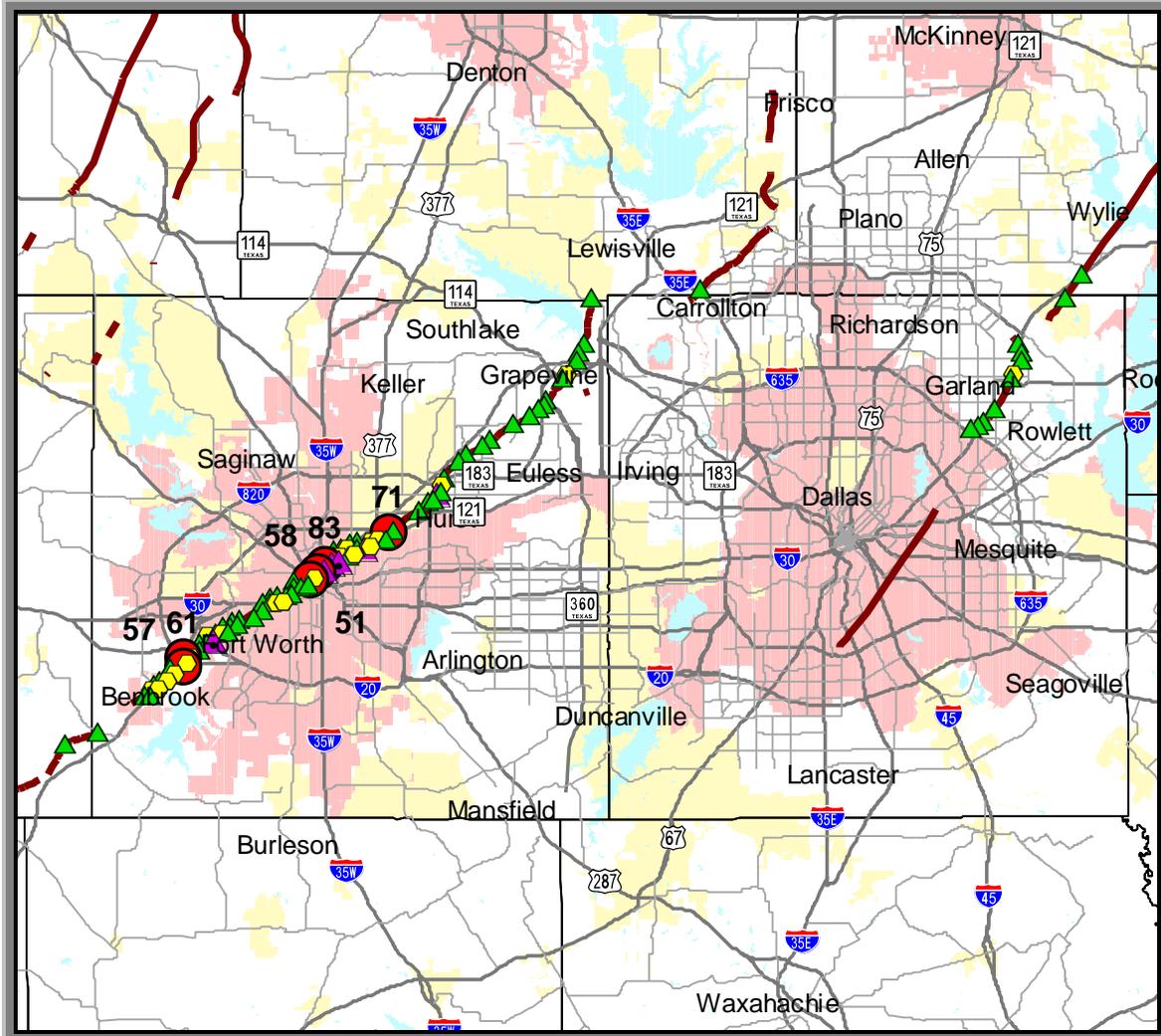
Traffic figures for vehicles in the path of the tornadoes are based on NCTCOG transportation modeling for major thoroughfares through the region. The data is an estimate of road volumes and capacities across more than 21,000 links throughout the metroplex, many of them calibrated to actual traffic count data. The models include estimates for freeways, arterials, and collectors, but do not include local residential streets. The numbers for scenario three are derived from those modeling numbers. For scenario three, we are estimating the number of cars that, as a function of volume, speed, time, and distance, should be located on the actual roadway pavement in the tornado's path at the time the tornado overtakes the route. **Hourly traffic** numbers provide an estimate of how many cars would actually cross the path during the hour of the tornado's primary impact. **Vehicles trapped** numbers are estimates of how many vehicles should theoretically be on the roadway in the tornado path when the tornado strikes (under varying traffic levels).

Hourly Vehicles on Routes Crossed by Tornadoes	Vehicles Trapped in Tornado Paths at Normal Roadway Vehicle Volumes	Vehicles Trapped in Tornado Paths if Roadways all Backed Up
*169376	*1737	79581

* Estimated based on daily modeling totals and hourly multipliers

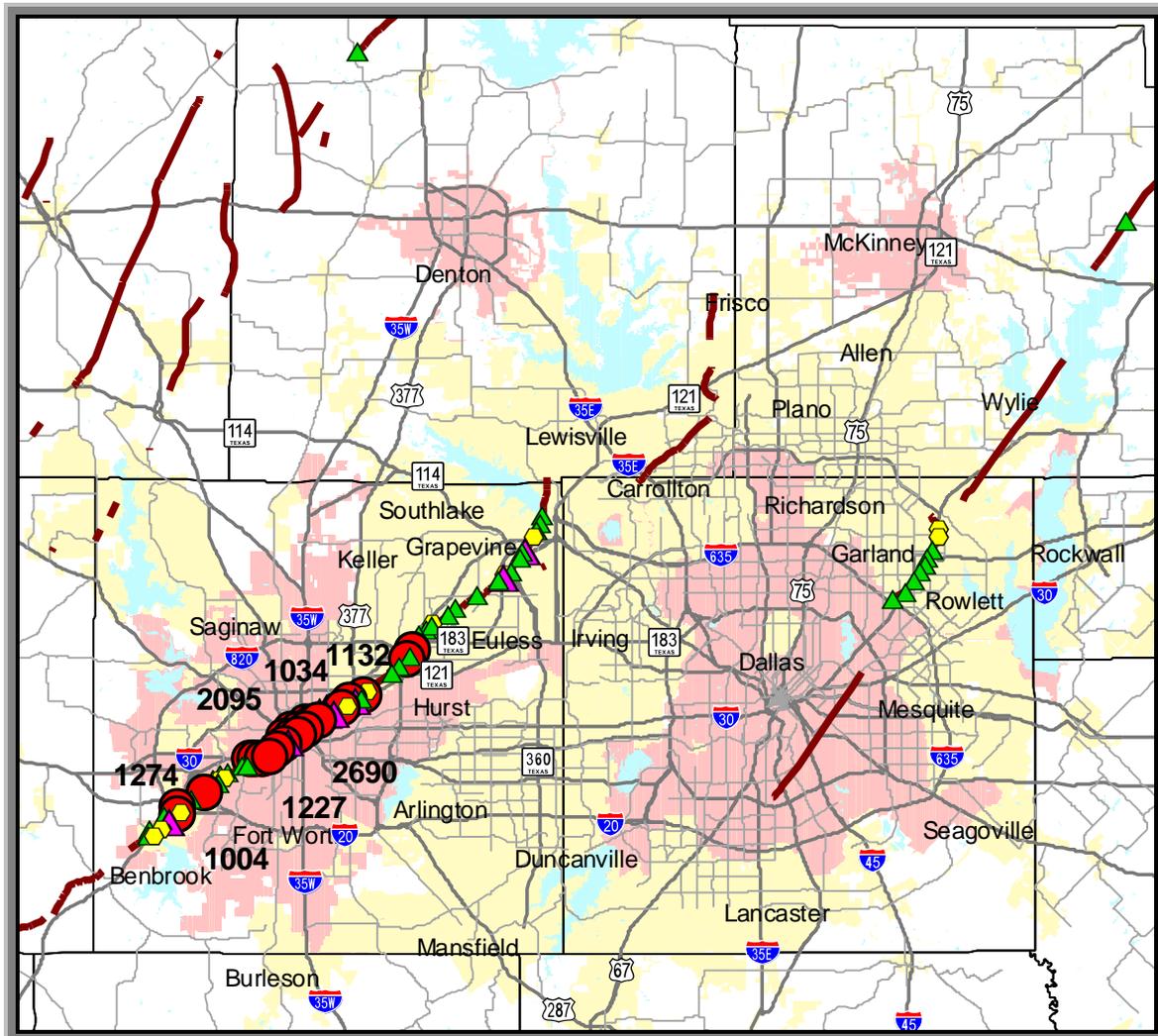


Tornado Damage Risk Assessment – Dallas-Fort Worth



Above: Areas with 3 or more vehicles potentially trapped in path of tornadoes. Region-wide in scenario three, 1737 vehicles are estimated to be in the direct path of tornadoes under such normal flow conditions. Each dot represents an area of no greater than .2 square miles. The dots represent a total of all modeled road data in those small areas. Note that the number of cars “trapped” is also dependent upon the width of the tornado path.

Tornado Damage Risk Assessment – Dallas-Fort Worth

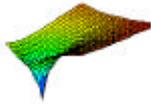


Legend

Number of Vehicles
in Path of Tornadoes

- ▲ 100 - 250
- ◆ 250 - 500
- ▲ 500 - 750
- > 750

Above: Areas with 100 or more vehicles potentially trapped in tornado paths if roadways backed up (traffic jam). If all lanes were backed up with an average of one vehicle per 35 feet, the above areas would find large numbers of vehicles located in the path at the time of the tornado strike. If all of the modeled routes were backed up this way, 79,000 vehicles would be in the path of tornadoes. Each dot represents an area of no greater than .2 square miles. The dots represent a total of all modeled road data in those small areas. Note that the number of cars "trapped" is also dependent upon the width of the tornado path.

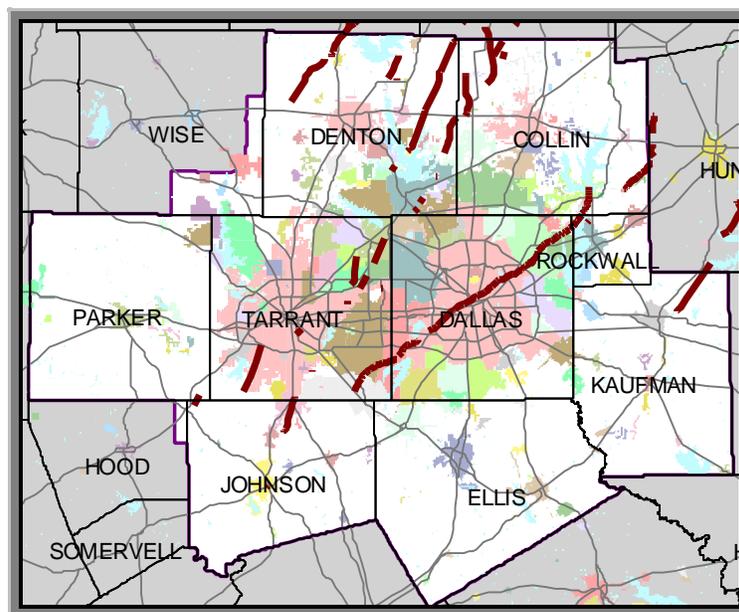


Tornado Damage Risk Assessment Dallas-Fort Worth Metroplex

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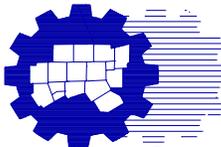
Scenario Four

Tornado Outbreak Data
Centered at $-96.63, 33.50$



All figures included in this summary are estimates based upon the best information available at the time of the study. A variety of other variables can be incorporated into future studies or come into play during a real event of this magnitude.

Last Update: January 11, 2001



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Data Analysis and Geographic Information System Data Compilation

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Special Thanks for Data Contributions and Suggestions

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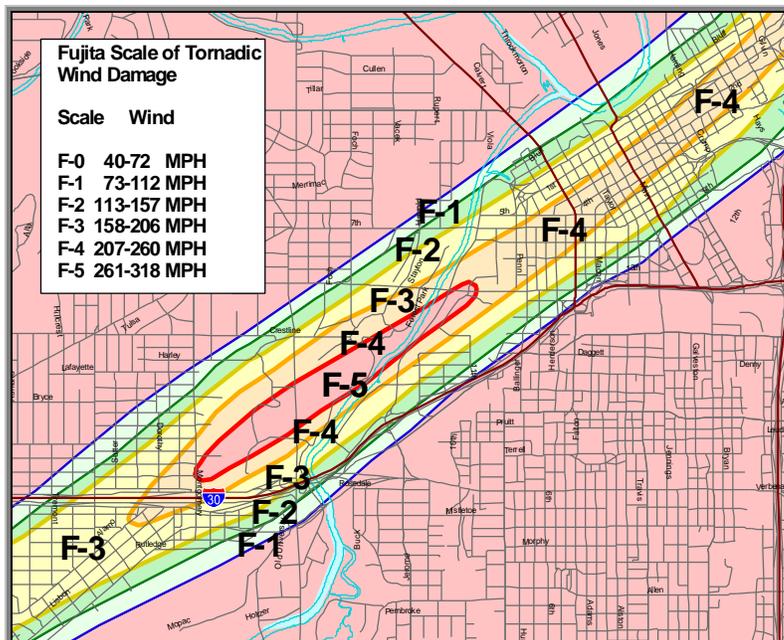
Study Overview

This study features the use of digitally mapped tornado path information from a real tornado outbreak laid atop Dallas-Fort Worth urban and demographic data. Modern computer technology can help estimate the magnitude that the tasks of warning, rescue, and recovery would require. If we make the very likely assumption that *Dallas-Fort Worth would see comparable damage in the same portions of the tornadoes that caused damage in Oklahoma*, we can then model this same event across the Dallas-Fort Worth Metroplex and assess how susceptible the area is to large tornado damage potential.

Five (5) separate distributions (scenarios) of the same Oklahoma tornado paths are modeled with the output including:

- The number of structures in the path
- Potential dollar damages to structures and contents
- Residents living in the path
- Employees working in the path
- Utility lines in the path
- The distribution of land use in the path
- Estimated roadway miles and vehicles travelling in the path

The goal is to stress the importance of planning and preparation for the day when this type of event does occur in Dallas-Fort Worth. A tornadic outbreak like the one in Oklahoma would cover an amazing amount of North Central Texas territory, and this study will help quantify that which would be in the way of the storms themselves.



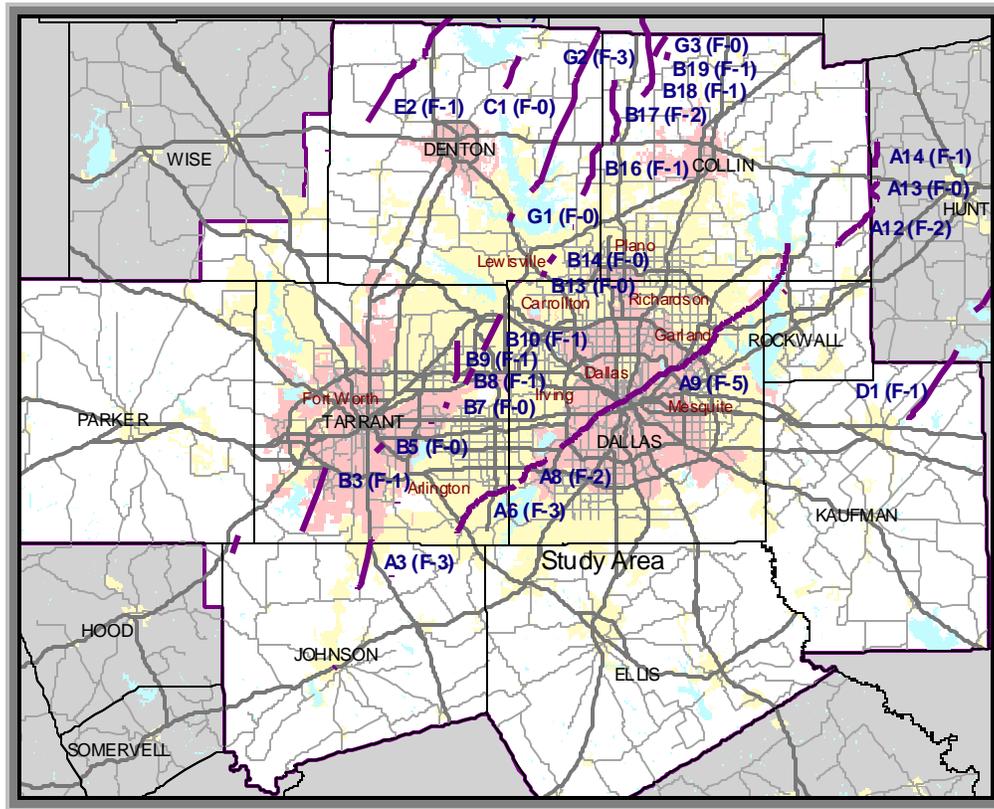
The Tornadoes used in this analysis were mapped using a distinct delineation of the Fujita Scale (F-Scale) damage regions as they occurred in Oklahoma. The F-Scale corresponds to magnitude of damage occurring to structures.

This document focuses on scenario four of the study. For

more information about study methodology, data, and procedures, please refer to the [study summary document](#).



Scenario 4



Scenario four centers the entire outbreak of tornadoes at -96.63,33.50 (long/lat decimal degrees). This positioning starts the big tornado “A9” near Cockrell Hill in Dallas County. Following the precise path direction that it did in Oklahoma, the storm moves through southwest Dallas and through the northwest side of downtown. The storm strengthens to threaten F-5 damage as it enters the Lakewood area of east Dallas, and slides northeast through Rowlett and Garland. Like scenario three, this is a \$3 billion potential property loss event. Sister tornadoes produced by the same thunderstorm would have cut damage paths through Arlington, Grand Prairie and Burleson. The alignment of scenario four would threaten the most employees in the study – about 94,000.

Scenario 4 – Summary of Structures in Path

Fujita Scale Contour	Structures Impacted	Property Value in Path	Potential Property Losses
0	76	\$8,863,509	\$455,173
1	11019	\$1,586,949,894	\$121,703,960
2	8797	\$1,287,566,904	\$801,038,321
3	6118	\$1,700,663,604	\$1,456,329,235
4	3964	\$362,666,563	\$362,666,563
5	910	\$66,733,295	\$66,733,295
Total	30887	\$5,013,443,000.00	\$2,808,000,000.00



Major Land Uses in All Tornado Paths

Nearly 40% of the land in the path of the tornadoes in scenario four can be classified as developed. This contributes to the \$2.9 billion damage estimate. The path of the big tornado “A9” covers more developed land than vacant land. This tornado path crosses over 1500 acres of lake water – mainly White Rock Lake and Lake Ray Hubbard.

Land Use Category	Impacted Acres	Maximum Fujita Scale	Impacted Square Miles	Percent of Total Area in Tornado Paths
Vacant	9654.50	5	15.08	45.78%
Single Family	4983.76	5	7.79	23.63%
Water	1573.88	5	2.46	7.46%
Parks & Recreation	945.89	5	1.48	4.48%
Retail	821.44	5	1.28	3.89%
Industrial	678.14	4	1.06	3.22%
Multi-family	603.08	5	0.94	2.86%
Institutional	594.76	5	0.93	2.82%
Office	253.04	5	0.40	1.20%
Parking	111.16	4	0.17	0.53%
Mobile Home Parks	73.30	4	0.11	0.35%
Airport	42.83	3	0.07	0.20%
Landfill	7.16	0	0.01	0.03%

Major Land Uses in the Path of Tornado “A9” (Moore,OK)

Land Use Category	Impacted Acres	Maximum Fujita Scale	Impacted Square Miles	Percent of Total Area in Tornado “A9” Path
Single Family	4298.28	5	6.72	35.12%
Vacant	2156.44	5	3.37	17.62%
Water	1465.43	5	2.29	11.97%
Parks & Recreation	858.09	5	1.34	7.01%
Retail	781.29	5	1.22	6.38%
Industrial	591.20	4	0.92	4.83%
Multi-family	581.26	5	0.91	4.75%
Institutional	538.43	5	0.84	4.40%
Office	236.52	5	0.37	1.93%
Mobile Home Parks	23.94	4	0.04	0.20%

Detailed Structure Summary

The table below provides structure damage estimates for all of the tornado paths. Damages are calculated based on appraisal data and the Fujita Scale category at the structure location.

Type	Total in Path	Property Value in Path	Potential Losses
Single Family Homes	17064	\$1,765,098,694	\$1,063,995,160
Apartment Units	10953	\$333,734,132	\$210,124,134
Mobile Homes	616	\$7,655,328	\$6,612,407
Commercial Properties	1263	\$2,820,373,600	\$1,469,457,831
Industrial Structures	319	\$86,582,016	\$59,050,148



Residents and Employees in Path

The table below provides an estimate of the number of persons occupying the structures in the path of the tornadoes. Numbers are based upon city data for household size, occupancy rates, major employer locations, and traffic survey zone employment data.

Category	Total Persons	Persons in F-2 or Greater Contour	Persons in F-4 or F-5 Contour
Residents at Home	69357	43203	9037
Employees at Work	94186	55992	7544

Estimated Number of Persons Occupying Residential Structures In the Path of Tornadoes

Fujita Scale Contour	Persons in Homes	Persons in Apartments	Persons in Mobile Homes
0	173	14	0
1	19758	5898	311
2	12895	6186	783
3	9361	3777	222
4	4521	3722	13
5	573	1150	0
Total	47281	20747	1329

Largest Damages by City

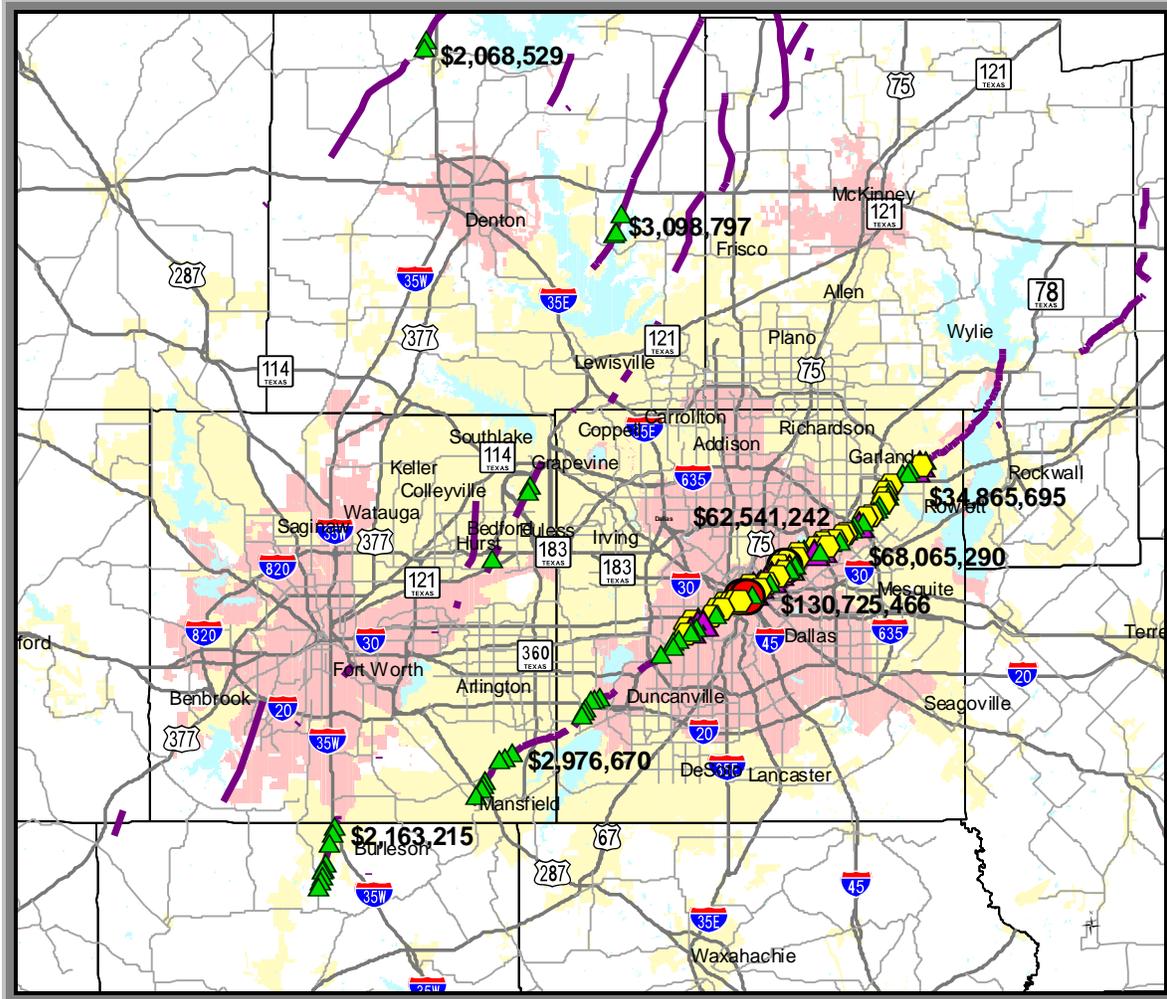
City	Structures in Path	Property Value in Path	Potential Losses	Maximum Fujita Scale	Employees in Path	Residents in Path
Dallas	22899	\$4,193,401,229	\$2,487,530,437	5	90317	47901
Garland	2813	\$231,668,343	\$132,825,620	4	2145	7367
Rowlett	997	\$151,271,825	\$91,798,716	5	107	3004
County Land or Undefined	721	\$87,158,945	\$28,244,953	4	23	1939
Grand Prairie	340	\$40,543,597	\$13,597,637	2	15	992
Arlington	587	\$31,118,013	\$11,343,994	2	286	1475
Cockrell Hill	1138	\$47,087,888	\$11,072,432	2	400	3508
Mansfield	262	\$34,262,918	\$10,476,429	2	88	743
Burleson	110	\$20,496,814	\$7,710,437	3	157	272
Grapevine	20	\$67,086,230	\$5,088,897	1	93	0
Bedford	258	\$43,730,615	\$3,359,865	1	237	569

Other Features in Path

Category	Total Number	Number in F-2 or Greater Contour	Number in F-4 or F-5 Contour
Schools	27	15	1
Miles of Roads	344.34	211.48	38.58
Miles of Railroads	18.06	12.66	0.81
Major Electrical Utility Lines Intersected by the Centerline of a Tornado	43	29	7



Tornado Damage Risk Assessment – Dallas-Fort Worth



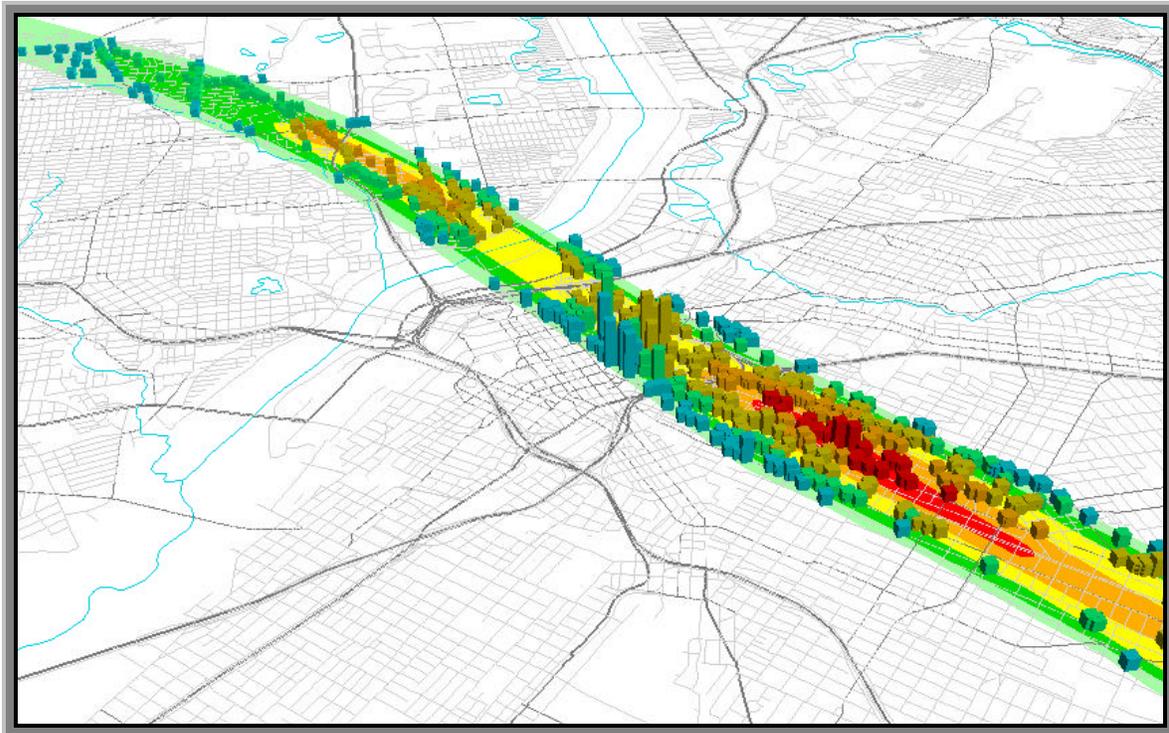
Legend	
Structural Damage Estimates in Dollars	
	\$1,000,000 - \$10,000,000
	\$10,000,000 - \$25,000,000
	\$25,000,000 - \$75,000,000
	> \$75,000,000

Above: The most significant damage areas as calculated for scenario four. Displayed points represent small area locations with total damages exceeding \$1,000,000. The small areas are no larger than .2 square miles and exist entirely within the tornado path. Their positioning has been generalized for the scale of mapping.

Percentage of City Current Single Family Housing Units Destroyed By Tornadoes

The table below describes the inventory of single family houses currently existing in several North Central Texas cities, and compares that to the number that would have been destroyed in scenario four. The City of Cockrell Hill would see a major loss of homes in this scenario, and Dallas would have to recover from a tremendous damage path.

CITYNAME	Houses Destroyed (F2 or Greater Contour)	Estimated Number of Current Single Family Units in 1999	Percent Destroyed
Cockrell Hill	166	896	18.53%
Rowlett	609	13149	4.64%
Dallas	7316	227914	3.21%
Garland	1280	56221	2.28%
Mansfield	92	7568	1.22%
Little Elm	2	317	0.65%
Burleson	33	6205	0.55%
Grand Prairie	115	29854	0.39%
Arlington	91	75920	0.12%

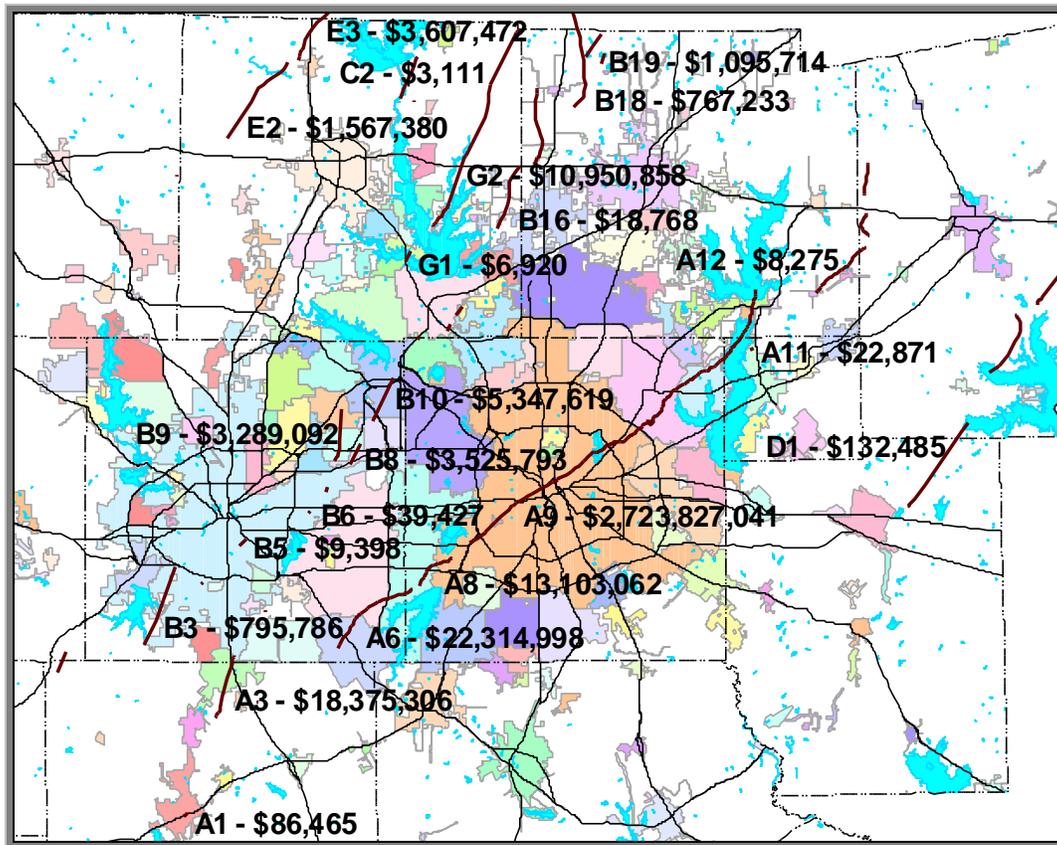


Above: Geographical box graph of significant commercial structures along a portion of the path of tornado "A9" through Dallas. Colors correspond to the F-Scale and the height corresponds to the number of stories of the structure in the path.

Population Threat and Losses by Tornado

In scenario four, the big tornado “A9”, would produce a huge amount of damage. This is a true nightmare of a tornado strike, with over \$2.8 billion attributed to this one tornado. Three other tornadoes from the same thunderstorm would produce expensive damage paths in Arlington, Burleson, and Grand Prairie. If the model path had been slightly more southeast, the damages would have been much higher – encompassing more of downtown Dallas with higher winds.

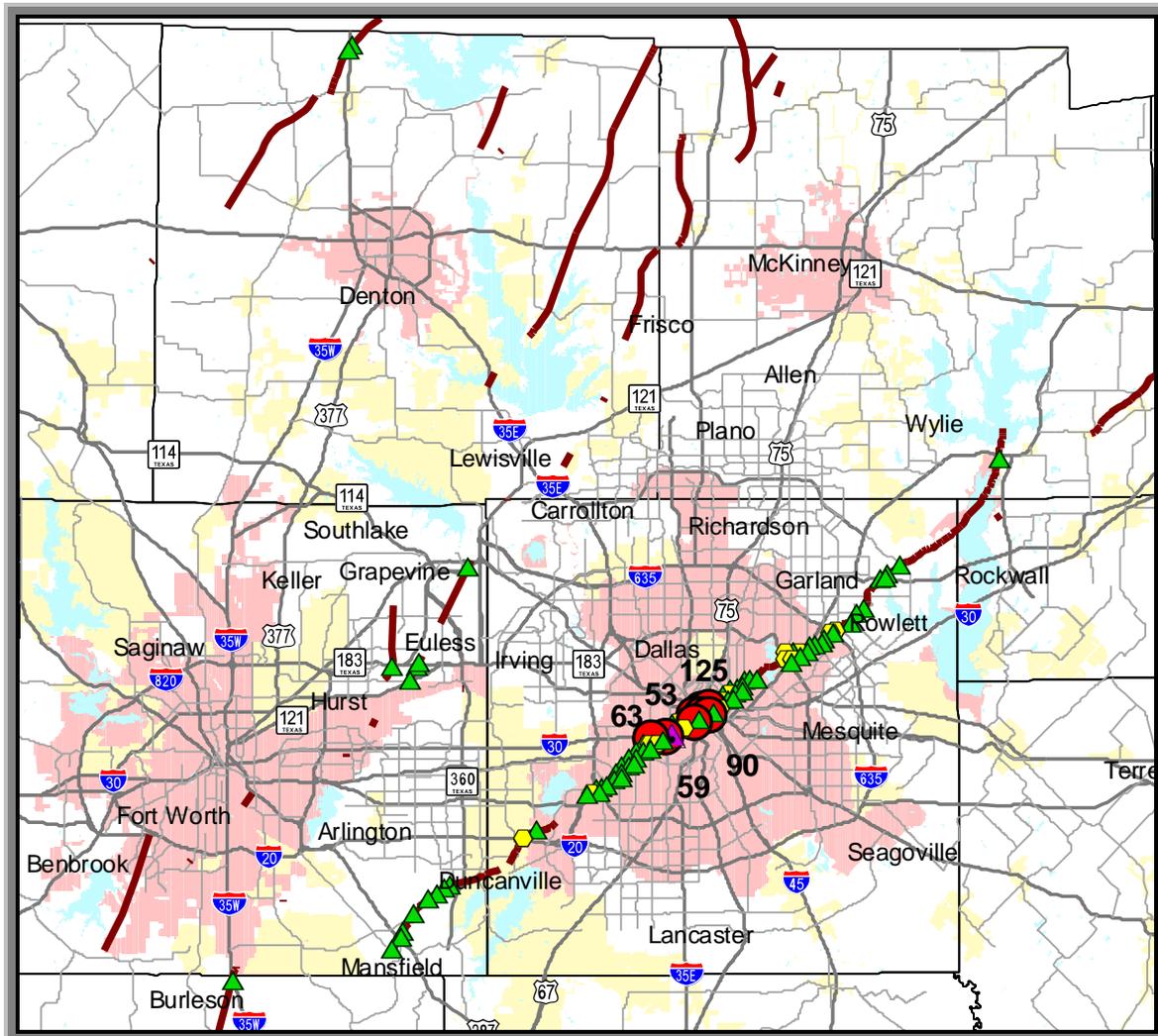
Tornado	Maximum Fujita Scale	Residents in the Path	Structures Impacted	Property Value in Path	Potential Losses
A9	5	61893	27896	\$4,625,407,214	\$2,723,827,041
A6	2	2318	883	\$67,975,789	\$22,314,998
A3	3	864	329	\$46,615,295	\$18,375,306
A8	2	892	306	\$37,948,740	\$13,103,062
G2	3	382	140	\$16,855,263	\$10,950,858
B10	1	75	48	\$70,380,852	\$5,347,619
E3	3	203	74	\$8,961,242	\$3,607,472
B8	1	866	382	\$46,290,588	\$3,525,793
B9	1	597	257	\$42,448,399	\$3,289,092
E2	1	450	166	\$19,953,824	\$1,567,380
B19	2	33	13	\$3,517,406	\$1,095,714



Above: Structural damage estimates by tornado for Scenario Four.



Tornado Damage Risk Assessment – Dallas-Fort Worth

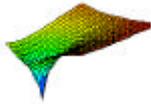


Legend

Number of Vehicles
in Path of Tornadoes

-  3 - 15
-  15 - 30
-  30 - 50
-  > 50

Above: Areas with 3 or more vehicles potentially trapped in path of tornadoes. Region-wide in scenario four, 1833 vehicles are estimated to be in the direct path of tornadoes under such normal flow conditions. Each dot represents an area of no greater than .2 square miles. The dots represent a total of all modeled road data in those small areas. Note that the number of cars "trapped" is also dependent upon the width of the tornado path.

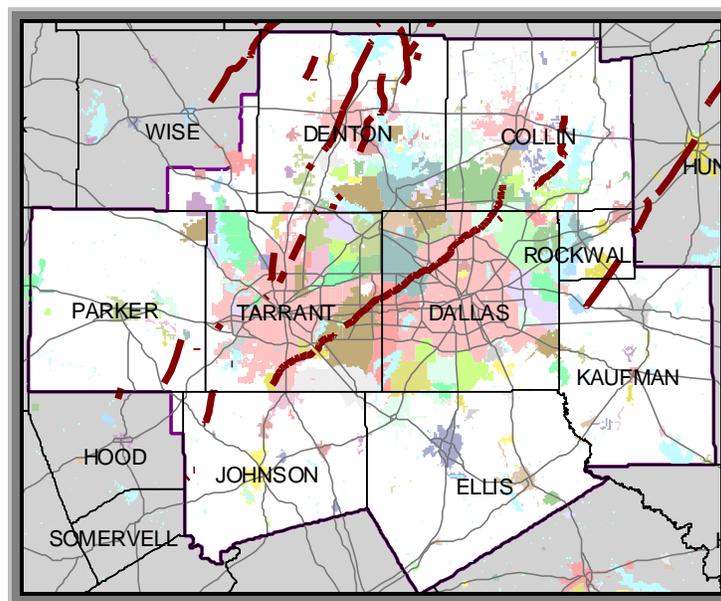


Tornado Damage Risk Assessment Dallas-Fort Worth Metroplex

A Regional Exercise in Demographic,
Environmental, and Urban Analysis
February, 2000

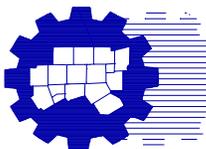
Scenario Five

Tornado Outbreak Data
Centered at $-96.84, 33.14$



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Last Update: January 11, 2001



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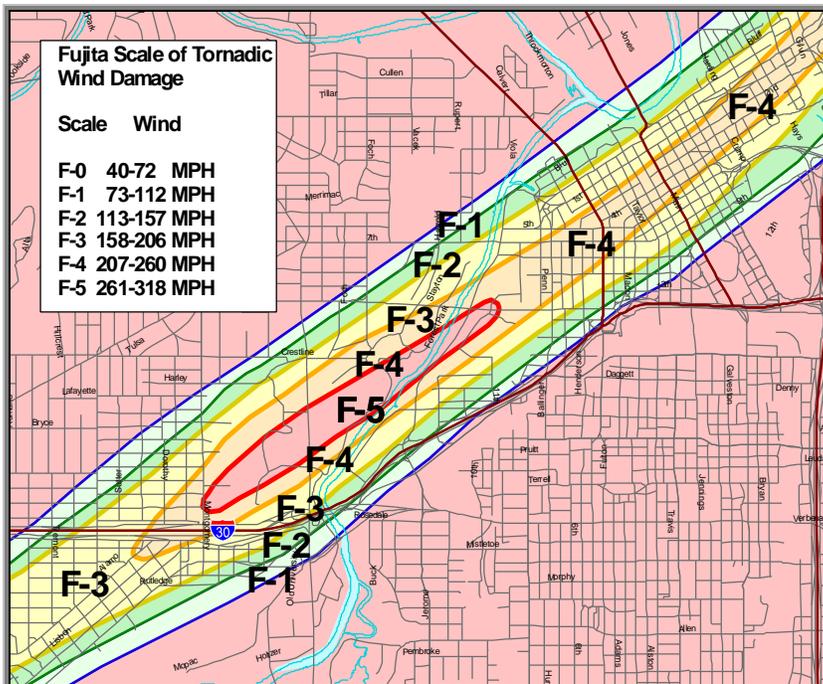
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Five (5) separate distributions (scenarios) of the same Oklahoma tornado paths are modeled with the output including:

- The number of structures in the path
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- Residents living in the path
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- Estimated roadway miles and vehicles travelling in the path

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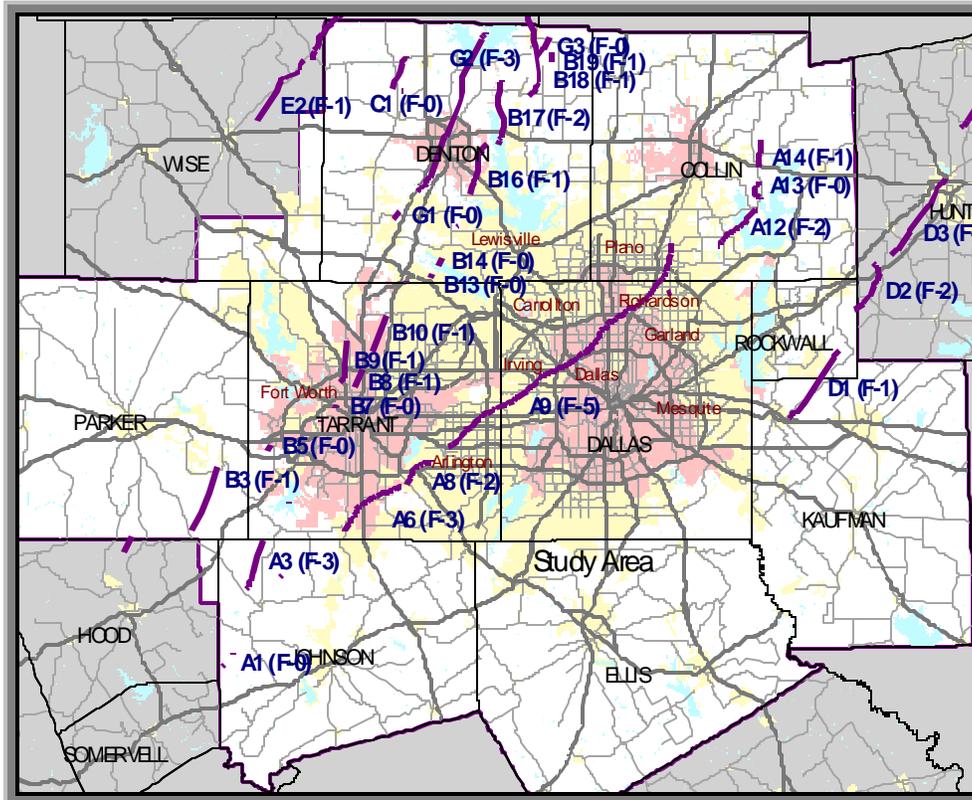
The Tornadoes used in this analysis were mapped using a distinct delineation of the Fujita Scale (F-Scale) damage regions as they occurred in Oklahoma. The F-Scale corresponds to magnitude of damage occurring to structures.

This document focuses on

scenario five of the study. For more information about study methodology, data, and procedures, please refer to the [study summary](#) document.



Scenario Five



Scenario five centers the entire outbreak of tornadoes at -96.84,33.14 (long/lat decimal degrees). Scenario five calculates to have the highest dollar risk of the scenarios. This route touches the big tornado “A9” down initially in Arlington. Following the precise path and direction that it did in Oklahoma, the storm moves through northeast Arlington, Grand Prairie, Irving, Dallas, and Richardson. This path crosses UT-Arlington, the Ballpark in Arlington, Six Flags over Texas, Texas Stadium, and expensive office property in Richardson. A large number of apartment complexes would be in the way in North Dallas – over 19,000 units altogether in this scenario. Over 17,000 houses are in the path as well, along with an amazing 84,000 residents.

Scenario 5 – Summary of Structures in Path

Fujita Scale	Structures Impacted	Property Value in Path	Potential Damages
0	508	\$57,341,105	\$2,760,376
1	15464	\$1,692,391,492	\$130,044,824
2	9518	\$1,309,717,551	\$833,337,409
3	9201	\$1,308,032,590	\$1,196,426,674
4	3513	\$650,186,547	\$650,186,547
5	574	\$46,553,369	\$46,553,369
Total	38778	\$5,064,222,000	\$2,859,000,000



Major Land Uses in Tornado Paths

Nearly 50% of the land in the path of the tornadoes in scenario five can be classified as developed. This contributes to the \$3 billion property loss estimate. Nearly 70% of the path of the big tornado “A9” occurs through developed acreage.

Land Use Category	Impacted Acres	Maximum Fujita Scale	Impacted Square Miles	Percent of Total Area in Tornado
Vacant	8150.40	5	12.73	40.12%
Single Family	5154.45	5	8.05	25.37%
Industrial	1287.20	5	2.01	6.34%
Retail	1274.36	5	1.99	6.27%
Institutional	800.20	5	1.25	3.94%
Multi-family	730.77	5	1.14	3.60%
Water	690.55	3	1.08	3.40%
Parks & Recreation	654.65	5	1.02	3.22%
Office	373.77	4	0.58	1.84%
Mobile Home Parks	115.39	4	0.18	0.57%
Landfill	8.37	2	0.01	0.04%
Airport	5.80	1	0.01	0.03%

Major Land Uses in the Path of Tornado “A9” (Moore,OK)

Land Use Category	Impacted Acres	Maximum Fujita Scale	Impacted Square Miles	Percent of Total Area in Tornado “A9” Path
Single Family	4265.63	5	6.66	34.85%
Vacant	2593.94	5	4.05	21.19%
Retail	1216.99	5	1.90	9.94%
Industrial	1137.93	5	1.78	9.30%
Multi-family	682.94	5	1.07	5.58%
Institutional	609.52	5	0.95	4.98%
Parks & Recreation	395.72	5	0.62	3.23%
Office	360.72	4	0.56	2.95%
Water	86.80	3	0.14	0.71%
Mobile Home Parks	49.50	4	0.08	0.40%

Detailed Structure Summary

The table below provides structure damage estimates for all of the tornado paths. Damages are calculated based on appraisal data and the Fujita Scale wind category at the structure location.

Type	Total in Path	Property Value in Path	Potential Losses
Single Family Homes	17287	\$2,039,340,760	\$1,170,205,081
Apartment Units	19053	\$534,207,672	\$305,435,283
Mobile Homes	582	\$9,109,008	\$5,330,942
Commercial Properties	1718	\$2,291,954,031	\$1,269,344,214
Industrial Structures	165	\$189,611,183	\$108,993,689



Residents and Employees in Path

The table below provides an estimate of the number of persons occupying the structures in the path of the tornadoes. Numbers are based upon city data for household size, occupancy rates, major employer locations, and traffic survey zone employment data.

Category	Total Persons	Persons in F-2 or Greater Contour	Persons in F-4 or F-5 Contour
Residents at Home	84023	49795	9037
Employees at Work	65976	34620	4034

Estimated Number of Persons Occupying Residential Structures In the Path of Tornadoes

Fujita Scale Contour	Persons in Homes	Persons in Apartments	Persons in Mobile Homes
0	740	266	94
1	19686	12803	639
2	10809	9379	181
3	12022	8057	312
4	4415	3314	41
5	623	642	0
Total	48295	34461	1267

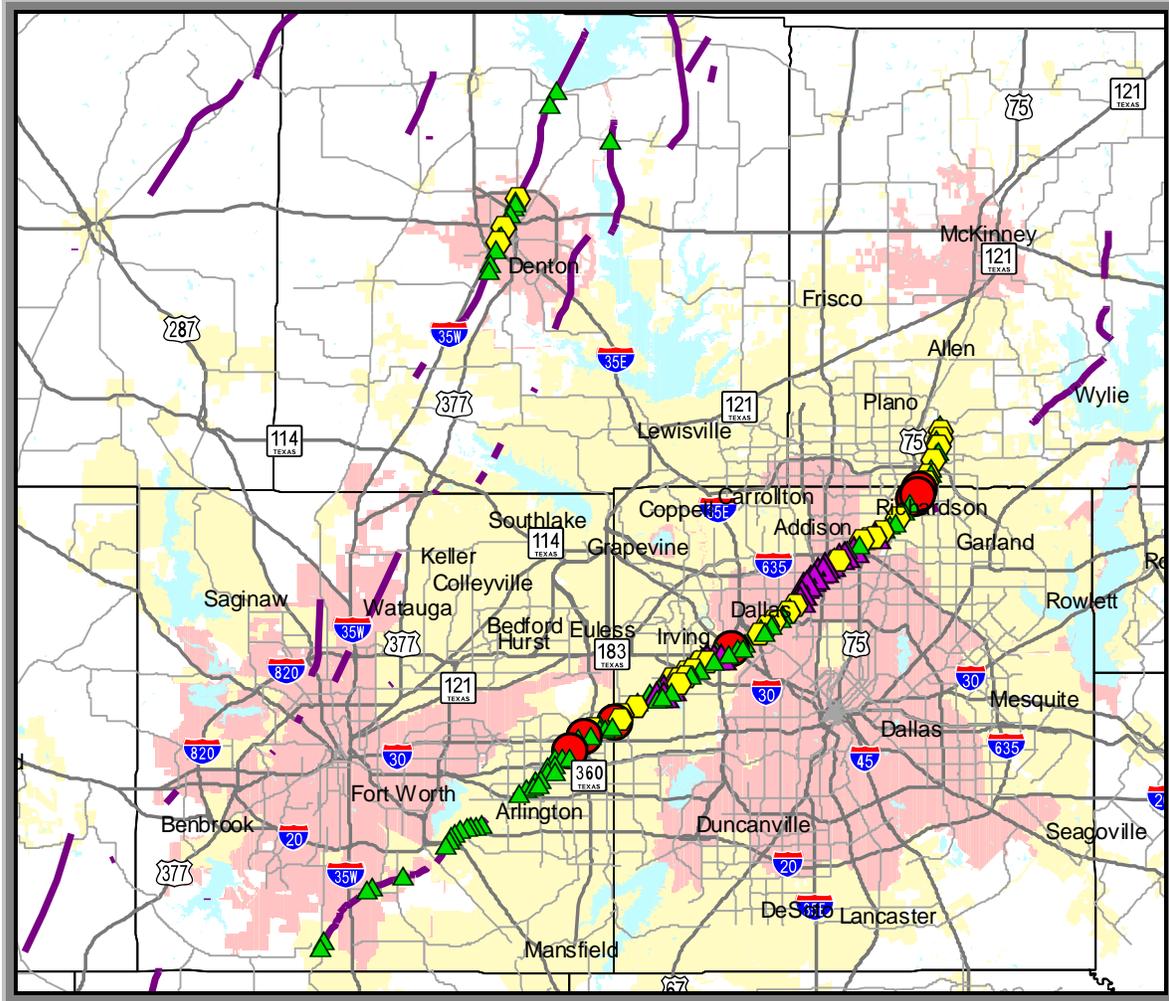
Largest Damages by City

City	Structures in Path	Property Value in Path	Potential Losses	Maximum Fujita Scale	Employees in Path	Residents in Path
Richardson	2646	\$1,181,684,411	\$725,265,311	4	20444	5903
Dallas	9975	\$1,137,064,101	\$682,759,258	5	6716	20968
Irving	10702	\$1,053,901,925	\$631,266,564	5	9695	24128
Arlington	8663	\$864,859,618	\$366,997,137	4	21812	16440
Grand Prairie	2179	\$315,129,208	\$227,908,255	5	2350	5772
Denton	1338	\$178,962,045	\$103,083,052	3	890	2648
Plano	1419	\$154,742,221	\$85,592,131	4	2058	3357
County Land or Undefined	591	\$56,829,540	\$15,712,998	3	79	1472
Fort Worth	447	\$43,037,057	\$6,760,349	3	1543	1024
Crowley	276	\$23,339,717	\$6,153,789	2	6	863
Everman	279	\$18,029,903	\$4,948,438	2	56	791

Other Features in Path

Category	Total Number	Number in F-2 or Greater Contour	Number in F-4 or F-5 Contour
Schools	16	11	3
Miles of Roads	344.90	186.07	31.79
Miles of Railroads	16.29	8.06	1.01
Major Electrical Utility Lines Intersected by the Centerline of a Tornado	43	30	4

Tornado Damage Risk Assessment – Dallas-Fort Worth



Legend

Structural Damage
Estimates in Dollars

- ▲ \$1,000,000 - \$10,000,000
- ◆ \$10,000,000 - \$25,000,000
- ▲ \$25,000,000 - \$75,000,000
- > \$75,000,000

Above: *The most significant damage areas as calculated for scenario five. Displayed points represent small area locations with total damages exceeding \$1,000,000. The small areas are no larger than .2 square miles and exist entirely within the tornado path. Their positioning has been generalized for the scale of mapping.*

Percentage of City Current Single Family Housing Units Destroyed By Tornadoes

The table below describes the inventory of single family houses currently existing in several North Central Texas cities, and compares that to the number that would have been destroyed in scenario four. The City of Irving would see a major loss of homes in this scenario.

CITYNAME	Houses Destroyed (F2 or Greater Contour)	Estimated Number of Current Single Family Units in 1999	Percent Destroyed
Irving	3884	32067	12.11%
Everman	77	1774	4.36%
Grand Prairie	1263	29854	4.23%
Crowley	65	1944	3.38%
Richardson	682	24922	2.74%
Denton	389	15087	2.58%
Dallas	2859	227914	1.25%
Arlington	384	75920	0.51%
Plano	279	58542	0.48%
Fort Worth	27	133889	0.02%



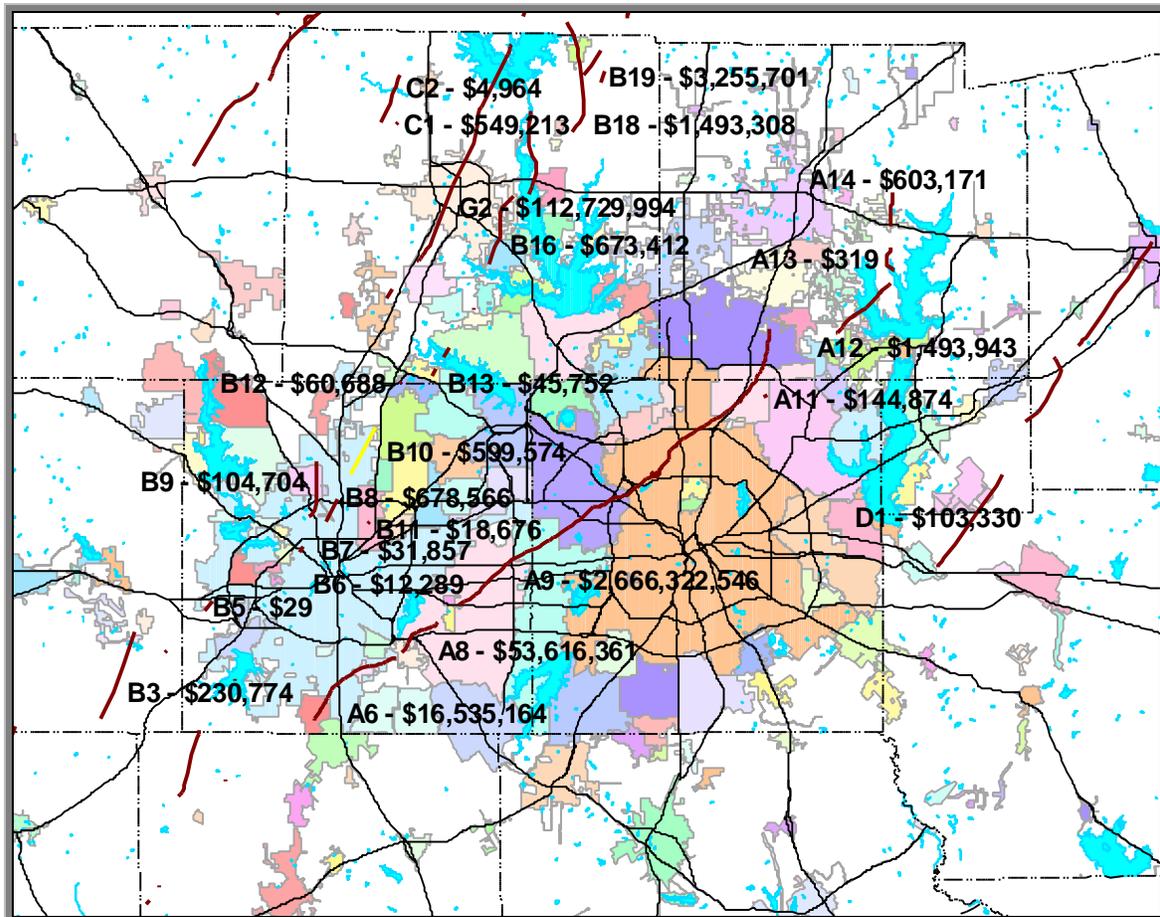
Aerial Image Maps Courtesy of VARGIS LLC

Above: Aerial image of tornado “A9” path across northeast Arlington. The Ballpark in Arlington and Six Flags over Texas are directly in the path, as is Interstate 30 and SH 360.

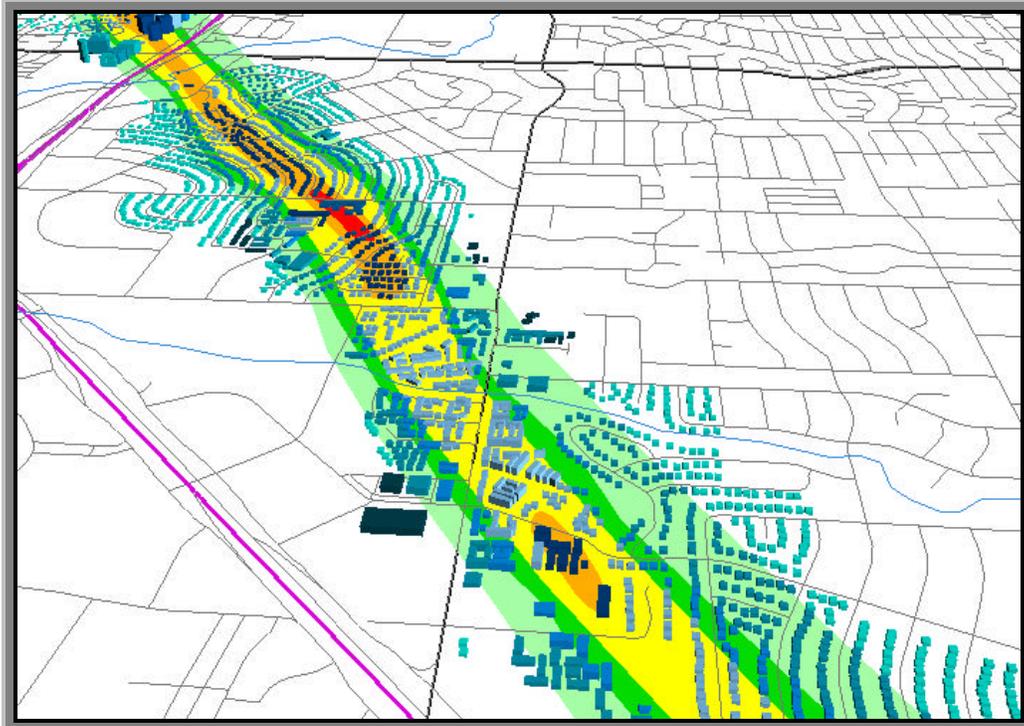
Population Threat and Losses by Tornado

In scenario five, the big tornado “A9”, produces a huge risk. This is a true nightmare of a tornado strike, with nearly \$2.7 billion in losses attributed to this one tornado. Tornado “A8”, the sister of tornado “A9”, would touch down in Arlington and threaten to do over \$50 million of damage. Denton would have taken its biggest hit from this scenario, with “G2” producing F-3 damage.

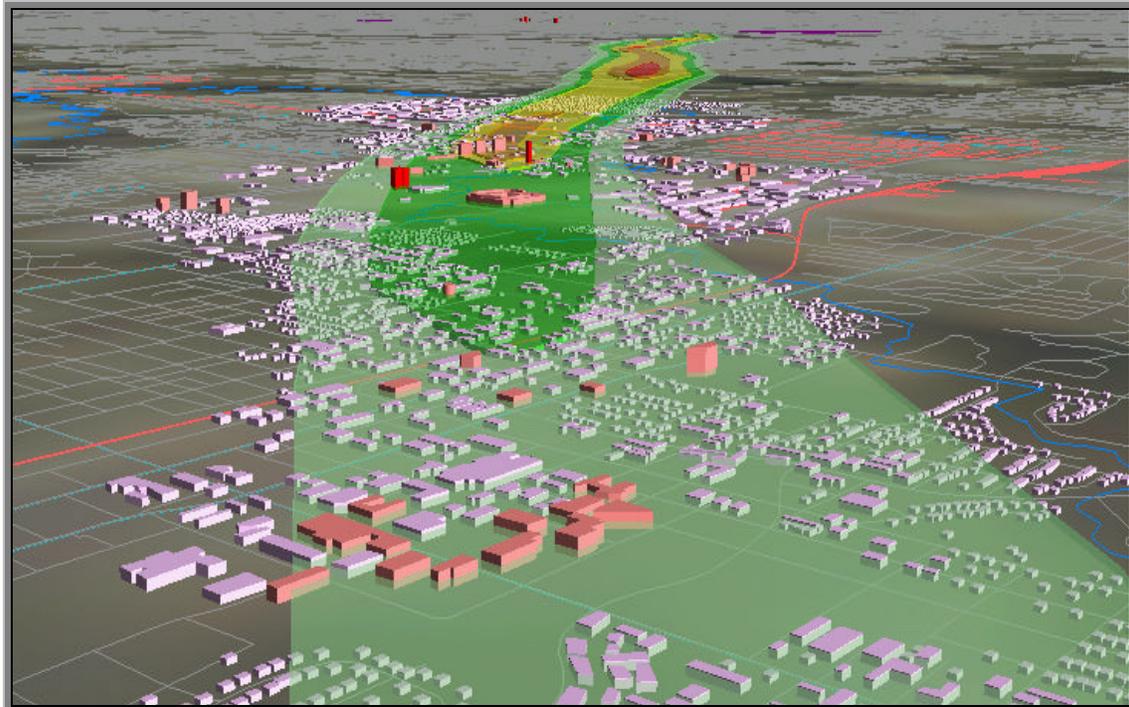
Tornado	Maximum Fujita Scale	Residents in the Path	Structures Impacted	Property Value in Path	Potential Losses
A9	5	74020	34409	\$4,569,996,115	\$2,666,322,540
G2	3	3203	1576	\$192,218,868	\$112,729,994
A8	2	2564	1192	\$138,472,668	\$53,616,361
A6	3	1886	668	\$66,350,989	\$16,535,164
B19	2	134	49	\$5,917,737	\$3,255,701
A12	1	311	114	\$19,013,832	\$1,493,943
B18	1	349	138	\$19,119,349	\$1,493,308
B8	1	571	246	\$8,865,941	\$678,566
B16	1	175	67	\$7,552,296	\$673,412
A14	1	88	36	\$7,729,281	\$603,171



Above: Structural damage estimates by tornado for Scenario Five

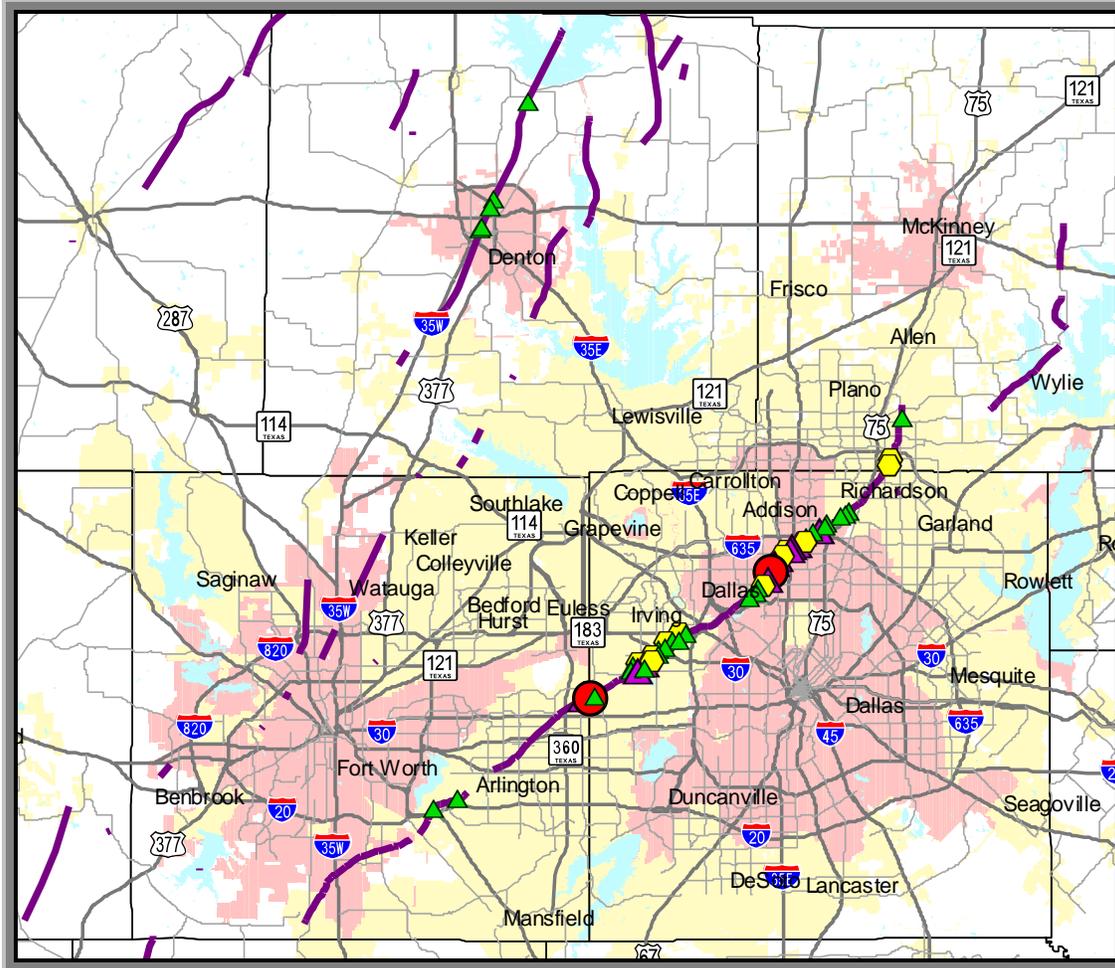


Above: *Damage Path looking southeast along U.S. 75 in North Dallas just north of I-635. This area features a large concentration of apartments, which are hit heavily in this scenario.*



Above: *Computer model of tornado "A9" damage path through Arlington. The University of Texas at Arlington is in the near left-center, with the Ballpark in Arlington, Six Flags, and the Brookhollow area in the upcoming path. The tornado path is nearly 1 mile wide.*

 **Tornado Damage Risk Assessment – Dallas-Fort Worth**



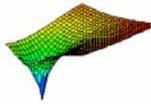
Above: Single family housing locations that would receive the most expensive damages in scenario five. Red circles mark areas with over \$50 million in total losses.

Estimated Traffic in the Path of Tornadoes

Traffic figures for vehicles in the path of the tornadoes are based on NCTCOG transportation modeling for major thoroughfares through the region. The data is an estimate of road volumes and capacities across more than 21,000 links throughout the metroplex, many of them calibrated to actual traffic count data. The models include estimates for freeways, arterials, and collectors, but do not include local residential streets. The numbers for scenario five are derived from those modeling numbers. For scenario five, we are estimating the number of cars that, as a function of volume, speed, time, and distance, should be located on the actual roadway pavement in the tornado's path at the time the tornado overtakes the route. **Hourly traffic** numbers provide an estimate of how many cars would actually cross the path during the hour of the tornado's primary impact. **Vehicles trapped** numbers are estimates of how many vehicles should theoretically be on the roadway in the tornado path when the tornado strikes (under varying traffic levels).

Hourly Vehicles on Routes Crossed by Tornadoes	Vehicles Trapped in Tornado Paths at Normal Roadway Vehicle Volumes	Vehicles Trapped in Tornado Paths if Roadways all Backed Up
*213349	*2485	87044

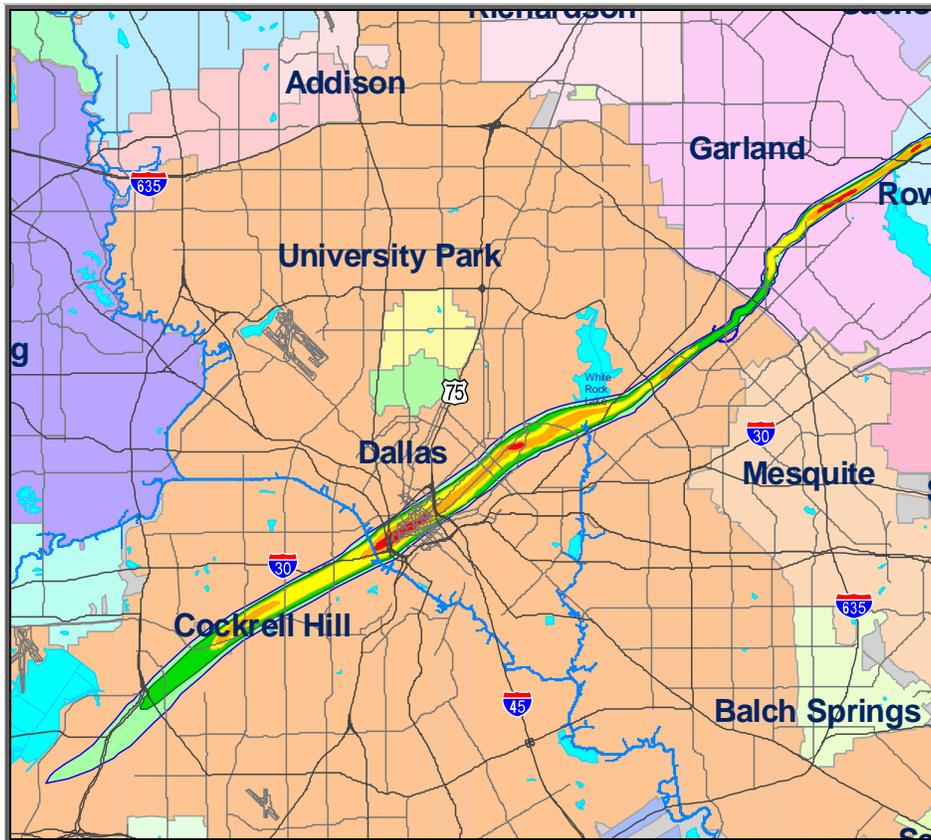
* Estimated based on daily modeling totals and hourly multipliers



Tornado Damage Risk Assessment Dallas-Fort Worth Metroplex

A Regional Exercise in Demographic,
Environmental, and Urban Analysis
February, 2000

Scenario 6



All figures included in this summary are estimates based upon the best information available at the time of the study. A variety of other variables can be incorporated into future studies or come into play during a real event of this magnitude.

Last Update: December 7, 2005

**Data Analysis and Geographic
Information System Data Compilation**

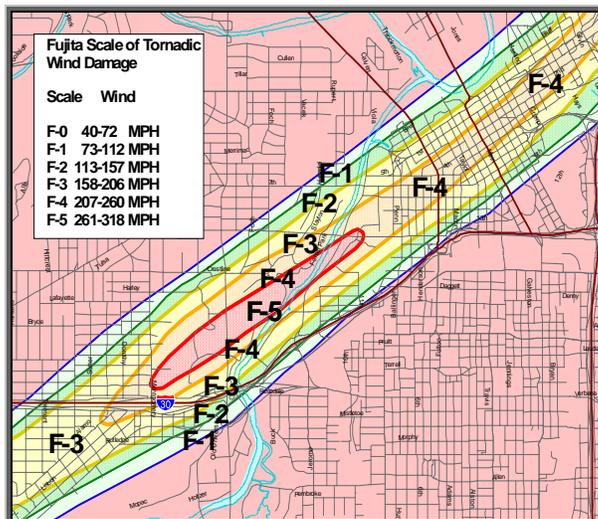
Scott Rae
Senior Research Associate
Department of Research and Information Services
North Central Texas Council of Governments

Study Overview

This study features the use of digitally mapped tornado path information from a real tornado outbreak laid atop Dallas-Fort Worth urban and demographic data. Modern computer technology can help estimate the magnitude that the tasks of warning, rescue, and recovery would require. If we make the very likely assumption that *Dallas-Fort Worth would see comparable damage in the same portions of the tornadoes that caused damage in Oklahoma*, we can then model this same event across the Dallas-Fort Worth Metroplex and assess how susceptible the area is to large tornado damage potential.

Six (6) separate distributions (scenarios) of the same Oklahoma tornado paths are modeled with the output including:

- The number of structures in the path
- Potential dollar damages to structures and contents
- Residents living in the path
- Employees working in the path
- Utility lines in the path
- The distribution of land use in the path
- Estimated roadway miles and vehicles travelling in the path



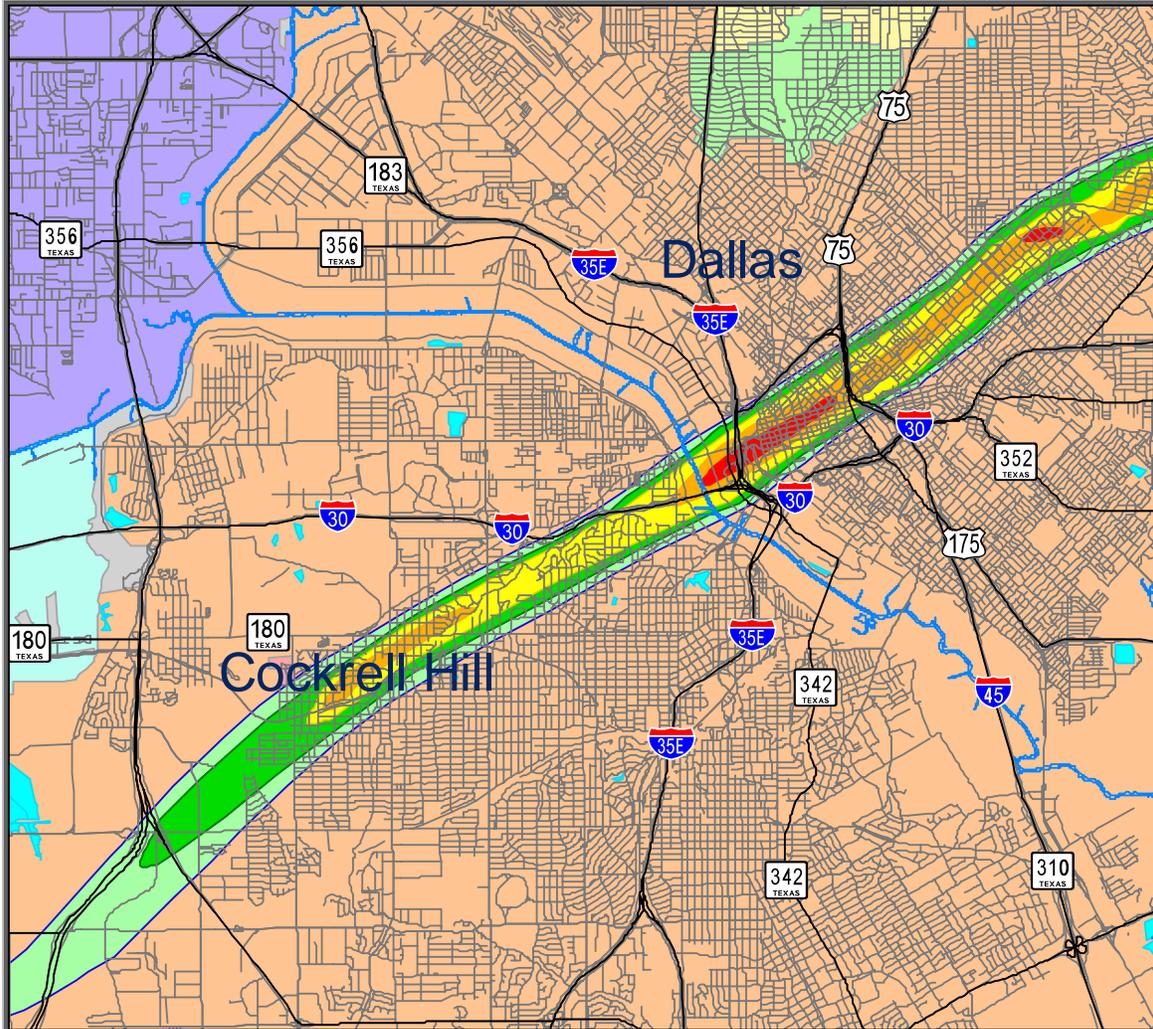
The goal is to stress the importance of planning and preparation for the day when this type of event does occur in Dallas-Fort Worth. A tornadic outbreak like the one in Oklahoma would cover an amazing amount of North Central Texas territory, and this study will help quantify that which would be in the way of the storms themselves.

The Tornadoes used in this analysis were mapped using a distinct delineation of the Fujita Scale (F-Scale) damage regions as they occurred in Oklahoma.

The F-Scale corresponds to magnitude of damage occurring to structures.



Scenario 6

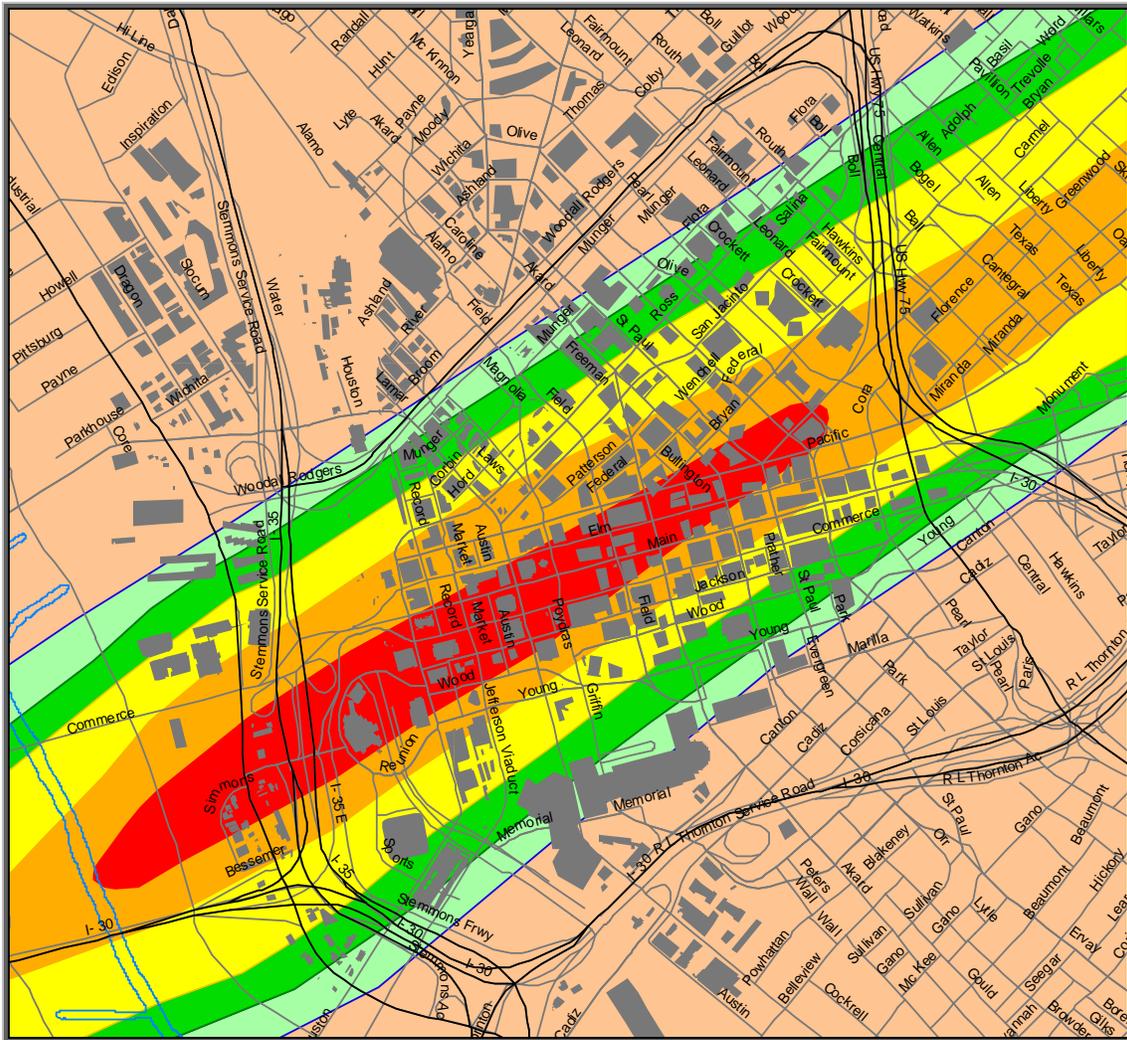


Scenario 6 – Summary of Structures in Path

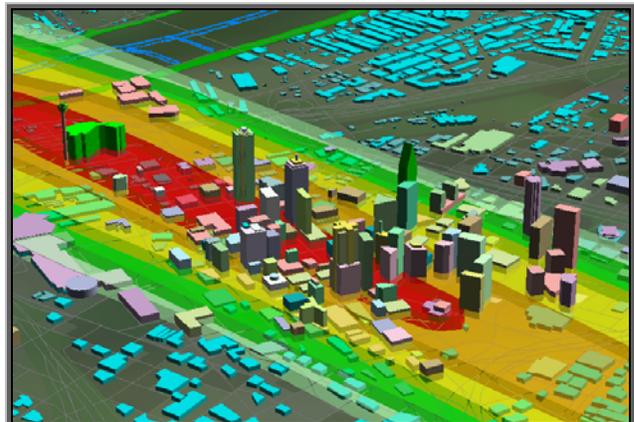
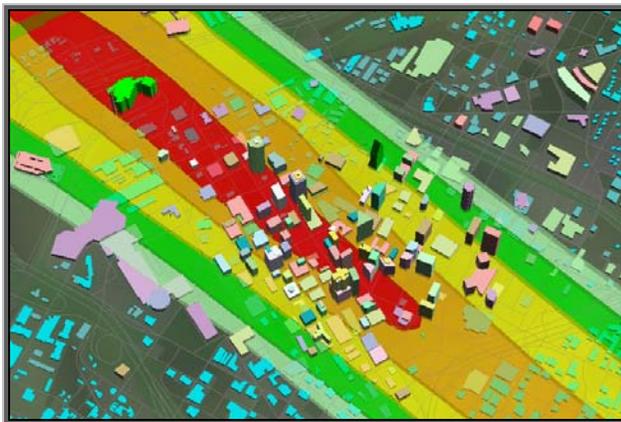
Fujita Scale	Structures Impacted	Property Value in Path	Potential Damages
1	10048	\$1,249,195,589	\$95,680,773
2	7812	\$1,422,638,821	\$839,442,009
3	6874	\$1,712,279,168	\$1,426,661,959
4	3313	\$1,593,709,786	\$1,593,709,787
5	234	\$1,053,665,547	\$1,053,665,545
Total	28284	\$7,031,488,000	\$5,009,160,000



Tornado Damage Risk Assessment – Dallas-Fort Worth



Tornado Path Through Downtown Dallas



Above Left: Computer Model of tornado "A9" path enhanced vertically and moving northeast across Dallas County. Variations in colors and shape represent differences in Fujita contour.



Detailed Structure Summary

The table below provides structure damage estimates for all of the tornado paths. Damages are calculated based on appraisal data and the Fujita Scale category at the structure location.

Type	Total in Path	Property Value in Path	Potential Losses
Single Family Homes	17615	\$1,830,429,040	\$1,120,960,121
Apartment Units	9402	\$301,120,386	\$156,951,208
Mobile Homes	189	\$1,919,603	\$1,481,882
Commercial Properties	1068	\$4,893,976,586	\$3,727,404,924
Industrial Structures	7	\$4,043,296	\$2,361,939

Residents and Employees in Path

The table below provides an estimate of the number of persons occupying the structures in the path of the tornadoes. Numbers are based upon city data for household size, occupancy rates, major employer locations, and traffic survey zone employment data.

Category	Total Persons	Persons in F-2 or Greater Contour	Persons in F-4 or F-5 Contour
Residents at Home	66150	43099	7818
Employees at Work	138849	127331	67025

Estimated Number of Persons Occupying Residential Structures In the Path of Tornadoes

Fujita Scale Contour	Persons in Homes	Persons in Apartments	Persons in Mobile Homes
1	477	28	0
2	4430	2814	67
3	13167	3133	144
4	14613	4194	27
5	16172	6720	158
Total	48861	16891	398

Largest Damages by City

City	Structures in Path	Property Value in Path	Potential Losses	Maximum Fujita Scale	Employees in Path	Residents in Path
Dallas	21158	\$6,461,046,218	\$4,684,209,459	5	136521	46053
Garland	3561	\$256,291,199	\$146,522,763	5	1613	9612
Rowlett	824	\$92,859,657	\$54,412,454	5	0	2500
County Land or Undefined	655	\$67,188,589	\$40,900,238	4	45	1691
Cockrell Hill	1156	\$51,229,940	\$37,423,461	4	400	3560
Grand Prairie	619	\$60,464,694	\$29,437,126	2	16	1826
Mansfield	308	\$42,392,252	\$16,253,287	3	225	905



Percentage of City Current Single Family Housing Units Destroyed By Tornadoes

The table below describes the inventory of single family houses currently existing in several North Central Texas cities, and compares that to the number that would have been destroyed in the scenario if they received comparable damage to the structures in Oklahoma.

CITYNAME	Houses Potentially Destroyed (F2 or Greater Contour)	Estimated Number of Current Single Family Units in 1999	Percent Destroyed
Dallas	7823	227914	3.43%
Garland	1907	56221	3.39%
Cockrell Hill	690	896	77.00%
Rowlett	520	13149	3.95%
Grand Prairie	353	29854	1.18%
Mansfield	138	7568	1.82%

Estimated Traffic in the Path of Tornadoes

Traffic figures for vehicles in the path of the tornadoes are based on NCTCOG transportation modeling for major thoroughfares through the region. The data is an estimate of road volumes and capacities across more than 21,000 links throughout the metroplex, many of them calibrated to actual traffic count data. The models include estimates for freeways, arterials, and collectors, but do not include local residential streets. The numbers for this scenario are derived from those modeling numbers. For this scenario, we are estimating the number of cars that, as a function of volume, speed, time, and distance, should be located on the actual roadway pavement in the tornado's path at the time the tornado overtakes the route. **Hourly traffic** numbers provide an estimate of how many cars would actually cross the path during the hour of the tornado's primary impact. **Vehicles trapped** numbers are estimates of how many vehicles should theoretically be on the roadway in the tornado path when the tornado strikes (under varying traffic levels).

Values Calculated for Volumes at 5:00 P.M.

^a Hourly Vehicles on Routes Crossed by Tornadoes	^b Vehicles Trapped in Tornado Paths at Normal Roadway Vehicle Volumes	^c Vehicles Trapped in Tornado Paths if Roadways all Backed Up
*256,000	*4,000	87,576

- Estimated based on daily modeling totals and hourly multipliers

Explanation:

^a**Hourly Vehicles on Routes Crossed by Tornadoes** -- During the Hour of 5:00-6:00 P.M., a total of 256,000 separate vehicles will move across the tornado path. This is an hourly total -- only a portion of them would be present at the time of a tornado passage.

^b**Vehicles Trapped in Tornado Paths at Normal Roadway Vehicle Volumes** - If you spread the hourly volume uniformly across roadways as a function of speed, 4000 cars would normally be on the routes crossing the tornado path at the time of tornado impact.

^c**Vehicles Trapped in Tornado Paths if Roadways all Backed Up** - If the roads were backed up due to congestion, accidents, panic, etc..., this is the number of cars that ultimately would fit on the roads. Imagine the roads as a parking lot -- with about 8 feet of space in between the vehicles -- and the number of cars you could fit on the roads within the tornado path exceeds 87,000.



Computer Estimate of Individual Named Routes in Path

Roadway	^a Hourly Vehicles on Routes Crossed by Tornado	^b Vehicles Trapped in Tornado Path at Normal Roadway Vehicle Volumes	^c Vehicles Trapped in Tornado Path if Roadways all Backed Up
IH30 WB	5218.28	229.47	1409.24
IH30 EB	5308.18	227.37	1474.48
COMMERCE ST	3581.30	163.52	2904.92
SH78	3573.67	148.99	1966.04
GASTON AVE	2318.36	140.49	3848.51
IH35E NB	7787.43	125.46	852.64
IH35E SB	8058.20	123.61	855.87
SP408 SB	2659.20	114.75	926.76
SP408 NB	2635.13	113.72	939.11
INDUSTRIAL BLVD	4071.98	102.45	1346.11
JEFFERSON BLVD	1727.91	92.29	3323.10
US75 NB	5117.39	90.92	914.17
US75 SB	5494.43	89.47	892.45
LIVE OAK ST	1434.01	86.20	3484.93
ELM ST	2587.86	65.51	1172.00
HAMPTON RD	3118.87	61.86	1006.01
SATURN RD	2235.37	48.58	740.55
MAIN ST	1887.20	47.11	1236.31
ABRAMS RD	1513.70	46.93	1503.99
MUNGER BLVD	2434.03	45.97	962.17
WOODALL ROGERS	6269.89	45.70	349.93
RPIH30 IH35E ST	2645.42	44.56	211.42
ROSS AVE	1695.69	42.80	1270.98
WESTMORELAND RD	1720.85	41.45	1055.81
LP12 SB	2193.64	41.26	529.61
WOODALL ROGERS	5688.37	35.50	282.17
LP12/BUCKNER BLVD	2735.76	34.37	510.70
BECKLEY AVE	1664.04	34.12	511.81
SYLVAN AVE	2192.79	33.70	909.44
IH35E OFFRAMP SB	3416.92	33.18	111.74
RPWOODALL RGRS	3068.85	32.62	151.79
IH635 NB	6106.17	32.09	213.09
IH635 SB	6025.88	31.39	211.25
HASKELL AVE	1216.50	30.15	513.55
BELT LINE/1ST ST S	3209.87	28.81	391.22
FIELD ST	2461.16	26.67	622.58
US75 OFFRAMP SB	2211.72	25.96	171.84
ILLINOIS AVE	1025.37	25.16	1317.95
PEAK ST	1140.67	25.14	512.55
PEARL ST	1894.46	25.06	632.36
WALTON WALKER NB	2031.23	25.00	249.58
GRIFFIN ST	2137.21	24.74	1074.79

Scenario 6

Fujita-Scale 1 and Greater

Fujita Scale Contour Within	Category	Impacted	*Total Value in Path	**Potential Damages
1	Single Family Homes	5828	\$599,928,530	\$47,137,240
2	Single Family Homes	5261	\$531,487,906	\$425,190,325
3	Single Family Homes	4747	\$503,800,456	\$453,420,409
4	Single Family Homes	1608	\$181,021,714	\$181,021,712
5	Single Family Homes	169	\$14,190,432	\$14,190,432
Total		17615	\$1,830,429,040	\$1,120,960,121
1	Apartment Units	3874	\$132,663,522	\$9,120,617
2	Apartment Units	2192	\$73,045,866	\$58,436,692
3	Apartment Units	1821	\$60,170,971	\$54,153,871
4	Apartment Units	1497	\$34,877,271	\$34,877,273
5	Apartment Units	16	\$362,754	\$362,754
Total		9402	\$301,120,386	\$156,951,208
1	Mobile Homes	74	\$729,535	\$291,814
2	Mobile Homes	13	\$142,680	\$142,679
3	Mobile Homes	69	\$793,464	\$793,464
4	Mobile Homes	32	\$253,923	\$253,923
Total		189	\$1,919,603	\$1,481,882
1	Commercial Buildings	268	\$514,225,965	\$39,010,245
2	Commercial Buildings	343	\$817,191,495	\$355,055,613
3	Commercial Buildings	233	\$1,146,100,277	\$916,880,217
4	Commercial Buildings	174	\$1,377,349,235	\$1,377,349,235
5	Commercial Buildings	48	\$1,039,109,612	\$1,039,109,612
Total		1068	\$4,893,976,586	\$3,727,404,924

* Total Value in Path is the total structure and content value located within the tornado paths.

** Potential Damages represents an estimate of property value damage based on the proportion of property value falling within different Fujita Scales.