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Multi-Hazard Risk Assessment: Forewarnings of Natural Hazards to the Year 2030

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Chapter 1 Introduction: Current Profile of the NCTCOG Region

Geography

The North Central Texas region is a physically, ecologically, culturally and socially diverse metropolitan region. The Dallas/Fort Worth Metroplex region is the largest inland metropolitan area in the nation, situated approximately 250 miles (400 km) north of the Gulf of Mexico. It is near the headwaters of the Trinity River, which lie in the upper margins of the Coastal Plain. The rolling hills in the area range from 500 to 800 feet (150 to 240 m) in elevation. The total population of the NCTCOG planning region is 5.7 million people as of January 2003. The region consists of 16 counties covering an area of 12,800 square miles, with a population and area greater than the state of Maryland. The North Central Texas Metropolitan Planning Area (MPA) encompasses more than three million acres of land in Collin, Dallas, Denton, Tarrant and Rockwall counties, as well as portions of Ellis, Johnson, Kaufman and Parker counties. More than 90% of all residential and commercial activities in North Central Texas occur within the MPA planning area. See HazMAP **map 1-1** and HazMAP **map 1-2**

Climate

According to the National Weather Service, the Dallas/Fort Worth climate is humid subtropical with hot summers. It is also continental, characterized by a wide annual temperature range. Precipitation also varies considerably, ranging from less than 20" to more than 50". Winters are mild, but "blue northers" occur about three times each month, and often are accompanied by sudden drops in temperature. Average low temperatures drop to 33°F in early to mid January. Periods of extreme cold that occasionally occur are short-lived, so that even in January mild weather occurs frequently.

The highest temperatures of summer are associated with fair skies, westerly winds, and low humidities. Characteristically, hot spells in summer are broken into three-to-five day periods by thunderstorm activity. There are only a few nights each summer when the low temperature exceeds 80°F. Summer daytime temperatures occasionally exceed 100°F. For over three weeks from late July to mid August, average high temperatures are at their peak of 96°F.

Throughout the year, rainfall occurs more frequently during the night. Usually, periods of rainy weather last for only a day or two, and are followed by several days with fair skies. A large part of the annual precipitation results from thunderstorm activity, with occasional heavy rainfall over brief periods of time. Thunderstorms occur throughout the year, but are most frequent in the spring. Hail falls on about 20 to 25 days a year, ordinarily with only slight and scattered damage. Windstorms occurring during thunderstorm activity are sometimes destructive. Snowfall is rare.

The average length of the warm seasons (freeze-free period) is about 248 days, or about 8 months. The average last occurrence of 32°F or below is mid March, and the average first occurrence of 32°F or below is in mid to late November. See HazMAP **map 1-3**

Geology

The geology of North Central Texas is made up of sedimentary rock strata, including a variety of limestones, sandstones, shales, and alluvial deposits. Bedrock is overlain by soil horizons of variable thicknesses. Rock strata ages at the surface ranges from Pennsylvanian-age (325-290 million years before present (mybp)) found in the northwestern corner of the region to large expanses of Cretaceous-aged rocks (120-65 mybp) throughout the central portions of the region. Tertiary-aged strata (60-35 mybp) make up easternmost portions of the region, while much younger unconsolidated alluvial deposits are found along major rivers and tributaries across the region, generally accredited as Pleistocene-aged (1.8 mybp – 11,000 tybp) or younger flood deposits.

The region is structurally positioned on the margins of the Texas craton, a large, relatively stable tectonic feature in west-central Texas. The western half of the region is separated from eastern portions by the linear Ouachita fold/thrust front near Dallas. The Ouachita front developed through North Texas during Paleozoic time (around 300 mybp) and exists now as an eroded and buried fold belt (about 8,000 feet below sea level), underlying parts of Ellis, Kaufman, Dallas, Navarro and Collin Counties. Several significant tectonic structures may be found in the eastern and western portions of north central Texas and are typically linked to the Ouachita front.

The eastern region includes the East Texas Embayment, a Mesozoic-aged graben (around 100 mybp) that is part of the greater Mesozoic/Tertiary-aged Gulf Basin, which extends southeast towards the modern Gulf of Mexico. The structure contains several petroleum-producing regions, including the Corsicana Oil Field, significant as the first major oil and natural gas field in Texas. Minor faults associated with the Luling-Mexia-Talco fault system parallel this graben feature but are generally inactive, subsidence-related normal faults with little appreciable throw.

West-central portions of the region are underlain by the Fort Worth basin, a large synclinal feature. Portions of Tarrant, Denton, Wise and Parker counties are areas of active exploration and drilling as a result of recent gas discoveries related to the Barnett Shale formation found throughout this region. The Newark East field of Denton County contains the largest active natural gas producing region in the State of Texas.

The northwestern quarter of the region is a surface exposure of the area's oldest rocks, due to uplift on the east margin of an arch feature related to the Fort Worth Basin and Ouachita Front formation. Uplift here has removed younger Cretaceous rocks, allowing the older westward-dipping strata to be exposed in Palo Pinto and western Wise and Parker Counties.

North Central Texas is generally characterized as having minor seismic activity. Several minor fault zones are present within the region but are not considered active. Microquakes have occurred along several faults within the region, which may be initiated by drilling and well injection activities. Other faults may be found in association with other regional structural features. In the North Central Texas area, the last indication of significant fault movement is about 11 million years ago, and no evidence of later faulting has been found in younger rocks. Other major regional fault systems are more active, such as Oklahoma, Missouri and West Texas. See HazMAP **map 1-4**

Soils

The soils of the NCTCOG region are varied in texture, composition and character, and due to the size of the region, change widely among the various physiographic regions of North Central Texas.

The Eastern Cross Timbers portion of the easternmost area of the NCTCOG region is characterized by well drained, rolling hills with sandy soils in the uplands, and narrow clay-rich river bottoms. Soils range from alfisols on uplands, to mollisols and entisols in flood bottoms.

The majority of the central and east-central portions of the NCTCOG region are comprised of uniform dark carbonate-rich alkaline soils, developed on a gently sloping to level area underlain by limestones, shales and marlstones. Clays may include montmorillionite and may be carbonatic. Soils in this region typically do contain high amounts of expansive clay minerals. Soil classes are primarily vertisols, alfisols on terraces and in uplands, and mollisols in flood bottoms.

In the center of the NCTCOG region, a thin standout portion of Eastern Cross Timbers soils types coexists with the surface exposures of the Eagle Ford Shale formation. West of this region, the topography and soil composition are that of the Grand Prairie region. This region is primarily an area of gently rolling to hilly, dissected limestone plateaus, which are relatively resistant to erosion. Carbonatic or montmorillionic vertisols dominate, with lesser alfisols and mollisols and entisols.

Westernmost portions of the NCTCOG region are typified by the widely ranging alfisols of the Western Cross Timbers region. These range from somewhat stoney, sandy or clayey argillaceous, acidic soils to more limited alkaline soils. The rocks underlying this region are varied, from limestones, to sandstones and shales of varying composition, and the topography is rugged to hilly.

See HazMAP **map 1-5** and HazMAP **map 1-6**

Hydrology

The North Central Texas region represents the largest urban metropolitan area in the nation located on an inland waterway. The majority of the region, or approximately 64.95 percent, is situated within the upper Trinity River basin, while the remaining land is situated in the Sabine River basin (5.86 percent), the Brazos River basin (27.37 percent) and the Red River basin (1.81 percent). The Metroplex depends on a number of reservoirs in the upper Trinity River basin, which impound water on several forks of the Trinity primarily for flood prevention or water supply purposes. At present, there are 38 major water reservoirs in the sixteen county region. These areas account for over 233,400 surface acres of water.

An extensive system of water transmission facilities brings water to many urban and suburban communities from the network of reservoirs. The region faces the challenges of water quality impacts resulting from urban activities, storm water discharges, and the discharge of treated wastewater from a large metropolitan center. The prairie waterways in North Central Texas, including the Trinity River, experience widely variable flow scenarios. These conditions range from critical low flow situations during drought periods, to periodic severe flooding events. NCTCOG is the area wide water quality management planning agency as designated in 1975 by the Governor and the Texas Commission on Environmental Quality. For over 25 years NCTCOG has been reporting on the water quality issues affecting the Upper Trinity River basin. See HazMAP **map 1-7**

Demographics, Housing & Employment

Since January 1, 2002, North Central Texas has added 152,600 persons for a January 1, 2003 total population of 5,714,150. The region has now averaged over 150,000 new persons per year for the past four years and this marks the seventh consecutive year to add over 100,000 persons.

According to the NCTCOG 2003 *Current Population Estimates* publication, single-family housing construction trailed last year's record growth only slightly as historically low interest rates continued to stimulate construction. Multi-family construction in 2002 actually outpaced 2001 by over 3,000 units. This resulted in a net increase of 2,200 units over last year. However, population growth was mitigated in a large part due to significant declines in multi-family occupancy rates. Multi-family markets have suffered losses from the aforementioned single-family shifts and tend to be most affected by employment losses from the current slumping economy.

The North Central Texas region as a whole grew 45.93% adding 935,107 new jobs to the area from 1990 to 2000. During this period of exceptional growth, the City of Dallas continued to lead the region in employment growth by adding 228,664 jobs bringing their total employment base to 1,038,314. The City of Fort Worth follows Dallas adding just under 120,000 jobs for a total of 449,793 in 2000. Irving and Plano were next adding 60,598 and 58,835 new jobs bringing their total employment to 165,435 and 115,048 respectively. Arlington was close behind adding just over 50,800 new jobs for a 2000 total of 140,947 jobs. Together, these five cities account for 55% of all job growth from 1990 to 2000. The labor market performance in the late 1990s was the strongest in a decade both nationally and locally. From 1990 to 2000, Flower Mound and Frisco experienced the fastest job growth in the region, with each city growing by 230%. Not far behind, the City of Coppell grew 190%. The City of Keller was next growing 171% followed by Colleyville and Allen each growing over 150%. It is interesting to note that the growth in each of these cities is due to numerous and varied sources rather than job increases by large individual employers.

According to the Texas Workforce Commission, the North Central Texas region is a major center of employment for telecommunications, transportation, construction, electronics, manufacturing, and data processing. Some of the products that are produced from more 1,000 plants of the region include planes, electronic equipment, helicopters, mobile homes, chemicals, foods, and plastics. The four core counties of the 16-county North Central Texas region, Dallas, Tarrant, Denton, and Collin counties, account for 94 percent of the major employer establishments of this region. As stated in the North Central Texas Council of Governments 2003 Major Employers publication, the three largest employers in North Central Texas include American Airlines, Lockheed Martin, and the University of North Texas. The Dallas/Fort Worth International Airport – the third busies airport in the world - continues to serve as the regional central business district (CBD) of North Central Texas. Approximately 2.1 million jobs, 83 percent of the MPA total, are within a 20-mile radius of the airport.

Land Use

See HazMAP **map 1-8** for the 2000 Regional Land Use Map

See HazMAP **map 1-9** for the 2000 Commercial Land Use Density Map

See HazMAP **map 1-10** for the 2000 Residential Land Use Density Map

See HazMAP **map 1-11** for the 2000 Vacant Land Use Density Map

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Chapter 2 — Critical Facilities

In order to understand what assets in the region can be affected by hazard events, an inventory of critical facilities was compiled. Using the Department of Homeland Security's *The National Strategy for the Physical Protection of Critical Infrastructures and Key Assets* as a guide, NCTCOG staff organized the region's assets into the following seven categories: essential facilities; critical transportation, utility and communications infrastructure; high potential loss facilities; hazardous material facilities; vulnerable populations; key assets; and areas of special consideration.

An extensive set of presentation maps using NCTCOG's Geographical Information System (GIS) has been assembled for critical facilities at a scale that demonstrates general spatial relationships but does not reveal specific spatial information that could endanger the facilities. The maps can be viewed here. ArcGIS shape files are also available. NCTCOG takes strides to keep these data as up-to-date as possible and always welcomes input from local communities.

Essential Facilities are those facilities that are essential to the health and welfare of the whole population of the NCTCOG region and are especially important during and after hazard events.

Essential facilities include:

• Hospitals • Medical facilities • Nursing homes/group homes Police stations	• Fire stations • Emergency operations centers • Evacuation shelters • Schools

See HazMAP **map 2-1**, **map 2-2**, **map 2-3**, **map 2-4**, **map 2-5**, **map 2-6** and **map 2-7**.

Critical Transportation, Utility, and Communications Infrastructure are those facilities whose loss of service/use would significantly disrupt the region and would have cascading effects on other types of critical facilities.

Critical Transportation Infrastructure is:

• Airways (airports, heliports) • Highways (roads, bridges, overpasses, tunnels)	• Railways (railroad tracks, bridges, tunnels, rail yards, depots/stations) • Waterways (canals, locks, ports, ferries, harbors, dry docks, piers, marinas)

See HazMAP **map 2-8**, **map 2-9**, **map 2-10**, and **map 2-11**.

Critical Utility Infrastructure is:

• Water production, transmission, and distribution (reservoirs, treatment plants, towers, transmission lines, groundwater aquifers, public wells, administrative districts)	• Energy production, transmission, and distribution (oil/natural gas wells, electric power plants, oil/natural gas pipelines, electric transmission lines, electric substations)

See HazMAP **map 2-12**, **map 2-13**, **map 2-14**, **map 2-15**, **map 2-16**, and **map 2-17**.

Critical Communications Infrastructure is:

- Equipment storage facilities
- Transmission dishes, towers, cable

High Potential Loss Facilities are facilities that may not be vital to the continuity of critical services but, if affected by a hazard event, may result in significant loss of life and property and adverse impacts to public health and safety in the long-term.

High Potential Loss Facilities are:

- Nuclear Power Plants
- Dams and Levees
- Military Installations

See HazMAP **map 2-18**, **map 2-19**, and **map 2-20**.

Hazardous Material Facilities are those industrial facilities that store hazardous materials such as corrosives, explosives, flammable materials, radioactive materials, and toxins.

Hazardous Materials Facilities include:

- Toxic Release Inventory sites
- Landfills
- Hazardous Materials Transportation Routes

See HazMAP **map 2-21**, **map 2-22**, and **map 2-23**.

Vulnerable Populations are those groups of people who may require special response assistance or special medical attention after a hazard event.

Vulnerable Populations include:

- Non-English speaking
- Non-English and Non-Spanish speaking
- Elderly

See HazMAP **map 2-24**, **map 2-25**, and **map 2-26**.

Key Assets represent a broad range of unique facilities, sites, and structures whose damage, disruption, or destruction could have significant consequences across multiple dimensions. Key assets may represent heritage, traditions, values and political power. Key assets may draw large amounts of tourism. Key assets may represent our national economic power and technological advancement. Key assets may include places where large numbers of people regularly congregate to conduct business or personal transactions, shop, or recreate. Given the regional and/or national-level fame of these sites and facilities, protecting them is important in terms of both preventing loss of life and preserving public confidence.

Key Assets include:

• Economic assets (major employers, major financial/commercial centers, downtowns, skyscrapers, sports stadiums, amusement parks) • Agricultural assets (farms, food-processing plants) • Historical assets (historic buildings, icons, monuments)	• Cultural assets (museums, cemeteries, archaeological sites, burial grounds) • Governmental assets (city halls, courthouses, post offices) • Natural resource assets

See HazMAP **map 2-27**, **map 2-28**, **map 2-29**, **map 2-30**, **map 2-31**, and **map 2-32**.

Areas of Special Consideration are areas of the region that could sustain relatively higher loss levels in terms of lives and dollars. These areas are delineated by factors such as density of development, land use, and land/structural value. Without the resources to specifically characterize building stock at a local level of detail, NCTCOG staff developed and mapped areas of special consideration across the MPA-Trinity. The map entitled "Estimated Total Structural Values" (see HazMAP **map 2-33**) shows the spatial representation of the total estimated structural value for the MPA-Trinity as distributed in uniform 2400 by 2400 foot grid cells. The total value of each grid cell is a function of the number of structures and the appraised value of the structures. Contents are calculated for each structure as a type and value. A select group of areas feature over $500 million in estimated structural value contained within an individual cell. In such cases, the cell usually contains multiple commercial structures of high value, such as near a downtown or major economic corridor.

References:

Department of Homeland Security. (2003) *The National Strategy for the Physical Protection of Critical Infrastructures and Key Assets*. Go to http://www.dhs.gov/dhspublic/display?theme=31&content=463

Federal Emergency Management Agency. (2001) *FEMA Manual 386-2: Understanding Your Risks*. Step 3: Inventory Assets.

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Chapter 3 Full Range of Hazards

The first step in the Multi-Hazard Risk Assessment process for 2003-2004 was to develop a list of all the natural and technological hazards that have occurred or could occur in the NCTCOG region. To kick-off this process, NCTCOG staff met with the Consultant Team for a day-long workshop in early June 2003. During this workshop, existing resources, plans, and reports from FEMA, Texas Division of Emergency Management, and other sources were reviewed to develop the comprehensive list (see below) of the full range of hazards. As explained further, the hazards in bold and all caps received detailed attention in this assessment.

Natural

• avalanches • coastal erosion • **DAM FAILURES** • **DROUGHTS** • **EARTHQUAKES** • **EXPANSIVE SOILS** • **SUMMER HEAT** • **FLOODING** • **HAIL** • **HIGH WINDS** • **SEVERE WINTER/ICE STORMS** • land subsidence	• **LANDSLIDES** • **LEVEE FAILURES** • **LIGHTNING** • **POOR AIR QUALITY** • sinkholes • storm surge • **STREAM BANK EROSION** • **TORNADOES** • tropical cyclones • tsunamis • volcanoes • **WILDLAND FIRES**

Technological

• biological agents • chemical agents • civil disobedience • epidemics • fuel pipeline accidents • hazardous materials events	• transportation accidents • nuclear agents • nuclear plant accidents • urban fires • utility (water or energy) interruption

NCTCOG and its team of consultants researched and analyzed the probability and impact of various hazards ranging from the improbable (volcanoes and avalanches) to the apparent (flooding and tornadoes). There is a preliminary screening of technological hazards in Chapter 4, and the natural hazards that did not merit further study are discussed briefly in Chapter 5. Chapter 6 through Chapter 21 represents a more detailed study of natural hazards that are relevant to the NCTCOG region.

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Chapter 4 Technological Hazards

For purposes of this document, hazards were considered technological if they are accidentally or intentionally caused by humans. In the June 3, 2003 workshop, NCTCOG staff and the consultant team identified a variety of human-caused hazards, including hazardous materials releases, attacks with biological, chemical, or nuclear agents, civil disobedience, epidemics, urban fires, transportation accidents, and utility interruptions. In the weeks following the June 3 workshop, NCTCOG staff and the consultant team conducted research and preliminarily screened these human-caused hazards as they related to the NCTCOG region. From the preliminary screening, it was evident that the NCTCOG region is vulnerable to these technological hazards.

However, despite performing a preliminary screening of technological hazards, NCTCOG staff and the consultant team did not perform more detailed assessments for this 2003-2004 planning cycle. NCTCOG has a strong interest in conducting more detailed analyses of technological hazards; however, such analysis was not within the scope of this effort for the 2003-2004 planning cycle. Some of the reasons why this effort did not go beyond a preliminary screening of technological hazards are: (1) FEMA guidance does not require that this initial hazard mitigation action planning process directly address technological hazards, (2) this initial effort has been subject to limited resources and time, and (3) some of the technological hazards are already being addressed in various programs and projects currently being undertaken by NCTCOG's Department of Emergency Preparedness, which has the knowledge and expertise to appropriately handle some of these hazards. The Department of Emergency Preparedness staffs the Regional Emergency Preparedness Planning Council and facilitates the work of its Technical Committee. The Department also works closely with state and federal agencies that are charged with emergency management, hazard mitigation, training, and response and recovery responsibilities. A preliminary screening of technological hazards is discussed below.

Preliminary Screening: *Transportation Accidents*

Transportation accidents involve a variety of modes including motor vehicles (car, truck, and bus), rail, watercraft, aircraft, and spacecraft. The primary consequences of transportation accidents are human injury and death and hazardous materials releases. Mass casualty incidents can be difficult because of location. Remote locations can have limited resources, can make response time slow, and can delay treatment of the injured. Heavily populated locations can have crowd control problems and slow response time due to congestion. A worst-case scenario for a transportation accident would involve mass casualties and a hazardous material release. The presence of hazardous materials would slow any response to the injured for fear of exposing emergency personnel. A mass casualty event could overwhelm local emergency personnel, local hospitals, and local blood banks. NCTCOG, as the Metropolitan Planning Agency for transportation, has an ongoing interest in transportation accidents.

Motor Vehicle Accidents

Privately owned vehicles and local bus services provide the primary means of transportation in the NCTCOG study area. Unsurprisingly, roadway/highway accidents are frequent occurrences. Roadway/highway accidents can be severe enough to be considered major emergencies, often involving multiple car pileups, road closures, detoured traffic, and delays in the emergency response capabilities of the local area. Roadway/highway accidents can also be deadly. In 1995, the United States experienced 44,347 transportation related deaths, 90% of which were highway related. Weather conditions such as rain and fog as well as traffic conditions such as congestion, construction, and high speeds are often cited as the major contributing factors in roadway/highway accidents. Roadway/highway accidents occur every day in the NCTCOG study area, with varying degrees of severity.

Aircraft Accidents

The Dallas/Fort Worth International Airport (DFW) is the third largest airport in the world, for both passenger and cargo traffic. Domestic and international service at DFW is provided by several major airlines. Two other major airports also serve the NCTCOG study area. Dallas Love Field serves both commercial airline and corporate user needs. Alliance Airport is a major industrial airport that can accommodate all types of commercial transport aircraft. Military, municipal, private, and emergency airfields are also located throughout the NCTCOG study area.

Air transportation accidents can be the result of equipment failure and adverse weather conditions. Down bursts, thunderstorms and ice are the primary weather related hazards that increase risk. Mass casualties and massive property damage can result from many different air transportation accident scenarios: one aircraft may explode in mid-air; two aircraft may collide in mid-air; debris from mid-air explosions may fall to the ground; one aircraft may crash into the ground; and so on. Despite the large number of planes flying over heavily populated areas, the number of air accidents that kill or injure non-passengers is quite small. In general, crashes are most likely to occur within five miles of an airport, typically along take-off and landing flight paths. The area within a five mile radius of most airports within the MPA-Trinity are heavily populated and, therefore, could result in mass casualties and massive property damage if an aircraft crashed in these areas, even if the aircraft were not a passenger aircraft.

There have been a few air transportation accidents in the NCTCOG study area over the past 30 years. In May 1972, a Delta Airlines DC-9 crashed while on a training flight. After performing a touch and go on runway 13 of the Greater Southwest International Airport, the aircraft encountered the wake turbulence from a departing DC-10, lost control, and crashed at the end of the runway, killing all three crew members and an FAA administrator. In August 1985, Delta Airlines flight number 191 crashed short of the runway while attempting to land at DFW. While descending, the passenger jet encountered severe microburst-induced wind shear and was pushed to the ground. The aircraft landed in a field, bounced in the air, and came down again on State Highway 114, a 6-lane highway adjacent to the airport. An automobile traveling on the highway was crushed by the jet's number 1 engine, killing the driver. Then, the plane veered left and crashed into two 4 million gallon water tanks at a ground speed of 220 knots. 136 of the 167 passengers on board were killed.

In May 1988, American Airlines flight number 70 overran the runway at DFW during an aborted takeoff due to a blown tire. Unable to stop because of severe brake wear, the DC-10 crashed in the empty field at the end of the runway. Of the 254 people on board, several sustained injuries. There were no deaths. In August 1988, Delta Airlines flight number 1141 crashed while attempting to depart runway 18L at DFW. The aircraft came to rest nearly 3/4 mile from the end of the runway, and a fire broke out on impact, killing 14 of the 108 people on board. In March 1989, Evergreen International flight number 17 crashed in Saginaw shortly after takeoff from Carswell Air Force Base, killing the two crew members on board. The cargo aboard this DC-9 contained hazardous materials, some of which were consumed by the post-crash fire and some of which were recovered by Air Force Explosive Ordinance Disposal technicians. In April 1993, American Airlines flight number 102 skidded off the runway while attempting to land at DFW in heavy crosswinds. Of the 202 people on board, 37 sustained injuries.

Rail Accidents

Rail accidents typically involve rail cars carrying people, cargo, or both, that leave the track. Like motor vehicle accidents and air transportation accidents, cargo trains carrying hazardous materials can place entire communities at risk. A derailment of a passenger train can result in multiple casualties and massive property damage. A rail accident can occur due to a number of factors including faulty tracks, faulty railcars and locomotives, operator error, or a collision with another train or motor vehicle crossing the track.

The NCTCOG study area is traversed by freight rail lines such as Union Pacific, Burlington Northern & Santa Fe, and Kansas City Southern and by various passenger lines such as Dallas Area Rapid Transit

(DART), the Trinity Railway Express, and Amtrak. Many of these lines run through densely populated areas.

Although rail accidents that involve mass casualties and/or hazardous releases are relatively rare occurrences in the NCTCOG study area, rail transportation accidents such as derailments and collisions with vehicles at crossings are not uncommon. In fact, Texas ranked first in the nation in 2002 with 325 vehicle/train collisions (Indiana was second with 175 collisions). According to the NCTCOG, there are over 2,000 vehicle/train crossings in North Texas, and almost 500 of those crossings are considered dangerous or in need of improvement. In the ten-year period between 1988 and 1998, there were 630 collisions between trains and automobiles/trucks/pedestrians in the Dallas-Fort Worth Metropolitan Area. In 2001, the Federal Railroad Administration recorded 39 vehicle/train collisions in Dallas, Tarrant, Collin, and Denton Counties, resulting in 6 deaths and 11 injuries. In 2002, the same 4-county area had 35 vehicle/train collisions, resulting in 5 deaths and 8 injuries.

Some Recent Rail Accidents in the NCTCOG region: In December 1998, Amtrak Train 21, en route from Chicago to San Antonio, derailed on Union Pacific Railroad tracks in Arlington. Three locomotives and six cars derailed, and, of the 198 passengers and 18 employees on board, 12 passengers and 10 employees were injured. No fatalities resulted from the accident, but damages were estimated at $1.4 million. In August 2003, a Dallas Area Rapid Transit (DART) train, consisting of two articulated light-rail-vehicles (LRV) collided with a sport-utility-vehicle at a grade crossing near Yale Boulevard and Greenville Avenue in Dallas. The woman driving the SUV was killed, and four people on the DART train were hospitalized with injuries. In February 2003, a 3-year-old girl was killed as her mother tried to drive around a lowered crossing arm near TI Boulevard in Dallas. In December 2001, a Trinity Railway Express train collided with a van in Irving, killing a 61-year-old man who had attempted to drive around the crossing arm. In October 2000, a DART train struck and killed a man walking on the track in Dallas. In June 1997, a DART train collided with a Caterpillar front-end loader (an earth moving machine) at a grade crossing in Dallas. Of the 20 passengers on the train, 19 sustained injuries. The operator of the front-end loader also sustained injuries. Damages were estimated about $920,000.

Watercraft Accidents

While there are many bodies of water in the NCTCOG study area used by small watercraft for recreational purposes, there are no bodies of water used by large passenger and cargo ships for navigable commerce purposes. Therefore, mass casualties and releases of substantial amounts of hazardous materials are unlikely.

Spacecraft Accidents

A spacecraft accident is a unique and unlikely event that has occurred within the NCTCOG study area. On February 1, 2003, Space Shuttle Columbia disintegrated 38 miles above north Texas, killing all seven astronauts on board. As the shuttle came apart, thousands of pieces of debris fell to the ground. Debris was scattered across 41 counties in north and east Texas and across 41 parishes in Louisiana. In Texas, the debris field resembled a corridor 10 miles wide and 240 miles long that stretched from near Dallas to the Toledo Bend Reservoir. Miraculously, no one on the ground was killed by failing debris, but the effort to secure and recover the debris was a massive undertaking shared by 15 state agencies, 17 federal agencies, and thousands of volunteers. A major priority for the response and recovery process was to find the hazardous materials that had been on board the shuttle, including a monomethyl hydrazine pressure vessel, pyrotechnic devices, and other explosives. In addition to simply locating these materials, emergency management officials had to coordinate with environmental officials to assess the impacts of the hazardous materials on the water quality of several bodies of water.

The disaster declaration process was also unique. Normally, the process begins locally, then it goes to the state level, and then federal assistance is requested. But, with this incident, President Bush initiated the emergency declaration (FEMA–3171-EM, Texas). As a result, the Public Assistance Program was activated, and financial assistance started flowing to help state agencies and local governments pay for the repair or replacement of disaster-damaged public facilities and equipment. Nine out of the sixteen counties in the NCTCOG study area were included in the Public Assistance declaration for debris removal and emergency protective measures (Collin, Dallas, Ellis, Hunt, Johnson, Kaufman, Navarro, Parker, and Tarrant).

While the source, location, and frequency of occurrence of transportation accidents vary across the NCTCOG region, the impact of these events are quite localized. As such, the responses to transportation accidents are also usually localized. For this reason, transportation accidents, per se, do not receive further consideration in this document; however, transportation accidents involving hazardous materials releases are addressed in further detail within the context of regional transportation routing.

References:

AirDisaster.com Accident Database. (2003) Retrieved September 19, 2003 from http://www.airdisaster.com.

Hartzel, T. (October 12, 2003) *Engineering a Solution at Crossings*. The Dallas Morning News.

Jordan, J. (October 2, 2003) *Woman Dies After Her SUV Collides with Light-Rail Train*. The Dallas Morning News.

National Transportation Safety Board. (2001) *Derailment of Amtrak Train 21 on the Union Pacific Railroad at Arlington, Texas*. Railroad Accident Report NTSB/RAR-01/02.

National Transportation Safety Board. (1998) *Grade Crossing Collision/Derailment of Dallas Area Rapid Transit Train 114 in Dallas, Texas*. Railroad Accident Brief Report NTSB/RAB/98-22.

Peninsulas Emergency Preparedness Committee. *Transportation Accidents.* Retrieved on September 17, 2003 from http://www.pep-c.org/transportationaccidents.

Preliminary Screening: *Urban Fires*

Urban fires occur primarily in urbanized cities and towns. Due to the relatively higher density in urbanized areas as compared to rural areas, urban fires have a higher potential to rapidly spread to and damage adjoining structures. Urban fires can damage and destroy residences, schools, commercial buildings, public facilities, and vehicles, and they can be triggered by natural occurrences, such as lightning and earthquakes, and human contributors such as cooking, heating, smoking and arson.

According to the National Fire Protection Association (NFPA), the United States has one of the highest fire death rates in the industrialized world. Each year, fire kills more Americans than all natural disasters combined.

Also, according to the National Fire Protection Association:

- At least 80% of all fire deaths occur in residences
- In 2001, direct property loss due to fires was an estimated $10.6 billion
- In 2001, there were 1,734,500 fires reported in the U.S. and, of these, 30% were structure fires
- Cooking is the leading cause of home fires and the leading cause of home fire injuries
- Careless smoking is the leading cause of fire deaths
- Arson is the second leading cause of residential fires and residential fire deaths
- Arson is the leading cause of deaths, injuries, and dollar losses in commercial fires
- The elderly and young children have the greatest risk of fire death

In Texas during 2001, there were 74,614 fires, or a fire every 7 minutes, reported to the Texas Fire Incident Reporting System (TEXFIRS). Of these, there were 21,033 fires in structures, resulting in 96 deaths, 1,066 injuries and $322 million in property damage. A structure fire occurred every 25 minutes, and 76% of all structure fires occurred in residential properties.

Source: TEXFIRS, January 2003 (Note: no data for Rockwall County were provided)

As depicted Table 4-1, there were 6,225 structure fires reported in the NCTCOG region in 2001. This represents 30% of the total number of structure fires reported throughout the entire state. Using this percentage of the state totals, it can be reasonably assumed that reported structure fires caused 29 deaths, 320 injuries, and $97 million in property damage in the NCTCOG region in 2001.

All urban areas of the United States are exposed to injury, death, and property damage as a result of urban fires, and the NCTCOG region (and especially the urbanized areas of the MPA-Trinity) is no exception.

Table 4-1

Structure Fires Reported in the NCTCOG Region (2001)		
County	**Reporting Departments**	**Structure Fires**
Collin	10	257
Dallas	22	3,444
Denton	16	296
Ellis	14	168
Erath	1	39
Hood	2	7
Hunt	8	100
Johnson	9	142
Kaufman	7	83
Navarro	5	70
Palo Pinto	1	51
Parker	9	30
Somervell	1	0
Tarrant	19	1,533
Wise	3	5
	Total	**6,225**

References:

Campbell, Colin A. Fire Chief. (December 1, 1999). *USFA No smoke detectors in most urban home fires* Retrieved on September 17 from 2003http://firechief.com/ar/firefighting_usfa_no_smoke/index.htm

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment.* Technological Hazards, Chapter 21.

Texas Fire Incident Reporting System (TEXFIRS). (January 2003). 2001 Fire Statistics. State Fire Marshal's Office. Texas Department of Insurance.

United States Fire Administration: Facts on Fire. Retrieved August 27, 2003 from http://www.usfa.fema.gov/public/factsheets/facts.shtm

Washington Military Department Emergency Management Division. Washington State Hazard Identification and Vulnerability Assessment. *Urban Fire.* Retrieved on September 17, 2003 from http://www.emd.wa.gov/3-map/a-p/hiva/27-hiva-th-urban-fire.htm

Preliminary Screening: *Hazardous Materials*

As evidenced by the responses to NCTCOG's Multi-Hazard Risk Assessment Survey, hazardous materials releases are one of the top concerns among local communities in the NCTCOG region. Hazardous materials are chemical substances that can create a threat to the environment or health if released or misused. Typically, these chemicals are in the form of explosives, flammable and combustible substances, poisons, and radioactive materials. Approximately 4.5 million facilities in the United States utilize, manufacture, or store potential hazardous materials, including fields within industry, agriculture, medicine, research, and consumer goods. In addition, many products containing hazardous chemicals are used and stored regularly in homes.

Hazardous materials are shipped daily along highways, railroads, waterways, and pipelines. The greatest risk of a hazardous materials release involves the transport of these substances, although chemical accidents in plants and natural hazards are risks, as well. Types of releases include: air emissions;

discharges into water; discharges as outflows from outfalls, runoff, or contaminated groundwater; discharges onto land; solid waste disposal in onsite landfills; injections into underground wells; and transfers of waste to facilities for treatment or storage, namely sewer treatment plants.

Depending on the form and type of hazardous material, results of exposure can involve death, serious injury, or long-lasting health effects to humans as a result of inhalation, ingestion, or direct contact with the skin. Hazardous materials can also damage buildings, homes, and property, and involve drastic effects to terrestrial and aquatic plants and wildlife.

Table 4-2

Hazardous Materials Release Hazard Event Profile				
Hazard	**Application Mode**	**Hazard Duration**	**Extent of Effects: static or dynamic**	**Mitigating and Exacerbating Conditions**
Hazardous Material release (fixed facility or transportation)	Solid, liquid and/or gaseous contaminants may be released from fixed or mobile containers	Hours to days	Chemicals may be corrosive or otherwise damaging over time. Explosion and/or fire may be subsequent. Contamination may be carried out of the incident area by persons, vehicles, water, and wind.	As with chemical weapons, weather conditions will directly affect how the hazard develops. The micro-meteorological effects of buildings and terrain can alter travel and duration of agents. Shielding in the form of sheltering in place can protect people and property from harmful effects. Non-compliance with fire and building codes as well as failure to maintain existing fire protection and containment features can substantially increase the damage from a hazardous materials release.
Source: FEMA Manual 386-7. (September 2002). *Integrating Human-Caused Hazards Into Mitigation Planning*. Pg. 2-6.				

See HazMAP **map 4-1** for a spatial representation of Hazardous Materials Fixed Facilities in the NCTCOG region. This map shows hazardous materials sites and waste facilities for the 16-county NCTCOG region. Data originates from the Toxics Release Inventory (2001) produced and maintained by the Environmental Protection Agency, as well as data maintained by the Texas Commission on Environmental Quality.

Hazardous Materials Along Transportation Facilities in the Dallas-Fort Worth Area

A strong and diverse Dallas-Fort Worth Area economy combined with prolonged periods of unprecedented growth in North Texas has resulted in extraordinary demands on the region's surface transportation system. Reducing traffic congestion, improving air quality, and finding ways to fund and implement alternative modes of travel are issues that extend well beyond traditional local government boundaries.

Multimodal transportation planning facilitated through a single policy direction for all modes of travel ensures that plans, programs, and policies are coordinated across various city, county, and agency service areas as well as jurisdictional boundaries, and that coordination is occurring among implementing agencies.

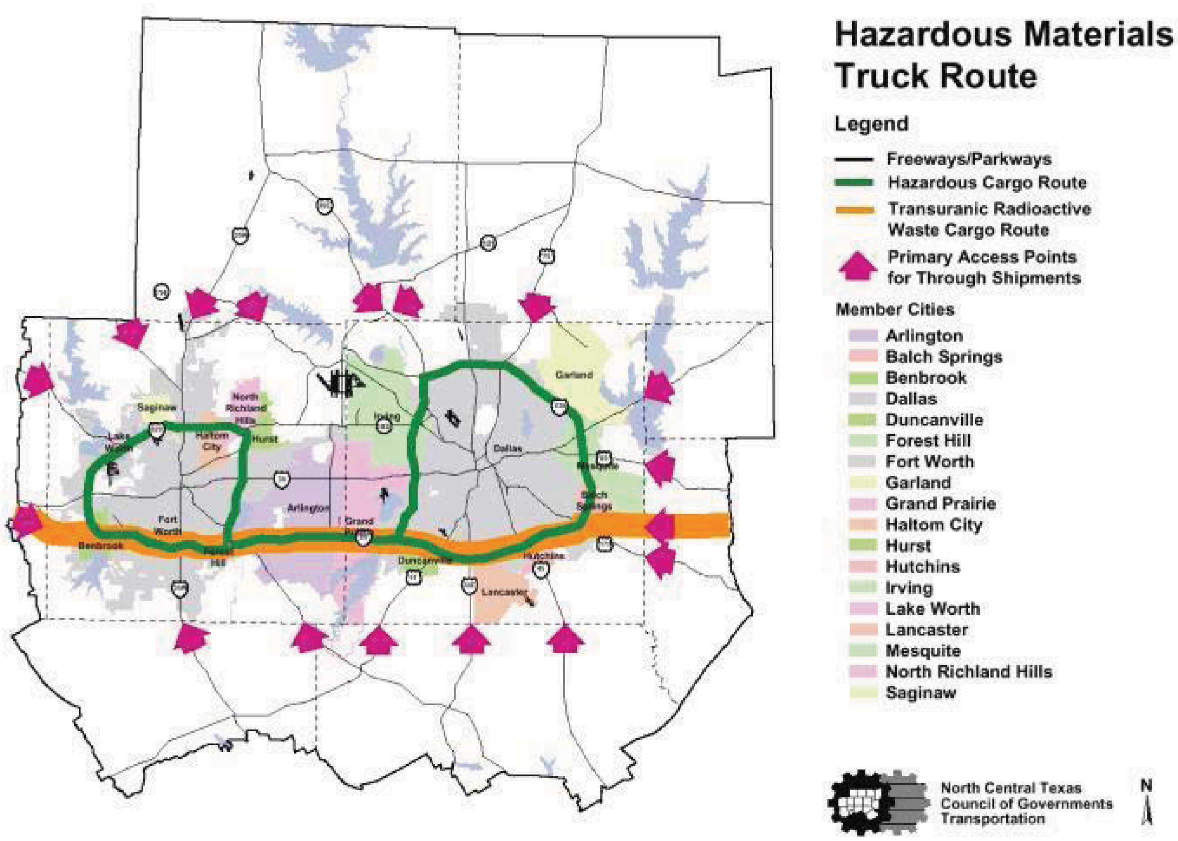
In North Central Texas, this direction is provided through a collaborative structure of committees and organizations creating partnerships in regional transportation planning and implementation. For over 25 years, the North Central Texas Council of Governments (NCTCOG) and the Regional Transportation Council (RTC) have served as the Metropolitan Planning Organization for regional transportation planning in the Dallas-Fort Worth Metropolitan Area.

NCTCOG's Executive Board establishes overall policy for comprehensive planning and coordination in the North Central Texas region, and oversees the administration of funds granted to the MPO. The Regional Transportation Council (RTC), various technical committees, and the NCTCOG Transportation

Department staff complete this metropolitan planning structure. The MPO works in cooperation with the region's transportation providers to improve the region's mobility and air quality.

In 1985, the North Central Texas Council of Governments (NCTCOG) undertook a comprehensive analysis of the region's hazardous materials routing (*Hazardous Materials Routing Study Phase 1: Establishing Hazardous Materials Truck Routes for Shipments through the Dallas-Fort Worth Area*). Through this effort came the recommendation that I.H. 20 provided the safest east-west route for hazardous material movements through the DFW Metropolitan Area (see Figure 4-1). The I.H. 820 Loop around Fort Worth and the I.H. 635/Loop 12/I.H. 20 ring around Dallas provided the means to safely transport hazardous materials around the central urban areas. As compared to other east-west highways, the I.H. 20 corridor had lower traffic volumes, a high design standard, and fewer population and employment activity areas. Similarly, the two outer urban loops had relatively lower congestion levels and adequate design standards for a more efficient transport of hazardous materials.

Figure 4-1



Between 1990 and 1998, population in the vicinity of I.H. 20 grew over 20 percent, and employment in the same area increased 40 percent. Consequently, these increases have added traffic traveling on the route. In 1995, congestion levels on at least 30 percent of the lane-miles in some segments of I.H. 20 were already at level-of-service (LOS) D or worse; Mobility 2025 forecasts indicate that additional segments of I.H. 20 will experience similar levels of congestion. As explained in Figure 4-2, the Regional Transportation Council intends to re-evaluate hazardous materials routing over the next 2 to 4 years as they develop and seek subsequent Federal Highway Administration approval of Mobility 2030, the next long-range transportation plan.

Figure 4-2

December 4, 2003

Mr. Wayne P. Owen Jr.
Planning & Development Manager
Tarrant Regional Water District
800 E. Northside Dr.
Fort Worth, Texas 76164

Dear Mr. Owen:

The Regional Transportation Council (RTC) supports the efforts of the Hazard Mitigation Action Planning Review Team to identify and respond to potential major natural, technological and security emergencies. Your efforts lay the groundwork for regional cooperation to reduce the severity and improve response to a major tornado, flood, terrorist or other emergency event.

The RTC, as the transportation policy body of the Metropolitan Planning Organization, is responsible for overseeing the metropolitan transportation planning process. An RTC roster is provided as Attachment 1. The RTC's work includes responsibility for planning hazardous material truck routes and coordinating with federal authorities on Transuranic Radioactive Waste Routes.

Attachment 2 illustrates the current hazardous material route map that we developed for the Dallas-Fort Worth region. This system has been approved by the Federal Highway Administration (FHWA) as part of the region's current long-range transportation plan, The Mobility 2025 Plan Update. Please include this in your current planning effort. These routes were developed as part of the Hazardous Materials Routing Study. This study followed FHWA guidelines related to Hazardous Materials Routing and utilizes the following methodological steps:

(1) Calculate Accident Probabilities based on truck volumes and accident rates on individual roadways

(2) Calculate Accident Consequences by evaluating the impact of an incident on the surrounding population and employment along a given roadway

(3) Combine the Accident Probability and Accident Consequence in a Composite Population Risk for each roadway segment under analysis

(4) Based on the Composite Population Risk, identify and designate minimum risk paths through the region

The RTC would like to identify funding sources to perform a re-evaluation of the region's transportation system with this same methodology. Our intention is to address this issue in the next 24 – 48 months and update our region's Hazardous Materials Routes to coincide with our pending development and subsequent FWHA approval of Mobility 2030.

Our original work focused on routes for trucks passing through the region. We would like to expand this to examine through trips, internal trips and the potential for new Hazardous Material Bypass Routes. If your sponsors can assist with funding or provide additional data to support our process, please contact Mike Sims (817) 695-9226 as soon as possible. I look forward to continued regional cooperation on this critical issue.

Thank you and your team members for your work on this issue.

Sincerely,

Michael Morris, P.E.
Director of Transportation

MS:tmb

cc: John Promise, Director of Environmental Resources, NCTCOG
UPWP 2003 – 2004 Element 5.04 Project File

Additionally, recognizing that trucking is just one of many modes of transportation that moves hazardous materials through the region, NCTCOG's Transportation Department has developed a Goods Movement program (http://www.dfwinfo.com/trans/goods_movement/index.html). Goods movement is the lifeblood of the Texas economy, and specifically the Dallas-Fort Worth (DFW) Metropolitan Area. The NCTCOG region represents one of the largest "inland ports" in the nation, where freight is moved, transferred, and distributed to destinations across the State and around the world. North Central Texas has one of the most extensive surface and air transportation networks in the world, providing extensive trade opportunities for the more than 600 motor/trucking carriers and almost 100 freight forwarders that operate out of the DFW area.

Managing the movement of Hazardous Materials along multi-modal transportation facilities is now one of several goals under the Goods Movement program. As found on NCTCOG's Goods Movement web page, goals of the Goods Movement program include:

- Promoting NAFTA Safety and Mobility Issues
- Promoting Safety at Highway/Rail Crossings
- Establishing New Process for Intermodal Freight Community Input
- Monitoring Goods Movement Traffic Throughout the Region
- Evaluating Accessibility of Intermodal Freight Carriers
- Ensuring Safety of Hazardous Materials Truck Routes
- Continuing MPO Involvement with Freight and NAFTA Groups

References:

FEMA. *Hazards: Informing the Public About Hazards.* Retrieved on September 17, 2003 from http://www.fema.gov/hazards/terrorism/terror.shtm

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment.* Technological Hazards, Chapter 22.

North Central Texas Council of Governments (NCTCOG). (October 1985). *Hazardous Materials Routing Study Phase 1: Establishing Hazardous Materials Truck Routes for Shipments through the Dallas-Fort Worth Area*.

North Central Texas Council of Governments (NCTCOG). (May 2001). *Mobility 2025 Update: Metropolitan Transportation Plan*. http://www.dfwinfo.com/trans/mtp/current/index.html

North Central Texas Council of Governments (NCTCOG). (November 2002). *Regional Mobility Initiatives*. Vol. VI, No. 2.

Preliminary Screening: *Nuclear Plant Accidents*

The primary risk associated with a nuclear plant accident is exposure to radiation. Radiation exposure comes from the release of radioactive material into the environment and is usually characterized by a plume formation. The area of effect is determined by the amount of radiation released from the plant, wind direction and speed, and precipitation, which quickly drive the radioactive material to the ground. Driving radioactive materials into the ground causes increased deposition of radionuclides.

A nuclear power plant converts the energy released by the splitting or fissioning of atoms to electrical energy. The major processes are the same as in a conventional power plant, except that coal or oil fired boilers are replaced by a nuclear reactor fueled by uranium. Nuclear power plants are designed with two principle safety objectives in mind: (1) containing radioactive materials to prevent off-site health effects, and (2) ensuring that the heat generated by the reactor is removed. If the heat is not removed, it could cause failures of the system designed to contain the radioactive materials used as fuel as well as the byproducts created during reactor operations (called fission products).

Radioactive materials are composed of atoms that are unstable, and give off excess energy until the atoms become stable. This excess energy is radiation, which is propagated as rays, waves or energetic particles that travel through the air or a material medium. Certain types of radiation can produce a harmful effect on the cells of the body. The longer a person is exposed to radiation, the greater the risk. People receive some radiation exposure each day from the sun, radioactive elements in the soil and rocks, household appliances like television sets and microwave ovens, and medical and dental x-rays.

The exposure of the human body to nuclear radiation causes damage to the cells in all parts of the body, which is called "radiation sickness." The severity of this sickness depends on the radiation dose received, the length of exposure and the condition of the body at the time. Early symptoms of radiation sickness will typically appear one to six hours after exposure and will include headache, nausea, vomiting and diarrhea. There is no first aid for exposure to nuclear radiation.

The State of Texas has two operating commercial nuclear power plants licensed by the U.S. Nuclear Regulatory Commission (NRC), and one of them is located in the NCTCOG region (see HazMAP **map 4-2**). The Comanche Peak Steam Electric Station (CPSES), a twin 1,150 megawatt pressurized light water reactor plant operated by Texas Utilities (TXU), is located on the Hood County-Somervell County line approximately 60 miles southwest of Fort Worth. The plant has about 1,300 employees and relies on nearby Squaw Creek reservoir for cooling water.

An accident at the Comanche Peak nuclear power plant could release radioactive fission products into the atmosphere in gaseous form or in the form of volatile and non-volatile solids; the primary concerns would be gamma and beta radiation. The likelihood of an accident at Comanche Peak that would release significant amounts of radiation into the environment is relatively remote. Although the risk of a severe accident at Comanche Peak is small, it should receive further consideration in future planning cycles because such an accident could affect a substantial number of people in the NCTCOG region.

References:

Comanche Peak website. (2001) Retrieved on August 20, 2003 from http://www.comanchepeakemergencyinfo.com

Energy Information Administration. (June 2003) *US Nuclear Reactors—Comanche Peak*. Retrieved on August 20, 2003 from http://www.eia.doe.gov/cneaf/nuclear/page/at_a_glance/reactors/comanchepk.html

FEMA. *Hazards: Informing the Public About Hazards.* Retrieved on September 17, 2003 from http://www.fema.gov/hazards/terrorism/terror.shtm

State of Texas—Division of Emergency Management. (2000) *Hazard Analysis*. Radiological Hazards: Section 10.

Sgt. Frank R. Santiago. *Nuclear hazards – a flash of insight.* Retrieved on September 17, 2003 from http://www.globalsecurity.org/military/library/news/2003/02/mil-030214-usmc05.htm. USMC News, Marine Corps Recruit Depot San Diego, California.

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment.* Technological Hazards, Chapter 23.

Preliminary Screening: *Illegal Dumping*

Illegal dumping is an issue that most every local government in the North Central Texas study area deals with. Not only is illegal dumping an economic concern for most local governments, it is also a public health and safety concern that can potentially cause significant health risks to local residents and businesses. Illegal dumping is the dumping of waste at an unauthorized location and can encompass different types of waste such as household garbage, construction and demolition debris, tires, hazardous waste, household hazardous chemicals, and much more. Illegal dumping is an intentional act that can have disastrous unintended effects.

For folks investigating or cleaning up an illegal dumpsite, there are several possible health concerns associated with the types of chemicals at the dumpsite, the vectors (or rodents) at the dumpsite, and other materials such as medical waste or sharp objects that can cause bodily harm. Chemicals dumped in or around waters of the state can pollute streams and lakes used for drinking water and can be very costly to clean up. Illegally dumped tires can collect water and provide an ideal breeding ground for mosquitoes, which contribute to spreading diseases such as the West Nile Virus. Enclosed chemicals in a barrel or drum can become volatile and cause serious bodily harm if sparked.

Illegal dumping can also pose a public safety problem. Often, dumping occurs in low- lying areas such as streams, ditches or other waterways. As a result, the dumped material reduces the natural capacity of the area to store and convey water, thereby exacerbating flooding. Swift moving water can carry illegally dumped debris downstream until it collects against structures such as bridges and culverts, resulting in “debris dams” that can cause streams to back up and flood. And, if the illegally dumped debris is carried downstream with enough force, it can damage or even destroy valuable public infrastructure. Significant quantities of tires can catch fire, either by arson or by spontaneous combustion, and can be very costly to extinguish (not to mention the air quality concerns associated with burning tires).

Illegal dumping is not just a litter problem that adversely affects the aesthetic value of property. Illegal dumping is a technological hazard that can have significant effects on public health and safety as well as on the natural environment. NCTCOG serves as the designated regional planning agency for municipal solid waste management and supports an aggressive Stop Illegal Dumping program (go to http://www.dfwinfo.com/envir/sw/SID/index.asp).

Preliminary Screening: *Civil Disobedience*

Civil disobedience is defined as the refusal to obey governmental demands or commands as a nonviolent and collective means of forcing concessions from the government. Some people think that violent action can constitute civil disobedience, however, the tradition of civil disobedience in the United States is non-violent. Civil disobedience is used in many different arenas and for many different reasons. The usual goal of civil disobedience is to create public support and pressure to force a change in the law in question.

Although civil disobedience has a long history in the United States, from the Boston Tea Party to some of the most important moments of the civil rights movement, there is no constitutional right to engage in civil disobedience. Therefore, a person who engages in civil disobedience must expect to be exposed to the maximum penalties of the law, which may include a fine and imprisonment. If the law under which the person is charged is subsequently proven to be unconstitutional, however, the disobedient will be acquitted.

An example of civil disobedience might be where a state has a "hunter harassment" law that specifically prevents protesters from demonstrating within 400 feet of any designated hunting area. An animal rights activist from that state consults an attorney to see if the law is constitutional. The attorney suggests that the law violates the free speech and equal protection guarantees of the federal Constitution, and may also violate similar provisions of the state constitution, consequently the activist decides to violate the law by carrying a sign saying "Stop Killing Animals" within 400 feet of a designated hunting area.

Visit NCTCOG's Department of Emergency Preparedness website at http://www.dfwinfo.com/ep/ to see NCTCOG's activities in regard to civil disobedience hazards.

References:

Francione, Gary L., Charlton, Anna E. Animal Rights Law. (1996-2002) *Demonstrating and Civil Disobedience A Legal Guide for Activists.* Retrieved on September 17, 2003 from www.animal-law.org/library/pamphlet.htm

Preliminary Screening: *Epidemics*

An epidemic is defined as any excessive and related incidence of a particular disease above what is normally expected in a population. Epidemics cause prolonged and widespread illness and death.

There are two major types of infectious diseases which can develop into epidemics: common source and host-to-host. Common source epidemics arise from a contaminated source, such as water or food, while host-to-host infections are transmitted from one infected individual to another via various, perhaps indirect, routes. Common source epidemics usually produce more new cases earlier and faster than host-to-host epidemics. Once the infected source is closed, sealed, or removed, the common source epidemic usually abates rapidly. Host-to-host epidemics are slower to grow and slower to diminish.

A history of epidemics in the United States is listed from 1793 to 1981 below:

- 1793 Philadelphia: more than 4,000 residents died from yellow fever.
- 1832 July–August, New York City: over 3,000 people killed in a cholera epidemic.
- October., New Orleans: cholera took the lives of 4,340 people.
- 1848 New York City: more than 5,000 deaths caused by cholera.
- 1853 New Orleans: yellow fever killed 7,790.
- 1867 New Orleans: 3,093 perished from yellow fever.
- 1878 Southern states: over 13,000 people died from yellow fever in lower Mississippi Valley.
- 1916 Nationwide: over 7,000 deaths occurred and 27,363 cases were reported of polio (infantile paralysis) in America's worst polio epidemic.
- 1918 March–November., nationwide: outbreak of Spanish influenza killed over 500,000 people in the worst single U.S. epidemic.
- 1949 Nationwide: 2,720 deaths occurred from polio, and 42,173 cases were reported.
- 1952 Nationwide: polio killed 3,300; 57,628 cases reported; worst epidemic since 1916.
- 1981-December 2001:total U.S. AIDS cases reported to Centers for Disease Control: 816,149; total AIDS deaths reported: 467,910. (Total world cases: 42 million; total AIDS deaths: 27.9 million.)

The most recent global epidemic is Severe Acute Respiratory Syndrome (SARS), a viral respiratory illness caused by a coronavirus, called SARS-associated coronavirus (SARS-CoV). SARS was first reported in Asia in February 2003. Over the next few months, the illness spread to more than two dozen countries in North America, South America, Europe, and Asia. Although the SARS global outbreak of 2003 was contained, it is possible that the disease could re-emerge.

According to the World Health Organization (WHO), during the SARS outbreak of February to July 2003, a total of 8,437 people worldwide became sick with SARS; of these, 813 died. In the United States, there were 192 cases of SARS among people, all of whom recovered. Through July 2003, laboratory evidence of SARS-CoV infection had been detected in only eight U.S. cases. Most of the U.S. SARS cases were among travelers returning from other parts of the world with SARS.

Due to our ability to travel with such ease and frequency, epidemics such as this can spread incredibly fast and have devastating affects. Individuals are at risk worldwide.

References:

Center for Disease Control (CDC). (August 19, 2003). Severe Acute Respiratory Syndrome. *Basic Information about SARS.* Retrieved September 17, 2003 from http://www.cdc.gov/ncidod/sars/factsheet.htm

History of Epidemics and Plagues. (October 2001). Retrieved on September 17, 2003 from http://uhavax.hartford.edu/bugl/histepi.htm#types

Infoplease.com. *Major U.S. Epidemics.* Retrieved on September 17, 2003 from http://www.infoplease.com/ipa/A0001460.html

Preliminary Screening: *Biological Agents*

Some of the most common hazards include biological hazards, typically from micro- and macro-biological sources. Micro-biological sources include viruses, bacteria and parasites; whereas, macro-biological sources include insects such as spiders, pets, and snakes. Botanical elements are also a source of biological hazards, including poisonous plants and allergic reactions from pollen. Biological agents have the ability to adversely affect human health ranging from allergic reactions to serious medical conditions, and even death. Many microbes reproduce rapidly and require minimal resources for survival.

Some of the most prevalent biological agents include the following: bloodborne pathogens such as hepatitis B virus (HBV), hepatitis C virus (HCV), or human immunodeficiency virus (HIV); foodborne diseases, such as botulism, brucellosis, Campylobacter enteritis, Escherichia coli, hepatitis A, listeriosis, salmonellosis, shigellosis, toxoplasmosis, viral gastroenteritis, taeniasis, and trichinosis; bacterial diseases, such as Legionnaires' Disease; viral diseases such as small pox; and spores from molds and fungi. Biological agents can also affect humans indirectly through damage to crops, wildlife, and ecosystems.

An extreme source of biological hazards may come from fine airborne particles derived from biological weapons, and may expose people to bacteria, viruses, or toxins. Terrorists may use biological agents to contaminate food or water because they are extremely difficult to detect. Infection from biological agents can occur as a result of inhalation, ingestion, contact with the mucous membranes of the eyes or nasal tissues, or penetration of the skin through open cuts. Biological agents as a result of weapons are fine particles and will not penetrate the materials of properly assembled and fitted respirators or protective clothing.

References:

Environmental Protection Agency, Region 10. *Field Safety Having the Right Attitude.* Retrieved on September 17, 2003 from http://www.epa.gov/region10/offices/oea/ieu/manual/safety01.htm

Office of Laboratory Security, Population and Public Health Branch, Health Canada. *ERT Technical Bulletin 2002-1, June 2002.* Retrieved on September 17, 2003 from http://www.ertresponse.com/PDF_Files/anthrax.pdf

Federal Emergency Management Agency (FEMA). *Hazards: Informing the Public About Hazards.* Retrieved on September 17, 2003 from http://www.fema.gov/hazards/terrorism/terror.shtm

U.S. Department of Labor Occupational Safety & Health Administration. *Safety and Health Topics: Biological Agents*. Retrieved on September 17, 2003 from http://www.osha.gov/SLTC/biologicalagents/index.html

Preliminary Screening: *Chemical Agents*

A chemical is an element, chemical compound or mixture of elements and/or compounds. According to OSHA Standard 1910.1200: a hazardous chemical is one in which there is a physical hazard or a health hazard. Further, a health hazard means a chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed individuals. The term "health hazard" includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic system, and agents which damage the lungs, skin, eyes, or mucous membranes. On the other hand, a physical hazard means a chemical for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive) or water-reactive.

Chemical agents can have many effects, including killing or incapacitating people, as well as destroying livestock or ravaging crops. Some chemical agents are odorless and tasteless and are difficult to detect, and may include dusts, mixtures, and common materials such as paints, fuels, and solvents. They can have an immediate effect (a few seconds to a few minutes) or a delayed effect (several hours to several days). Effects to humans may include, but are not limited to, skin and eye irritation, mutagenic effects, reproductive effects, tumorigenic effects, and acute toxicity.

An extreme case of chemical hazards includes risks from chemical weapons. Chemical agents through the use of chemical warfare may include nerve agents, blister/vesicant agents, blood agents, and pulmonary agents.

References:

FEMA. *Hazards: Informing the Public About Hazards.* Retrieved on September 17, 2003 from http://www.fema.gov/hazards/terrorism/terror.shtm

Interactive Learning Paradigms Incorporated. *The OSHA Hazard Communication Standard, (Subpart Z, Toxic and Hazardous Substances, 29 CFR 1910.1200).* Retrieved on September 17, 2003 from http://www.ilpi.com/msds/ref/hazardous.html

Preliminary Screening: *Nuclear Agents*

The primary risk associated with nuclear hazards is exposure to radiation. Nuclear hazards are mainly caused by accidents at nuclear power plants, but radioactive storage sites, and radioactive waste dumps may also contribute to increased levels of radioactivity. In addition, hospitals, universities, research laboratories, industries, major highways, railroads, or shipping yards could be the site of a radiological accident. In extreme cases, exposure may occur as a result of a nuclear weapon detonation.

Radiation exposure could come from the release of radioactive material from a source into the environment, and is usually characterized by a plume formation. The area of effect is determined by the amount of radiation released from the plant, wind direction and speed, and precipitation, which would quickly drive the radioactive material to the ground. Driving radioactive materials into the ground would cause increased deposition of radionuclides.

Nuclear accidents can be classified in three separate categories, which include criticality, loss-of-coolant, and loss-of containment accidents. Criticality accidents involve nuclear assemblies, research, production, or power reactors and chemical operations. Loss-of-coolant accidents occur when a reactor coolant system results in a break or large opening. Loss-of-containment accidents release radioactivity either from containment vessels at fixed facilities or damaged packages during transportation accidents.

Radioactive materials are composed of atoms that are unstable, and give off excess energy until the atoms become stable. This excess energy is radiation, which is propagated as rays, waves or energetic particles that travel through the air or a material medium. Certain types of radiation can produce a harmful effect on the cells of the body. The longer a person is exposed to radiation, the greater the risk. People receive some radiation exposure each day from the sun, radioactive elements in the soil and rocks, household appliances like television sets and microwave ovens, and medical and dental x-rays.

The exposure of the human body to nuclear radiation causes damage to the cells in all parts of the body, which is called "radiation sickness." The severity of this sickness depends on the radiation dose received, the length of exposure and the condition of the body at the time. Early symptoms of radiation sickness will typically appear one to six hours after exposure and will include headache, nausea, vomiting and diarrhea. There is no first aid for exposure to nuclear radiation.

References:

FEMA. *Hazards: Informing the Public About Hazards.* Retrieved on September 17, 2003 from http://www.fema.gov/hazards/terrorism/terror.shtm

Sgt. Frank R. Santiago. *Nuclear hazards - a flash of insight.* Retrieved on September 17, 2003 from http://www.globalsecurity.org/military/library/news/2003/02/mil-030214-usmc05.htm. USMC News, Marine Corps Recruit Depot San Diego, California.

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment.* Technological Hazards, Chapter 23.

Preliminary Screening: *Utility-Energy Interruptions*

Texas utilizes natural gas, fossil fuels, hydroelectricity, nuclear power, and wind to generate electricity, although most of the electricity is generated from plants that burn natural gas or coal. Of these energy generators, 39% is coal, 49% natural gas, 11% nuclear, and 1% renewable (hydroelectric and wind-powered). ERCOT (the Electric Reliability Council of Texas) is the corporation that administers the electric power grid for the state of Texas, serving approximately 85 percent of the state's electric load. Currently, the ERCOT service area oversees the operation of over 70,000 megawatts of generation and 37,000 miles of transmission lines.

The main source of energy is used for generation of electricity and is conducted through bulk-power systems and distribution systems. Bulk power systems include electrical generators, transmission networks, and control centers. Bulk-power system outages affect large areas and can have significant regional and national implications. Outages on the distribution system, although more numerous, generally have only localized effects. On bulk power systems, every action can affect all other activities on the grid. Outages can increase in severity and cascade over large areas.

The majority of outages are caused by inclement weather conditions (severe summer heat and severe winter/ice storms) affecting transmission lines. Other reliability factors affecting energy supplies, according to the National Energy Policy, include electricity shortages and disruptions, overloaded and congested circuits, dramatic increases in gasoline prices due to low inventories, a strained supply system, and continued dependence on foreign suppliers. Terrorism is the newest threat to energy supply. Additional constraints upon the energy supply include higher prices due to dependence on foreign oil, and pipeline and refinery problems.

Transportation fuels account for approximately two-thirds of the nation's oil consumption, while the industrial sector accounts for 25 percent. Residential and commercial uses, such as heating oil and propane account for most of the rest.

Accidental and intentional interruptions to the supply of energy can have severe impacts on commerce, transportation, communications, government, health care, and home life. Any prolonged interruption of the supply of basic energy would be devastating to the economy and security.

When energy such as electricity is interrupted, it can have cascading effects on other utilities such as the water and wastewater supply. Water supply can be impacted because there is no electricity to pump the water from the source, through the system, and to the end-users. Similarly, without electricity, sewage treatment plants may be unable to treat wastewater.

Major Outages in the U.S., Texas and Dallas Area

Over the past 40 years, there have been several major power outages across the United States, throughout Texas, and in the NCTCOG region. The following historical event information was compiled by the *Dallas Morning News* research staff:

In November 1965, New York City, along with most of the Northeast and portions of Canada, experienced a massive nighttime power failure. In March 1984, a failed circuit knocked out power to 3 million power customers in California, Nevada, Arizona, New Mexico, Texas and Utah. In January 1979, a severe ice storm in the Dallas area left 25,000 customers without power during the first week of the new year. In September 1995, Failures in major power lines between New Mexico and Arizona left 263,000 customers in El Paso, Texas' Upper Rio Grande Valley and southern New Mexico. In April 1996, tens of thousands of people in four states were left without electricity when a power plant failed in the Texas panhandle. In August 1996, a sporadic power outage struck at least seven Western states. In January 1997, freezing weather across Texas knocked out power to 80,000 residents, primarily in southeast Texas. In December 2000, about 235,000 homes were without power in Texas, Arkansas and Louisiana when an artic front moved through in mid-December. In January 2001, a cold wave knocked out power to 120,000 homes and businesses in Texas, Oklahoma and Arkansas for up to a week around New Year's Day. And, of course, in August 2003, the biggest power failure in United States history struck the Midwest and Northeast and parts of Canada for the better part of four days.

According to Dave Michaels of the *Dallas Morning News*, since "about 85 percent of Texas uses a self-contained grid that relies on power generated within the state, utility officials in Texas said a power outage similar to the [Great Blackout of 2003] is unlikely."

Additionally, because of our nation's overwhelming dependence on fossil fuels, an interruption in the supply of petroleum energy (such as the Oil Crisis of the early-mid 1970s) can also have debilitating effects on the nation.

Source: Dallas Morning News Research, 2003.

Preliminary Screening:
Utility-Water Interruptions

According to the 2001 Region C Water Plan (which covers most of the NCTCOG region), 92% of the drinking water was supplied by surface reservoirs, and 8% was supplied by groundwater in 1997. Fourteen reservoirs serve as water supply for the NCTCOG region, and a few other reservoirs located outside the NCTCOG region also supply drinking water to the region.

The main causes of water supply interruptions are contaminations and failures of water supply infrastructure. Water supply interruptions can be either accidental or intentional.

No Texas communities have unlimited water supply, and few have water treatment and distribution systems adequate to meet future growth. Still fewer are totally confident that their water supplies are protected from pollution.

Development in the NCTCOG region has threatened water quality. Rivers, lakes, and streams have been affected by the discharge of waste, by polluted runoff from urban, agricultural, and resource development, and by accelerated erosion and sedimentation. Even water stored in underground reservoirs is not immune to contamination.

The lack of water supply due to a prolonged interruption can lead to drought conditions causing declines in rangeland production, losses to agriculture and the families and industries associated with it. Water supply contamination also poses serious health threats due to the speed in which disease travels through water. Individuals may become ill and even die from contaminated water. If the contamination leads to an epidemic, it could severely tax the health care system in regards to diagnosis, treatment and prevention. The community could also be affected by loss of productivity and wages.

References:

Brooke Pace and Brodie Herb. (2001). *Moving Forward with Renewable Energy* http://www.ecconet.com/ecconet/CommunityChat/spotlights/Archive/archive_renewenergy.htm

Chenault, Edith A. (June 1998). *Drought Impacting Texas Rangelands.* Retrieved September 15, 2003 from http://agnews.tamu.edu/dailynews/stories/ANSC/Jun2698a.htm

Dallas Morning News Research. *Major Outages in the U.S., Texas and Dallas Area*. Retrieved August 15, 2003 from http://www.dallasnews.com/sharedcontent/dallas/graphics/08-03/0814blackout/

Electric Reliability Council of Texas, Inc. Retrieved on September 17, 2003 from http://www.ercot.com/

King County Emergency Management. (September 14, 1998). Technological Hazards. *Food and Water Supply Contamination.* Retrieved September 17, 2003 from http://www.metrokc.gov/prepare/hiva/food.htm

Members of the National Energy Policy Development Group. (2001). *Report of the National Energy Policy Development Group.* U.S. Government Printing Office, Washington D.C.

Michaels, D. (August 15, 2003). *Cities Have Plans to Handle Outages*. Retrieved from the Dallas Morning News website at http://www.dallasnews.com/cgi-bin/bi/gold_print.cgi

Public Utility Commission of Texas. *Consumer Connection: Facts About Renewable Energy.* Retrieved on September 17, 2003 from http://www.puc.state.tx.us/ocp/electric/elecfacts

Regional Water Planning Group. (2001). *Region C Water Plan*. Retrieved October 27, 2003 from http://www.regioncwater.org

Secretary of Energy Advisory Board, U.S. Department of Energy. (1998). *Maintaining Reliability in a Competitive U.S. Electricity Industry Final Report of the Task Force on Electric System Reliability*.

Texas Water Resources Institute (February 1981). Texas Water Resources. *Texas Water Problems No Laughing Matter.* Retrieved on September 17, 2003 from http://twri.tamu.edu/newsletters/TexasWaterResources/twr-v7n1.pdf

Wiser, R. (2001). *The Renewables Portfolio Standard in Texas: An Early Assessment*. Ernest Orlando Lawrence Berkeley National Laboratory, Berkley, California.

Young, D. (September 4, 2003). *Report Blasts America's Infrastructure*. Associated Press, Washington

Preliminary Screening: *Fuel Pipeline Accidents*

The people of Texas as well as the state's important environmental resources are particularly vulnerable to destruction from pipeline accidents such as leaks, fires and explosions.

The simple fact is that Texas has more miles of pipeline than any other state. Fuel pipeline accidents have occurred in the NCTCOG region, and, according to recent studies and reports, the risks are increasing everyday. To generally characterize the growing risk of fuel pipeline accidents, we have compiled a selection of germane passages from the award-winning four-part investigative special report by Jeff Nesmith and Ralph K.M. Haurwitz entitled “Pipelines: The Invisible Danger,” which originally appeared in the Austin American Statesman from July 22-29, 2001.

“Out of sight and unnoticed, America’s sprawling oil and natural gas pipelines are leaking on the scale of a ruptured supertanker.”

“They [pipelines] are fouling the environment and causing fires and explosions that have killed more than 200 people and injured more than 1,000 in the past decade. And the numbers are increasing steadily.”

“The federal government relies on a small, underfunded and understaffed agency [the Office of Pipeline Safety (OPS), a unit of the U.S. Department of Transportation] to police a powerful and wealthy industry.”

“For decades, the agency [OPS] hasn’t known the precise whereabouts of thousands of miles of pipelines under its jurisdiction”

“’There is almost an absence of regulation,’ said Jim Hall, until recently chairman of the National Transportation Safety Board, the independent federal agency that investigates airlines crashes, train wrecks and other transportation disasters.”

“The nation has essentially two pipeline systems. About 157,000 miles of hazardous liquid pipelines carry crude oil to refineries and refined products such as gasoline, diesel fuel, and petrochemical feedstocks to market. Virtually all of America’s natural gas is transported through a second system consisting of about 333,000 miles of cross-country transmission lines and 1.7 million miles of local gas company distribution lines.”

“Both systems contain aging infrastructure. Several thousand miles of hazardous liquid pipe are more than 80 years old. Most of the remainder was laid in the 1950s and 1960s. Last year, a dozen liquid pipelines more than 70 years old failed in America. One-fourth of the country’s natural gas pipe is more than 50 years old.”

“There is consensus—among the industry, its regulators and its critics—that the [OPS] database underrepresents the quantity of oil products that escapes from pipelines.”

“Enormous quantities of natural gas escape from a separate pipeline system plagued by pinhole leaks, any one of which could give way to a neighborhood-leveling explosion at any moment.”

“The federal government gives pipelines companies broad authority to inspect their own lines and decide when they should be repaired or taken out of service. But a yearlong examination found this system of loose regulation subjects the public and the environment to increased risk.”

“Many pipeline operators have never pressure-treated their lines or examined them with internal inspection devices.”

“’We’re talking about that piece of pipe being in the ground, operating at high pressure, transporting a volatile liquid in the ground for 50 years without any type of internal inspection of that particular section of pipe,’ Hall told officials at the meeting on pipeline safety in Austin. ‘So that is why we feel so strongly that time is running out for us in many of these areas, that we may begin to see an increased frequency of these types of accidents.’”

“Thousands of miles of ‘gathering lines’ are not regulated at all in rural areas, and many of them are known to be leaking. Nationally, there are more than 200,000 miles of these lines, which carry natural gas and crude oil from wellheads to collection points. Texas has 43,000 miles of gathering lines. The amount of oil that drips into creeks, streams and underground water reservoirs from these lines may never be known because companies are not required to report such leaks to the OPS.”

“Many of the nation’s aging pipelines were built in remote areas but are now surrounded by homes, schools, and shopping centers.”

“Sometimes, the stresses endured by a pipeline lead to silent, chronic leaks that go undetected for months, even years.”

“Despite a spotty record of finding and dealing with leaks, the pipeline industry has kept maintenance expenditures nearly flat during recent years.”

“Even a small hole in a pipeline can lead to a catastrophe.”

“Three elderly people were killed on Jan. 14, 2000, when natural gas accumulated beneath a house in Garland, near Dallas, and exploded. A report by the Texas Railroad Commission, which oversees some of the pipelines in the state, said the gas migrated from a crack in the area where two sections of 4-inch wide plastic pipe were fused under a nearby alley.”

“Until an oil spill was discovered in the John Heinz National Wildlife Refuge near Philadelphia International Airport in February 2000, OPS inspectors had never visited the 50-year-old pipeline from which the oil was pouring.”

“’I’m not sure we even knew that pipeline was there,’ said OPS official Linda Daugherty.”

On August 24, 1996, near Kemp, Texas (outside of Dallas) a high-pressure liquid butane pipeline leaked and exploded, killing two teenagers who inadvertently triggered the blast with an ignition spark from their truck.

On March 9, 2000, a buried 28-inch-diameter pipeline owned and operated by Explorer Pipeline Company ruptured and released over 500,000 gallons of gasoline near Greenville, Texas. The released gasoline flowed into a dry creek bed, which was a tributary of East Caddo Creek. As heavy rains began to fall, the released gasoline continued downstream until it eventually reached Lake Tawakoni, a major water supply reservoir for Dallas and other communities. The chemical MTBE (methyl tertiary butyl ether), a component of gasoline, was found in the reservoir.

HazMAP **map 2-16** and **map 2-17** illustrate the complex system of petroleum production, transmission and distribution infrastructure in the NCTCOG region.

References:

Danielle Dawn Smalley Foundation, Inc. website located at http://64.226.100.73/

Nesmith, Jeff and Ralph K.M. Haurwitz. (July 22, 2001) *Pipelines: The Invisible Danger*. Austin American-Statesman

During the June workshop, NCTCOG staff and the Consultant Team performed an initial screening of the natural hazards list in the attempt to answer the question: "Given the limited resources of this effort, which hazards are worth looking at in more detail?" Through this initial screening and some preliminary research, it became apparent that some natural hazards had very limited exposure and were not very relevant to the NCTCOG region. As a result, some natural hazards were not worth looking at in more detail and were eliminated from further analysis and mitigation consideration during 2003-2004. Those natural hazards are explained below:

Hazard Identification: *Coastal Erosion*

Coastal erosion is a hydrologic hazard defined as the wearing away of land and loss of beach, shoreline, or dune material as a result of natural coastal processes or manmade influences. The NCTCOG study area lies about 200 miles away from the Texas Gulf Coast and is highly unlikely to be affected by coastal erosion. Thus, coastal erosion hazards will not receive any further consideration in this document.

References:

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment.* Hydrologic Hazards, Chapter 14.

Hazard Identification: *Storm Surges*

Storm Surges occurs when the water level of a tidally influenced body of water increases above the normal astronomical high tide. Storm surge commonly occurs with coastal storms caused by massive low-pressure systems with cyclonic flows that are typical of tropical cyclones, nor'easters, and severe winterstorms. The coast of the North Atlantic Ocean and the coast of the Gulf of Mexico are most susceptible to storm surge. Since the NCTCOG study area lies about 200 miles away from the coast of the Gulf of Mexico, it is highly unlikely to be affected by storm surge. Thus, storm surge hazards will not receive any further consideration in this document.

References:

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment.* Hydrologic Hazards, Chapter 13.

Hazard Identification: *Land Subsidence and Sinkholes*

Land subsidence is the loss of surface elevation due to the removal of subsurface support. Although there is a range of land subsidence impacts, there are really only 2 major forms: (1) regional lowering and (2) localized collapse.

Regional lowering of land elevation occurs gradually over time and is usually the result of sediment compaction caused by underground fluid withdrawal (such as extraction of groundwater, petroleum and geothermal fluids), natural compaction, and hydrocompaction. Because of groundwater withdrawal and extraction of oil and gas, the Houston area is one of the most prominent areas in the country affected by land subsidence due to sediment compaction. The National Research Council (1991) has estimated that Houston's cumulative damage from subsidence has exceeded $100 million and has aggravated the area's susceptibility to flooding and storm surge. To mitigate this impact, a special district called the Harris-Galveston Coastal Subsidence District is responsible for regulating groundwater withdrawal through a permitting process.

Generally, subsidence poses a greater risk to property than to life. The average annual damage from all types of subsidence is conservatively estimated to be at least $125 million. Damage consists primarily of direct structural damage and property loss and depreciation of land values, but also includes business and personal losses that accrue during periods of repair.

Localized collapse of surficial materials into underground voids is the most dramatic form of subsidence and is caused by human activities such as coal mining as well as natural processes. Collapses caused by natural processes are called sinkholes. Sinkholes are common where the rock below the land surface is limestone, carbonate rock, salt beds, or rocks that can naturally be dissolved by ground water circulating through them. As the rock dissolves, spaces and caverns develop underground. Sinkholes are dramatic because the land usually stays intact for a while until the underground voids get too big. If there is not enough support for the land above the voids, then a sudden collapse of the land surface can occur.

Two potential problems associated with the existence or formation of sinkholes are flooding and pollution.

Sinkhole flooding can develop due to the plugging of natural sinkhole drains by sediment and overwhelming the natural sinkhole drains by increases in runoff due to artificial surfaces; the accompanying restriction of subsurface drainage causes an increase in ponding or flooding, and increased runoff from roads, parking lots, and structures is the most significant cause of sinkhole flooding.

The pollution of groundwater resources can be a problem because sinkholes have long been used as dumps for waste materials. The dumping of solid wastes, such as dead animals, garbage, and refuse, into sinkholes is a major hazard to groundwater resources. Liquid wastes dumped into sinkholes can enter the groundwater system undiluted through the underground drainage routes or conduits.

Because of the geologic makeup of the NCTCOG study area, regional lowering has not occurred and is not very likely to occur in the foreseeable future. Major regional aquifers are located primarily in clean, well-consolidated sandstone formations, and bear most of the region's commercial or public service water wells. These formations are generally stable and are not prone to either lowering or collapse. Other local wells tap the widespread, shallow and generally unconsolidated alluvial deposits found throughout the region, but most are of relatively low extraction volume and well density. Some subsidence on local alluvium is possible, but is unlikely on regional scales under normal recharge conditions due to the general topographic discontinuity between deposits.

Widespread local collapse is also improbable in the NCTCOG study area. The most susceptible areas to local collapse subsidence correspond to the variegated limestone formations of the southwestern portion of the NCTCOG study area, primarily those related to the Cretaceous-aged Fredericksburg and Trinity Groups of limestones found throughout Erath, Hood and Somervell counties. Although these formations are karstic in nature and form many caves and sinkholes in areas along their exposure in central Texas, this is not a common occurrence in north central Texas. Limestone thicknesses are both limited and variable, and limestones are repeatedly interbedded with sand and shale zones, adding necessary non-dissolvable structural support, preventing most major collapses. In conclusion, sinkholes are possible in the NCTCOG study area, but the damage would be extremely localized. Thus, land subsidence and sinkholes will not receive any further consideration in this document.

References:

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment.* Geologic Hazards, Chapter 9.

Virginia Division of Minerals and Resources. (1990). Department of Mines, Minerals and Energy. *Sinkholes.* Retrieved September 16, 2003 from http://www.mme.state.va.us/DMR/PUB/Brochures/sink.html

Hazard Identification: *Tsunami*

Tsunami is a Japanese word meaning "harbor wave" referring to large seismic sea waves, impulsively generated by shallow-focus earthquakes. They are typically induced by a rapid, vertical thrust along the subsurface fault line between two tectonic plates or the earth's crust. When a large mass of earth on the ocean bottom impulsively sinks or uplifts, the column of water directly above it is displaced and forms tsunami wave on the surface. Tsunamis are also caused by volcanic activity and submarine landslides, but these events occur less frequently than earthquakes.

A tsunami wave can travel across the ocean at speeds up to 500 miles per hour, depending on the location and source of the event. A tsunami is relatively unnoticeable until the shoaling effects of the nearshore continental shelf interact with the wave, boosting wave heights to up to 50 feet or more.

When a tsunami hits a coastline it can cause significant damage to shore protection structures, and buildings, severe erosion, extensive inland flooding and loss of life.
Events affecting the United States and its territories have been responsible for approximately 470 fatalities and hundreds of millions of dollars in property, infrastructure, transportation, and lifeline damage.

Hawaii is subject to remote-source tsunamis generated by earthquakes throughout the Pacific. The remaining tsunami-prone areas along the coasts of the continental United States, Alaska, Puerto Rico and the U.S. Virgin Islands are affected by locally generated events caused by subduction, underwater landslides, and volcanic activity. Since 1770, more than 46 remote-source generated tsunamis and 18 local tsunamis have been observed along the West Coast.

Since the NCTCOG study area lies about 200 miles away from the nearest coastal shoreline, it is not likely to be affected by a tsunami event. Thus, tsunami hazards will not receive any further consideration in this document.

Reference:

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment.* Seismic Hazards, Chapter 17.

Hazard Identification: *Volcanoes*

Volcanoes are vents in the surface of the Earth through which magma and associated gases and ash erupt; also, the form or structure, usually conical, that is produced by the ejected material. Volcanic eruptions can be classified as non-explosive or explosive.

Nonexplosive eruptions are generally caused by an iron- and magnesium-rich magma (molten rock) that is relatively fluid and allows gas to escape readily. Lava flows on the Island of Hawaii are typically of nonexplosive eruptions.

In contrast, explosive eruptions are violent and are derived from a silica-rich magma that is not very fluid. These eruptions are common in the Cascade Range (Washington, Oregon, and California) and in the volcanic chain of Alaska. Explosive eruptions produce large amounts of fragmental debris in the form of airborne ash, pyroclastic flows and surges, debris flows, and other hazards on and beyond the flanks of the volcano, endangering people, infrastructure, and buildings.

Eruptions of volcanoes can generate serious hazards, such as glowing rivers of molten rock or lava flows; shock waves and fiery blasts of debris from volcanic explosions, called pyroclastic surges; red-hot avalanches of rock fragments racing down mountainsides, called pyroclastic flows; and suffocating blankets of volcanic ash falling from the sky. Any of these eruptions can be deadly.

The greatest risks from volcanic eruptions are to those in or near the direct paths or channels of flowing material and debris. Beyond the flanks of volcanoes, the most hazardous areas are the floors and valleys that head on volcanoes. Risks associated with volcanic hazards decrease as distance from the volcano increases.

In the 1980s, volcanoes worldwide killed over 28,500 people. This decade experienced more worldwide volcanic activity and crises than any other in recorded history. The cataclysmic Mount St. Helens eruption in 1980 resulted in approximately 60 deaths and over $1.5 billion in damage. Other volcanic activity during the 1980s included Mauna Loa and Kilauea in Hawaii, Long Valley Caldera in California, and Redoubt in Alaska.

The United States has more than 65 potentially active volcanoes, with the greatest activity in the Western States, Alaska and Hawaii, more than all other countries except Indonesia and Japan. Most are located in Alaska, and 55, including eight on the mainland, have been active since the United States was founded.

Mullineaux (1976) defined hazard zones for volcanoes in the Western United States based on three categories: ashfall, lava flow, and other flow phenomena such as avalanches, debris flows, or flood. According to this study, there are no volcanic hazard zones within the State of Texas. Thus, volcano hazards will not receive any further consideration in this document.

References:

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment.* Other Natural Hazards, Chapter 18.

Hazard Identification: *Avalanches*

Mass wasting is defined as any event in which solid earth material moves down a slope. The effects of mass wasting are the relocation of variably sized masses of soil and rock into an unwanted or unexpected location, as a response to natural or artificial downcutting or slope cutting, loading of slopes past the angle of repose or to the point of structural failure, or to anomalously high precipitation with respect to the soil and rock type.

There are several types of mass wasting, including avalanches of snow or ice, landslides, slumps and creep.

Avalanches are large, rapidly descending masses of snow, ice, soil, rock, or mixtures of these materials, sliding or falling in response to the force of gravity. Avalanches, which are natural forms of erosion and often seasonal, are usually classified by their content (such as a debris, ice or snow avalanche). Avalanches occur on slopes averaging 25 to 50 degrees, and the majority of avalanches start on slopes between 30 and 40 degrees. Speeds can reach over 200 mi per hr (300 km per hr). They are triggered by such events as earthquake tremors, human-made disturbances, or excessive rainfall on high gradient slopes, often where materials are loosely consolidated or weathered. Destruction from avalanches results both from the avalanche wind (the air pushed ahead of the mass) and from the actual impact of the avalanche material.

The most common types of snow avalanches are loose-snow avalanches, which are composed of dry, fresh snow deposits that accumulate as a cohesionless and unstable mass atop a stable and cohesive snow or slick ice sublayer; and slab avalanches, which are generally composed of a thick cohesive snowpack deposited or accumulated on top of a light, cohesionless snow layer or slick ice sublayer.

Only approximately 10,000 of the estimated 100,000 snow avalanches that occur each year are reported. There have been numerous incidents of property damage, injury and death each year. Since 1970, an average of 144 persons have been trapped in avalanches, causing an annual average of 14 injuries and 14 deaths. Avalanches are considered a hazard throughout the Rocky Mountain, Pacific Northwest and Alaskan regions. The state of Colorado leads the nation in deaths from avalanches, with an average of six to eight persons lost each season. Skiers, snowmobilers, and climbers in wooded and sloped areas in avalanche zones are the most vulnerable.

Due to the relatively minimum amounts of snowfall and icefall in the North Central Texas study region, there is little definable risk for avalanches; however it should be noted that the North Central Texas region has a varied topography with elevations ranging from 231 feet in Navarro County to 1,671 feet in Erath County, and slopes can range up to vertical locally and average as much as 48 degrees incline per 100 linear feet. As a result, large accumulations of snow and ice on higher slopes over long periods of time without thaw could potentially create localized avalanche hazards with respect to utility lines, roads and other human structures, such as buildings, barns or fences. However, since this scenario is highly unlikely and would not be a widespread phenomenon, avalanche hazards will not receive any further consideration in this document.

References:

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment.* Geologic Hazards, Chapter 6.

National Weather Service (NWS) National Weather Service Forecast Office, Riverton, WY. *Bridger-Teton National Forest Back Country Avalanche Hazard & Weather Forecasts*. Retrieved on September 16, 2003 from http://www.crh.noaa.gov/riw/avalanch1.htm.

Hazard Identification: *Tropical Cyclones (Hurricanes and Tropical Storms)*

Hurricanes and tropical storms are among the most devastating naturally occurring hazards in the United States. A tropical cyclone is defined as a low-pressure area of closed circulation winds that originates over tropical waters. In the Northern Hemisphere, winds rotate counterclockwise. A tropical cyclone begins as a tropical depression with wind speeds below 39 mph. As it intensifies, a tropical cyclone may develop into a tropical storm with wind speeds between 39 mph and 74 mph. When wind speeds go beyond 74 mph, the tropical storm is known as a hurricane. The Gulf of Mexico and the Atlantic Coast areas are the most susceptible to tropical cyclones.

After a hurricane or tropical storm makes landfall, it begins to break apart, and remnants of the storm can continue moving inland. These remnants have been known to bring heavy precipitation, high winds, and tornadoes to locations within the NCTCOG study area. For instance, a remnant of the September 1900 Hurricane that devastated Galveston made its way into north central Texas, where it produced heavy rains. In 1934, a tropical disturbance moved inland along the middle Texas coast and eventually found its way to Kaufman County, where it caused damage from straight-line winds. In 1981, the remnants of Pacific Hurricane Norma came across north central Texas, bringing torrential rain (10-13 inches between Denton and Bridgeport) and a few weak tornadoes. In 1995, the remnants of Tropical Storm Dean brought heavy rain to Hood and Somervell counties. Six to ten inches of rain fell near Glen Rose, and street flooding occurred across the NCTCOG study area.

Thus, it is obvious that tropical cyclones involve both atmospheric and hydrologic characteristics. As just described, those characteristics commonly associated with tropical cyclones can include high winds, storm surge, high waves, torrential rainfall and flooding, coastal erosion, thunderstorms, lightning, and sometimes tornadoes. While tropical cyclones do not directly impact the NCTCOG study area, other associated hazards do affect the region. These associated hazards are individually addressed elsewhere in this document. However, because the Texas Gulf Coast is 200 miles away and because tropical cyclones do not directly impact the NCTCOG study area, tropical cyclones, per se, will not receive any further consideration in this document.

References:

http://www.srh.noaa.gov/fwd/texashurricane.htm

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment.* Atmospheric Hazards, Chapter 1.

Hazard Identification: *Landslides*

Mass wasting is defined as any event in which solid earth material moves down a slope. The effects of mass wasting are the relocation of variably sized masses of soil and rock into an unwanted or unexpected location, as a response to natural or artificial downcutting or slope cutting, loading of slopes past the angle of repose or to the point of structural failure, or to anomalously high precipitation with respect to the soil and rock type.

A landslide is one type of mass wasting. A landslide is the movement of a mass of earth or rock from a higher elevation to a lower level under the influence of gravity. There are two categories of landslides: (1) slope failures such as rockslides, rockfalls and slump, and (2) sediment flows such as earthflows, mudflows, and debris flows.

Risk Assessment: *Slope Failures*

Rockslides are the rapid downhill movement of large masses of rock with little or no hydraulic flow. Rockfalls are generally considered rockslides occurring over very steep if not vertical slopes. Rockslides, and to a lesser extent rockfalls, can and do occur locally, most often in the harder limestone and sandstone formations of central and western portions of the NCTCOG region.

Rockfalls are limited to those locations that have exposed rock outcrops either due to artificially created road cuts, or natural stream bank incision. More resistant rock formations such as the cliff-forming Austin Chalk, Trinity Group limestones or any of the Pennsylvanian-age sandstones of Palo Pinto and Wise Counties may be likely rockfall regions.

A slump is defined as the small volume movement of soils due to subsurface failure. Slumps are generally marked by movement of a coherent mass a short distance along a curved surface, generally above a weak layer of soil or rock which detaches from the substrate causing gravity sliding. Slumps are less dangerous because they move relatively slowly but can still cause destruction to human construction, and can block roads and undermine and/or bury objects.

Risk Assessment: *Sediment Flows*

Solifluction is the flowage at rates measured on the order of centimeters per year of regolith containing high amounts of water. Solifluction produces distinctive lobes on hill slopes, which occur in areas where the soil remains saturated with water for long periods of time. Similar to creep, except in that solifluction typically occurs in the presence of long-standing water saturated soils.

Flows with a high (20-50%) volume of water and sediment mixture are called slurry flows, and two types are identified. Mudflows are rapid and dangerous streams of mud and debris that pour down valleys, canyons or ditches until water flow subsides, depositing the mud in a local 'basin', be it a flood plain, road or parking lot. Mudflows are much more highly saturated with water than granular flows such as earthflows or creep, and as a result are more dependant on precipitation than soil and regolith stability. Debris flows, a step down from mudflows, typically have less water in the mixture and flow with less volatility downslope.

Mudflows are most common in areas with little or no vegetative cover to stabilize the topsoil and regolith. Flash floods may generate mudflows or debris flows as large quantities of sediment are picked up and carried in suspension down drainages. Soil loss and relocation are important economic factors in rural areas, and this may be related to stream bank erosion and overall loss of crop yield. Artificial mudflows are possible with water main breakages or other unexpected large volume water loss events.

Earthflows are the primary type of granular-type flows. These events occur when soil or clay containing less than 0-20% pore water on a slope slides downhill over a period of several hours to months; the fluid-like behavior is given these flows by mixing with air. Earthflows are usually not serious threats to life because of their slow movement, but can cause problems including blockage of roads and highways, destabilization of levees and bridges, and alteration of floodplain and catchbasin topography. Earthflows can also do extensive damage to property, regional utilities, etc.

Earthflows have a moderate occurrence along the trend and strike of the Woodbine sandstone outcrop in west-central Denton, Tarrant and Johnson Counties, as well as along the western face of the Mountain Creek Escarpment where the Austin Chalk is exposed above it's contact with the upper Eagle Ford Shale formation. The United Stated Geological Survey has also indicated that a high susceptibility to landslides and related mass wasting occurs in eastern Dallas, Ellis and Collin Counties, all of Rockwall County, and western Kaufman, Navarro and Hunt Counties. They typically occur during and after periods of high rainfall.

This trend is based on the relative instability of the Cretaceous upper Taylor Group and Navarro Group of rocks due to the presence of a distinct and thick clay-rich soil. This clay soil may act as a slip layer when saturated during periods of high precipitation on even moderate slopes. Earthflows may also be associated with slump events that are also common in this area. The primary difference between earth flows and slumps are the initiating circumstances; earth flows require water saturation as the trigger and slumps depend on subsurface structural failure.

Creep is the very slow migration of soil, regolith and rock down slope over long periods of time. Creep often occurs so slowly it takes years to see its effects, which can be considerable. Creep may tilt trees and overturn telephone poles over periods of 5-50 years in some areas. Creep may especially adversely affect real estate values and foundation damage, and may increase the costs and susceptibility of pole and/or buried utilities due to damage or destruction caused by lateral movement of soils. Creep occurs on almost all soil types on a slope, but some soils may show pronounced or accelerated creep. In the NCTCOG area, these areas tend to coincide with susceptibility for earthflow generation.

Humans have triggered a number of tragic landslides that have caused great damage and loss of life. In the Los Angeles area of California, extensive real estate development carried out on hillsides has resulted in widespread mudflows after winter rains have saturated the over-steepened embankments of soil. In some areas, slow-moving earthflows have been initiated by the lubrication of certain types of underlying clays by septic tank effluent.

Several natural and human factors may contribute to or influence landslides. The three principal natural factors are topography, geology, and precipitation. The principal human activities are cut-and-fill construction for highways, construction of buildings and railroads, and mining operations. Landslides are often correlated with other natural hazards. For instance, flooding may trigger landsliding because both involve heavy precipitation, runoff, and ground saturation. Or, a dam may fail because of upstream landsliding or collapse of the slopes bordering the reservoir or dam abutements.

Landslides occur in all the states in the United States. They have damaged or destroyed roads, railroads, pipelines, electrical and telephone transmission lines, mining facilities, petroleum wells and production facilities, residential and commercial buildings, canals, sewers, bridges, dams, reservoirs, port facilities, airports, forests, fisheries, parks, recreation areas, and farms.

In the United States, landslides cause 25 to 50 deaths annually, billions of dollars in economic losses, and major environmental degradation, and these losses will undoubtedly increase until the nation adopts a comprehensive and coordinated strategy to alleviate landslide risks at the federal, state, local, and private levels. Today, no such strategy exists. States, local governments, transportation departments, and numerous federal agencies, including the U.S. Geological Survey (USGS), handle landslide hazards independently of one another.

The most important types of landslides in North Central Texas are earthflows, mudflows, creep and slump. Rockslides are uncommon due to the lack of tall, rocky outcroppings and relatively few susceptible formations to rockslides. Several more resistant areas of the Cretaceous Austin Chalk (Ellis, Dallas, Collin), or of the various limestones and sandstones of western and southwestern NCTCOG region, may experience very limited rockslide susceptibility in manmade outcrops, roadcuts or due to stream incision.

Earthflows and other types of mass wasting are possible throughout the central and eastern portions of the NCTCOG region. The soils associated with the Cretaceous Taylor Group and Cretaceous Navarro Group of rock formations, present in eastern Ellis, Kaufman, Rockwall, eastern Dallas, eastern Collin, and Hunt, have relatively high susceptibilities for the occurrence of mass wasting events, especially earthflows, slump, and creep, due to high clay content in soil and regolith. Levees, bridge embankments and earthen dams are especially susceptible to slump and earthflow damage, as well as long term creep. Mudflow damages are lesser hazards due to vegetative stabilization and are most often associated with floods and high rain events in which large quantities of unwanted sediment are deposited in catchbasins. Topsoil, stripped from construction sites and plowed fields, may also be localized mudflow generation areas.

Recent Landsliding in the NCTCOG Region

Dr. Donald F. Reaser, a Professor of Geology at the University of Texas at Arlington, has been doing research on landsliding in north central Texas. For more than forty years, the area between the towns of Forney and Terrell in Kaufman County has been relatively stable geologically, although the tract is underlain by argillaceous strata (marl and shale) that form thick expansive soils.

Recently, small-scale landslides have remodeled the land surface, collapsed some wooden structures, severed sewer and water pipes, snapped telephone cables, and resulted in leaning power poles and fence posts. Currently, an investigation is being conducted to determine probable causes of downslope movement in this area. Preliminary data suggest that the mass wasting is related to locally heavy rains during the last few years. From 1990-1992, rainfall in the region ranged from 25 percent to 60 percent above normal. The excessive precipitation caused the local water table to rise near ground level and collapse several low hills. Because of increased weight and pore pressure as well as decreased friction, the saturated argillaceous mass became unstable and moved downslope in response to gravitational forces.

Dr. Reaser's research interests include studies of environmental problems in the north Texas area with special emphasis on the formation of earthflows and the detrimental effects of expansive soils.

Source:
http://www.uta.edu/geology/geohomepage/98%20research.htm

Summary Slope and soil characteristics are the two major determining factors in landslide hazards. As depicted on HazMAP **map 6-1**, the United States Geological Survey (USGS) has delineated large portions of the NCTCOG region as areas of high past incidence of mass wasting events (landslides) as well as areas which may be susceptible to future mass wasting events (landslides) based on rock/soil characteristics and slope. Generally, where the slope is higher, the risk of mass wasting events (landslides) is higher; and, where the slope is lower, the risk is lower. But, overall, the risk of mass wasting events (landslides) in the NCTCOG region is sufficient enough to merit mitigation consideration.

References:

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment.* Geologic Hazards, Chapter 9.

HazMAP

Chapter 7 Selected Geologic Hazards: Expansive Soils

Hazard Identification Soils and soft rock that tend to swell or shrink due to changes in moisture content are commonly known as expansive soils. In the United States, two major groups of rocks serve as parent materials of expansive soils, and occur more commonly in the West than in the East. The first group consists of ash, glass, and rocks of volcanic origin. The aluminum silicate minerals in these volcanic materials often decompose to form expansive clay minerals of the smectite group, the best known of which is montmorillonite. The second group consists of sedimentary rock containing clay minerals, examples of which are the shales of the semiarid West-Central States. Because clay materials are most susceptible to swelling and shrinking, expansive soils are often referred to as swelling clays.

Changes in soil volume present a hazard primarily to structures built on top of expansive soils. Most engineering problems caused by volume changes in swelling clays result from human activities that modify the local environment. They commonly involve swelling clays beneath areas covered by buildings and slabs or layers of concrete and asphalt, such as those used in construction of highways, canal linings, walkways, and airport runways.

The most extensive damage occurs to highways and streets. Damage to the built environment results from differential vertical movement that occurs as clay moisture content adjusts to the changed environment. In a highway pavement, differential movement of 0.4 inches within a horizontal distance of 20 ft is enough to pose an engineering problem if high standards for fast travel are to be maintained.

Buildings are capable of withstanding even less differential movement before structural damage occurs. Generally, a differential movement of 0.25 in between adjacent columns will cause cracking in loadbearing walls of a 20-ft wide bay. With differential movement of 1.5 in over a span of 20 ft, beams are likely to be structurally damaged.

Houses and one-story commercial buildings are more apt to be damaged by the expansion of swelling clays than are multi-story buildings, which usually are heavy enough to counter swelling pressures. However, if constructed on wet clay, multi-story buildings may be damaged by shrinkage of the clay if moisture levels are substantially reduced, such as by evapotranspiration or by evaporation from beneath heated buildings.

The most obvious manifestations of damage to buildings are sticking doors, uneven floors, and cracked foundations, floors, walls, ceilings, and windows. If damage is severe, the cost of repair may exceed the value of the building.

Probably the greatest amount of small building damage has impacted those constructed when clays were dry, such as during a drought, followed by soaking rains that prompt swelling of clays. Other reported cases of damage involve volume increases due to moisture from broken or leaking water and sewer lines, watering of lawns and shrubbery, and modifications of the surface that produce ponding.

Risk Assessment Many of the soils found in the central and eastern portions of the NCTCOG region are clay-rich, fine-grained soils. These soils contain a class of clay minerals called “smectites”, which have the property of exaggerated bulk volume changes in the presence or absence of water. These smectitic soils in the NCTCOG region originate primarily from the calcareous Cretaceous–aged marls and clay rock formations, notably of the Austin and Taylor Groups. Extreme wetting and drying cycles on this soil accentuate the shrinking and swelling effects, and, as a result, these soils are commonly termed Vertisols due to their distinctive vertical shrink-swell features, clayey texture and common large, vertical cracks when dry. One of the best known and classic of these vertisols is the Houston Black, a Blackland Prairie soil that stretches over 2 million acres of land between Dallas and Houston. This soil has been nominated by the Professional Soil Scientists of Texas to be named the State Soil of Texas due to its unique and common influence on the lives of Texans.

Shrinking and swelling of these vertisols can come at a high economic price. Some of the most expansive of soils may gain or lose up to 75% of its original soil volume, causing radical gain and loss of a structure foundation's continuity. In addition, soil expansion and loss is rarely uniform across large areas; some areas with locally higher clay content may expand much more than a nearby siltier or sandier soil unit.

Other problems are caused by high plasticity soils. When soil has dried and cracked, water can travel along the cracks for several feet in all directions. If the soil around your foundation is dried and cracked, then water placed next to the foundation will run through the cracks and accumulate at the bottom of the grade beam (the thick portion of the foundation that is under the exterior walls). In some cases, an accumulation of water in the soil at the base of a foundation can cause the soil to lose some of its load bearing capacity. If the soil loses enough load-bearing capacity, the house will sink into the ground.

In addition, water that collects under the foundation, regardless of origin, is a major problem. "Upheaval" relates to the situation in which the internal and, on rare occasion, external areas of the foundation raises above the "as-built" position. In high-plasticity soils, this phenomenon results, almost without exception, from the introduction of moisture underneath the foundation. Once the slab heaves, the reinforcing steel is stressed into what amounts to a permanent elongation.

Expansive soils are one of the nation's most prevalent causes of damage to buildings and construction. Annual losses are estimated in the range of $2 billion to $7 billion. However, because the hazard develops gradually and

North Texas — Current national leader in home construction, possible future leader in foundation repair

From 1990 to 2000, the Dallas-Fort Worth area experienced the greatest percentage population growth of the 10 largest metropolitan areas in the United States, according to the U.S. Census Bureau. To accommodate this population growth, the Dallas-Fort Worth region added 448 square miles of urban areas. In Denton County, urban areas grew from 158 square miles in 1990 to 197 square miles in 2000.

Dr. Harry Williams, associate professor of geography at the University of North Texas, is exploring how urbanization pressures have resulted in housing construction on soils poorly suited for development. Williams' research is described in his article "Urbanization Pressure Increases Potential for Soils-Related Hazards, Denton County, Texas." The article is slated for publication in the international journal Environmental Geology in the fall 2003 issue.

"There's a lot of housing being developed on poorly-suited soils," Williams said. "Unfortunately, many people will probably have foundation problems in the future." Williams says 90 percent of soils underlying Frisco, Hebron, Little Elm and The Colony, located in the southeast corner of Denton County, are rated low to very low for urban suitability, because of expansive soils -- soils that swell.

"Expansive soils can damage foundations, pavements and pipelines, because hundreds of tons of pressure can develop in these soils as they absorb moisture." Williams said.

According to a 1982 Federal Emergency Management Agency report, expansive soils have caused billions of dollars of damage in the United States. Today, damage from expansive soils is more costly than damage caused by earthquakes, floods, tornadoes and hurricanes combined.

"Slab foundations, commonly found in single-family dwellings, are particularly vulnerable to expansive soil damage," Williams said. "These foundations are used extensively in new housing in the Dallas-Fort Worth area, because of lower construction costs."

Williams' research is based on several variables related to soil suitability and urbanization. He mapped these variables, layer by layer, into a geographical information system (GIS). The GIS map shows suitability of soils for urban development based on United States Department of Agriculture soil survey reports and pre- and post-1990 urban areas obtained from the U.S. Census Bureau. The USDA soil survey reports rate soil suitability for urban development based on propensity to flood, high water table, wetness, shrink-swell potential, soil strength, soil texture and soil corrosivity to uncoated steel and concrete.

The results of Williams' analysis show a dramatic shift in the nature of soils in pre-1990 and post-1990 urban areas. Before 1990, approximately 77 percent of the 158 square miles of urban areas in Denton County was constructed on soils deemed either medium or high suitability for urban development. In 1990-2000, approximately 53 percent of the 39 square miles of additional urban areas was constructed on soils deemed either very low or low suitability for urban development.

Source: University of North Texas News Release (September 3, 2003) available at http://web2.unt.edu/news/print.cfm?story=8636 seldom presents a threat to life, expansive soils hazards have received limited attention, despite their costly effects. The losses include severe structural damage, cracked driveways, sidewalks and basement floors, heaving of roads and highway structures, condemnation of buildings, and disruption of pipelines and sewer lines. The destructive forces may be upward, horizontal, or both.

Design and construction of structures without attention paid to the existence and behavior of expansive soils can worsen a readily manageable situation. Where expansive soils are not recognized, improper building or structure design, faulty construction, inappropriate landscaping and long term maintenance practices unsuited to the specific soil conditions can become a continuing and costly problem. Design problems might include improper foundation loading, improper depth or diameter of drilled pier, insufficient reinforcing steel, and insufficient attention to surface and underground water.

Construction problems related to expansive soils include lack of reinforcing steel, insufficient or improperly placed reinforcing steel, mushroom-topped drilled piers, and inadequate void space between soils and grade beams. Allowing clays to dry excessively before pouring concrete and permitting the ponding of water near a foundation during and after construction also are contributing factors in expansive soil- related construction problems. Building without allowance for basement or ground floor movement in known expansive soils areas is a very common source of property damage. Improper landscaping problems include inadequately managing surface drainage and planting vegetation next to the foundation so irrigation water enters the soil.

Expansive soils are a profound nationwide problem, as shown by Jones and Holtz (1973):
"Each year, shrinking or swelling inflict at least $2.3 billion in damages to houses, buildings, roads, and pipelines – more than twice the damage from floods, hurricanes, tornadoes, and earthquakes…Over 250,000 new homes are built on expansive soils each year. 60 percent will experience only minor damage during their useful lives, but 10 percent will experience significant damage--some beyond repair. One person in 10 is affected by floods, but one in five is affected by expansive soils. Swelling clays are one of the most significant, widespread, costly, and least publicized geologic hazards."

Although several visual methods for identification of potentially expansive clays exist, only a competent, professional soil engineer and engineering geologist should be relied upon to identify this potential hazard. Some warning signs for swell might include: a) soft, puff, "popcorn" appearance of the surface soil when dry; b) surface soil that is very sticky when wet; c) open cracks (desiccation polygons) in dry surface soils; d) lack of vegetation due to heavy clay soils; e) soils that are very plastic and weak when wet but are "rock-hard" when dry.

Engineering soil tests include index tests and design tests. Rapid, simple index tests are used to determine whether more complex design tests are necessary. Some index properties that may aid in the identification of probable areas of expansive clay include Atterberg limits, plasticity index, grain size determination, activity ratio, dry unit weight, and moisture content (Asphalt Institute, 1964). The primary design tests for expansive soils are the consolidation swell* test for buildings, and the California Bearing Ratio* swell test for roads (Asphalt Institute, 1964).

Damage from expansive clays can affect, to some extent, virtually every type of structure in Texas. Some structures, such as skyscrapers in downtown Dallas, generally have well engineered foundations that are too heavily loaded for swelling damage to occur. At the opposite extreme are public schools and single family homes, which are generally constructed on a minimal budget and which may have under-designed lightly-loaded foundations that are particularly subject to damage from soil movements. Homeowners and public agencies that assume they cannot afford more costly foundations and floor systems often incur the largest percentage of damage and costly repairs from expansive soil.

No figures are available for the total damage to homes in Texas from expansive clays. However, several examples are known where the cost of repairs has exceeded the value of the house. Additionally, highways in some areas of Texas have required frequent and very expensive reconstruction or maintenance due to damage from expansive clay.

Summary As depicted on HazMAP **map 7-1**, the central and eastern portions of the NCTCOG region are especially susceptible to expansive soil hazards. Soils that contain large percentages of swelling clays may experience volume changes of up to 40% in the absence or presence of water. This type of plastic deformation is common in the Blackland Prairie areas of the NCTCOG region, including Dallas, Ellis, Collin, Kaufman, Rockwall Counties, and portions of Johnson, Tarrant, and Hunt Counties. Over time, expansive soil hazards can have detrimental impacts on a variety of structures and facilities across many jurisdictions in the NCTCOG region. As a result, expansive soil hazards pose sufficient enough risk to receive mitigation consideration.

References:

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment.* Expansive Soils, Chapter 11.

HazMAP

Chapter 8 Selected Geologic Hazards: Earthquakes

Hazard Identification An earthquake is a sudden motion or trembling caused by an abrupt release of accumulated strain on the tectonic plates that comprise the Earth's crust. The theory of plate tectonics holds that the Earth's crust is broken into several major plates. These rigid, 50- to 60-mile thick plates move slowly and continuously over the interior of the earth, meeting in some areas and separating in others.

As the tectonic plates move together they bump, slide, catch, and hold. Eventually, faults along or near plate boundaries slip abruptly when the stress exceeds the elastic limit of the rock, and an earthquake occurs. The ensuring seismic activity and ground motion provoke secondary hazards: surface faulting, ground failure, and tsunamis.

The vibration or shaking of the ground during an earthquake is referred to as ground motion. In general, the severity of ground motion increases with the amount of energy released and decreases with distance from the causative fault or epicenter. When a fault ruptures, seismic waves are propagated in all directions, causing the ground to vibrate at frequencies ranging from 0.1 to 30 Hz. Seismic waves are referred to as P waves, S waves, and surface waves.

Seismic activity is described in terms of magnitude and intensity. Magnitude (M) characterizes the total energy released, and Intensity (I) subjectively describes effects at a particular place. While an earthquake has only one magnitude, its intensity varies throughout the affected region.

The Magnitude of a seismic event is most commonly measured by the Richter Magnitude Scale, developed in 1935 by Charles Richter of the California Institute of Technology. Using the Richter Scale, Magnitude is expressed in whole numbers and decimals. An earthquake of 5.0 is a moderate event; 6.0 is a strong event; 7.0 is a major earthquake, and a great earthquake exceeds 8.0.

The Intensity level is most commonly measured by the Modified Mercalli Intensity Scale (MMI). This scale is composed of 12 increasing levels of intensity ranging from imperceptible to catastrophic. These levels are an evaluation of the severity of ground motion at a given location measured relative to the effects of the earthquake on people and property.

Surface faulting can occur as the result of an earthquake and is defined as the differential movement of the two sides of a fracture. Faults actually occur deep within the earth, but their effects on the surface can be severe. Surface faulting is a hazard to structures built across active faults. Surface faulting can damage railways and highways and buried infrastructure such as pipelines and tunnels.

Ground failure is another potential effect of an earthquake due to liquefaction. Liquefaction is caused when clay-free soil deposits, primarily water-saturated sand and coarse silts, react to vibrations, temporarily lose strength, and behave as viscous fluids. Liquefaction takes place when seismic shear waves pass through a saturated granular soil layer, distort its granular structure, and cause some of the void spaces to collapse.

Deaths and injuries from surface faulting are unlikely, but casualties can occur through damage to structures. A variety of structures have been damaged by surface faulting including houses, apartments, commercial buildings, nursing homes, railroads, highways, tunnels, bridges, canals, storm drains, water wells, waterlines, gaslines, and sewer lines. Damage to these structures has ranged from minor to very severe. An example of severe damage occurred in 1952 when three railroad tunnels in California were badly damaged. As a result, traffic on a major line linking northern and southern California was stopped for 25 days, despite an around the-clock repair effort.

The zone of greatest seismic activity in the United States is along the Pacific Coast in Alaska and California. However, the Central and Eastern States have also experienced seismic activity: the Boston vicinity (1755); the central Mississippi Valley at Madrid, MO; (1811-1812) Charleston, SC (1880's) and Hebgen Lake, MT (1959).

Risk Assessment

The Dallas-Ft. Worth area is located in Seismicity Uniform Building Code (U.B.C.) Zone Zero, the lowest earthquake hazard region in the United States. Intensity data for historic earthquakes from the Texas, Oklahoma, and the New Madrid Seismic Zones have been extrapolated to the Dallas-Ft. Worth area to determine maximum credible horizontal ground accelerations. The data indicates that the maximum horizontal acceleration in competent bedrock for the Dallas-Ft. Worth area will not exceed 0.04E^g or a modified Mercalli intensity of VI to VII. This acceleration would be for low frequency, high-magnitude events similar to the New Madrid earthquakes of 1811-1812. Based on recent attenuation estimates, there is a 90 percent probability that horizontal accelerations will not exceed 0.04E^g for any 50-yr period.

Geophysical field investigations at the Superconducting Super Collider (SSC) site in Ellis County revealed no unusual rock foundation properties at the site that would lead to anomalous ground motions during earthquakes. In addition historical records do not show evidence of induced seismicity within 100 miles of the site. However, moderate seismic events up to magnitude 4.0 due to reservoir flooding during enhanced oil recovery may be possible within 100 miles of the site, although maximum horizontal accelerations from such an event in the East Texas oil fields would be well below the 0.04 g historical maximum for the SSC site. Portions of the far northwestern NCTCOG region in Wise and Denton Counties are geographically closer to seismicity centers near the Red River and, therefore, do contain some potential for greater maximum horizontal accelerations. Nevertheless, no historical precedent is available.

There are no known active geological faults within the NCTCOG region. A Department of Energy (DOE) examination of low-sun-angle photography during the SSC survey indicates that the area does not include any active fault scarps or traces of older faults which may have undergone recurrent movement. Inactive normal faults of the Balcones fault system do occur at the site as well as throughout the southern and eastern NCTCOG region. Observed faults form a set of normal faults and antithetic normal faults with small graben structures evident in surface exposures. Displacements rarely, if ever, exceeded 100 feet. Most faults extend for less than 1 mile and follow an enechelon pattern along a rough northeast line.

There is no definable potential for liquefaction where studied at the SSC site. For a maximum credible earthquake, with a maximum ground acceleration of 0.04 g, the ground shaking at the site would be well below that required to produce liquefaction in alluvial deposits which, moreover, display cohesion (clay content) sufficient to yield very low liquefaction susceptibility. Due to the widespread presence of cohesive clay-rich soils in the NCTCOG region, a regional inference is that widespread liquefaction is unlikely as a credible problem. In some lower-cohesion local sands and gravels, it might be possible for local liquefaction to occur in a nonhistoric event; however, lack of any occurrence history makes this a nonsequential factor.

For earthquakes, 90% Improbable means 10% Probable (and that is still worth worrying about)…In northeastern Texas, including the NCTCOG region, the greatest earthquake hazard probability is from very large earthquakes (magnitude 7 or above, Mercalli IV) that occur outside of Texas, particularly in Oklahoma or the Missouri/Arkansas/Tennessee area. The most active regional tectonic boundaries responsible for current mid-continent earthquake activity are related to fault systems in southern Oklahoma and in the New Madrid region of southwestern Missouri.

The northwestern corner of the NCTCOG region is located a mere 20 miles from the last known earthquake epicenter in Texas (April 2003), just west of Gainesville, Texas. This region lies only 80 miles from the active Meers Fault in Oklahoma. The Meers Fault has been known to generate earthquake magnitudes from 4-6 on the Richter scale and has the potential for larger and more damaging earthquakes. Based on a USGS Mercalli plot, northern sections of the NCTCOG region could experience as high as 5.0 level damage from a large earthquake along this fault system.

The second primary threat to north central Texas originates from the Reelfoot Rift system near New Madrid, Missouri. Although very distant, this fault system is the most active in the continental United States outside of the West Coast and is capable of catastrophic earthquakes. A 8.0+ magnitude quake similar to those of the great 1811-1812 New Madrid quakes could generate considerable low frequency ground acceleration motion throughout the NCTCOG region, which would be damaging to taller, older or poorly built structures. The more damaging high frequency and surface waves would, most likely, dissipate long before reaching north central Texas.

A third set of factors to consider are lesser earthquakes, historically up to 4.0 Magnitude, caused by oil and gas production activity. Currently, a large amount of hydrocarbon production is occurring in the northwestern portions of the NCTCOG region. Denton, Wise and Tarrant Counties are actively producing large volumes of natural gas. Natural gas extraction has been responsible for creating small earthquakes within the formations in which it is produced. In the case of the North Texas natural gas play, the primary formation is the Barnett gas play.

(The Barnett Shale gas play is now the 19th largest in the United States and also the youngest. Natural gas production from the Barnett Shale in just Denton and Wise Counties has reached over 340 million cubic feet per day. The Barnett Shale gas play area is now moving south into Johnson and Hill Counties as well as Tarrant and Dallas Counties. The 1998 updated U.S. Geological Survey projects 40-acre spacings which lead to a forecast of 10.0 trillion cubic feet for the Barnett Shale gas play. A 10.0 trillion cubic feet gas volume is equivalent to a 1.67 billion barrel oil field. In contrast, the entire U.S. consumes 20+ trillion cubic feet per year. The greater Dallas-Ft. Worth area alone consumes 2-3 billion cubic feet per day. More recent estimates conclude that the Barnett Shale can produce reserves of 40-50 billion cubic feet per square mile.)

Another oil and gas producing area in the NCTCOG region is the area known as the East Texas Embayment, compromising most of Hunt, Rockwall, eastern Kaufman and Navarro Counties. The first major oil field in Texas was born of this region in Corsicana (Navarro County) in the late Nineteenth century. This field is very mature, contains limited production, and is not actively a site for exploration.

Given the increased oil and gas production rates in an area so rapidly expanding in population and development (such as in northern Tarrant County), any seismic hazard study should give extra attention to the local geologic structure and potential responses from excessive gas withdrawal in the subsurface. It should also be noted that the presence of the Ouachita Trend and the Mexia-Talco fault system in the southeastern areas of the NCTCOG region could see previously unconsidered local reactivation if drilling continues further to the south and east with the Barnett play. More study is needed on the potential geologic ramifications of this new drilling trend.

Below are some relevant passages as well as the “Regional Hazard Assessment for Northeast Texas” that have been excerpted from Chapter 12 of *State of Texas Hazards Analysis*, by the Governor's Division of Emergency Management, Department of Public Safety, Austin, Texas, 1998:

“Within the twentieth century there have been more than 100 earthquakes large enough to be felt; their epicenters occur in 40 of Texas's 254 counties. Four of these earthquakes have had magnitudes between 5 and 6, making them large enough to be felt over a wide area and produce significant damage near their epicenters.”

“The earthquake hazard level is not zero anywhere in Texas; small earthquakes are possible almost anywhere, and all regions face possible ill effects from very large, distant earthquakes.
In most parts of Texas, the earthquake hazard level is small compared to the hazard attributable from other natural phenomena, such as hurricanes, tornadoes, and floods. Thus, there is no need for Texas to

enact sweeping changes in construction practices or take other drastic measures to mitigate earthquake hazard. However, Texans need to begin learning about earthquakes. Over the past 70 years Texas has changed from a sparsely populated state with an economy dominated by agriculture to an economically diverse state with various large, technical manufacturing industries centered in a few densely populated urban regions. For reasons of safety, economy, and (in some cases) law, Texans need to consider earthquake hazards when designing or siting various structures which are essential for providing medical or emergency management services, which house sensitive manufacturing processes, or which store hazardous wastes."

Regional Hazard Assessment:
Northeast Texas (Largest Cities - Dallas-Fort Worth)

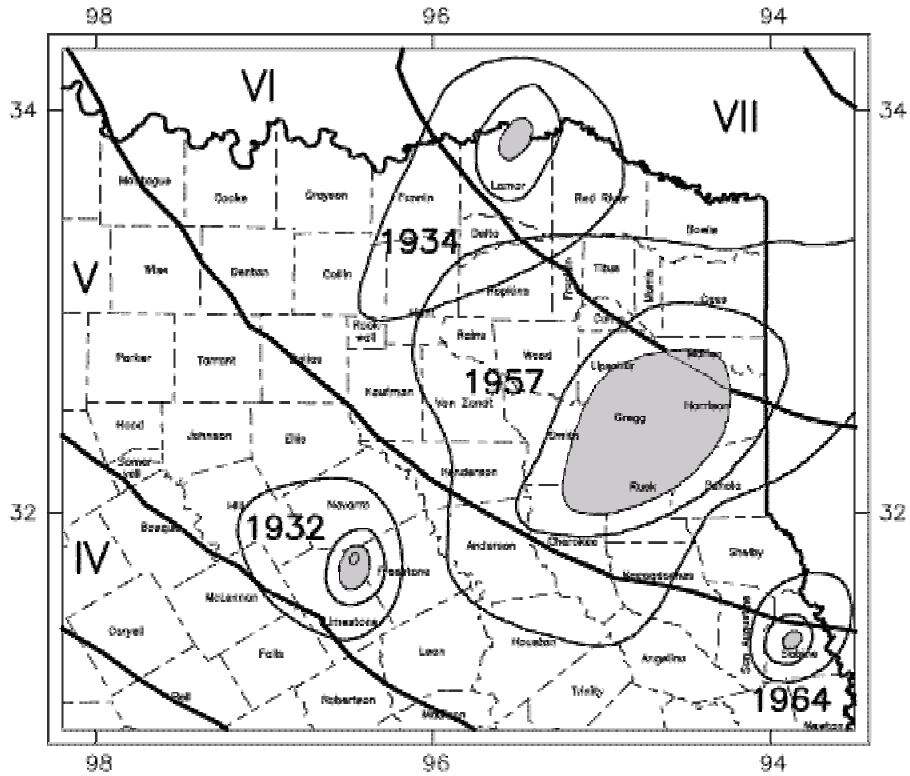
Counties Affected (41): Anderson, Bowie, Camp, Cass, Cherokee, Collin, Cooke, Dallas, Delta, Denton, Fannin, Franklin, Freestone, Grayson, Gregg, Harrison, Henderson, Hopkins, Hunt, Kaufman, Lamar, Limestone, Marion, Montague, Morris, Nacogdoches, Panola, Rains, Red River, Rockwall, Rusk, Sabine, San Augustine, Shelby, Smith, Tarrant, Titus, Upshur, Van Zandt, Wood, Wise

Hazard Level: This region is at risk from very large, distant earthquakes which might occur in Missouri-Tennessee or Oklahoma; the earthquakes that pose such a hazard are rare, probably occurring only once per 500 years or less. Such distant earthquakes would be most likely to damage large buildings or poorly reinforced masonry structures. Earthquakes with epicenters within this region are rare and small (see Figure 12N-A); several earthquakes with magnitudes 3 to 4.5 will probably occur each century. These pose little or no risk unless their epicenters are extremely close to poorly built or very sensitive structures. Justification: Throughout this region the 1811-1812 Missouri-Tennessee earthquakes, although distant, probably produced Modified Mercalli Intensities of VI and higher.

Significant Historic Earthquakes Affecting Northeast Texas

Throughout most of this region, the most intense shaking experienced over the past two centuries originated from several earthquakes with magnitude about 8 which occurred in Missouri-Tennessee in 1811-1812, or an earthquake with magnitude 5.6 which occurred in eastern Oklahoma in 1882. Although such distant earthquakes are unlikely to produce severe damage they can cause failure in very large structures, or structures which are designed with absolutely no earthquake-resistant features.
Small earthquakes with epicenters in this region occasionally do occur--some of natural origin and some apparently induced by petroleum production. These include:

- A magnitude 4.0 earthquake with an epicenter near Mexia, probably induced by oil production, that occurred on 9 April 1932.
- A magnitude 4.2 earthquake centered in Lamar County north of Paris that occurred on 12 April 1934.
- A magnitude 3.0 earthquake that occurred in Gregg County near Gladewater on 19 March 1957. This quake may have been induced by petroleum production in the East Texas Field.
- A magnitude 3.3 earthquake in Cooke and Denton County near Pilot Point and Valley View; this occurred on 18 September 1985.
- A magnitude 3.4 earthquake centered near Commerce in Hunt County; this occurred on 31 May 1997.
- Events of these magnitudes seldom produce damage further than about a few miles from the epicenter.



Felt Areas Of Representative Historical Earthquakes In Northeastern Texas

Shaded regions indicate areas of intensity V and above for earthquakes of 1932 (Limestone County), 1934 (northern Lamar County), 1957 (Gregg County), and 1964 (Sabine County). Thick lines indicate estimated boundaries of Modified Mercalli Intensities for the 1811-1812 Missouri-Tennessee earthquakes.

Source: *State of Texas Hazards Analysis*, Chapter 12, Figure 12N-A, the Governor's Division of Emergency Management, Department of Public Safety, Austin, Texas, 1998.

Summary The north central Texas region is not known to have a significant risk from major earthquakes. Due to its position on a relatively stable geologic platform with no known active fault systems, the region experiences only minor seismic activity, generally due to oil and gas extraction and injection well activities. However, as depicted in HazMAP **map 8-1**, there are potential sources of hazardous seismic activity for the greater region. The Meers Fault system of southwestern Oklahoma and the Reelfoot Rift region of southern Missouri pose some risk to the NCTCOG region in terms of very high magnitude, yet distant, seismic events. The Meers Fault region of Oklahoma historically has recorded seismic events of 4 and 5 Richter, and the Meers Fault region lies only 100 miles from points in the NCTCOG region. The Reelfoot Rift, some 1000 miles away from the NCTCOG region, has experienced earthquakes up to 8 and 9 Richter, which are strong enough to cause 4 and 5 Richter damage here in the NCTCOG region. These distant earthquakes can affect large and sensitive structures in the NCTCOG region. Sensitive structures--including dams, towers, very tall buildings, bridges, and highway overpasses--should be constructed with the possibility of earthquakes in mind. Therefore, the principal hazard is from rare, distant, but very large earthquakes occurring outside of Texas. Based on these analyses, the risk of an earthquake hazard in the NCTCOG region is sufficient enough to merit mitigation consideration.

References:

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment.* Seismic Hazards, Chapter 16.

Governor's Division of Emergency Management, Department of Public Safety (1998). *State of Texas Hazards Analysis*. Chapter 12.

HazMAP

Chapter 9 Selected Severe Weather Hazards: Tornadoes

Hazard Identification Tornadoes are considered to be the most erratic, most unpredictable and most violent of all atmospheric storms. Winds in the strongest of these storms can exceed 250 miles per hour. By definition, a tornado is often described as a violently rotating column of air, in contact with the ground, either pendant from a cumuliform cloud or underneath a cumuliform cloud, and often (but not always) visible as a condensation funnel cloud. Significant damage can occur even when the condensation funnel does not reach the ground.

Tornadoes generally fall into two types of categories. A Type I tornado is associated with thunderstorms containing a larger parent circulation, often called a "supercell". Large and violent tornadoes, almost without exception, fall into this class. The generally weaker Type II tornado (or non-supercell tornado) is a smaller circulation that forms along windshift lines and other boundaries without a vigorous parent circulation. The intensity of these storms is rated using the Fujita Scale of wind damage, which was developed decades ago in response to identifiable trends in structural failures due to wind. A tornado is given a Fujita rating of 0-5, based on the most intense damage along its path. Wind velocities necessary to produce the particular damage are often associated with the Fujita category, but that practice is often misleading at best. The Fujita wind estimates are intended to be based upon the expected damage to a well-built residential structure. Poorly built structures can suffer significant structural damage under lesser winds than the Fujita Scale might suggest.

Tornadic storms can occur anywhere throughout the United States, but they are far more frequent in a zone that stretches from northern Texas through Oklahoma and into Nebraska, commonly called "Tornado Alley." The North Central Texas region is the largest metropolitan area in Tornado Alley. Tornadoes seem to occur more frequently in Tornado Alley because recent research suggests that Tornado Alley is a breeding ground for conditions which are ripe for tornado formation—high instability, strong veering (turning) of the wind direction in the lowest half mile of the atmosphere, and often in the vicinity of weak boundaries. The flat terrain enhances rapid movement of air, while high humidity of the Gulf Stream further induces instability in the atmosphere. Tornadic storms can occur at any time of year and at any time of day, but they are typically more common in the spring months during the late afternoon and evening hours. A typically smaller, high frequency period can emerge in the fall during the brief transition between the warm and cold seasons.

Since 1950, approximately 280 tornados have been observed as occurring in the NCTCOG region, 63 of which have had a F-Scale of F2 or F3. A few of the more well-known tornadoes in the North Central Texas region are as follows: an F3 tornado that moved through Dallas and Collin Counties on April 2, 1957 caused 200 injuries, 10 fatalities, and $4 million in damages. On June 19, 1965 severe tornadoes and flooding caused Navarro County to be declared a Presidential Disaster Declaration. On April 25, 1994 an F4 tornado within Dallas County claimed 3 lives and injured 48 persons. And most recently, Tarrant County received a Presidential Disaster Declaration when severe storms and tornadoes devastated the county on March 28, 2000.

Because it lies in Tornado Alley, the NCTCOG region has developed a long history with tornadoes. According to the map below developed by the Storm Prediction Center at the National Oceanic and Atmospheric Administration (NOAA) entitled "Tornado Activity in the United States," the North Central Texas area is only one of two hot spots in the entire United States where there have been more than 15 recorded tornadoes per 1,000 square miles.

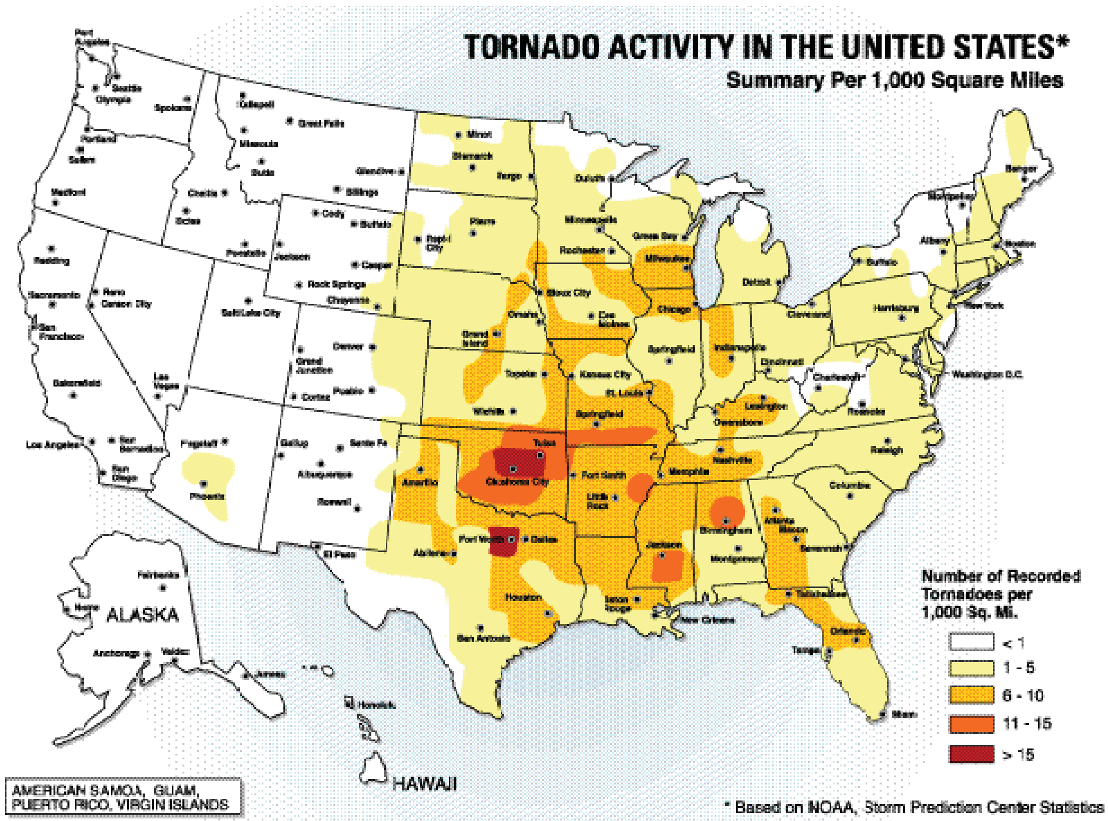


Figure I.1 The number of tornadoes recorded per 1,000 square miles

Risk Assessment:
Estimating North Central Texas Tornado Damages from a "Typical" Tornado

In order to estimate a typical impact it was necessary for NCTCOG to estimate a typical Texas tornado. This is a far-from-perfect task in that there are no perfect data kept about tornadoes. As a "best guess" opportunity, the 50-year data set from the Storm Prediction Center offered the best data available and was cross-verified with data from the Tornado Project. Each tornado record in the dataset, at its best, offered an averaged description of the tornado's width, length, and damage. This is far from ideal, in that a true path is extremely dynamic in all parameters. But, again, it was the best available. See HazMAP **map 9-1**

Over 1200 tornadoes in the dataset had information on the beginning point and ending point of the tornado path, as well as median path width. Averaging this collection of records reveals an average path description of:

- 10 miles long
- 0.15 miles wide
- 960 impacted acres

It should be noted that possible limitations of the data such as the possible exclusion of some actual tornadoes or possible errors in reporting the beginning/ending points could attribute for any perceived skewing of the average path description.

Nevertheless, for the purpose of statistical representation, the typical "unit" tornado used for this region's analysis has a straight 10-mile long continuous path with a 0.15 mile wide impact width. This average unit tornado has been mapped in HazMAP **map 9-2**. This represents approximately 960 acres of impact area. The next task is to describe, on average, what 960 acres represents in North Central Texas.

Risk Assessment: *The "Typical" Profile*

The ideal way to predict potential damages or losses from a tornado is to run the specific boundary across a detailed map of development data for the region. This process has been tested successfully in recent years by NCTCOG with large tornado paths. The "typical" tornado path is considerably smaller than the largest possible tornado path that our region could see, so the number of possible alignments for the "typical" path is infinitely large and would be difficult to represent. As a result, we have chosen to demonstrate what a typical path represents in terms of structures under different land use scenarios. To do that, we identify the land use and structural composition of a typical acre in our region.

The best data available at NCTCOG for the relationship of structures to land use for the 2003-2004 planning cycle was for Dallas County. For the purpose of structural damage estimates, Single-Family, Multi-Family, Commercial, and Industrial land uses can be combined and referred to as "structural" land uses. These are the primary categories in the land use data upon which identifiable appraised improvements (buildings) are constructed. The larger the percentage of land uses devoted to these categories, the larger the odds of impact become. A tornado has to hit something to cause damage, and an acre of land use categories such as vacant, water, and park do not offer nearly the same density of structures as a typical acre of single-family or multi-family. Although there are a lot of variations in the number of structures per acre even in these structural categories, the average acre in Dallas County can be described with the following profile:

Land Use and Density for a "Typical" (Average) Acre in Dallas County		
Category	**Percentage of Total Acreage**	**Average # of Structures or Apartment Units Per Acre**
Single Family	22.7%	3.8 Units Per Acre
Multi-Family	2.6%	25 Units (Apartment) Per Acre
Commercial/Industrial	10.4%	2.75 Commercial Structures Per Acre
Vacant	35%	-
Roadway	11%	-
Other	18.3%	-

Appraisal information from the Dallas County Appraisal District also indicates average values for these categories. The average single-family home in Dallas County was about $100,000 in 2002. An estimated average value per apartment unit was $30,000 in 2002. An estimated average value per commercial building was $180,000. In order to calculate a possible loss per magnitude of damage, a likely low end value for structure value and high end were calculated. These were used a bit arbitrarily, but represented the average values (rounded) in several Dallas county cities. These values are represented below:

Average Per Unit Structural Value for Dallas County					
Category	**Average Value**	**Low Average (City Average)**	**City (Low)**	**High Average (City Average)**	**City (High)**
Single-Family	$100,000	$56,000	Seagoville	$290,000	University Park
Multi-Family	$30,000	$23,000	Lancaster	$55,000	Coppell
Commercial	$180,000	$63,000	Lancaster	$290,000	Coppell

Tornado damages are officially classified according to the Fujita Scale. This is a damage scale that is assigned based on the magnitude of damage that occurs to any structure in a tornado path. There is no official correlation between Fujita Scale damage rating and appraised structure value; a few studies and discussions with experts in damage assessment resulted in the following general expectations:

Average Loss Expected By Fujita Damage Scale		
Fujita Scale	**Damage Description**	**Percentage of Appraised Structure Value Lost due to Damage**
F1	Moderate Damage. Roof surface peeled off; window breakage; attached garages may be destroyed.	0% to 20%
F2	Considerable damage. Roofs torn off frame houses; light object missiles generated.	50% to 100%
F3	Severe Damage. Roof and some walls torn off well constructed houses;	100%
F4 and above	Devastating Damage. Well-constructed houses leveled; structures with weak foundations blown off some distance; large missiles generated.	100%

It is important to note that the Fujita Scale was designed with a "well-constructed" frame house as the standard for assessing failures in building construction. Commercial properties may or may not experience the same failures under high wind speeds that a house might. Thus, the Fujita scale is largely a residential scale, with much more care required in assessment after wind damage to a commercial structure. A wider range of construction techniques and materials can be found in a community of buildings classified as commercial. A concrete/steel reinforced building, for instance, is much more durable than a typical community convenience store, yet both may be considered commercial in city land use/appraisal data sets.

As a result, calculations performed using the above numbers are presented as an average, with site-specific variations expected, but not easily quantified. They provide an "average expectation" or "typical impact".

Risk Assessment: *An Average Expectation*

Using the typical profile of an acre in Dallas County, we can extrapolate that to our typical tornado. We can further incorporate the average Fujita Scale structural loss percentages to get some idea of the cost represented by those averages. A sample calculation for F2:

Minimum F2 Loss =	Acres * structures per acres * 0.5 * (Lowest Average Cost Per Structure)
Maximum F2 Loss =	Acres * structures per acres * 1.0 * (Highest Average Cost Per Structure)

Since the average acre of land in Dallas County is 35% developed with structural land use categories, the actual number results for our 960-acre typical tornado on a typical Dallas County land is:

Land Developed Percentage 35%								
Category	**Acres**	**Structures**	**F1 Loss (In $Millions)**		**F2 Loss (In $Millions)**		**F3-F5 Loss (In $Millions)**	
			Low	**High**	**Low**	**High**	**Low**	**High**
Multi-Family	24	613	0	3.3	6.7	33.7	13.5	33.7
Single-Family	213	812	0	23.5	22.3	235.5	44.6	235.5
Commercial	97	268	0	7.7	8.0	77.7	16.0	77.7
TOTAL	334	1693	0	34.5	37.0	346.9	74.1	346.9

Most of Dallas County and the region is truly not the average, but some variation from it. By applying the same proportion of land use composition, densities, and losses to the other categories of structural land development, we can extrapolate these loss estimations for low and high-density areas. These categories have been mapped to aid in visual representation of the various density rankings. See HazMAP **map 9-3**. Several other maps of various density rankings are included here for reference. See HazMAP **map 9-4**, **map 9-5**, **map 9-6**, **map 9-7**, and **map 9-8**. The average losses for these 4 other categories are as follows:

Land Developed Percentage 10%								
Category	Acres	Structures	F1 Loss (In $Millions)		F2 Loss (In $Millions)		F3-F5 Loss (In $Millions)	
			Low	High	Low	High	Low	High
Multi-Family	7	175	0	0.2	1.9	9.6	3.8	9.6
Single-Family	61	232	0	1.1	6.4	67.2	12.7	67.2
Commercial	28	76	0	0.7	2.3	22.0	4.5	22.0
TOTAL	96	483	0	2.0	10.6	98.8	21.0	98.8

Land Developed Percentage 25%								
Category	Acres	Structures	F1 Loss (In $Millions)		F2 Loss (In $Millions)		F3-F5 Loss (In $Millions)	
			Low	High	Low	High	Low	High
Multi-Family	17	438	0	2.4	4.8	24.1	9.6	24.1
Single-Family	152	580	0	16.8	15.9	168.2	31.9	168.2
Commercial	70	192	0	5.5	5.7	55.6	11.5	55.6
TOTAL	239	1210	0	24.7	26.4	247.9	53.0	247.9

Land Developed Percentage 50%								
Category	Acres	Structures	F1 Loss (In $Millions)		F2 Loss (In $Millions)		F3-F5 Loss (In $Millions)	
			Low	High	Low	High	Low	High
Multi-Family	35	876	0	4.8	9.6	48.1	19.2	48.1
Single-Family	305	1160	0	33.6	31.9	336.4	63.8	336.4
Commercial	140	384	0	11.1	11.5	111.3	23.0	111.3
TOTAL	480	2420	0	49.5	53.0	495.8	106.0	495.8

Land Developed Percentage 75%								
Category	Acres	Structures	F1 Loss (In $Millions)		F2 Loss (In $Millions)		F3-F5 Loss (In $Millions)	
			Low	High	Low	High	Low	High
Multi-Family	53	1313	0	7.2	14.4	72.5	28.8	72.5
Single-Family	457	1740	0	50.4	47.8	504.6	95.7	504.6
Commercial	209	576	0	16.7	17.2	167.0	34.5	167.0
TOTAL	719	3629	0	74.3	79.4	744.1	159.0	744.1

Risk Assessment:
The Impact of a Large, Violent Long-Track Tornado

Although the typical tornado is likely a good measuring point for the typical damage expectation for the Metroplex, the threat of a much larger, stronger, and persistent tornado is very real in the Metroplex. As with extremely large hail, 100-year floods, and other extreme phenomena, the statistical probability of such a storm occurring at a specific location in any given year is small, but over a larger number of years, it is an almost certainty. Storm experts are clear to point out that it is not a matter of "if", but "when". Violent class tornadoes are those that produce damage in the F-4 to F-5 range. There is no rule that says they have to have a wide damage path or a slim one, but of particular concern are those that can reach widths of 1/2 mile or more and travel 25 to 50 miles. Examples of such storms include Wichita Falls, Texas (1979), Wichita, Kansas (1990), Waco, Texas (1953), and Moore, Oklahoma (1999). In particular, the Moore, Oklahoma damage path was well mapped by experts in tornadoes and wind engineering. Often, the conditions present to favor strong tornado development can extend to multiple storms across a region, resulting in a tornado outbreak. The Moore tornado was accompanied by 70 other regional tornadoes in a 6-hour period.

For a visual comparison of damage path dimensions of notable national and regional tornadoes, see HazMAP **map 9-9**.

As part of the Spring 2000 severe weather-planning season, the North Central Texas Council of Governments, in cooperation with the National Weather Service, developed a Tornado Damage Risk Assessment (to see the original study, go to Appendix D of this document or go to **http://www.dfwinfo.com/weather/study/index.asp**). The project estimated the potential impact of the Moore, Oklahoma tornado outbreak (1999) if it were to occur over the Dallas/Fort Worth Metroplex. Using over 55 damage path scenarios, GIS technology was used to estimate *structures, property, residents, employees, and traffic* that would be in tornado damage paths. An assessment of property values was also included, and potential damages were estimated based on mapped Fujita scale damage contours. In some cases, population at risk exceeded 150,000. Potential structural damages in some scenarios reached estimates exceeding $4.5 billion. If a mile-wide portion of the Moore tornado were to move into downtown Dallas, over 100,000 employees and nearly $3 billion dollars of property would be inside of the tornado simultaneously.

Characteristics of the Moore, Oklahoma F-5 Tornado Impact Area

Fujita Scale	Width(Feet)	Acres	Square Miles	Path Miles	Main Hour
5	5280	12,242	19.12	37.5	7 P.M.

Fort Worth tornado (White) and Moore Tornado Paths

Comparison of Moore, Oklahoma Tornado to the Fort Worth Tornado of March 28, 2000

	Fort Worth	Moore
Total Damage Area	344 Acres	12,242
Significant Damage Area (F-2+)	63 Acres	7,750 Acres
Path Percentage With Significant Damage	20%	63%
Path Length	6 Miles	37.5 Miles

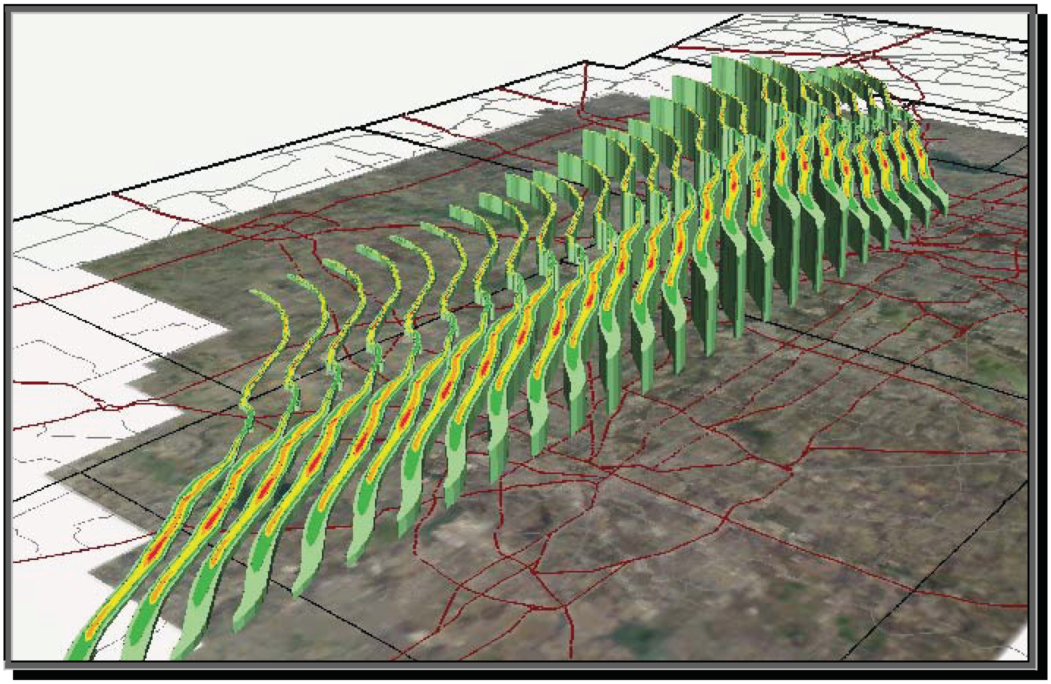


Figure 9-1

Figure 9-1 shows 25 of the 55 ultimate paths tested in the risk assessment. Each path was evaluated separately to identify both demographic and development characteristics that fell within its boundaries and within the particular Fujita-scale damage contours. The extruded paths on the map are based on the level of development falling within the path's impact area. Higher paths are more heavily developed than lower ones. Tarrant County is in the foreground on this map and Dallas County is to the right center.

Paths With the Largest Potential Damages				
Primary County	**Structures Impacted***	**Residents in Path**	**Potential Damages**	**Land Percentage Developed#**
Dallas	33,320	73,000	$4.7 Billion	63.1%
Dallas	28,100	58,000	$4.2 Billion	51.9%
Dallas	30,700	62,200	$3.9 Billion	52.7%
Dallas	38,350	78,900	$3.7 Billion	62.8%
Dallas	40,150	80,900	$3.4 Billion	56.9%
Dallas	25,800	52,000	$3.2 Billion	46.1%
Dallas	28,950	64,300	$3.1 Billion	63.1%
Dallas/Tarrant	30,280	68,300	$2.7 Billion	56.4%
Tarrant	20,350	42,400	$2.5 Billion	49.2%
Tarrant	19,500	45,700	$2.5 Billion	48.3%
Dallas	21,650	50,200	$2.5 Billion	47.5%
Tarrant	33,250	67,200	$2.2 Billion	51.7%
*Single Family Homes, Apartment Units, and Commercial Property Buildings # Structural Land Uses: Residential, Commercial, Industrial				

As expected, these paths are highly developed and, thus, present risks. When all of the 50 paths are averaged together, a typical profile is described in the table below:

Average Impact from a Large, Violent Long-Track Tornado (Average of over 50 Tornado Paths)			
Structures and Residents in Path		**Values in Path**	
Total Structural Units*	20,140	Total Property Value	$2.7 Billion
Single-Family Units	11,800	Estimated Damages	$1.5 Billion
Multi-Family Units	7,350	Residential Damages#	$1.04 Billion
Residents	46,770		
* Single Family Homes, Apartment Units, and Commercial Property Buildings # Fujita Scale is based on residential structural damages, so these numbers are more reliable than commercial estimates, which feature more varieties of construction. Damage level is harder to project accurately for commercial properties without more detailed investigation.			

If we summarize just the paths that are 50% or more developed with residential, commercial, and industrial land uses, the numbers jump, as indicated in the table below:

Average Impact from a Large, Violent Long-Track Tornado Where Paths are 50% or More Developed			
Structures and Residents in Path		**Values in Path**	
Total Structural Units*	30,950	Total Property Value	$4.5 Billion
Single-Family Units	15,800	Estimated Damages	$2.5 Billion
Multi-Family Units	13,700	Residential Damages#	$1.6 Billion
Residents	69,400		

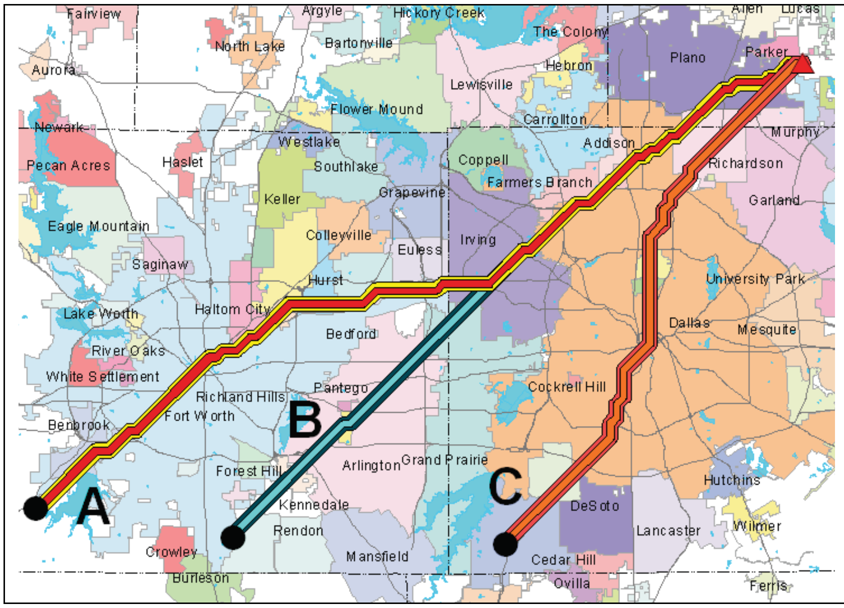
Risk Assessment:
Example of a Potentially High-Impact Path

Several of the scenarios that passed through the northern portions of Dallas County contained very large numbers of people and expensive property. Such a combination is particularly threatening in a wide violent-class tornado. With such high winds, there is little hope of structures avoiding demolition, particularly residential buildings. Total loss is highly likely. The below path is one of those that ranked high in potential risk.

Characteristics of Potentially High-Impact Path	
Structures in Path	33,300
Property Value in Path	$7.9 Billion
Potential Damages	$4.7 Billion
Residents Living in Path	73,000
Percent of Path that is Developed	63.13%

Computer-Determined Worst Paths

When Dallas-Fort Worth development information is tabulated, the computer can be remarkably efficient in determining its own worst path for a tornado. Based on number of structures distributed across the surface, the computer can use a cost-path analysis to choose a route containing the most structures possible to impact.



The computer is asked, given three random starting points and a destination, to find the worst possible damage path between the 2 locations. The concept of a least-cost path is modified slightly to make the highest values and the largest number of structures more attractive to the tornado. The tornado width is then calculated as 1/4 wide and again at 1/2 mile wide. The quantity and value of structures can then be tabulated.

	1/4	Mile	Width		1/2	Mile	Width
Path	Structures	Residents	Property in Path		Structures	Residents	Property In Path
A	60,000	122,000	$13 Billion		103,000	212,000	$15 Billion
B	36,000	81,000	$11 Billion		70,000	157,000	$18 Billion
C	33,000	73,000	$10 Billion		69,000	149,000	$18 Billion

Summary An assessment of the best available historical tornado data shows that the risk of a tornado hazard is uniform across the NCTCOG region. Furthermore, quantitative analyses of the “typical” or “unit” tornado event reveal devastating impacts to existing lives and property in areas of Dallas County with various levels of structural density. And, as evidenced by the responses to the Multi-Hazard Risk Assessment Survey, tornado hazards are one of the top concerns among local communities in the NCTCOG region. As a result, tornado hazards deserve mitigation consideration.

References:

Note: This tornado risk assessment for the 2003-2004 planning cycle expands on a previous study by the North Central Texas Council of Governments and the National Weather Service entitled “Tornado Damage Risk Assessment Dallas-Fort Worth Metroplex: A Regional Exercise in Demographic, Environmental , and Urban Analysis” (January 2000). This previous assessment utilized innovative methods to analyze the potential damage impact of the May 3, 1999 Oklahoma tornado outbreak if it had occurred over North Central Texas. The entire study can be found in Appendix D of this document or at **http://www.dfwinfo.com/weather/study/index.asp**.

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment.* Atmospheric Chapter 3.

National Oceanic and Atmospheric Administration (NOAA) U.S. Department of Commerce. (July 7, 2003) *Tornadoes.* Retrieved September 14, 2003 from http://www.noaa.gov/tornadoes.html

National Weather Service (NWS). *Search results for Fujita Tornado Scale*. Retrieved September 14, 2003 from http://www.crh.noaa.gov/arx/tornado/fujitascale.htm

Severe Convective Storms. Chapter 5 - Tornadoes and Tornadic Storms. Robert Davies-Jones, R.Jeffrey Trapp, and Howard Bluestein. Edited by Charles A. Doswell III. American Meteorological Society 2001.

Tornado Alley. Howard B. Bluestein. Oxford University Press 1999.

Tornado Project (2000). Retrieved November 2003 from http://www.tornadoproject.com

HazMAP

Chapter 10 Selected Severe Weather Hazards: Hail

Hazard Identification A hailstorm is an outgrowth of a severe thunderstorm in which balls or irregularly shaped lumps of ice greater than 0.75 inches in diameter fall with rain. Early in the developmental stages of a hailstorm, ice crystals form within a low-pressure front due to warm air rising rapidly into the upper atmosphere and the subsequent cooling of the air mass. Frozen droplets gradually accumulate on the ice crystals until, having developed sufficient weight, they fall as precipitation.

The size of hailstones is a direct function of the severity and size of the storm. High velocity updraft winds are required to keep hail in suspension in thunderclouds. The strength of the updraft is a function of the intensity of heating at the Earth's surface. Higher temperature gradients relative to elevations above the surface result in increased suspension time and hailstone size.

Although hailstorms can occur in almost every state, the Great Plains states, especially northeastern Colorado and southeastern Wyoming, receive more hail yearly than any other part of the United States. According to the Weather Channel, hail in this area of the country is most likely to fall late in the afternoon during the months of May and June and is often responsible for extensive crop loss, property damage and livestock deaths.

Significant property and crop damage has been reported as a result of hailstorms in the in Denver Colorado, eastern Texas-Oklahoma region. The Property Loss Research Bureau indicates that a hailstorms occurring in April and May of 1995 in the Texas-Oklahoma region maybe been the worst on record in terms of non-agricultural property losses.

Other severe hail hazard events that have occurred in the NCTCOG region include hailstorms with 5-inch hailstones on April 27, 1968 and June 22, 1955. A hailstorm that occurred on October 21, 1996 with 4.5-inch hailstones caused approximately $400,000 in property damage. A hailstorm with hailstones measuring 1.75-inches caused approximately $250,000 in property damage on October 10, 2001.

On April 28, 1992, a severe thunderstorm outbreak rumbled across southern Oklahoma and through North Central Texas, producing a swath of hail damage in one of the costliest severe weather events ever for the region. Hail up to 4.5 inches in diameter was recorded during the event, which lasted several hours and ultimately resulted in losses of over $750 million. See HazMAP **map 10-1**

On May 5, 1995, a devastating supercell produced softball-sized hail in Tarrant County, accompanied by flash flooding and high winds. Over a hundred people, most of which were attending the outdoor Mayfest celebration in downtown Fort Worth, were injured. Insured damage reached nearly $1.1 billion, making it one of the insurance industry's most expensive thunderstorms in history.

On April 5, 2003, a severe thunderstorm rolled across the north central portions of the NCTCOG region. Hail accumulated in a series of eastward moving thunderstorms, originating in Tarrant County and training due east over one of the most densely populated and highly valued areas of the DFW Metroplex. To see a typical NEXRAD image of the hail event that resulted in losses of over $880 million, see HazMAP **map 10-2**.

Risk Assessment:
Magnitude and Distribution of Hail in North Central Texas

The size of hail is not a variable recorded at hourly or daily climatic stations operated by the National Weather Service (NWS). The best data that are available for determining the magnitude and distribution of hail in North Central Texas is the U.S. Storm Event data that are collected as part of the NWS spotter network. These data are collected by observers who provide the data to the NWS, but these data may only be available for short periods of record at any given location. The data are collected if the person is available and aware of the event. There is a greater concentration of the Storm Event data in the populated counties where there are more people to observe the events. Over the 16-county area, there are 3,152 storm events with hail sizes greater than 0.75 inches that were recorded or observed since 1955. These data were observed at 990 locations throughout the study area with data being observed in all counties in the study area.

Figure 10-1 illustrates the locations at which the size of hail was observed and indicates the number of events observed at each location. At some locations, up to 91 events have been observed since 1955. The few locations with 42 or more events are in the central and more populous counties in the study area. Also see HazMAP **map 10-3**.

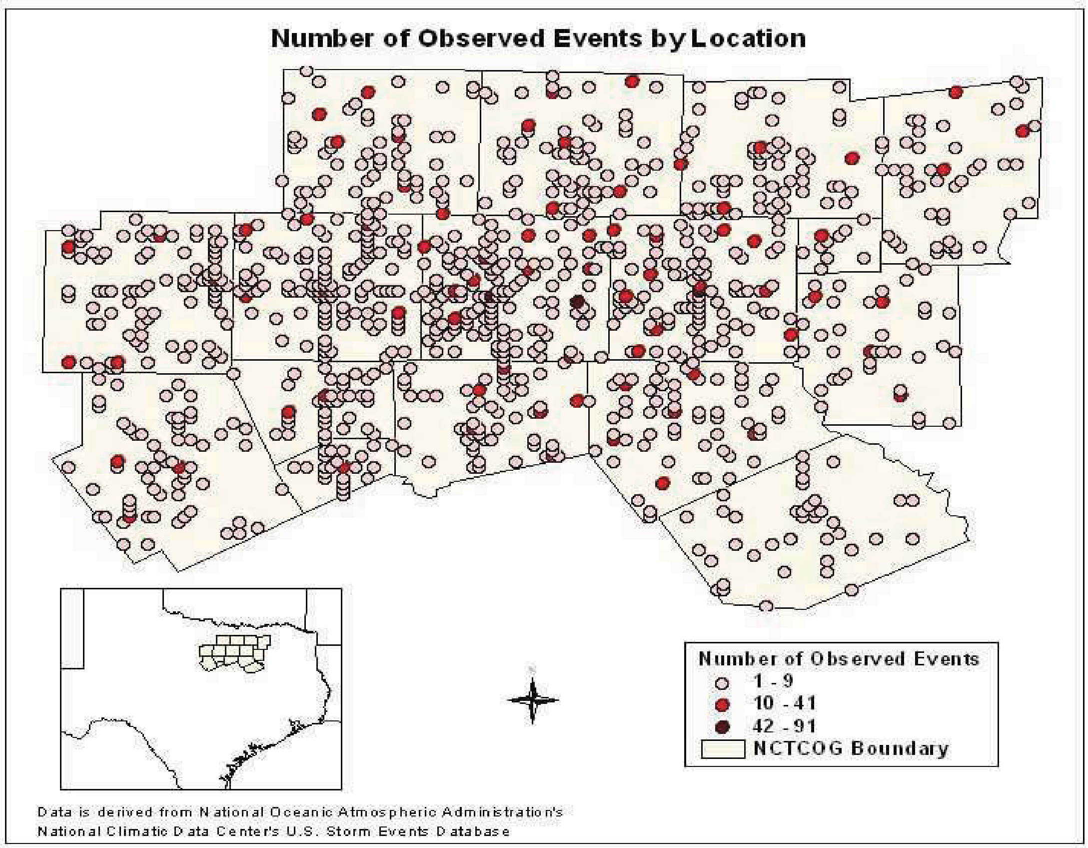


Figure 10-1. The number of hail events observed at each location in the spotter network

The hail data from the Storm Event data are not suitable for frequency analysis because they do NOT represent all events greater than a given magnitude that have occurred at that location and the number of events observed at each location varies significantly (Figure 10-1). Therefore, it is not appropriate to estimate statistics like the mean or median hail size since all significant hail events were not recorded at all locations. The hail data recorded as part of the Storm Event network range from 0.75 (the observation threshold) to 5.0 inches and are reported in increments of 0.25 inches. One qualitative approach for determining the magnitude of the hazard is to identify the number of times that the hail size equaled or exceeded a given value at each location. Figure 10-2 illustrates the number of times that the hail size equaled or exceeded 2 inches, and Figure 10-3 illustrates the number of times that the hail size exceeded 3 inches at each of the locations.

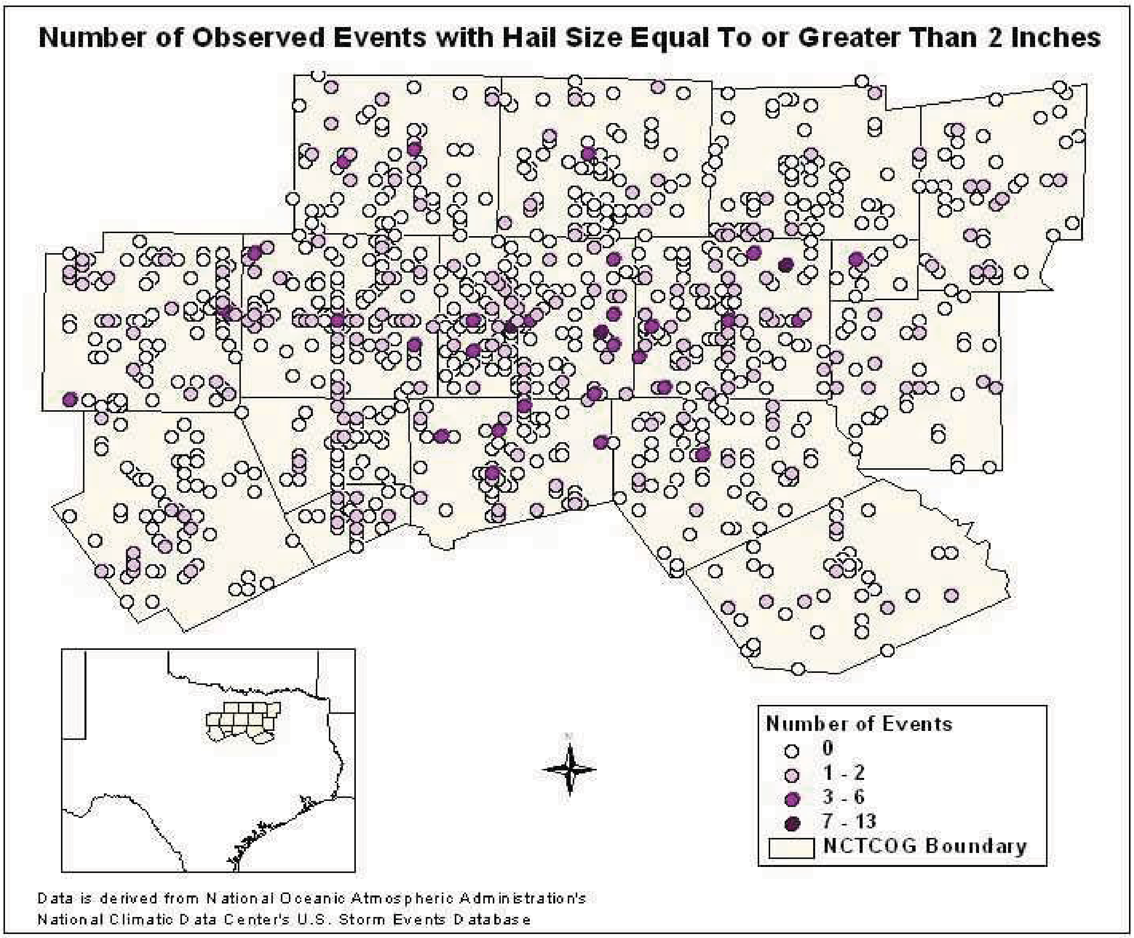


Figure 10-2. The number of times the hail size equaled or exceeded 2 inches at each location

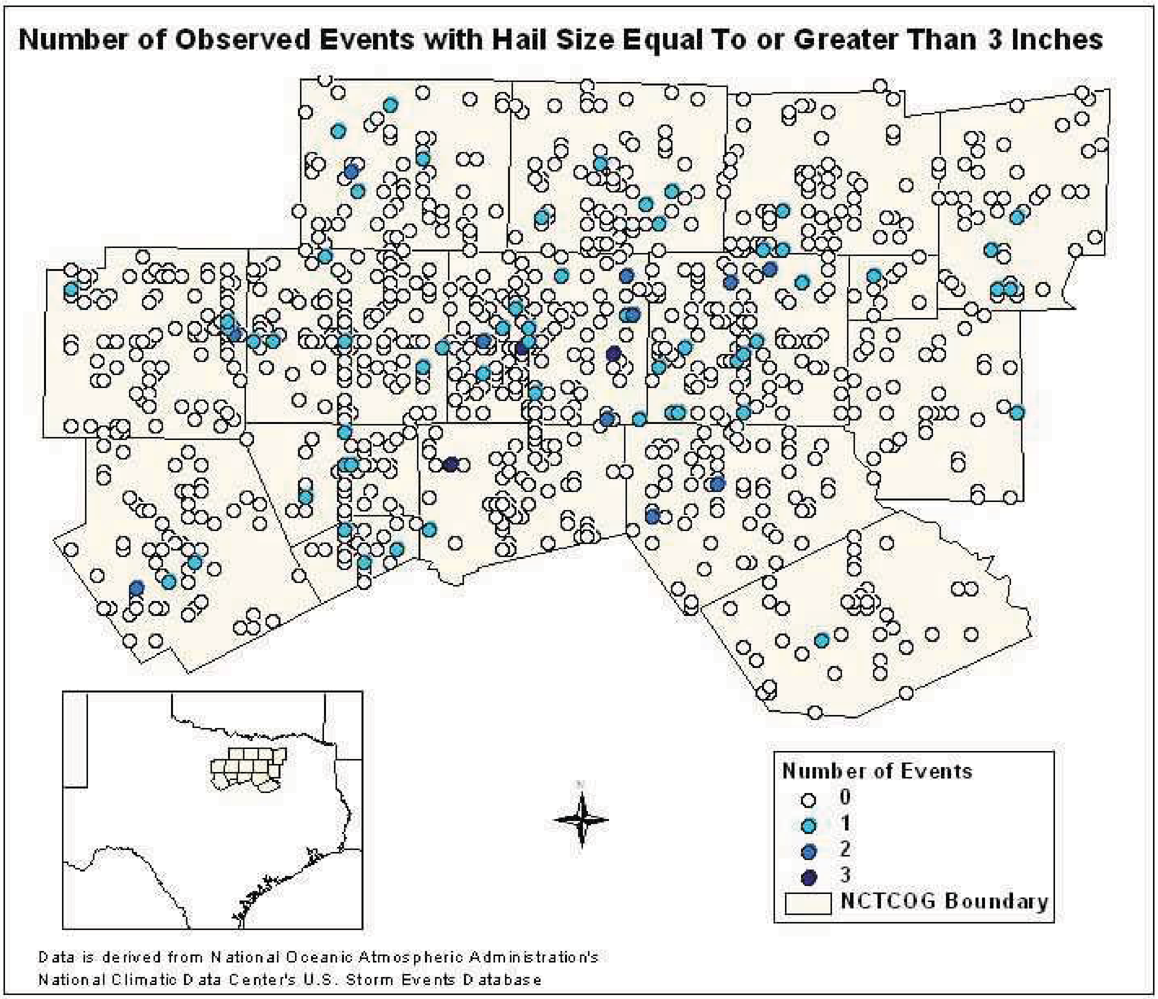


Figure 10-3. The number of times the hail size equaled or exceeded 3 inches at each location

Figure 10-2 and Figure 10-3 indicate that more hail events have been observed in the central more populous counties where there are more people who participate in the spotter network. It is likely that the more extreme events also occurred in the outlying counties but were not observed due to the paucity of people in the spotter network.

Figure 10-4 shows the distribution and location of the maximum hail size that have been observed since 1955 at the 990 locations in the spotter network. As can be noted in Figure 10-4, all counties except the most southeast county (Navarro) have experienced hail in the 3.5- to 5.0-inch range. Likewise the distribution of hail ranging from 2.25 to 3.5 inches is fairly uniform across the study area. This suggests that extreme hail events can occur over the entire study area.

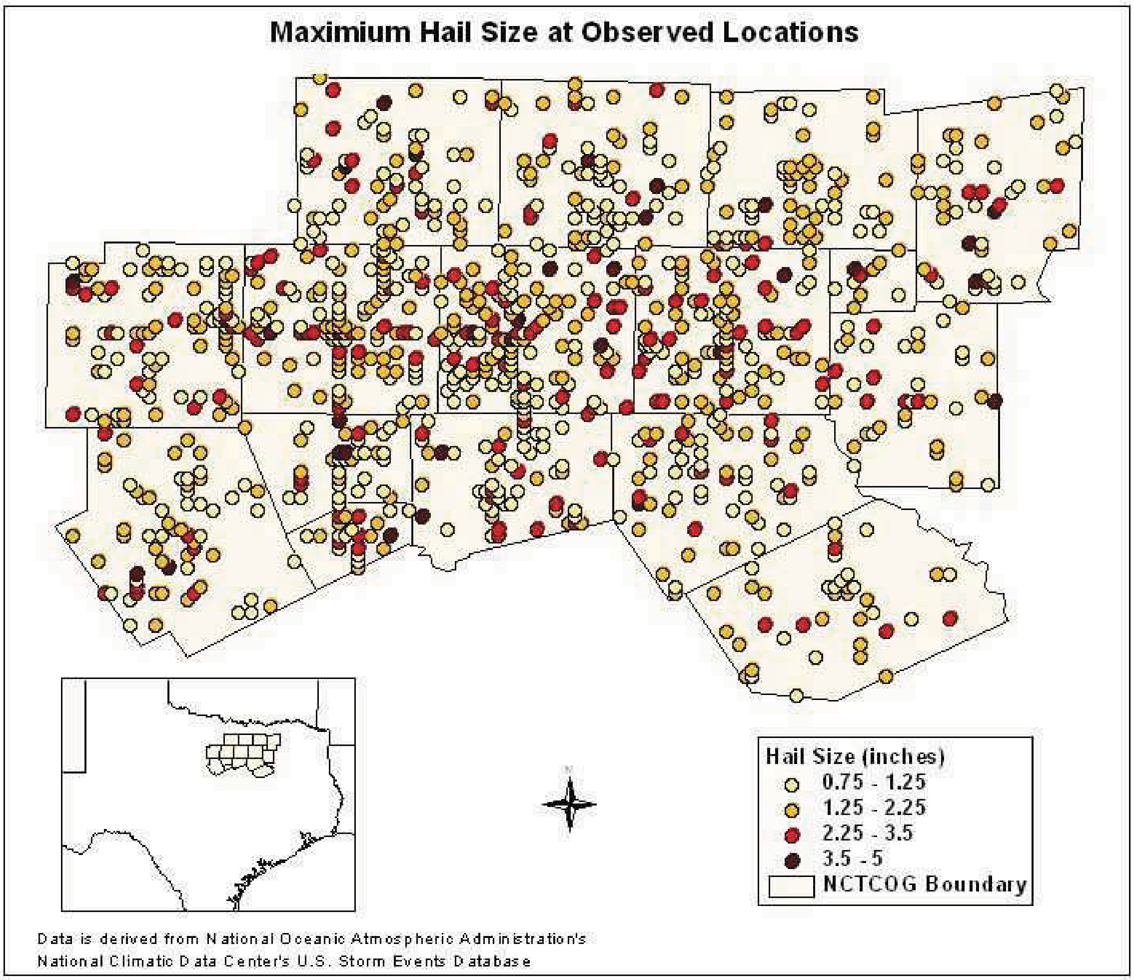


Figure 10-4. Distribution and location of the maximum hail size observed at locations throughout the study area since 1955

Summary Hail events exceeding 0.75 inches in size have been observed at 990 locations throughout the 16-county study area. These data were observed as part of the NWS spotter network where volunteer observers record the data and provide them to NWS. The greater number of hail events were observed in the more populous counties where there are more people participating in the spotter network. However, the extreme hail events seem to be uniformly distributed over the entire study area (see Figure 10-4). The data in Figure 10-4 indicate that extreme hail events can occur anywhere in the NCTCOG region. Given the data available, one would conclude that there is no significant variation in the hail hazard over the 16-county study area.

Based on a qualitative analysis of the impacts from historical hail events and based on a quantitative analysis of the magnitude and distribution of historical hail events, the risk is sufficient enough to merit mitigation consideration.

References:

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment.* Atmospheric Chapter 5.

National Oceanic and Atmospheric Administration Storm Prediction Center (NOAA SPC). (2003). *Storm Prediction Center Archives – Historical Severe Weather Data*. Retrieved July 2003 from http://www.spc.noaa.gov/archive/

The Weather Channel Interactive, Inc. (1995-2003). *Storm Encyclopedia – Hail.* Retrieved September 13, 2003 from http://www.weather.com/encyclopedia/thunder/hail

HazMAP

Chapter 11 Selected Severe Weather Hazards: High Winds

Hazard Identification Wind is defined as the motion of air relative to the earth's surface. The horizontal component of the three-dimensional flow and the near-surface wind phenomenon are the most significant aspects of the hazard. Extreme windstorm events are associated with extra-tropical and tropical cyclones, winter cyclones, and severe thunderstorms and accompanying mesoscale offspring such as tornadoes and straight-line winds.

Straight-line winds are often responsible for most of the wind damage associated with a thunderstorm. These winds are often confused with tornadoes because of similar damage and wind speeds. However, the strong and gusty winds associated with straight-line winds blow roughly in a straight line unlike the rotating winds of a tornado.

Downbursts or microbursts are examples of damaging straight-line winds. A downburst is a small area of rapidly descending rain and rain-cooled air beneath a thunderstorm that produces a violent, localized downdraft covering 2.5 miles or less.

Wind speeds in some of the stronger downbursts can reach 100 to 150 miles per hour, which is similar to that of a strong tornado. The winds produced from a downburst often occur in one direction, and the worst damage is usually on the forward side of the downburst.

In the mainland United States, the mean annual wind speed is reported to be 8 to 12 mph, with frequent speeds of 50 mph and occasional wind speeds of greater than 70 mph. For coastal areas from Texas to Maine, tropical cyclone winds may exceed 100 mph.

Property damage and loss of life from windstorms are increasing due to a variety of factors. Use of manufactured housing is on an upward trend, and this type of structure provides less resistance to wind than conventional construction. Uniform building codes for wind resistant construction are not adopted by all states, and population trends show rapid growth in the highly exposed areas.

Areas experiencing the highest wind speeds are coastal regions from Texas to Maine, under the influence of North Atlantic Ocean and Gulf of Mexico windstorms associated with tropical cyclones, and the Alaskan coast, under the influence of winter low-pressure-system windstorms in Gulf of Alaska and North Pacific Ocean.

North Central Texas experiences severe windstorms. Since 1955 over 160 windstorms with wind speeds exceeding 70 mph have been recorded in the NCTCOG region. On April 19, 1995 Somervell County experienced a windstorm with wind speeds of 120 mph. Tarrant County was subjected to windstorms with wind speeds of 115 mph on May 4, 1960 and April 19, 1976. A windstorm event on March 2, 1997 in Navarro County resulted in approximately $500,000 in property damage, 4 injuries and 2 fatalities. In the April 23, 2003 thunderstorms that rolled through the NCTCOG region, 100 mph winds were responsible for destroying dozens of mobile homes, injuring seven people, and causing an estimated $4 million in damage in Johnson County. More recently in August 2003, high winds wreaked havoc with the construction industry. A construction worker was killed on August 24 when straight-line winds caused a wall to collapse at the construction site of a new Home Depot in Carrollton. Less than two days later, downburst winds estimated at 65-70 mph killed one man and injured four others at a residential construction site in McKinney.

See HazMAP **map 11-1** for a Map of Reported High Wind Events since 1955

Risk Assessment:

Magnitude and Distribution of Wind Speeds in North Central Texas

There are two databases that characterize the magnitude and frequency of wind speeds and both of these databases are archived at the National Climatic Data Center (NCDC) in Asheville, North Carolina. These databases consist of the U.S. Storm Event data and daily peak gust data collected at hourly climatic stations operated by the National Weather Service (NWS). The Storm Event data provide good regional coverage of the hazard but do NOT represent all events greater than a given magnitude that occurred at that location. The daily peak gust data are only available at a few locations throughout the 16-county area but do include all events greater than a given magnitude at that location. The daily peak gust data are more appropriate for frequency analysis and were used to characterize the wind hazard. Additional climatic stations outside the study area were also used due to the paucity of climatic stations in the study area.

The Storm Event data are collected as part of the NWS spotter network. These data are collected by observers who provide the data to NWS but may only be available for short periods of record. The data are collected if the person is available and aware of the event. There is a greater concentration of Storm Event data in the populated counties where there are more people to observe the events. Over the 16-county area, there are 1,881 storm events with wind speeds greater than 50 knots (58 miles per hour) recorded since 1955. These data were observed at over six hundred locations ranging from one event at some locations to as many as 65 events at other locations. Therefore, these data are somewhat biased as to regional distribution and are not appropriate for statistical analysis since only selected events are observed at most of these locations.

The daily data as used in this study are Daily Surface Data collected at first order NWS climatic stations and are described as Summary of the Day – First Order. The period of record for the eight climatic stations in and near the study area that have at least 20 years of data are summarized in Table 11-1. The four stations within the study area are those in Dallas and Tarrant Counties. The other four stations were added to the analysis to define the regional variation across the study area.

Table 11-1. Summary of National Weather Service climatic stations in and near the study area with at least 20 years of record for peak wind gusts

COUNTY	STATION_NA	BGN_YR	BGN_MO	END_YR	END_MO
DALLAS	DALLAS HENSLEY FIELD NAS	1948	1	1997	1
TARRANT	DALLAS-FORT WORTH INTL AP	1974	9	1995	11
TARRANT	FORT WORTH GREATER SW INT'L A	1953	5	1974	8
TARRANT	FORT WORTH NAS	1958	1	2003	5
WICHITA	WICHITA FALLS MUNICIPAL ARPT	1951	6	1993	5
TAYLOR	ABILENE REGIONAL AP	1973	1	1996	4
McLENNON	WACO REGIONAL AP	1972	1	1993	6
CADDO	SHREVEPORT REGIONAL ARPT	1952	11	1995	9

The locations of the eight climatic stations for which daily peak wind gusts are available are shown in Figure 11-1 where the study area is highlighted. As illustrated in Figure 11-1, the stations in the study area are all located near the center of the 16-county area. Additional stations outside the study area were located to define any regional trends. The four stations located outside the study area are the closest stations to the study area that had at least 20 years of peak wind gust data.

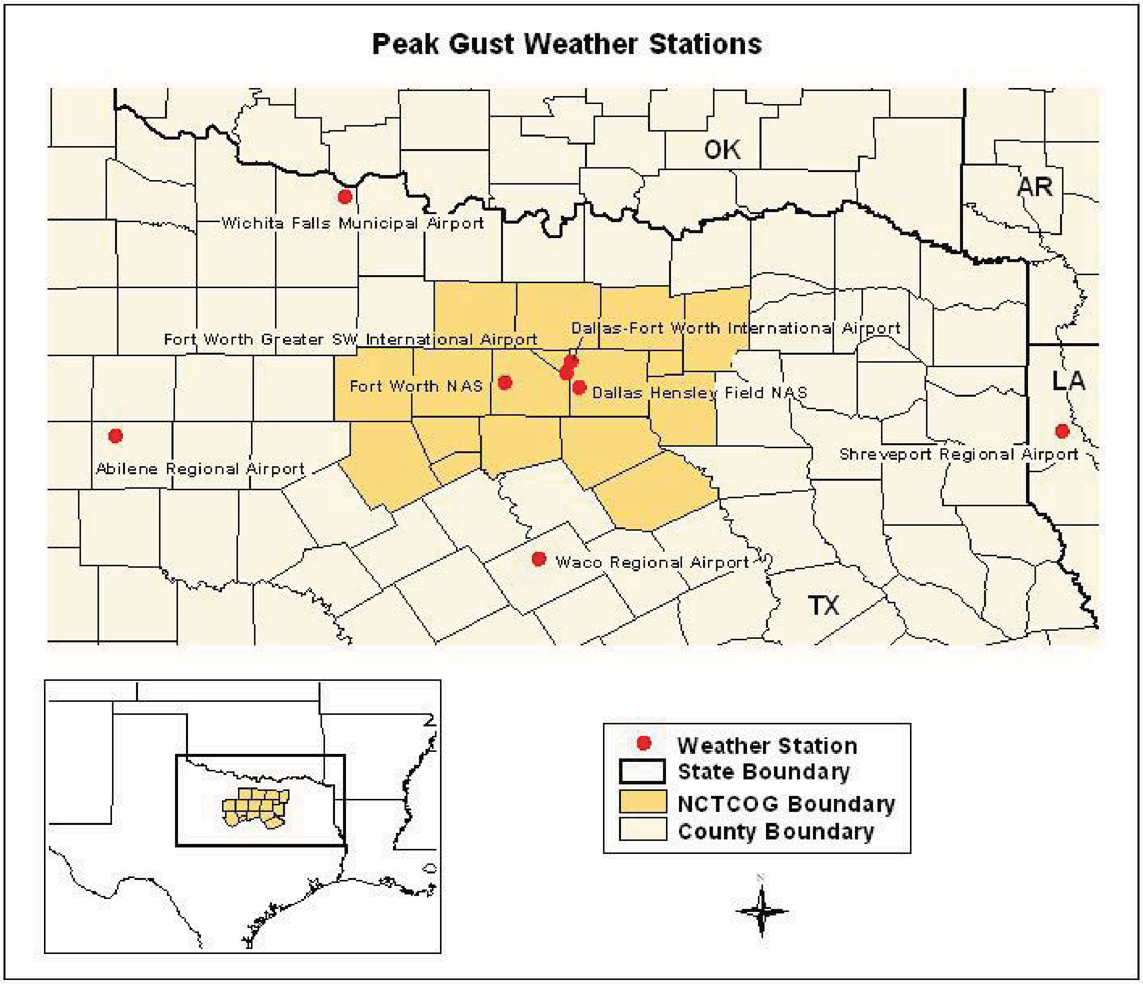


Figure 11-1. Location of the climatic stations and the study area in North Central Texas

The wind speeds are characterized by the peak gusts in miles per hour. For the eight stations in Table 11-1, two data sets were assembled that includes the annual maximum peak gusts and the top peak gusts above a threshold. For the latter data base, at least the top 100 peak gusts were compiled regardless of the year of occurrence. Both data sets were analyzed to determine which one provided the most reasonable results.

Analysis Approach: The 2-, 10-, 50-, and 100-year peak gusts were estimated using four methods for both the annual maximum and peak gusts above a threshold data series. The four methods included fitting the two data series to the Pearson Type III and Generalized Pareto distributions, and using both the Weibull and Cunnane plotting positions. The Pearson Type III distribution was used because it is a flexible three parameter distribution used in flood frequency analysis and procedures for fitting the distribution are well documented in Bulletin 17B (Interagency Advisory Committee on Water Data, 1982). The Generalized Pareto distribution was used because it has been used to define the frequency of peak wind gusts above a threshold (Rosbjerg and Madsen, 1992; Heckert and others, 1998; and Barton and Nishenko, 1994).

Plotting position formulas can be used to determine the recurrence intervals of climatic and hydrologic data, independent of using a theoretical frequency distribution. The basic plotting position formula for determining the recurrence interval in years is (N+1-2a) / (m-a) where N is the years of record, m is the rank with m=1 for the largest value, and "a" is constant unique to a given plotting position. The two plotting positions used for this study were the Weibull plotting position (N+1/m) with a=0 and the Cunnane plotting position (N+0.2)/(m-0.4) with a=0.4. The Weibull plotting position was used because it is very intuitive where the largest event in 100 years is assigned a recurrence interval of 101 years. The Cunnane plotting position was used because it is an unbiased plotting position and is a relatively distribution-free plotting position, implying it is appropriate when the underlying distribution of the data is not known (Cunnane, 1978). For the Cunnane plotting position, the largest event in 100 years is assigned a recurrence interval of 167 years.

Analysis Results: The plotting position formulas were applied by plotting the peak gust wind speeds versus recurrence interval on log-log paper. This approach is equivalent to fitting the data to a Generalized Pareto distribution because, for this distribution, the logarithms of the peak gust wind speed is linearly related to the logarithms of recurrence interval. The peaks above a threshold had a more linear relation with recurrence interval than the annual maximum data. This happening is illustrated in the following two graphs using data for Dallas Hensley Field in Dallas County.

Figure 11-2 is a plot of the logarithms of peak gusts above a threshold versus the logarithms of recurrence interval and this relation is shown to be nearly linear. Peak wind gusts for various recurrence intervals were estimated with the equation given in Figure 11-2. These estimates are summarized later for all eight stations.

Figure 11-3 is a plot of the logarithms of the annual maximum data versus the logarithms of the recurrence interval and this relation is not nearly as linear as the relation in Figure 11-2. Similar results were found for all eight stations. For this reason, the peaks above a threshold were chosen as the preferred data series for the final frequency analysis.

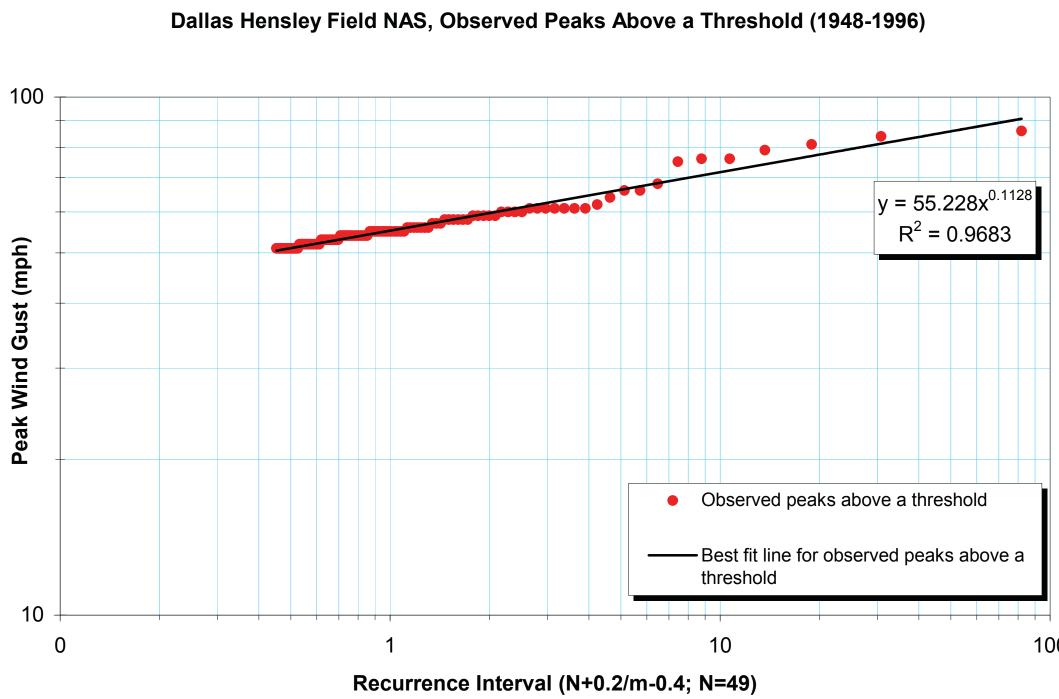


Figure 11-2. Frequency curve based on the Cunnane plotting position of the peak wind gusts above a threshold for Dallas Hensley Field in Dallas County for the period 1948 to 1996

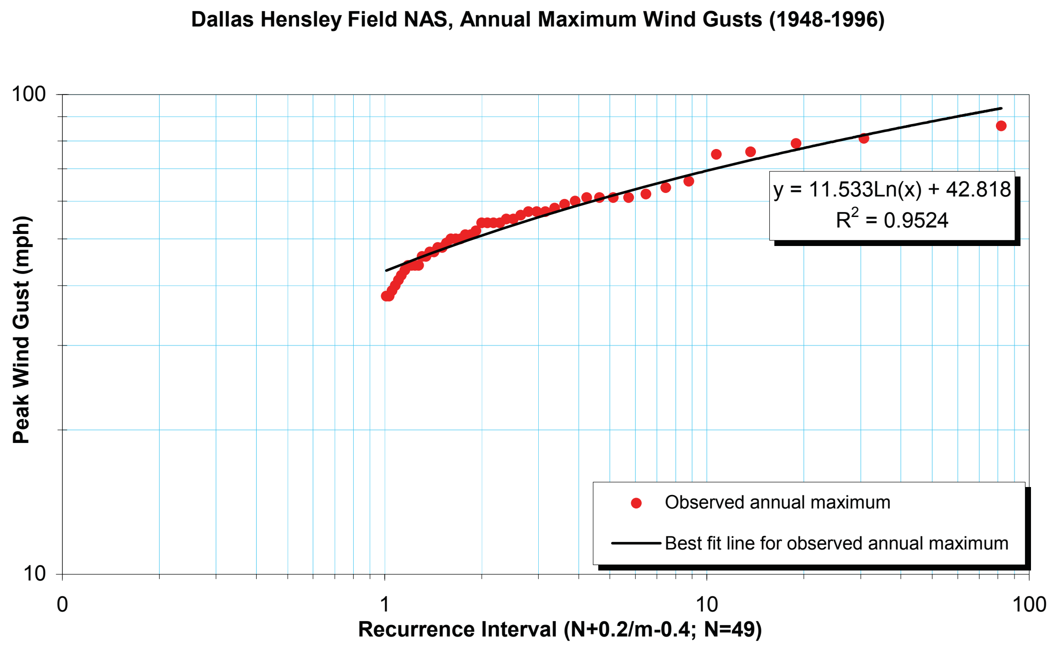


Figure 11-3. Frequency curve based on the Cunnane plotting position of the annual maximum peak gusts for Dallas Hensley Field in Dallas County for the period 1948 to 1996

The 2-, 10-, 50-, and 100-year recurrence interval events for peak gusts above a threshold are summarized in Table 11-2 for the four frequency methods. As can be noted in Table 11-2, the peak wind gust estimates from the two plotting positions are consistently higher than for the two frequency distributions. The plotting position formulas were considered the better estimates based on a comparison with the data. Furthermore, the Cunnane plotting position was considered the best approach because this formula provides unbiased estimates and agrees more closely with the frequency distribution estimates.

As can be noted in Table 11-2, the frequency estimates for the stations with 21-23 years of record are also significantly less than similar estimates for the three stations with 43 or more years of record (Wichita Falls, Dallas Hensley Field, and Shreveport, LA). This is a result of time sampling error where the short record stations did not experience some of the more severe events that were recorded at the long-term stations. Therefore, the three stations with 43 or more years of record were used to determine the magnitude and frequency of peak wind gusts for the 16-county study area. The 2-, 10-, 50- and 100-year peak wind gusts for the three long-term stations are shown in Figure 11-4.

The variation in frequency estimates is minor from Wichita Falls to Dallas Hensley Field (see Figure 11-4 and Table 11-2). There is a more significant decrease in frequency estimates from Dallas Hensley Field to Shreveport, LA but the distance between the two stations is greater. The values in Figure 11-4 indicate that the frequency estimates are essentially constant across the 16-county study area. Therefore, it is reasonable to use the frequency estimates for Dallas Hensley Field, shown in Figure 11-2, as being representative of the study area.

The implication is that the wind hazard does not vary significantly over the 16-county study but does change outside the study area as reflected by three long-term stations in Figure 11-4. As shown in Figure 11-2 and Table 11-2, the 2-year event is 60 miles per hour (mph), the 10-year event is 72 mph, the 50-year event is 86 mph, and the 100-year event is 93 mph for the study area.

Table 11-2. Summary of frequency estimates for the eight stations based on the peak wind gusts above a threshold

Distribution or method:	Pearson Type III	Pareto	Weibull PP	Cunnane PP
Location (years of record)				
Dallas Hensley Field (49)				
2-year estimate (mph):	54	55	60	60
10-year estimate (mph):	66	65	72	72
50-year estimate (mph):	78	78	87	86
100-year estimate (mph):	84	84	95	93
Dallas-Fort Worth Int'l AP (21)				
2-year estimate (mph):	44	44	52	51
10-year estimate (mph):	52	52	61	61
50-year estimate (mph):	60	60	73	71
100-year estimate (mph):	64	64	78	76
Fort Worth Greater SW Int'l AP (21)				
2-year estimate (mph):	50	51	62	61
10-year estimate (mph):	61	61	75	74
50-year estimate (mph):	74	73	91	89
100-year estimate (mph):	80	79	99	97
Fort Worth NAS (20)				
2-year estimate (mph):	47	44	59	59
10-year estimate (mph):	57	56	78	77
50-year estimate (mph):	81	74	103	100
100-year estimate (mph):	92	85	116	113
Waco Regional AP (21)				
2-year estimate (mph):	43	43	51	51
10-year estimate (mph):	51	50	60	59
50-year estimate (mph):	61	59	70	69
100-year estimate (mph):	66	64	75	74
Shreveport Regional AP (43)				
2-year estimate (mph):	51	51	58	58
10-year estimate (mph):	62	62	70	69
50-year estimate (mph):	72	74	82	81
100-year estimate (mph):	76	79	87	86
Abilene Regional AP (23)				
2-year estimate (mph):	45	45	53	53
10-year estimate (mph):	53	53	63	63
50-year estimate (mph):	61	62	76	74
100-year estimate (mph):	65	67	82	80
Wichita Falls Municipal AP (43)				
2-year estimate (mph):	56	55	61	61
10-year estimate (mph):	66	65	74	73
50-year estimate (mph):	76	77	89	87
100-year estimate (mph):	81	83	96	94

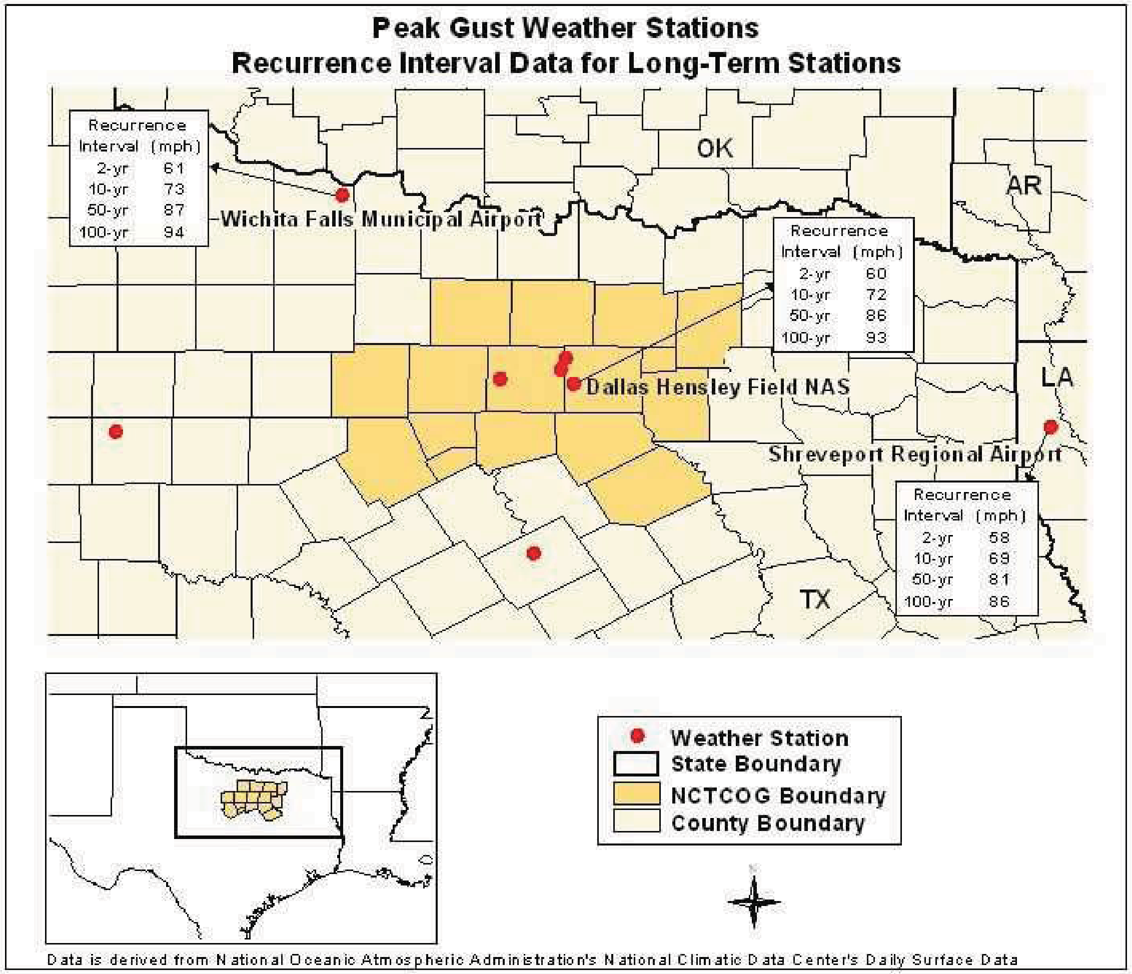


Figure 11-4. Frequency estimates at the three long-term stations based on the Cunnane plotting position for the peak wind gusts above a threshold

The two long-term stations outside the study area that were used in Figure 11-4 are Wichita Falls and Shreveport, LA. The frequency curves for these two stations based on the peak wind gusts above a threshold are given in Figure 11-5 and Figure 11-6. The 2-, 10-, 50- and 100-year estimates are given in Table 11-2 for these two long-term stations.

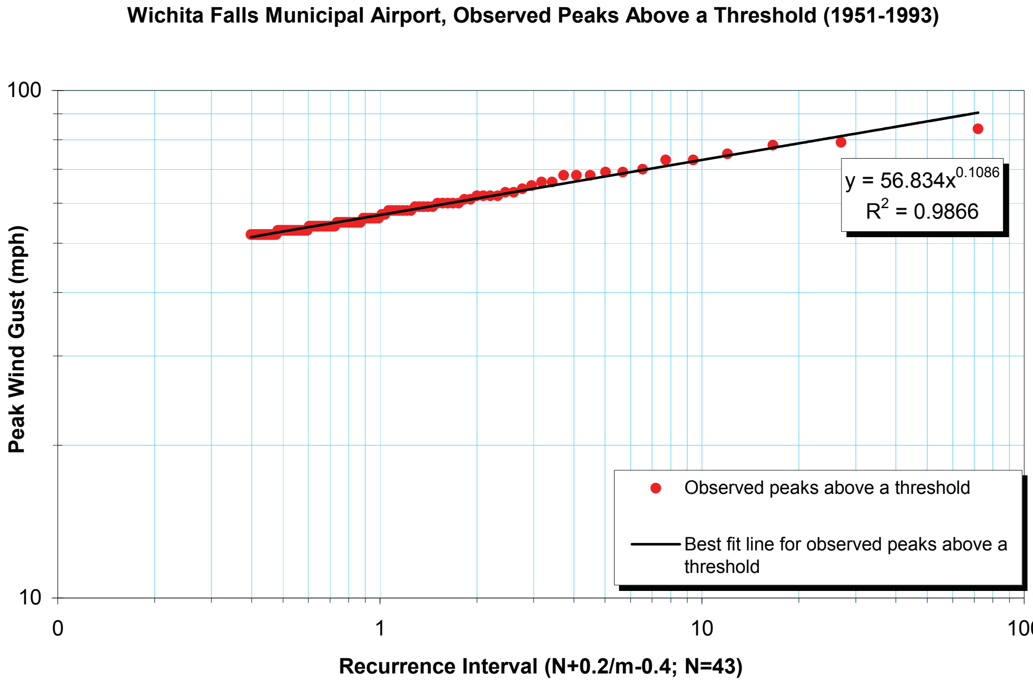


Figure 11-5. Frequency curve based on the Cunnane plotting position of the peak wind gusts above a threshold for Wichita Falls Municpal Airport for the period 1951 to 1993

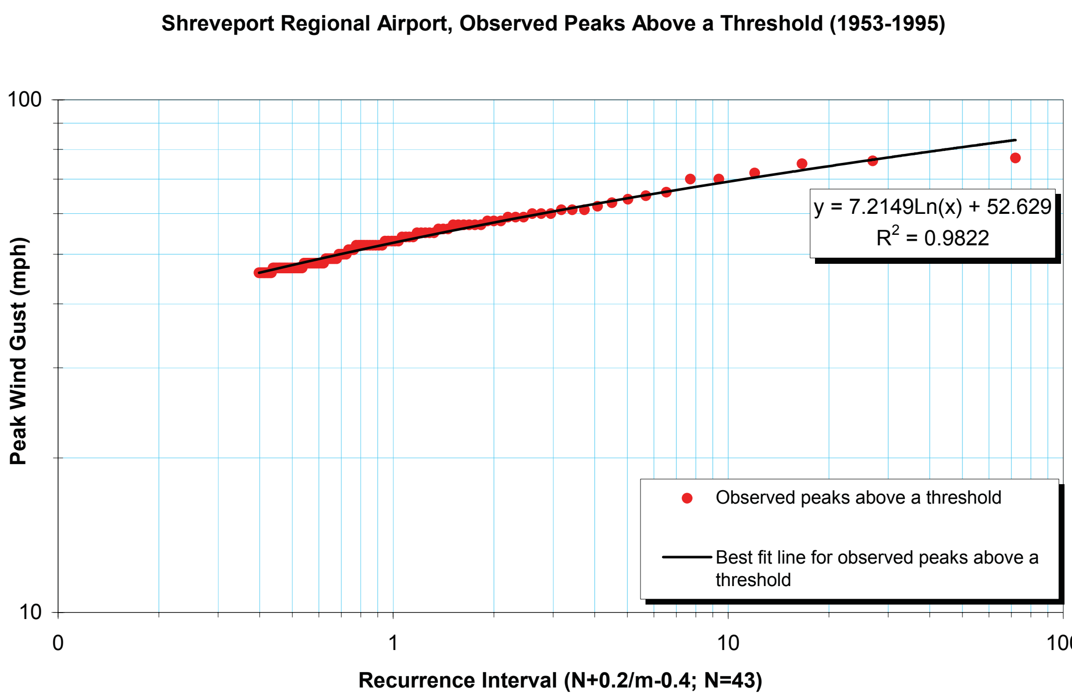


Figure 11-6. Frequency curve based on the Cunnane plotting position of the peak wind gusts above a threshold for Shreveport Regional Airport for the period 1953 to 1995

Summary Frequency analyses were performed at eight climatic stations in and around the 16-county study area using annual maximum wind gusts and peak wind gusts above a threshold. Frequency estimates for the 2-, 10-, 50- and 100-year events were made by fitting the two data series to a Pearson Type III frequency distribution, a Generalized Pareto distribution, and using the Weibull and Cunnane plotting positions. Comparison of these frequency estimates to the data indicated that the most defensible analysis approach was the use of peaks above a threshold using the Cunnane plotting position.

There were four climatic stations in Dallas and Tarrant Counties that had 20 or more years of peak wind gust record. Because these stations were located in the center of the study area, data for four additional stations were obtained to define any regional variation across the study area. The frequency estimates for the five stations with 21-23 years of record were significantly less than the three long-term stations with 43 years or more of record. The differences were attributed to the fact that some of the more significant wind events were not observed at the short record stations. The three long-term stations were used for the final frequency analysis. The variation in frequency estimates across the study area were not significant and the long-term station at Dallas Hensley Field was used to define the magnitude and frequency of peak wind gusts in the study area. As shown in Figure 11-2 and Table 11-2, the 2-year event is 60 miles per hour (mph), the 10-year event is 72 mph, the 50-year event is 86 mph, and the 100-year event is 93 mph for the study area.

Based on a qualitative analysis of the impacts from historical high wind events and based on a quantitative analysis of the magnitude and frequency of historical high wind events, the risk of a high wind hazard is both significant and uniform across the NCTCOG region; thus, high wind hazards deserve mitigation consideration.

References:

Barton, C., and Nishenko, S., 1994, *Natural Disasters – Forecasting Economic and Life Losses: Selected Issues in the USGS Marine and Coastal Geology Program*, Denver Federal Center, Denver, Colorado, 4 p.

Cunnane, C., 1978, *Unbiased Plotting Positions – A Review: Journal of Hydrology*, Vol. 37, pp. 205-222.

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment*. Atmospheric Chapter 4.

Heckert, N.A., Simiu, E., and Whalen, T., 1998, *Estimates of Hurricane Wind Speeds by "Peaks Over Threshold" Method*: ASCE Journal of Structural Engineering, Vol. 124, No. 4, pp. 445 to 449.

Interagency Advisory Committee on Water Data, 1982, *Guidelines For Determining Flood Flow Frequency*: Bulletin 17B of the Hydrology Subcommittee, Office of Water Data Coordination, U.S. Geological Survey, Reston, Virginia, 183 p.

National Oceanic and Atmospheric Administration Storm Prediction Center (NOAA SPC). (2003). *Storm Prediction Center Archives – Historical Severe Weather Data*. Retrieved July 2003 from http://www.spc.noaa.gov/archive/

Rosbjerg, D., and Madsen, H., 1992, *Prediction in Partial Duration Series with Generalized Pareto-Distributed Exceedances*: Vol. 28, No. 11, pp. 3001-3010.

HazMAP

Chapter 12 Selected Severe Weather Hazards: Lightning

Hazard Identification Thunderstorm and lightning events are generated by atmospheric imbalance and turbulence due to the combination of the following conditions: unstable warm air rising rapidly into the atmosphere; sufficient moisture to form clouds and rain; and upward lift of air currents caused by colliding cold and warm weather fronts, sea breezes or mountains.

Lighting is generated by the buildup of charged ions in a thundercloud, and the discharge of a lightning bolt interacts with the best conducting object or surface on the ground. The air channel of a lightning strike reaches temperatures higher than 50, 000 degrees Fahrenheit. The rapid heating and cooling of the air near the channel causes a shock wave, which produces thunder.

Lightning damage can result in electrocution of humans and animals; vaporization of materials along the path of the strike; fire caused by the high temperature produced by the strike and a sudden power surge that can damage electrical and electronic equipment. Millions of dollars of direct and indirect damages result from lightning strikes on electric utility substations and distribution lines. While property damage is the major hazard associated with lightning, it should be noted that lightning strikes kill nearly 100 people each year. Richard Kithil, President and CEO of the National Lightning Safety Institute, says that "accurate information [about lightning-induced damage] is elusive" but that "on-going research suggests realistic lightning costs and losses may reach $4-5 billion per year" due to lightning's role in forest fires, structure fires, hazardous materials storage incidents, aircraft-related in-flight mishaps, airline delays, power outages, and electrical infrastructure malfunctions.

Risk Assessment Thunderstorms and lightning strikes occur nearly everywhere in the United States. Florida has the highest occurrence of lighting strikes due to the frequency of thunderstorms in the area, followed by Southern Alabama, Northeastern New Mexico and Northern Arizona.

Texas recorded 150, 115, and 107 deaths due to lightning in the 1960s, 1970s, and 1980s respectively. Between 1959 and 1994, 334 injuries were reported in Texas, ranking the state 8^{th} in the country.

As an example of the kind of impacts that lightning can have on the NCTCOG region, one needs to look no further than Tuesday, August 12, 2003. On that evening, lightning associated with a violent thunderstorm wreaked havoc in Fort Worth. Lightning strikes were responsible for starting four major structure fires in the city. Additionally, a 19-year-old man was directly killed by a lightning strike in southwest Fort Worth when he attempted to go jogging soon after the rain from the thunderstorm had passed.

Further research for this risk assessment revealed that historic lightning event data are available from the private sector at considerable expense. Alternately, one historic lightning event dataset is available publicly (NOAA's Storm Events database), but this dataset is extremely limited because it lists only 62 recorded lightning events in the NCTCOG region between 1996 and 2003. Thus, given the limited resources of this current planning cycle and the limited availability of public data, a quantitative assessment was not feasible. Instead, we chose a simple, qualitative approach in order to acknowledge the obvious fact that lightning hazards occur throughout the NCTCOG region.

Summary Since every thunderstorm produces lightning and since the north central Texas region lies in Tornado Alley where thunderstorms are a frequent occurrence, one assumes that lightning is a natural hazard that deserves mitigation consideration throughout the region.

References:

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment.* Atmospheric Chapter 2

Kathryn Field (interviewer). Telephone interviews and e-mail correspondence with representatives of Vaisala (www.lightningstorm.com). July and August 2003.

Kithil, Richard. *Annual USA Lightning Costs and Losses*. Retrieved November 7, 2003 from the National Lightning Safety Institute website at http:www.lightningsafety.com/nlsi_lls/nlsi_annual_usa_losses.htm

National Weather Service (NWS). (August 2003) *Lightning the Underrated Killer.* Retrieved September 15, 2003 from http://www.crh.noaa.gov/fsd/lightning.htm.

NOAA Technical Memorandum NWS SR-193 (NOAA). (October 1997). *Lightning Fatalities, Injuries, and Damage Reports in the United States From 1959-1994*. Retrieved September 16, 2003 from http://www.nssl.noaa.gov/papers/techmemos/NWS-SR-193/techmemo-sr193.html

HazMAP

Chapter 13 Selected Severe Weather Hazards: Severe Winter/Ice Storm

Hazard Identification Winter storms originate as mid-latitude depressions or cyclonic weather systems, sometimes following the path of the jet stream. A winter storm or blizzard, combines heavy snowfall, high winds, extreme cold and ice storms. Many winter depressions give rise to exceptionally heavy rain and widespread flooding and conditions worsen if the precipitation falls in the form of snow. The winter storm season varies widely, depending on latitude, altitude and proximity to moderating influences.

The occurrence of large snowstorms, ice storms and severe blizzards can have a substantial impact on communities, utilities and transportation systems, often resulting in the loss of life due to accidents of hypothermia. Heavily populated areas are at high risk because the severe weather can cause communication and power lines to go down. High levels of snow can accumulate, building faster than it can be cleared and heavy icing can impact utility systems and transportation routes. Damage to buildings often occurs in areas where the normally anticipated snowfall depths are not considered in building codes. Roof collapses damage residential, commercial and industrial structures.

The degree of exposure to severe winter storms depends on the normal severity of the region's winter weather. Nearly the entire United States, with the exception of the extreme southern states, Hawaii and the U.S, territories can be affected by severe winter storms. Alaska, the Upper Midwestern and Northeastern states tend to be more susceptible than others, but generally these regions are better prepared for severe winter weather. The regions where extreme winter weather is less common tend to experience more damage and disruption when the storms hit.

Areas along the Gulf Coast and Southeast regions of the United States are generally unaccustomed to snow, ice, and freezing temperatures. Once in a while, cold air penetrates south across Texas and Florida, into the Gulf of Mexico. Temperatures fall below freezing killing tender vegetation, such as flowering plants and the citrus fruit crop. Wet snow and ice rapidly accumulate on trees with leaves, causing the branches to snap under the load. Motorists are generally unaccustomed to driving on slick roads and traffic accidents increase. Some buildings are poorly insulated or lack heat altogether. Local municipalities may not have available snow removal equipment or treatments, such as sand or salt, for icy roads.

While snowstorms are not frequent in Texas, ice storms create dangerous driving conditions, may freeze pipes and down power lines. On January 2001, a severe ice storm caused Hunt County to declare a Presidential Disaster Declaration. A north eastern Texas ice storm ending on January 2, 1979, which had lasted 6 days, was said to be the worst ice storm in Texas in 30 years. An eastern Texas ice storm ending on January 1, 1999 caused power outages lasting more than two days.

Risk Assessment:
Magnitude and Frequency of Winter Ice Storms in North Central Texas

Winter ice storms occur in North Central Texas when precipitation occurs during the winter and the temperature is near or below freezing. Ice accumulation is not measured or recorded at climatic stations operated by the National Weather Service (NWS). For this study, we used a combination of precipitation and minimum temperatures as a surrogate for winter ice storms or as a measure of potential winter ice storms. Daily precipitation and daily minimum temperature are measured and recorded at NWS first order climatic stations and are archived at the National Data Climatic Center (NCDC) in Asheville, North Carolina as part of the Daily Surface Data. In order to evaluate if daily precipitation and minimum temperature could be used to characterize winter ice storms, these data were retrieved for six climatic stations in Dallas and Tarrant Counties that had at least 20 years of data. These stations and their periods of record are given in Table 13-1. The locations of these stations are shown in Figure 13-1.

Summary Of National Weather Service Climatic Stations In Dallas And Tarrant Counties					
COUNTY	STATION_NAME	BGN_YR	BGN_MO	END_YR	END_MO
DALLAS	DALLAS LOVE FIELD	1948	1	2000	4
DALLAS	DALLAS HENSLEY FIELD NAS	1945	3	1997	4
TARRANT	BENBROOK DAM	1953	10	2003	4
TARRANT	DALLAS-FORT WORTH INTL AP	1974	10	2003	4
TARRANT	EAGLE MOUNTAIN LAKE	1978	4	2002	4
TARRANT	GRAPEVINE DAM	1953	10	2003	4

Table 13-1. Summary of National Weather Service climatic stations in Dallas and Tarrant Counties with 20 or more years of daily precipitation and minimum temperature data

There are other climatic stations with daily precipitation and minimum temperature in and around the 16-county study area. However, the objective was to retrieve data for a few stations and evaluate if this approach was feasible. Daily precipitation data were used in the analysis if the precipitation equaled or exceeded 0.25 inches and the minimum temperature for that day and the previous day were below 33 degrees Fahrenheit. The assumption was that if the minimum temperature were below 33 degrees for the previous and current day, then precipitation would likely occur as ice or freezing rain resulting in a winter ice storm.

Analysis Approach

The 2-, 10-, 50-, and 100-year precipitation values were estimated using both the Weibull and Cunnane plotting position formulas. Plotting position formulas can be used to determine the recurrence intervals of climatic and hydrologic data, independent of using a theoretical frequency distribution. The basic plotting position formula for determining the recurrence interval in years is (N+1-2a) / (m-a) where N is the years of record, m is the rank with m=1 for the largest value, and “a” is constant unique to a given plotting position. The Weibull plotting position is (N+1/m) with a=0 and the Cunnane plotting position is (N+0.2)/(m-0.4) with a=0.4.

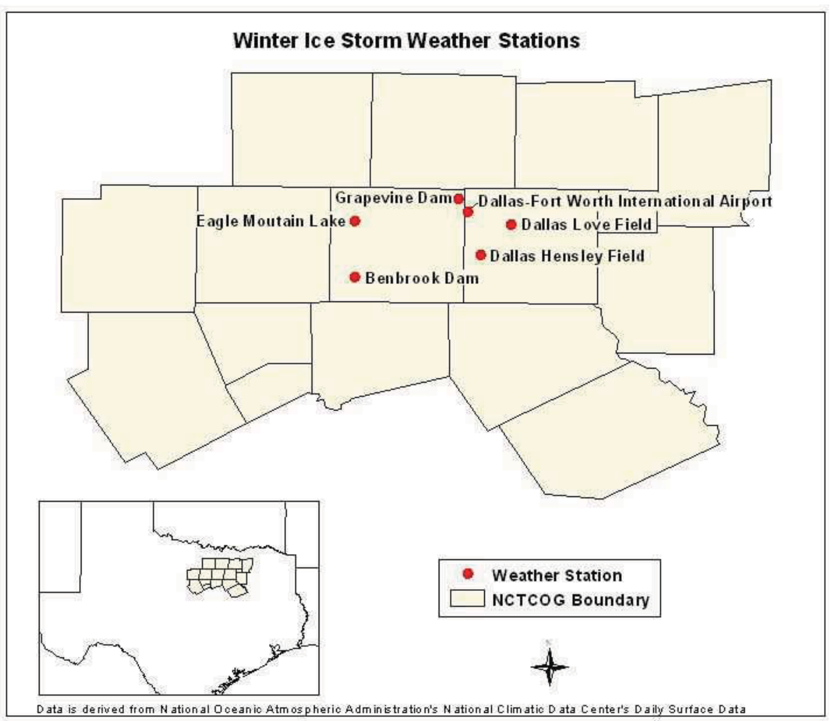


Figure 13-1. Locations of the six climatic stations in Dallas and Tarrant Counties with 20 or more years of daily precipitation and minimum temperature data

The Weibull plotting position was used because it is very intuitive where the largest event in 100 years is assigned a recurrence interval of 101 years. The Cunnane plotting position was used because it is an unbiased plotting position and is a relatively distribution-free plotting position, implying it is appropriate when the underlying distribution of the data is not known (Cunnane, 1978). For the Cunnane plotting position, the largest event in 100 years is assigned a recurrence interval of 167 years.

The data series of daily precipitation represents peaks above a threshold since only events in excess of 0.25 inches were selected where the minimum daily temperature was below 33 degrees for the previous and current day. For some years there were multiple events and there were no events for some years.

The peaks above a threshold were plotted versus recurrence interval on log-log paper. If the data fit a straight line on log-log paper, it is analogous to fitting the data to a Generalized Pareto distribution, a distribution used frequently for peaks above a threshold. Therefore, even though the precipitation data are not being fit to a frequency distribution, there is some theoretical basis for plotting precipitation values versus recurrence interval on log-log paper.

Analysis Results The frequency estimates based on the Cunnane plotting position were selected as being most reasonable in comparison to the observed data. For four of the six climatic stations, the precipitation data versus recurrence interval was approximately a straight line. An example is given in Figure 13-2.

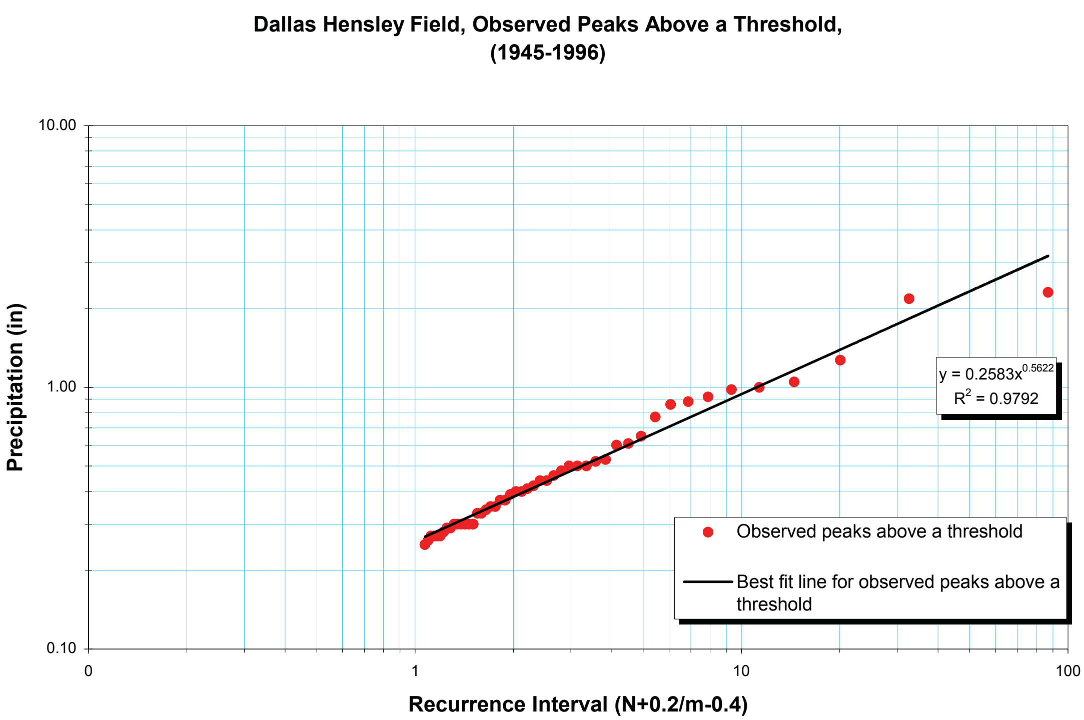


Figure 13-2. Frequency curve based on the Cunnane plotting position of precipitation values above a threshold for Dallas Hensley Field for the period 1945 to 1996.

The 2-, 10-, 50-, and 100-year precipitation values were estimated from the equation given in Figure 13-2. The estimates for Dallas Hensley Field and the other climatic stations are given later.

The plot of precipitation versus recurrence interval was not always as linear as the data given in Figure 13-2. An example of a nonlinear relation is given in Figure 13-3.

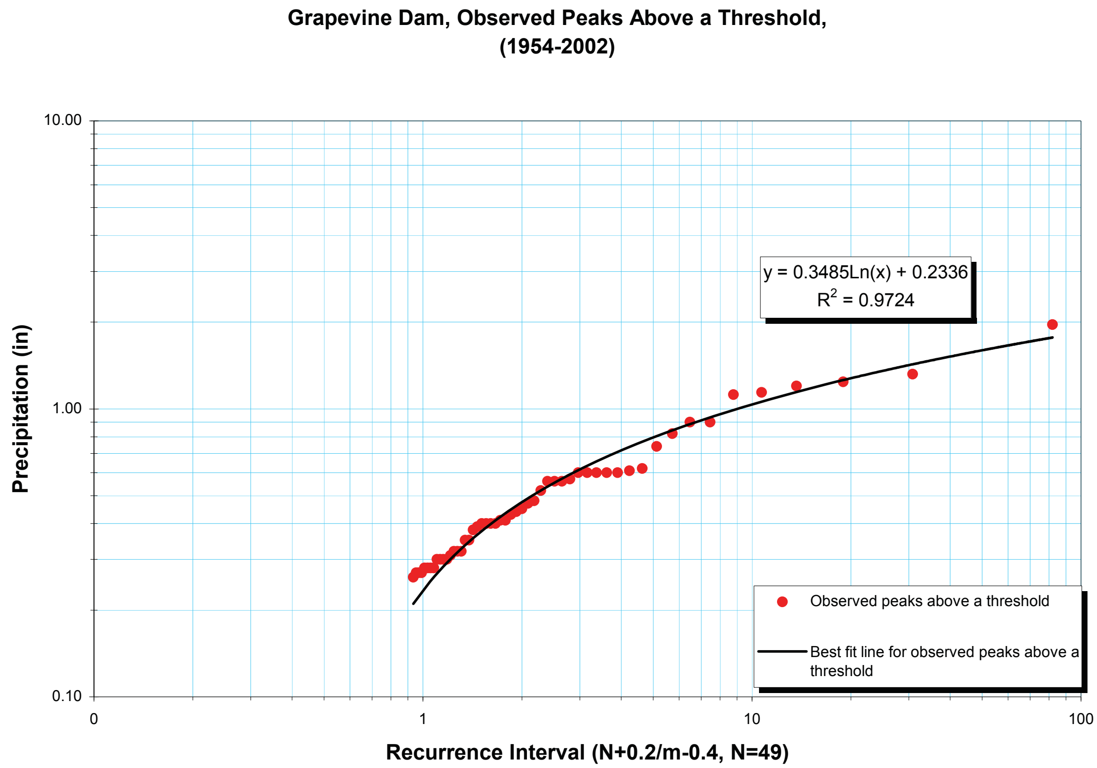


Figure 13-3. Frequency curve based on the Cunnane plotting position of precipitation values above a threshold for Grapevine Dam for the period 1954 to 2002

As illustrated in Figure 13-3, the relation between precipitation above a threshold and recurrence interval is not linear so precipitation was related to the logarithm of recurrence interval. As with the example in Figure 13-2, the 2-, 10-, 50-, and 100-year estimates were made using the equation in Figure 13-3.

The frequency estimates for all six climatic stations are given in Table 13-2 for both the Weibull and Cunnane plotting positions. The frequency curve plots for the other four climatic stations are illustrated in Figures 13-4, 13-5, 13-6, and 13-7.

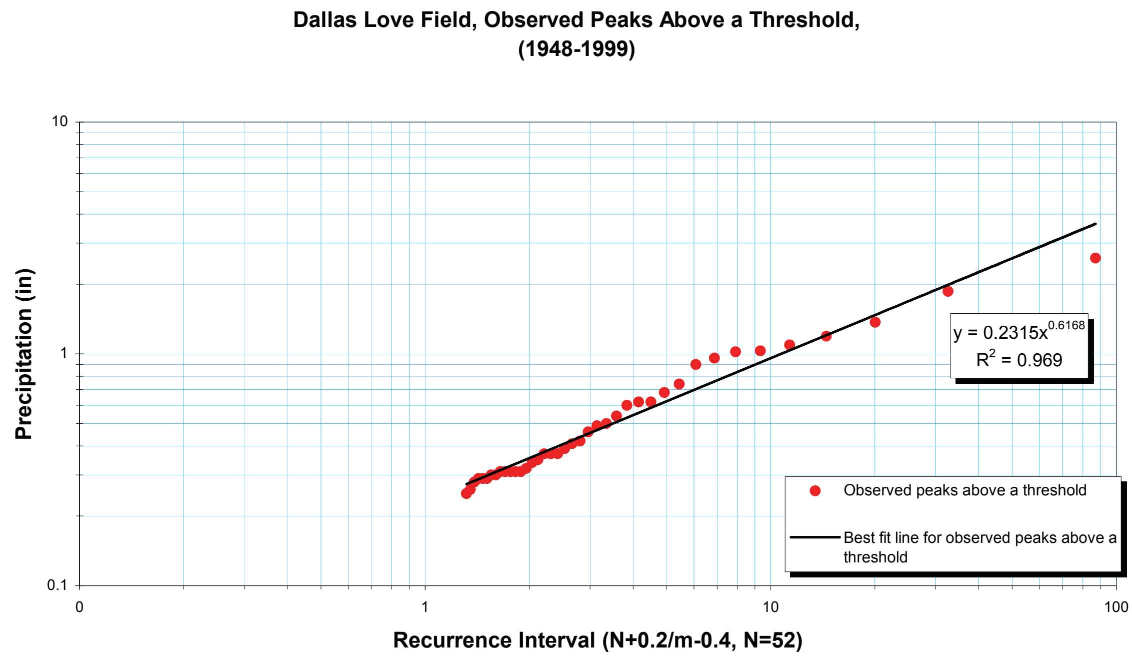


Figure 13-4. Frequency curve based on the Cunnane plotting position of precipitation values above a threshold for Dallas Love Field for the period 1948 to 1999

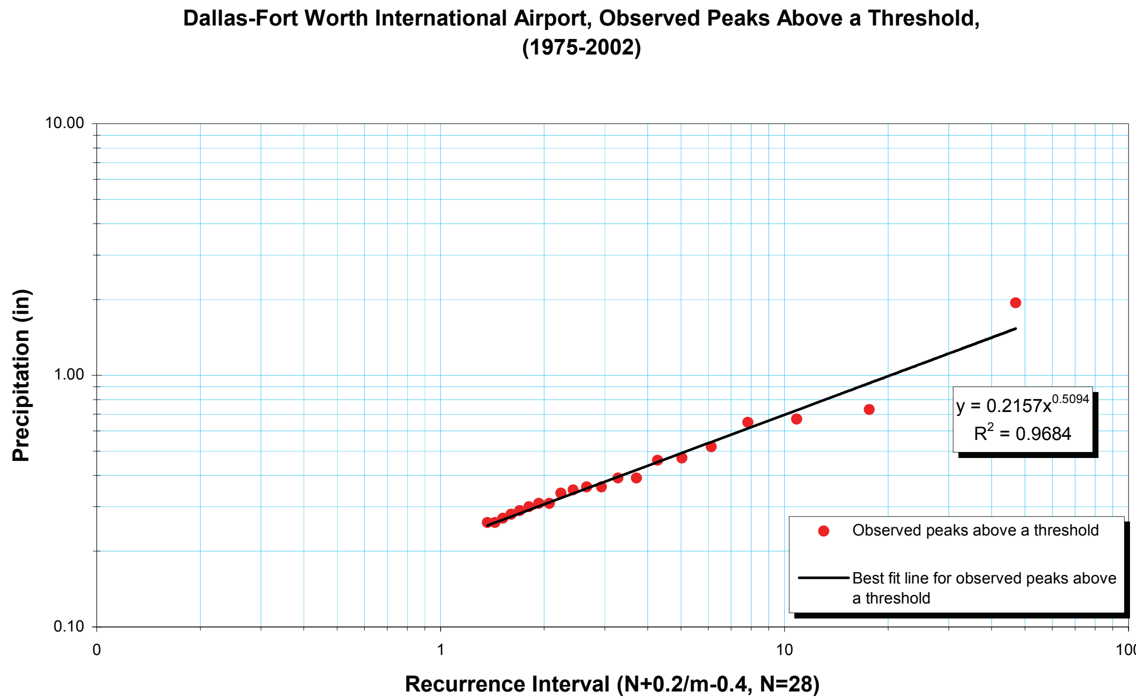


Figure 13-5. Frequency curve based on the Cunnane plotting position of precipitation values above a threshold for Dallas-Fort Worth International Airport for the period 1975 to 2002

Eagle Mountain Lake, Observed Peaks Above a Threshold, (1978-2002)

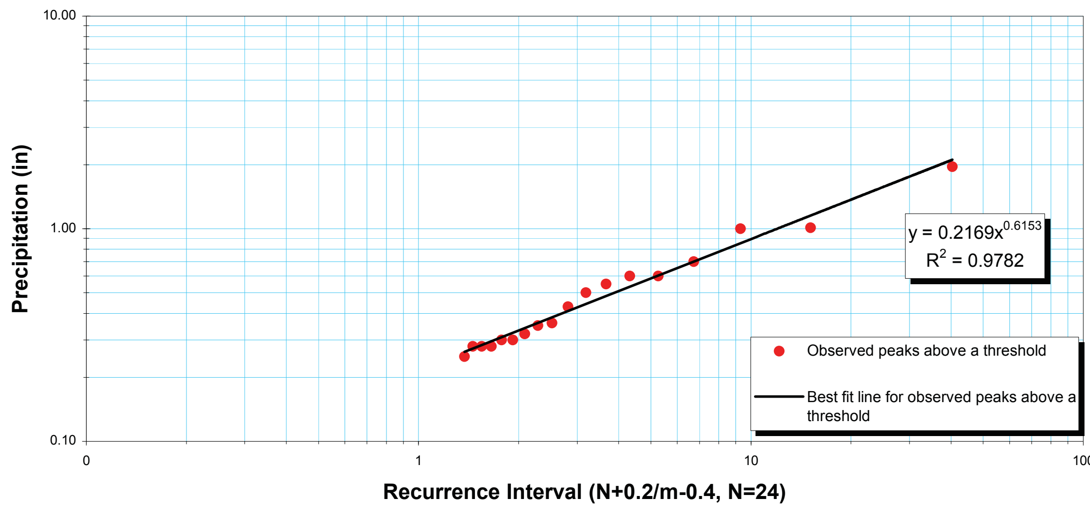


Figure 13-6. Frequency curve based on the Cunnane plotting position of precipitation values above a threshold for Eagle Mountain Lake for the period 1978 to 2002

Benbrook Dam, Observed Peaks Above a Threshold, (1954-2002)

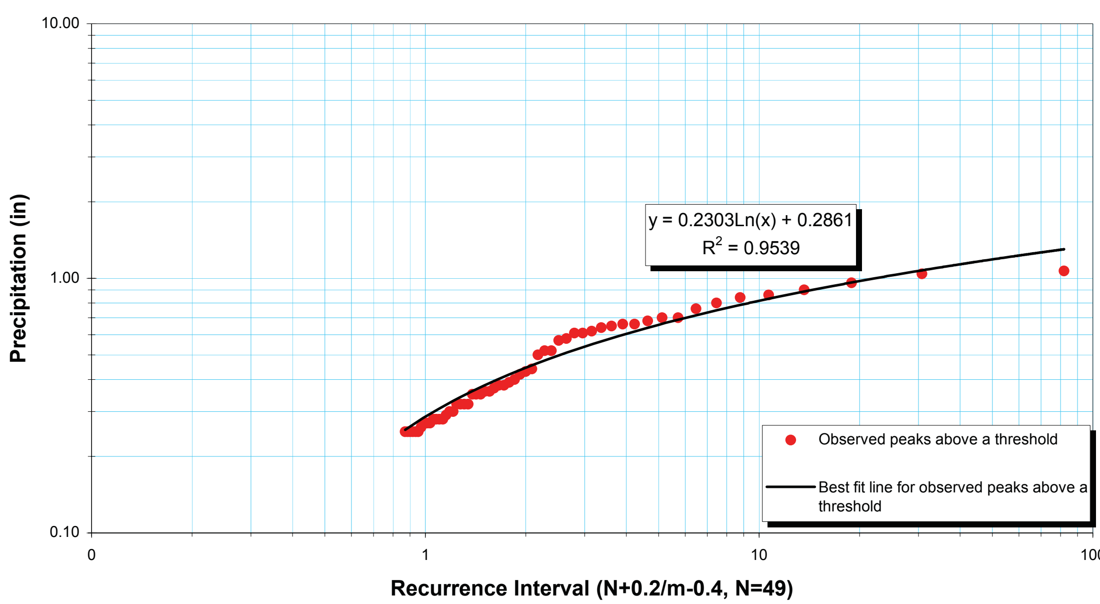


Figure 13-7. Frequency curve based on the Cunnane plotting position of precipitation values above a threshold for Benbrook Dam for the period 1954 to 2002

As illustrated in all of the frequency plots, the frequency curves are well defined up to at least the 10-year event. The frequency curves are not well defined in the range of the 50- and 100-year events. Two of the climatic stations, Dallas-Forth Worth International Airport and Eagle Mountain Lake, have 28 and 24 years of record, respectively, and extrapolation to the 50- and 100-year events is uncertain. For these reasons, the 10-year event based on the Cunnane plotting position was chosen to define the winter ice storm hazard.

Table 13-2. Summary of frequency estimates for two plotting positions for the six climatic stations based on the precipitation data above a threshold

	2-year estimate (inches)		10-year estimate (inches)		50-year estimate (inches)		100-year estimate (inches)	
Distribution:	Weibull	Cunnane	Weibull	Cunnane	Weibull	Cunnane	Weibull	Cunnane
Dallas Love Field (52)	0.35	0.35	1.04	0.96	3.05	2.59	4.86	3.96
Dallas Hensley Field (52)	0.38	0.38	1.01	0.94	2.67	2.33	4.07	3.44
Grapevine Dam (49)	0.48	0.48	1.07	1.04	1.67	1.60	1.93	1.84
Dallas-Fort Worth Int'l AP (28)	0.31	0.31	0.76	0.70	1.89	1.58	2.80	2.25
Eagle Mountain Lake (24)	0.33	0.33	1.01	0.89	3.12	2.41	5.06	3.69
Benbrook Dam (49)	0.45	0.45	0.85	0.82	1.24	1.19	1.42	1.35

The regional distribution of the 10-year event based on the Cunnane plotting position is shown in Figure 13-8. The values are also given in Table 13-2.

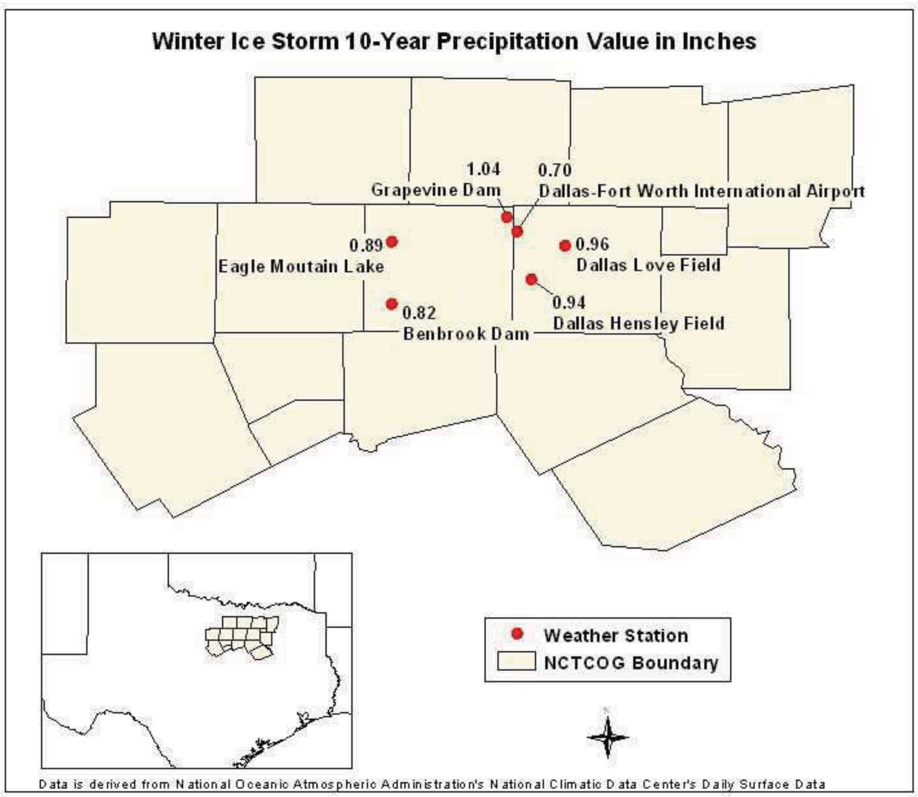


Figure 13-8. Regional distribution of the 10-year winter precipitation event

As illustrated in Figure 13-8, the largest variation in 10-year precipitation is between Grapevine Dam and Dallas-Fort Worth International Airport, two stations that are very close together. This variation may be due to time-sampling error as the latter station only has 28 years of record. If the estimates for the two stations are averaged, the result is 0.87 inches and the averaged results are more consistent with the other stations shown in Figure 13-8. There is a slight decrease in the 10-year precipitation in the westerly direction but the difference is within the uncertainty of the frequency estimates.

Based on data in Figure 13-8, one would conclude there is not a significant variation in the winter ice storm hazard across Dallas and Tarrant Counties, the only two counties for which analyses were performed. Additional data for other counties in and around the study area could be retrieved and analyzed and this would be helpful in defining any regional trends in the winter ice storm hazard across the 16-county study area.

Summary The analyses based on data for six climatic stations in Dallas and Tarrant Counties indicate that daily precipitation and minimum temperature can be used to define the winter ice storm hazard. The Cunnane plotting position approach was used for the final frequency estimates because this approach was most reasonable in comparison to the observed data. The 10-year event was used to characterize the winter ice storm hazard because the frequency curves were well defined up to at least the 10-year event. Above the 10-year event there was some scatter in the precipitation frequency curves and a resultant increase in the uncertainty of the estimates. The 10-year precipitation event was reasonably consistent across the two counties studied with a possible slight decrease in the westerly direction. The 10-year precipitation event is approximately 0.90 inches across Dallas and Tarrant Counties.

While analyzing additional data for climatic stations across the rest of the NCTCOG region would have helped to define a regional trend, such an analysis was beyond the scope and resources of this initial effort. However, in order to supplement the assessment of winter ice storm events on a regional level beyond just Dallas and Tarrant Counties, NCTCOG staff used available road condition advisories data from the Texas Department of Transportation (TXDoT). Taking into consideration that advisories occur when ice or snow accumulations make roadway travel unsafe and also taking into consideration that advisories are issued for roads ranging from minor arterials to major cross-regional highways, NCTCOG staff used the data to analyze the number of “ice/snow event” days per 1,000 road miles. HazMAP **map 13-1** illustrates road condition advisories due to winter weather events as issued by TXDoT for the period between 1995 and 2003. The map shows that all the counties in the region are at risk from winter ice storm hazards.

Based on a qualitative analysis of the impacts from historical severe winter ice storm events and based on a quantitative analysis of the magnitude and frequency of historical severe winter/ice storm events, the risk of a severe winter ice storm in the NCTCOG region is sufficient enough to merit mitigation consideration.

References:

American Lifelines Alliance (ALA). (2003). Ice Storm Summaries. Retrieved on September 15, 2003 from http://americanlifelinesalliance.org/pdf/IceStormSummaries.pdf

Cunnane, C., 1978, Unbiased Plotting Positions – A Review: Journal of Hydrology, Vol. 37, pp. 205-222.

Federal Emergency Management Agency (FEMA). (1997) Multi Hazard Identification and Risk Assessment. Atmospheric Chapter 7.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service. Winter Storms, the Deceptive Killers (November 1991) Retrieved September 15, 2003 from http://www.crh.noaa.gov/lot/webpage/nwsredcross.html

Hazard Identification Severe summer heat is characterized by a combination of a very high temperatures and exceptionally humid conditions. When persisting over a period of time, it is called a heat wave. Many areas of the country, including the NCTCOG study area, are susceptible to heat waves.

Risk Assessment The major human risks associated with severe summer heat include heatstroke, heat exhaustion, heat syncope, and heat cramps. Most at risk are outdoor laborers, the elderly, children, and people in poor physical health. The effects of severe summer heat are always more pronounced in urbanized areas than in rural areas. Within the urbanized MPA-Trinity of the NCTCOG study area, the problem is exacerbated by what is known as the heat island effect, in which the concrete and metal infrastructure absorbs radiant heat energy from the sun during the day and radiates that heat energy during the night. This cyclical process essentially “traps” the heat in the urbanized area and makes it as much as 10 degrees warmer than the surrounding hinterland.

In other parts of the country and other parts of the world, severe summer heat hazards can have devastating consequences. For instance, in 1995, a two-week-long heat wave hit Chicago, and the heat index peaked at 119 degrees Fahrenheit. There were 465 deaths directly attributable to the heat wave, and more than half of the victims were 75 years of age or older.

During the summer of 2003, a heat wave scorched Europe and killed more than 19,000 people, according to official estimates by the Associated Press. Throughout July and August, the heat wave set new records across Europe. France experienced temperatures up to 104 degrees, and southern Germany experienced temperatures of 105 degrees. London, England experienced 96 degrees, the hottest temperature in its history. The heat wave caused billions of dollars in property damage due to crop failures, livestock failures, wildfires and melting Alpine glaciers. But, by far, the greatest losses were human lives. The European heat wave of 2003 was one of the most deadly natural disasters of the past century.

During the summer months, the NCTCOG study area is frequently affected by severe heat hazards. Persistent domes of high pressure establish themselves over the study area, which set up hot and dry conditions. This high pressure prevents other weather features such as cool fronts or rain events from moving into the area and providing necessary relief. Daily high temperatures range into the upper 90’s and low 100’s. When combined with moderate to high relative humidity levels, the heat index moves into dangerous levels, and a heat index of 105 degrees is considered the level where many people begin to experience extreme discomfort or physical distress.

Severe summer heat is an invisible killer. Although a heat wave does not happen with the spectacle of other hazards such as tornadoes and floods, the National Center for Environmental Health reports that, from 1979 to 1999, excessive heat exposure caused 8,015 deaths in the United States. In other words, during this period, more people in the U.S. died from severe summer heat than from hurricanes, lightning, tornadoes, floods, and earthquakes combined.

A heat wave in Texas that broke all previous records occurred in the summer of 1980. There were 69 100-degree days, the most of any year. Additionally, the thermometer exceeded 100 at Dallas-Fort Worth

Airport on 42 consecutive days, from June 23rd to August 3rd. The warmest temperatures ever recorded the Dallas-Fort Worth area --- 113 degrees --- occurred June 26th and 27th. July averaged the warmest ever. There were 37 maximum temperatures that tied or set records, the most for a single year. There were 60 deaths statewide, and near 1300 nationwide.

In the summer of 2000, a ridge of high pressure established itself over the north central Texas region. During this time, the region suffered under the longest period of rain-free days in its history (84 consecutive days without rain) and also experienced a severe summer heat event (46 days with temperatures of 100 degrees or higher). This was a severe heat event because the north central Texas region normally only experiences about 15 days of 100 degree temperatures.

The summer of 1998 can also be called a severe heat event. The average high temperature from June through September was 100 degrees, and many of the 1998 statistics rank second only to the summer of 1980.

In the north central Texas region, many people are usually aware of the severe summer heat hazard and are accustomed to the potentially dangerous health effects. However, the region also frequently suffers from property damage due to severe summer heat. For example, during the extreme heat wave of 2000, a 30-inch water main ruptured under a street in downtown Dallas, spilling 20 million gallons of water, flooding many streets and buildings, and causing about $1.5 million in damage. In the summer of 2003, severe summer heat was blamed for two unrelated train derailments of Union Pacific trains in north Texas. According to Union Pacific officials, the causes of the derailments are “sun kinks,” which occur when severe heat expands the rail and moves it out of alignment.

Summary It is clear that the NCTCOG region has been and will continue to be affected by severe summer heat. Based on a qualitative analysis of the impacts that a severe summer heat hazard would have on the social, economic, and environmental components of the NCTCOG region, the risk of a severe summer heat hazard is sufficient enough to merit mitigation consideration.

Severe summer heat is also associated with other hazards such as poor air quality, drought, wildfire, expansive soil and water supply interruption. These associated hazards are individually addressed elsewhere in this document.

References:

Center for Disease Control and Prevention National Center for Environmental Health. (July 24, 2003) *Extreme Heat.* Retrieved September 13, 2003 from http://www.cdc.gov/nceh/hsb/extremeheat/

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment.* Atmospheric Chapter 8.

National Weather Service. *North Central Texas Annual Weather Review: 1980's.* Retrieved September 15, 2003 from http://www.srh.noaa.gov/fwd/climo/annreview/1980s.html

Associated Press. (September 26, 2003). *European Heat Wave Death Toll Tops 19,000*. The Michigan Daily.

HazMAP

Chapter 15 Selected Climatic Hazards: Drought

Hazard Identification

Drought can be defined as a water shortage caused by the natural reduction in the amount of precipitation which occurs over an extended period of time, usually a season or more in length. It can be aggravated by other factors such as high temperatures, high winds, and low relative humidity. The severity of drought can depend on the duration, intensity, geographic extent, and the regional water supply demands made by human activities and vegetation.

During severe droughts, agricultural crops do not mature, wildlife and livestock are undernourished, land values decline, and unemployment increases. Droughts can cause a shortage of water for human and industrial consumption, hydroelectric power, recreation, and navigation. Water quality may decline and the number and severity of wildfires may increase.

Droughts can be grouped as meteorologic, hydrologic, agricultural, and socioeconomic and are summarized below:

Meteorologic drought is defined solely on the degree of dryness, expressed as a departure of actual precipitation from an expected average or normal amount based on monthly, seasonal, or annual time scales.

Hydrologic drought is related to the effects of precipitation shortfalls on streamflows and reservoir, lake, and groundwater levels.

Agricultural drought is defined principally in terms of soil moisture deficiencies relative to water demands of plant life, usually crops.

Socioeconomic drought associates the supply and demand of economic goods or services with elements of meteorologic, hydrologic, and agricultural drought. Socioeconomic drought occurs when the demand for water exceeds the supply as a result of a weather related supply. The World Meteorological Organization calls this a water management drought, in which water supply shortages are caused by failure of water management practices or facilities to bridge normal and abnormal dry periods and equalize the water supply throughout the year. The incidence of this type of drought can increase because of a change in the amount of rainfall, a change in societal demands for water (or vulnerability to water shortages), or both.

Risk Assessment

According to Todd Votteler, Ph.D., a recognized expert in Texas water issues, “drought is the most complex, and least understood, of all natural hazards, affecting more people than do other natural hazards, but differing from them in important ways. Unlike earthquakes, hurricanes and tornadoes, drought unfolds at an almost imperceptible pace, with beginning and ending times that are difficult to determine, and with effects that often are spread over vast regions. Drought is also the most costly of all natural disasters. Agricultural losses in Texas from the 1996 drought have been estimated at $2 billion, and losses from the 1998 drought have been estimated at $2.1 billion, with some estimates much higher” (Votteler, 2000).

People throughout the United States in high-rainfall areas and low-rainfall areas may be subject to drought. Ironically, drought is considered by many to be a normal condition in Texas. In every decade of the last century, Texas was a victim of one or more serious droughts. The drought of the 1930’s caused significant declines in rangeland production, which was thought to have never fully recovered to pre-drought conditions. (Chenault, 1998). The severe to extreme drought that affected every region of Texas in the early to mid-1950s was the most serious drought to strike Texas in recorded weather history. In fact, the drought reached its worst in the late summer of 1956 in North Central Texas.

According to Votteler, Texas experiences so many droughts in part because of it location along 30 degrees north latitude, a climate transition zone called the Great American Desert (the same latitude where many of the earth's deserts are found). To help characterize drought frequency, Votteler cites a Texas Water Commission study which found that a drought with a duration of 6 months to a year is more likely to occur somewhere in Texas than average precipitation during the same period. A drought with a duration of 3 months is likely to occur in some part of the state every 9 months. A drought with a duration of 6 months or longer will likely occur once every 16 months, and a drought with a duration of 12 months is likely somewhere in the state once every 3 years. Over the past decade, in addition to the aforementioned droughts in 1996 and 1998, Texas also suffered droughts in 2000 and 2002. According to AgNews, Texas experienced agricultural losses (crop failures and additional indirect expenses incurred by ranchers) exceeding $1 billion in 2000 and $316 million in 2002.

Table 15-1

Droughts in North Central Texas: 1892-1996

Year	Drought Duration (in days)
1893	67
1901	70
1909	72
1910	64
1917	63
1924	73
1925	72
1943	72
1948	73
1954	68
1956	61
1963	63
1970	63

Source: Texas Almanac, 1998-99 Edition

Texas is divided into ten climatic divisions that range from substantially heavy precipitation through semi-arid to arid climates. The entire NCTCOG region lies within Climatic Division Number 3: North Central Texas.

Table 15-1 shows the duration of droughts in the North Central Texas Climatic Division between 1892 and 1994. For this purpose, droughts have been arbitrarily defined as when the area has less than 75 percent of the 1931-1960 average precipitation.

Table 15-2 shows the number of years of drought and the number of separate droughts in North Central Texas. According to this table, North Central Texas has had 12 drought years, consisting of eight 1-year droughts and two 2-year droughts for a total of 10 drought events.

Figure 15-1 shows a U.S. Drought Monitor summary map from the United States Department of Agriculture for August 19, 2003. Drought Monitor summary maps identify general drought areas, delineate drought impact types, and label droughts by intensity. Maps such as this one are updated weekly and can be obtained at the National Drought Mitigation Center website at http://drought.unl.edu/dm.

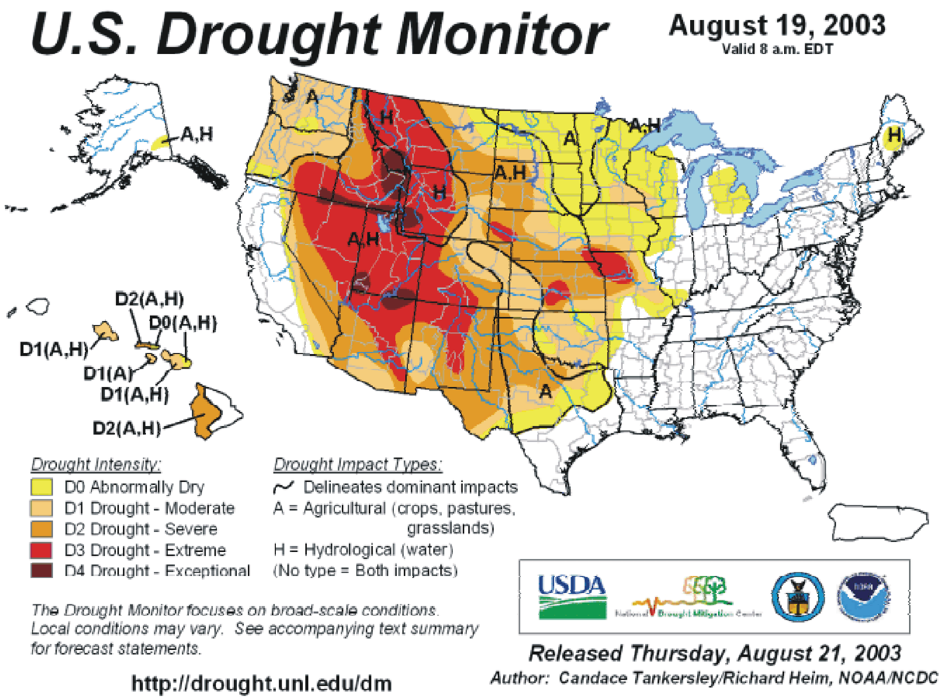
Table 15-2

Drought Frequency in North Central Texas: 1892-1996

Years	# of Droughts
1	8
2	2
3	-
Total Droughts	10
Total Drought Years	12

Source: Texas Almanac, 1998-99 Edition

Figure 15-1



The Palmer Drought Severity Index

The Palmer Index was developed by Wayne Palmer in the 1960s and uses temperature and rainfall information in a formula to determine dryness. It has become the semi-official drought index.
The Palmer Index is most effective in determining long term drought—a matter of several months—and is not as good with short-term forecasts (a matter of weeks). It uses a 0 as normal, and drought is shown in terms of minus numbers; for example, minus 2 is moderate drought, minus 3 is severe drought, and minus 4 is extreme drought.

The Palmer Index can also reflect excess rain using a corresponding level reflected by plus figures; i.e., 0 is normal, plus 2 is moderate rainfall, etc. The advantage of the Palmer Index is that it is standardized to local climate, so it can be applied to any part of the country to demonstrate relative drought or rainfall conditions. The negative is that it is not as good for short-term forecasts, and is not particularly useful in calculating supplies of water locked up in snow, so it works best east of the Continental Divide.

The Crop Moisture Index (CMI) is also a formula that was also developed by Wayne Palmer subsequent to his development of the Palmer Drought Index. The CMI responds more rapidly than the Palmer Index and can change considerably from week to week, so it is more effective in calculating short-term abnormal dryness or wetness affecting agriculture. CMI is designed to indicate normal conditions at the beginning and end of the growing season; it uses the same levels as the Palmer Drought Index.
It differs from the Palmer Index in that the formula places less weight on the data from previous weeks and more weight on the recent week.

The drought of record in Texas (the drought between 1950 and 1959) is illustrated below on the Palmer Drought Severity Index. The drought reached its worst in late summer of 1956 when the Palmer Index scale reached –6.53 in North Central Texas.

Figure 15-2

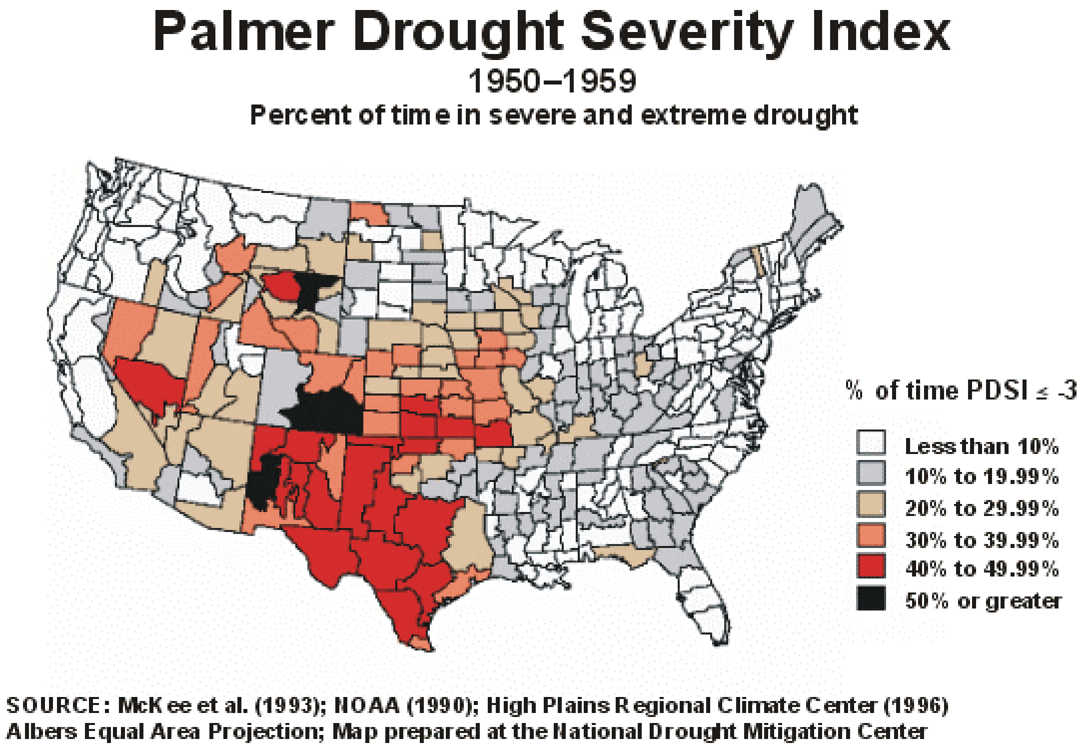
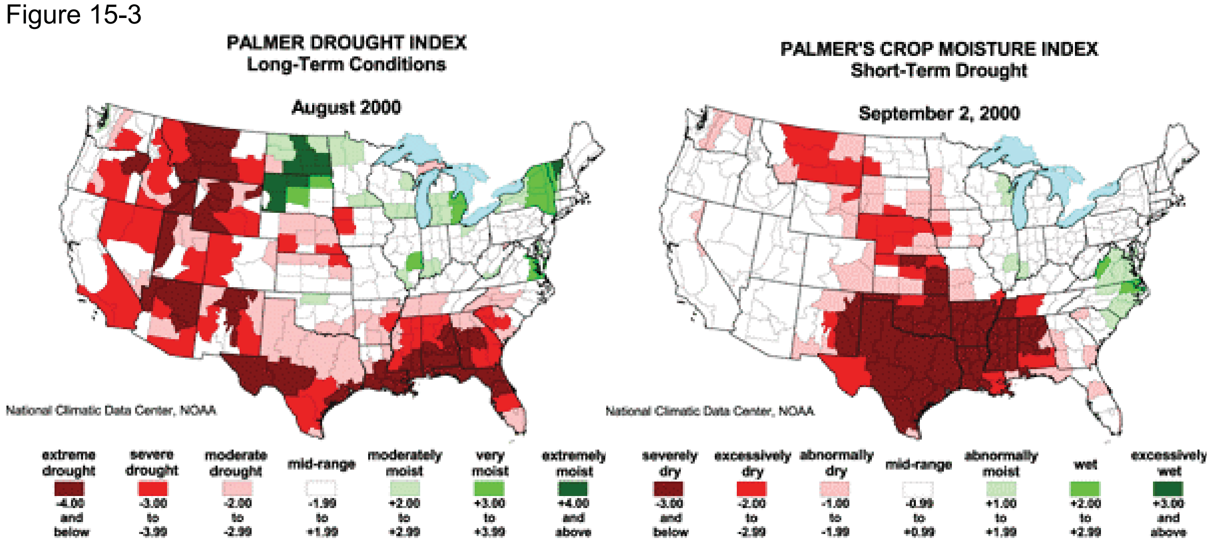


Figure 15-3 demonstrates how the summer 2000 drought can be represented differently by the Palmer Drought Index and the Palmer Crop Moisture Index. According to the Palmer Drought Index, north central Texas was experiencing only a moderate drought in August of 2000. But, according to Palmer's Crop Moisture Index, north central Texas was severely dry.

Figure 15-3



Summary It is clear that the NCTCOG region has been and will continue to be affected by drought.

Based on a qualitative analysis of the impacts that a drought would have on the social, economic, and environmental components of the NCTCOG region, the risk of a drought is sufficient enough to be considered for mitigation.

Because different types of drought are defined by various meteorologic, hydrologic, agricultural and socioeconomic factors, several other hazards such as extreme heat, wildfire, expansive soil, and water supply interruption can be associated with drought. These associated hazards are individually addressed elsewhere in this document.

References:

Chenault, Edith A. (June 1998) *Drought Impacting Texas Rangelands.* Retrieved September 15, 2003 from http://agnews.tamu.edu/dailynews/stories/ANSC/Jun2698a.htm

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment.* Hydrologic Hazards Chapter 15.

National Oceanic and Atmospheric Administration (NOAA). (2003) *The Palmer Drought Severity Index*. Retrieved October 15, 2003 from http://www.drought.noaa.gov/palmer.html

State of Texas—Division of Emergency Management. (2000) *Hazard Analysis*. Drought/Dust Storms, Section 5.

Texas A&M University Agriculture Program, AgNews. (June 12, 2002). *Drought Returns to Texas Agriculture, Resulting in $316 Million in Losses*. Retrieved September 15, 2003 from http://agnews.tamu.edu/dailynews/stories/DRGHT/Jun1202a.htm

Texas A&M University Agriculture Program, AgNews. (October 18, 2000). *Texas Drought Losses Exceed $1 Billion For 2000*. Retrieved September 15, 2003 from http://agnews.tamu.edu/dailynews

Votteler, T. (July 2000) *Drought Is a Normal Condition in Texas*. Texas Water Foundation. Retrieved August 17, 2003 from http://www.texaswater.org/water/drought/drought2.htm

HazMAP

Chapter 16 Selected Climatic Hazards: Wildland Fires

Hazard Identification A wildland fire is any fire occurring on grassland, forest, or prairie, regardless of ignition source, damages or benefits. According to the 2000 National Fire Plan, authorities now consider the wildland fire risk as “the most significant fire service problem of the Century.”

There are four categories of wildfires that are experienced throughout the United States described below.

- Wildland fires are fueled almost exclusively by natural vegetation. They typically occur in national forests and parks, where Federal agencies are responsible for fire management and suppression.
- Interface or intermix fires are urban/wildland fires in which vegetation and the built-environment provide fuel.
- Firestorms are events of such extreme intensity that effective suppression is virtually impossible. Firestorms occur during extreme weather and generally burn until conditions change or the available fuel is exhausted.
- Prescribed fires and prescribed natural fires are fires that are intentionally set or selected natural fires that are allowed to bum for beneficial purposes.

Fires can be caused by arson, debris burns, lightning strikes, (especially during a seasonal drought). Multiple fires can be started and can quickly become out of control. People are becoming more vulnerable to wildfires by choosing to live in wildland settings.

There are three principal factors that have a direct impact on the behavior of wildfires--topography, fuel and weather:

- Topography can have a powerful influence on wildfire behavior. The movement of air over the terrain tends to direct a fire's course. Gulches and canyons can funnel air and act as a chimney, intensifying fire behavior and inducing faster rates of spread. Similarly, saddles on ridgetops tend to offer lower resistance to the passage of air and will draw fires. Solar heating of drier, south-facing slopes produces upslope thermal winds that can complicate behavior.
- Fuels are classified by weight or volume (fuel loading) and by type. Fuel loading, often expressed in tons per acre, can be used to describe the amount of vegetative material available. If fuel loading doubles, the energy released also can be expected to double. Each fuel type is given a burn index, which is an estimate of the amount of potential energy that may be released, the effort required to contain a fire in a given fuel, and the expected flame length. Different fuels have different burn qualities. Some fuels burn more easily or release more energy than others. Grass, for instance, releases relatively little energy, but can sustain very high rates of spread.
- Weather. Of all the factors influencing wildfire behavior, weather is the most variable. Extreme weather leads to extreme events, and it is often a moderation of the weather that marks the end of a wildfire's growth and the beginning of successful containment. High temperatures and low humidity can produce very vigorous fire activity. The cooling and higher humidity brought by

sunset can dramatically quiet fire behavior. The rate of spread of a fire varies directly with wind velocity. Winds may play a dominant role in directing the course of a fire.

Risk Assessment

Despite increasing expenditures on wildland fire suppression over the last 20 years, the average acreage burned nationally has not decreased. As suppression expenditures have increased, there continue to be increases in loss of property and greater impacts to communities and the environment. Wildfires have destroyed millions of acres of forestland, burned homes, barns and other structures, injured and killed people, pets and wildlife. Recovery efforts have cost billions of dollars. It is impossible to assess fully the extent of wildfire damage due to incomplete reporting. The U.S. Forest Service, which compiles statistics for wildfires on Federal lands, is the primary Federal source of information.

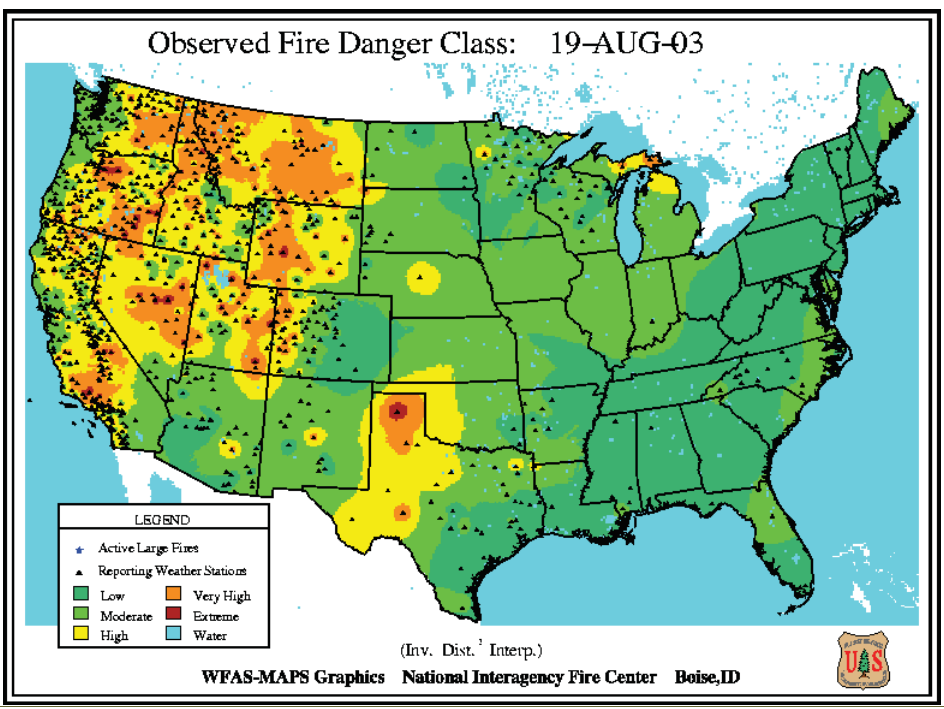
Economic impacts are increasing primarily because of the continuing growth of urban/wildland interface communities. In 1974, the problem of structure loss in wildfires was first comprehensively described as an issue of singular importance. Butler is credited with coining the term "urban/wildland (fire) interface" to describe this pattern of building loss resulting from vegetation fire exposure.

Twenty-five years later in a letter to the President after the devastating 1999-2000 fire season, the Secretaries of Agriculture and Interior wrote, "explosive growth in the wildland urban interface now puts entire communities and associated infrastructure, and the socioeconomic fabric that holds communities together, at risk from wildland fire."

Virtually all of the continental United States has experienced and will continue to experience wildland fires. Wildland fires are the most destructive in California, but they have become an increasingly frequent and damaging phenomenon elsewhere.

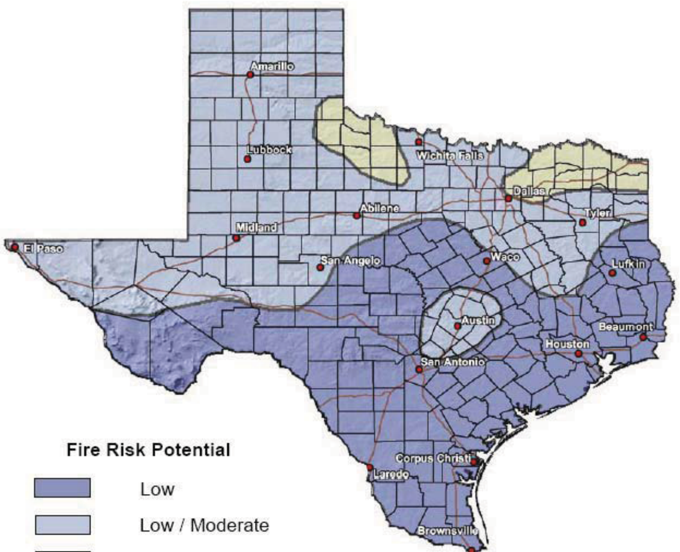
The National Interagency Fire Center maintains the Wildland Fire Assessment System (WFAS), an internet-based information system. The WFAS provides a national view of weather and fire potential, including national fire danger and weather maps and satellite-derived greenness maps. In Figure 16-1, the fire danger class (as of August 19, 2003) was "moderate" for nearly the entire NCTCOG region. The far western edge of the NCTCOG region was very close to a "high" danger class.

Figure 16-1



The Texas Forest Service also maintains an on-line Wildland Fire Risk Potential map. Notice in Figure 16-2, the wildland fire risk potential (as of October 31, 2003) was “moderate” for the northeastern portion of the NCTCOG region.

Figure 16-2
State Wildland Fire Risk Assessment (As of October 31, 2003)



Wildland Fire Risk Potential	
Category	**Description**
Low	The probability of wildland fire starts are low. Both live and dead fuel moistures are well above critical thresholds. Drought is not a contributing factor. The difficulty of control on any fires that do occur are expected to remain well within local resource capabilities.
Low / Moderate	A mixture of areas with both low and moderate probability of fire starts. Both live and dead fuel moisture levels remain above critical thresholds. Drought is not a contributing factor. The difficulty of control on fires that occur are expected to remain within local resource capability.
Moderate	An area with mostly a moderate probability of fire starts. Both live and dead fuel moistures still remain above critical thresholds. Drought is in its early stages. The difficulty of control of most fires that occur can be expected to remain within local resource capability, though some fires may require multiple resources.

Source: Texas Forest Service (Tom Spencer: Fire Risk Assessment Coordinator)

In anticipation of the Summer 2003 fire season, Rich Gray, Texas Forest Service urban wildland interface coordinator, said that people have a misconception about wildfires. “They don’t think they are at risk in Texas. The reality is that we do have devastating wildfires here, and every year homes are needlessly lost to wildfires.”

According to the National Interagency Fire Center’s Historical Wildland Fire Statistics, Texas has never had an “historically significant” wildland fire (“historically significant” being defined by the impact to lives and property). Nevertheless, in recent years, many areas of the NCTCOG region have experienced wildland fires, with some wildfires being serious enough to result in Fire Suppression Assistance (FSA) grant authorizations. Federal fire suppression aid in the form of FSAs is provided through the President’s Disaster Relief Fund and made available by FEMA to assist in fighting fires when they threaten to cause a major disaster.

In February 1996, wildland fires ravaged Parker, Wise, and Denton counties as well as several other neighboring counties in north central Texas. Despite being the middle of winter, unusually hot and dry conditions fueled nearly 50 separate wildland fires, the worst of which was in the Poolville area (35 miles northwest of Fort Worth in northern Parker County). Over 23,000 acres burned, 50 people were injured, and at least 45 homes were destroyed. Governor Bush declared the area a disaster area, and President Clinton approved a Fire Suppression Assistance grant. According to Ron Davis of the Texas Forest Service, February 22^{nd} was “the worst day of fire behavior in the state of Texas” in his 22 years of fighting wildland fires.

During the summer of 1997, wildland fires erupted in 4 north central Texas counties, including Erath County and Palo Pinto County. Dry, drought-like conditions were responsible for fueling a wildland fire that destroyed one mobile home and burned 350 acres. To prevent any loss of electrical service to citizens in the area, power lines were successfully rerouted around the wildland fires.

During the summer of 1998, the El Nino phenomenon affected burning conditions. The entire state of Texas was experiencing record-high temperatures, record-low rainfall and near-record drought conditions. The wildland fire threat across the state, including the NCTCOG region, was extreme. In early August, five Fire Suppression Assistance grants were approved, including one for the Weatherford Fire in Parker County. The Weatherford Fire burned 100 acres and threatened a residential subdivision. In the subdivision, two homes burned, 50 were in danger, and all the families were evacuated.

During the summer of 2001, wildland fires raged in the northern part of the state. Wildland fires in Collingsworth and Johnson counties burned more than 14,000 acres by July 18 and had exceeded the capability of local resources to contain them. As with previous wildland fires, high temperatures and gusty winds caused the fire to spread.

Summary Based on a qualitative assessment of historical wildland fires and based on the acknowledgment of the relationships between high temperatures and low amounts of rainfall on wildland fire, the risk of a wildland fire hazard is significant not only in the rural and sparsely populated areas of the NCTCOG region but also in the newly urbanizing areas of the region where natural vegetation and the built environment are coming together (the urban/wildland interface). It is clear that the NCTCOG region has been and will continue to be affected by wildland fires. Therefore, the risk of a wildland fire hazard merits mitigation consideration.

Wildfires are also associated with other hazards such as poor air quality, drought, and extreme heat. These associated hazards are individually addressed elsewhere in this document.

References:

C. P. Butler. “The Urban/Wildland Fire Interface.” In *Western States Section/ Combustion Institute Papers*, Vol. 74, No. 15 (1974).

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment.* Other Natural Hazards, Chapter 19.

“Raging Wildfires Leave Path of Destruction in Texas.” (February 22, 1996). Retrieved November 7, 2003 from http://www.cnn.com/us/9602/texas_wildfires/index.html

Texas Forest Service News Release (May 29, 2003). *Simple Steps Can Make Homes More Resistant to Wildfires*. Retrieved November 7, 2003 from http://txforestservice.tamu.edu

“Texas Wildfires Nearly Contained.” (February 23, 1996). Retrieved November 7, 2003 from http://www.cnn.com/us/9602/texas_wildfires/23/1am/index.html

The Wildland Fire Assessment System (WFAS). Retrieved on August 21, 2003 from the USDA Forest Service at http://www.fs.fed.us/land/wfas/fd_class.gif

HazMAP

Chapter 17 Selected Climatic Hazards: Poor Air Quality

Hazard Identification

Air quality, or ambient air, is the composition of specific pollutants measured at one location and time. Six pollutants are established: sulfur dioxide, nitrogen oxides, particulate matter, carbon monoxide, ozone and lead. When the following pollutants contaminate the air, it is commonly referred to as air pollution or poor air quality.

Ozone pollution is the most widespread air quality problem in the United States. Ozone pollution is also a key component of smog. Ozone is a gas that is formed in the atmosphere when three atoms of oxygen combine. Within the issue of ozone pollution, there are really two types of ozone: stratospheric ozone and ground-level ozone.

Stratospheric ozone naturally occurs high in the atmosphere when intense sunlight causes oxygen molecules (O_2) to break-up and re-form as ozone molecules (O_3). Stratospheric ozone is popularly called “good ozone” because it shields humans, vegetation, property, and microorganisms from the harmful effects of the sun’s ultraviolet light.

One way that ozone forms low in the atmosphere, at ground level, is when certain substances naturally emitted by trees and other vegetation, soil microorganisms, and lightning react together to form low, background concentrations of ozone. If ground-level ozone were produced only from natural sources of emissions, it would be of no concern (since both animal and plant life tolerate natural background concentrations of ozone). However, many contemporary human activities result in emissions of additional chemical compounds, called precursors, which also react in the air to form what is popularly called “bad ozone” and other harmful gases.

Ozone is not emitted directly into the air. Instead, it is formed in sunlight, which initiates a series of complex atmospheric chemical reactions. These reactions primarily involve 2 main precursors: nitrogen oxide (NOx) and volatile organic compound (VOC) emissions. Nitrogen oxide emissions are almost entirely produced as a by-product of high-temperature combustion in cars, trucks, boats, construction equipment, power generators, industrial processes, and natural gas furnaces. Volatile organic compounds include many organic chemicals that vaporize easily, such as those found in gasoline and industrial solvents. In addition, biogenic, or natural, emissions from trees and plants are another major source of VOCs. The concentration of ozone in the air is determined not only by the amounts of ozone precursor chemicals, but also by weather and climate factors. Intense sunlight, warm temperatures, stagnant high-pressure weather systems and low winds cause ozone to accumulate in harmful amounts during the summer months in north central Texas.

Risk Assessment

Poor air quality can damage the environment and property. Plants and animals and their habitats can be harmed by air pollution. Air pollution has thinned the protective ozone layer above Earth. It can damage buildings, monuments, statues, and other structures. Air pollution can also result in haze, which reduces visibility and can sometimes interfere with aviation.

Legal uncertainty, bureaucratic unpredictability, and simply the costs of implementing air pollution reduction measures can drastically increase the costs of doing business, which can have significant economic impacts. For instance, in February 2003, Toyota rejected North Texas as a location for its new truck plant because of this area’s air pollution problems. Furthermore, failure to improve air quality and comply with federal requirements could lead to other sanctions such as the withholding of federal transportation funding.

In addition to its impacts to the environment and to the economy, poor air quality can also cause health problems, including burning eyes and nose, itchy irritated throat, headaches, nausea, coughing or wheezing, and difficulty breathing. Research has shown that some contaminants found in polluted air can cause cancer, birth defects, brain and nerve damage, and long-term injury to the lungs and breathing passages. Above certain concentrations and durations, air pollutants can be extremely dangerous and can lead to severe injury or death. Doctors and scientists acknowledge heavy correlations between poor air quality and respiratory illnesses, but they stop at proclaiming an unquestionable causal relationship.

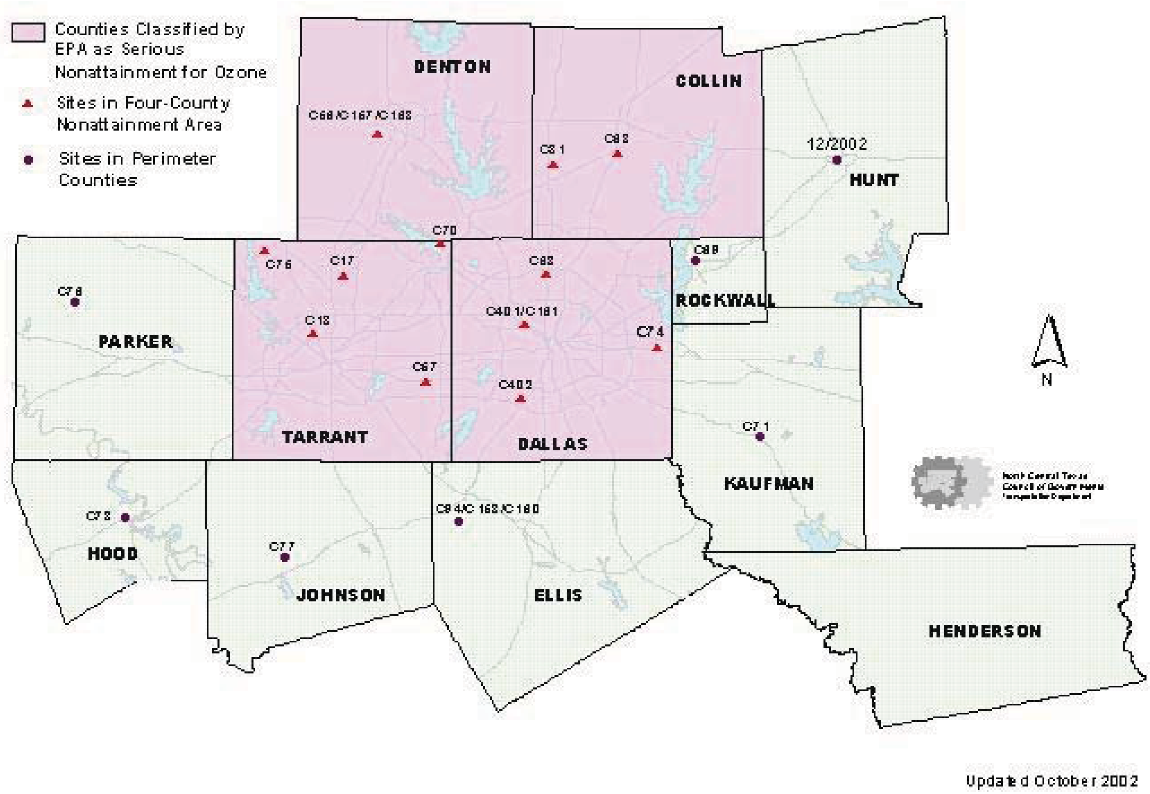
In a recent Dallas Morning News article, writer Scott Farwell quotes Dr. Arnold Schecter, a physician and a professor of environmental sciences at the Dallas branch of the University of Texas-Houston School of Public Health. According to Dr. Schecter, “Not every person exposed to cigarette smoke becomes sick, and we can say the same thing about air pollution. But…populationwide, if you have more pollution, you will have more sickness.”

In that same article, Mr. Farwell cites two important statistics from the American Lung Association: (1) nearly a half-million people in the Dallas-Fort Worth region live with diseases that are aggravated by air pollution, and (2) scientists estimate that between 50,000 and 100,000 people die each year of diseases related to air pollution.

In Texas, there are four urban areas that do not meet federal standards for ozone. One of those urban areas, the Dallas/Fort Worth area Consolidated Metropolitan Statistical Area (CMSA), includes 12 counties: Denton, Collin, Dallas, Tarrant, Johnson, Ellis, Kaufman, Parker, Rockwall, Hunt, Hood, and Henderson. Four of these counties (Denton, Collin, Dallas and Tarrant) hold “nonattainment” status for ground-level ozone. The rest of the eight counties are “near nonattainment” status for ground-level ozone. The Dallas/Fort Worth area is classified as a “serious” ozone nonattainment area by the Environmental Protection Agency (EPA).

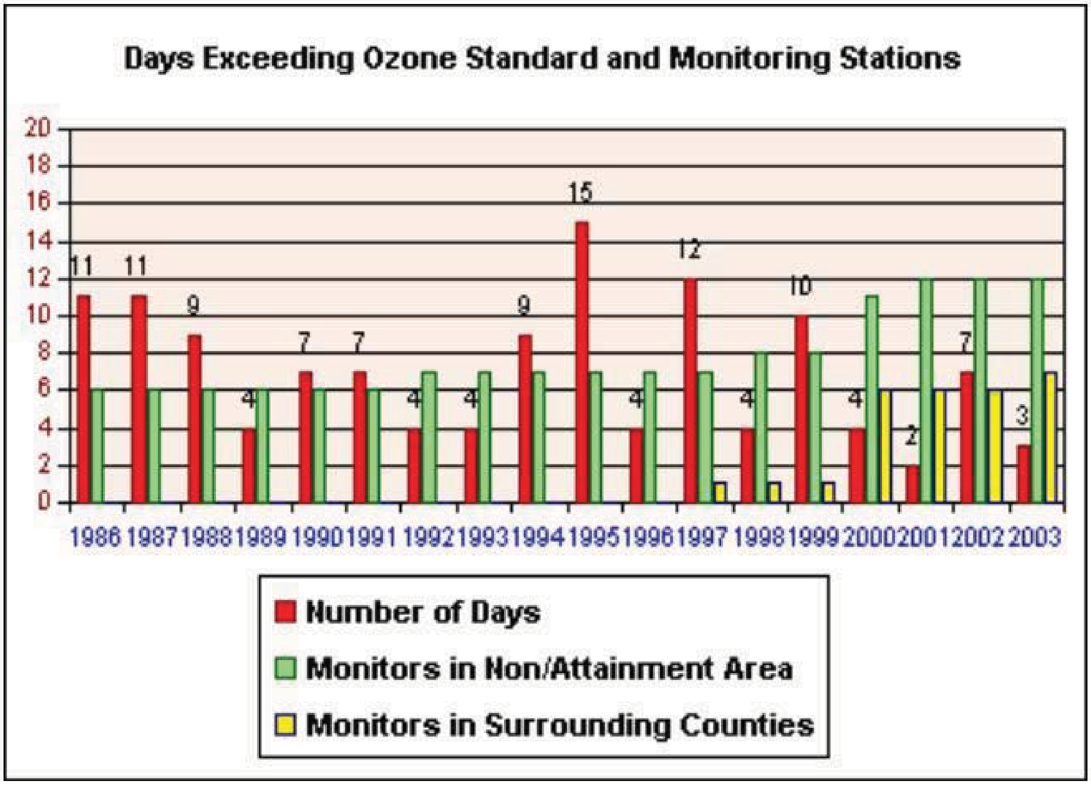
Figure 17-1.

DFW CONSOLIDATED METROPOLITAN STATISTICAL AREA
Air Quality Monitoring Sites



The 1990 Clean Air Act Amendments authorized the EPA to designate areas failing to meet National Ambient Air Quality Standards (NAAQS) for ozone as nonattainment and to classify them according to severity. The Dallas/Fort Worth area was classified a “moderate” nonattainment area and was required to demonstrate attainment by November 1996. A State Implementation Plan (SIP) was submitted but failed to help the Dallas/Fort Worth area reach national air quality standards by the deadline. As a result, the EPA reclassified the Dallas/Fort Worth area from “moderate” to “serious,” resulting in a new attainment deadline of November 1999. The Dallas/Fort Worth area failed to reach attainment by the November 1999 deadline. By April 2000, a new SIP for the Dallas/Fort Worth area was approved by the Texas Natural Resource Conservation Commission (now TCEQ) with subsequent revisions in August 2001. This SIP shows attainment for the Dallas/Fort Worth area by 2007. Final approval of this SIP by the EPA is pending. Currently, the Dallas/Fort Worth portion of the SIP is undergoing a major mid-course review for submission in 2004.

Figure 17-2.



Days Exceeding Ozone Standard and Monitoring Stations
20
18
16
14
12
10
8
6
4
2
0
11
11
9
4
7
7
4
4
9
15
4
12
4
10
4
2
7
3
1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003
Number of Days
Monitors in Non/Attainment Area
Monitors in Surrounding Counties

Figure 17-3.

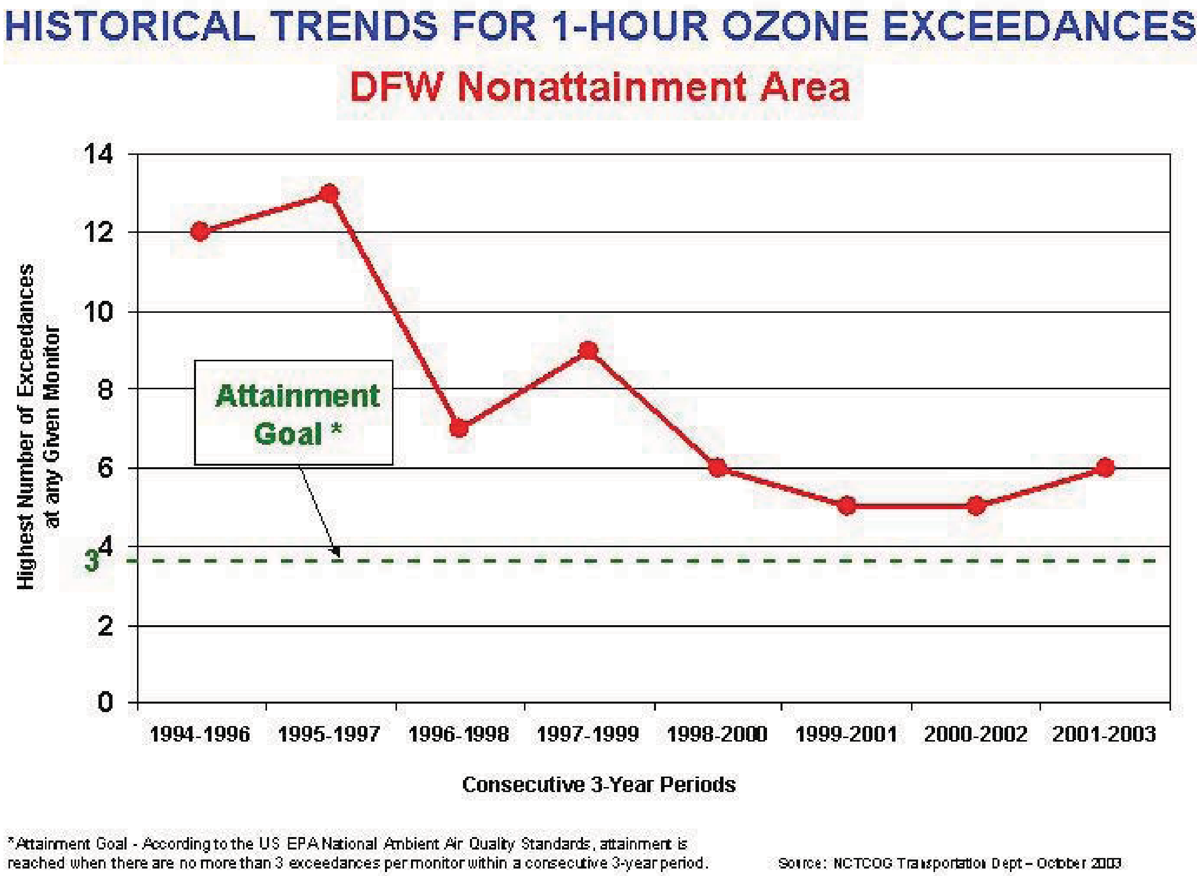
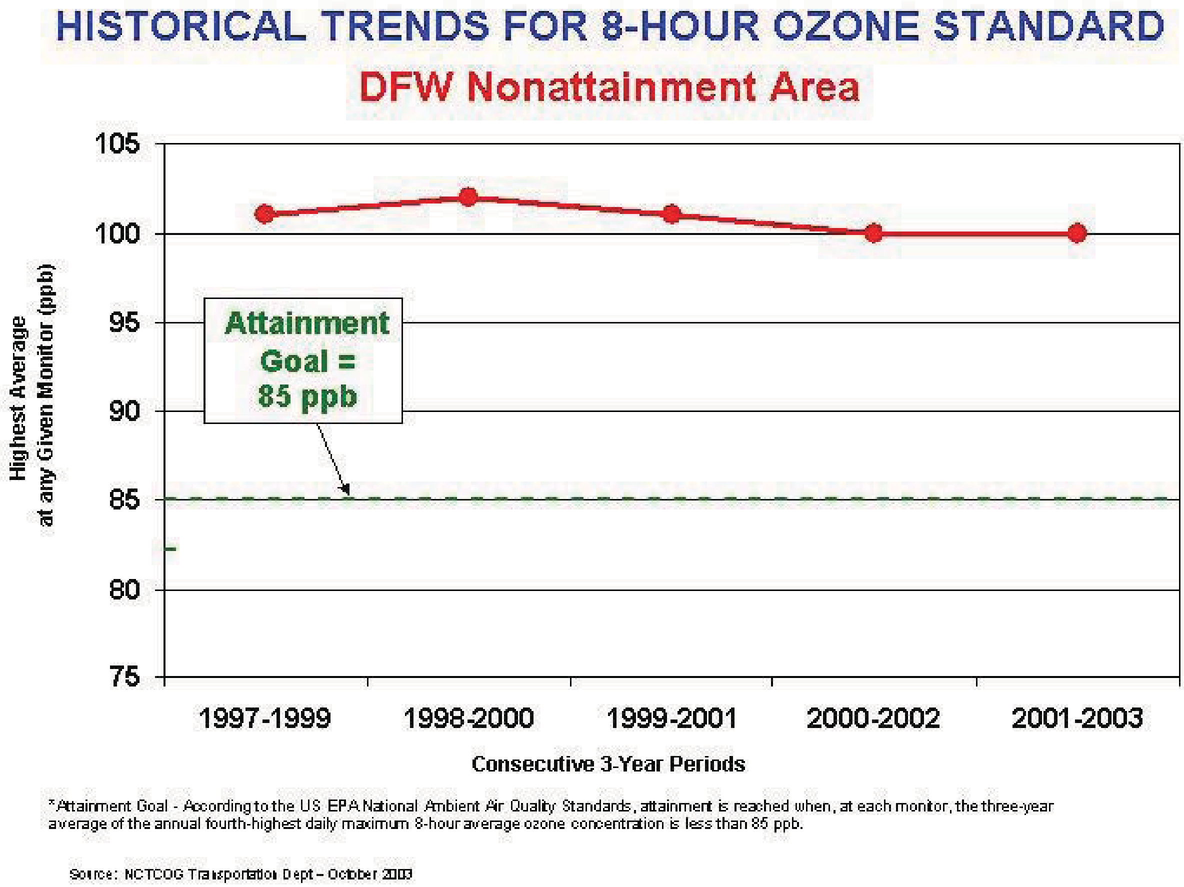

HISTORICAL TRENDS FOR 1-HOUR OZONE EXCEEDANCES
DFW Nonattainment Area
Highest Number of Exceedances at any Given Monitor
14
12
10
8
6
4
3
2
0
Attainment Goal *
1994-1996
1995-1997
1996-1998
1997-1999
1998-2000
1999-2001
2000-2002
2001-2003
Consecutive 3-Year Periods
*Attainment Goal - According to the US EPA National Ambient Air Quality Standards, attainment is reached when there are no more than 3 exceedances per monitor within a consecutive 3-year period.
Source: NCTCOG Transportation Dept – October 2003

Figure 17-4.



Summary

Over the past 30 years, the Dallas-Fort Worth area has welcomed tremendous growth while also resisting tough action against air pollution and poor air quality. However, because the Dallas-Fort Worth area has failed to reach attainment over the previous decade, it is being forced to re-evaluate existing control measures and consider new strategies in order to reach attainment. Recently, Collin County Judge Ron Harris, Chairman of the North Texas Clean Air Steering Committee, admitted in the Dallas Morning News, "I think it just took us—me—a long time to even acknowledge that there was a problem. Now I am a believer and am working accordingly.

With the tremendous growth now being experienced in areas outside of the four core counties and with a tougher ozone standard being considered, poor air quality is quickly becoming an issue across nearly the entire NCTCOG region. In fact, in December 2003, Richard Greene, Regional Administrator of EPA Region 6 and a former 5-term mayor of Arlington, issued recommendations that all 12 counties in the Dallas-Fort Worth Consolidated Metropolitan Statistical Area (CMSA) be included within the nonattainment designation for the upcoming 8-hour ozone standard. In a recent Dallas Morning News article, Mr. Greene acknowledged, "We should have paid more attention 20 years ago. We should have been more visionary about the future. Instead, we said, 'We'll worry about that tomorrow.'"

Tomorrow is today. Poor air quality is now a significant hazard throughout the entire region and merits mitigation consideration.

References:

Environmental Health Center, A Division of the National Safety Council. (May 16, 2002). *Background on Air Pollution – 1. The Clean Air Act.* Retrieved on September 15, 2003 from http://www.nsc.org/ehc/mobile/acback.htm.

Environmental Protection Agency (EPA). (2003). *Air Data – Air Quality Index Summary Report*. Retrieved on September 15, 2003 from http://www.epa.gov/air/data/monaqi.html?st~TX~Texas.

Environmental Working Group (EWG). (2000). *EWG Policy Analysis- Fuzzy Air: Why Texas is the Smoggiest State*. Retrieved September 15, 2003 from http://www.ewg.org/reports/fuzzyair/fuzzyair.pdf

Farwell, Scott. (September 14, 2003). *Smog's Toll on Society*. Dallas Morning News. Page 31A.

Loftis, Randy Lee. (September 14, 2003). *Why Hasn't D-FW Cleared the Air?* Dallas Morning News. Pages 1A, 30A-31A.

Goldsteen, Joel B., PhD. (1999). *The ABC's of Environmental Regulation.* Government Institutes, Inc. Rockville Maryland. pp. 36-37.

Texas Environmental Profiles (TEP). (1999). *Air Quality in Texas - Federal Clean Air Act Compliance in Texas*. Retrieved on September 15, 2003 from http://www.texasep.org/html/air/air_3cmp.html

HazMAP

Chapter 18 Selected Hydrologic Hazards: Flooding

Hazard Identification Flooding is defined as the accumulation of water within a water body and the overflow of excess water onto adjacent floodplain lands. The floodplain is the land adjoining the channel of a river, stream, ocean, lake, or other watercourse or water body that is susceptible to flooding.

The statistical meaning of terms like "25-year storm" and "100-year flood" can be confusing. Simply stated, a floodplain can be located anywhere; it just depends on how large and how often a flood event occurs. Floodplains are those areas that are subject to inundation from flooding. Floods and the floodplains associated with them are often described in terms of the percent chance of a flood event happening in any given year. As a community management or planning term, "floodplain" most often refers to an area that is subject to inundation by a flood that has a one percent chance of occurring in any given year (commonly and incorrectly referred to as the 100-year floodplain).

What Is a 100-Year Flood?

Floods are random, variable events. Hydrologists characterize them as 50-year, 100-year, or 500-year floods. What exactly is a "100-year flood"? It is a flood that has a one-percent chance of being equaled or exceeded in any given year.

A young Missouri farmer has provided an ingenious explanation of the possibility of experiencing a 100-year flood. He described a bag full of 100 marbles with 99 clear marbles and one black marble. Every time you pull one of those marbles out and it's black, you've got a 100-year flood. After each draw, you put the marble back in the bag and shake it up. It's possible, although not likely, that you could pull the black one out two or even three times in a row.

A 100-year flood has a 26 percent chance of occurring over the life of a 30-year mortgage and a 63 percent chance of occurring over the next 100 years. No one, especially those living in high-risk floodplains, should be misled into believing that a 100-year flood occurs only once in a century. In addition, although the 100-year flood is usually the only type people hear about, flood events of all sizes can also occur.

As commonly applied, the concept of a 100-year floodplain can be misleading. Technically, only the outer edge of a 100-year floodplain has a risk of one percent of being flooded in any given year. The risk rises for sites closer to the river, and also at lower elevations, yet many people think of the entire area between the water body and the outer edge of the 100-year floodplain as subject to the same risk. This risk variability is not usually shown on floodplain maps. It should be kept in mind that mapping floodplain boundaries is at best an imperfect science.

To see FEMA's spatial representation of Q3 flood zones for 100-year and 500-year flood events in the MPA-Trinity, go to HazMAP **map 18-1**.

According to the Federal Interagency Floodplain Management Task Force, flooding in the United States can be separated into several types:

Hazard Identification: *Riverine Flooding* Includes overflow from a river channel, flash floods, alluvial fan floods, and ice jam floods. Overbank flooding of rivers and streams is the most common type of flood event. Flooding in large rivers usually results from large-scale weather systems generating prolonged rainfall over wide areas. These same weather systems can cause flooding in smaller basins that drain to major rivers.

Hazard Identification: *Flash Floods* Are characterized by a rapid rise in water level, high velocity and large amounts of debris. Major factors in flash flooding are the intensity and duration of rainfall and the steepness of watershed and stream gradients. The amount of watershed vegetation, the natural and artificial flood storage areas and the configuration of the streambed and floodplain are also factors. Flash floods may also result from the failure of a dam or the sudden breakup of an ice jam. They are capable of tearing out trees, undermining buildings and bridges and scouring new channels.

Hazard Identification: *Localized Urban Drainage Problems* Can be caused by heavy local precipitation flooding areas other than delineated floodplains or along recognizable drainage channels. If local conditions cannot accommodate intense precipitation through a combination of infiltration and surface runoff, water may accumulate and cause flooding problems. Flooding of this nature generally occurs in areas with flat gradients and generally increases with urbanization, which speeds the accumulation of floodwaters because of impervious areas.

Risk Assessment Flooding occurs in all 50 States. FEMA indicates that the States with the most land area subject to flooding are Texas, Louisiana, Florida, and Arkansas. Since 1965, 30 Presidential Disaster Declarations have been declared in Texas. Of these 30 declarations, 5 have been declared in the NCTCOG area.

In any given year, damaging floods are likely to occur on at least one major river or stream in Texas, affecting thousands of homes and businesses, and often, resulting in the loss of life. Floods in Texas killed more people between 1989 and 1998 than in any other state—145 out of a national total of 957 people killed in floods. On the average, Texas suffers $254 million in losses (direct crop and property damage) each year from flooding.

Flood Event History for North Central Texas Since 1884 (from USGS Open File Report 03-193):

North-central, Texas	
May 20 to 21, 1884	
Substantial rainfall caused the Trinity River at Fort Worth to overflow, inundating the bottomlands for a mile on either side and washing away a few cabins. The crest was the highest known since 1866. At Waco, the Brazos River crested at 32 feet as recorded by the USGS.	
Deaths and Damage:	Unknown
Max. Precipitation:	13.00 in.
Severity:	Major Storm
Storm Center(s):	**Parker Co., Weatherford**
References:	None

North and Central Texas	
May 22 to 25, 1908	
As much as 9 in. of rainfall caused flooding throughout much of North and Central Texas.	
Deaths and Damage:	Eleven lives were lost and property damage exceeded $5 million in the Dallas area.
Max. Precipitation:	9.20 in.
Severity:	Major Storm
Storm Center(s):	**Uvalde Co., Sabinal** **Dallas Co.**
References:	Dallas Morning News, 1999

North-Central Texas	
November 5 to 9, 1918	
The largest amounts of rainfall occurred in Erath and Bosque Counties. In a 24-hour period from the 7th to the 8th, the city of Kopperl in Bosque County recorded 7.6 in.	
Deaths and Damage:	Unknown
Max. Precipitation:	16.21 in. (Erath Co.) 11.59 in. (Erath Co.)
Severity:	Major Storm
Storm Center(s):	**Erath Co., Stephenville** **Erath Co., Dublin**
References:	U.S. Army Corps of Engineers, unpub. data

Northeast Texas	
October 21 to 24, 1919	
The largest amounts of rainfall occurred in Fannin and Denton Counties. The city of Bonham in Fannin County measured 9.4 in.	
Deaths and Damage:	Unknown
Max. Precipitation:	9.40 in. (Fannin Co.) 6.75 in. (Denton Co.)
Severity:	Major Storm
Storm Center(s):	**Fannin Co., Bonham** **Denton Co., Denton**
References:	U.S. Army Corps of Engineers, unpub. data

North-Central Texas	
April 23 to 25, 1922	
Rainfall moved from the Panhandle to north-central and east Texas.	
Deaths and Damage:	Flooding in Fort Worth claimed 11 lives and about $1 million in property damage.
Max. Precipitation:	Unknown
Severity:	Major Storm
Storm Center(s):	**Tarrant Co., Fort Worth**
References:	Dallas Morning News, 1999; U.S. Army Corps of Engineers, unpub. data

Central and East Texas	
April 24 to 27, 1922	
This large storm covered much of Central and East Texas. The maximum rainfall depths were about 12 in. in the Weatherford area.	
Deaths and Damage:	Unknown
Max. Precipitation:	11.40 in. (Parker Co.) 9.30 in. (Nacogdoches Co.)
Severity:	Major Storm
Storm Center(s):	**Parker Co., Weatherford** **Nacogdoches Co., Nacogdoches**
References:	U.S. Army Corps of Engineers, unpub. data

North-Central Texas	
April 5 to 30, 1942	
The largest amounts of rainfall occurred in Tarrant and Cooke Counties. Tarrant County had nearly 17 in. of rain while Cooke County had about 16.5 in. The highest daily total, 5.7 in., occurred in Cooke County on the 25th.	
Deaths and Damage:	Unknown
Max. Precipitation:	17.00 in. (Tarrant Co.) 16.50 in. (Cooke Co.)
Severity:	Major Storm
Storm Center(s):	**Tarrant Co., Ft. Worth** **Cooke Co., Gainesville**
References:	U.S. Army Corps of Engineers, unpub. data

White Rock Creek in Dallas	
April 19 to 20, 1942	
According to long-time area residents, this was the greatest flood since at least 1886. The rain produced historically significant peak discharges at several streamflow-gaging stations. Although official rainfall stations adjacent to the watershed did not receive extraordinary rainfall, there were unofficial reports of as much as 12 in. on the upper watershed. Two days of general thunderstorm activity in the area prior to this storm contributed to a higher-than-normal rate of flood runoff.	
Deaths and Damage:	Unknown
Max. Precipitation:	12.00 in.
Severity:	Major Storm
Storm Center(s):	**Dallas Co., Dallas**
References:	Asquith and Slade, 1995; Gilbert, 1963

Southeast Texas	
July 2 to 6, 1942	
Rainfall of 10-14 in. along the entire Gulf coast caused flooding throughout much of southeast Texas.	
Deaths and Damage:	Unknown
Max. Precipitation:	13.00 in. (Navarro Co.) 12.90 in. (Guadalupe Co.) 12.10 in. (Victoria Co.)
Severity:	Major Storm
Storm Center(s):	**Navarro Co., Eureka** **Guadalupe Co., Seguin** **Victoria Co., Victoria Air Base**
References:	U.S. Army Corps of Engineers, 1954

North-Central Texas	
May 16 to 17, 1949	
Excessive rain ranging from 2 to 10 in. in the upper Trinity River Basin on May 16th and 17th produced the flood of record in Fort Worth with extensive flooding of business and residential areas and leaving residents without city water for about 3 days. Dallas had the second highest flood of record with severe flooding along lowlands outside of the levee district, and several sections of south Dallas, unprotected by levees. The same excessive precipitation that caused the Fort Worth-Dallas flood also caused moderate flooding along the Brazos River from Granbury to Waco on the 17th and extended into the Sulphur and Sabine River Basins.	
Deaths and Damage:	Unknown
Max. Precipitation:	12.00 in.
Severity:	Major Storm
Storm Center(s):	**Tarrant Co., Kennedale**
References:	U.S. Army Corps of Engineers, unpub. data

Fort Worth	
May 17, 1949	
Maximum recorded rainfall was 12 in. on Village Creek in the West Fork Trinity River Basin southeast of Fort Worth.	
Deaths and Damage:	Ten lives were lost, and damage was $15 million in Fort Worth and vicinity.
Max. Precipitation:	12.00 in.
Severity:	Major Storm
Storm Center(s):	**Tarrant Co., Fort Worth**
References:	Breeding, 1949

North-Central Texas	
June 13 to 14, 1949	
From 2 to 10 in. of rain fell in the upper Trinity River Basin on the 13th and 14th centered near Richardson, Garland, and Carrollton. Most of the rain fell during the night. Streets in Carrollton were reported knee deep in water, and all highways leading north of Dallas were blocked by floodwaters at 12:30 a.m. on the 14th.	
Deaths and Damage:	Unknown
Max. Precipitation:	10.00 in.
Severity:	Major Storm
Storm Center(s):	**Dallas Co., Richardson**
References:	U.S. Army Corps of Engineers, unpub. data

Bosque River Watershed	
May 18 to 19, 1955	
Rainfall began about 7:30 p.m. May 18 and continued for 5.5 hours. A gage 9 mi west of Stephenville in the Green Creek watershed recorded 2.00 in. during one 30-minute period. Bucket surveys indicated that higher intensities were near the center of the storm. Maximum recorded rainfall was 12.0 in. 5 mi east of Lingleville.	
Deaths and Damage:	Damage was estimated at $680,000.
Max. Precipitation:	12.00 in.
Severity:	Major Storm
Storm Center(s):	**Erath Co., Lingleville**
References:	Soil Conservation Service, 1955b

Green Creek Watershed	
April 29 to May 3, 1956	
Maximum recorded precipitation was 14.54 in. in the upper North Bosque River Basin. In Erath County 3 mi northeast of Stephenville, 11.57 in. was measured during the period, with a maximum intensity of 3 in. during 45 minutes Apr. 30. As much as 8 in. of rain was reported in that area during 2.5 hours Apr. 30.	
Deaths and Damage:	There was no loss of life. Damage was estimated at $80,000.
Max. Precipitation:	14.54 in.
Severity:	Major Storm
Storm Center(s):	**Erath Co., Stephenville**
References:	Hendricks, 1964a, p. 26-28; Soil Conservation Service, 1956a

Texas and Adjacent States	
April to June 1957	
Total rainfall on much of the eastern two-thirds of Texas for the 3-month period exceeded that normally recorded for a 12-month period. These rains effectively broke the infamous 1950s drought.	
Deaths and Damage:	Unknown
Max. Precipitation:	19.32 in.
Severity:	Catastrophic
Storm Center(s):	**Palo Pinto Co., Brazos**
References:	Yost, 1963, p. 5-9

Trinity, Brazos, Colorado, Guadalupe, Nueces River Basins	
September 28 to October 4, 1959	
As much as 12 in. of rain caused extensive flooding in the upper Trinity River Basin on Big Fossil, Big Sandy, Chambers, and Richland Creeks and produced historically significant peak discharges at several streamflow-gaging stations. In the middle Brazos River Basin, floods (exceeding all previously known) on North Bosque River and Cowhouse Creek followed rain totaling more than 14 in. at some places. Spring Creek in the middle Colorado River Basin reached its highest stage since 1882 following rainfall that exceeded 10 in. Johnson Creek, in the headwaters of the Guadalupe River, recorded the second highest flood known since at least 1852. Flash flooding on the upper Nueces River Basin followed heavy rain Oct. 3-4. Unofficial totals of as much as 16 in. of rain were reported.	
Deaths and Damage:	One person drowned during the flood. Big Fossil Creek flooded parts of Richland Hills, a suburb of Fort Worth, causing an estimated $300,000 in damage. Damage to agricultural interests and rural public properties was estimated at $700,000 by the U.S. Weather Bureau.
Max. Precipitation:	16.00 in.
Severity:	Major Storm
Storm Center(s):	**Tarrant Co., Fort Worth**
References:	Asquith and Slade, 1995; Hendricks, 1964b, p. 70-74

Fort Worth Vicinity	
June 24 to 25, 1961	
A small-area storm of high intensity caused flash flooding in Richland Hills near Fort Worth. Three rain gages in the area recorded rainfalls of 3.64-4.71 in. A bucket survey was conducted on upper Big Fossil Creek where 7.7, 8.0, and 8.7 in. of rain were recorded.	
Deaths and Damage:	Unknown
Max. Precipitation:	8.70 in.
Severity:	Major Storm
Storm Center(s):	**Tarrant Co., Fort Worth**
References:	Rostvedt, 1965b, p. 57

Mineral Wells Vicinity	
July 25 to 27, 1962	
Heavy rain of 5-17 in. fell within a 40-mi radius of Mineral Wells July 25-27. The area upstream from Greenville Ave. in Dallas had an average rainfall of 6.2 in. July 27. That same area recorded 2 in. the previous day.	
Deaths and Damage:	Property damage exceeded $1.5 million.
Max. Precipitation:	6.20 in.
Severity:	Major Storm
Storm Center(s):	**Dallas Co., Dallas**
References:	Rostvedt and others, 1968a, p. 97

Near Crandall	
July 26 to 27, 1962	
A flood-producing storm began about midnight July 26 and continued intermittently until about noon July 27. Crandall recorded 11.4 in. during the 6-hour period midnight to 6:00 a.m. July 27.	
Deaths and Damage:	There was no loss of life. Crop and pasture damage from the floodwaters was estimated at $26,000.
Max. Precipitation:	11.40 in.
Severity:	Major Storm
Storm Center(s):	**Kaufman Co., Crandall**
References:	Soil Conservation Service, 1962

Haltom City near Fort Worth	
September 6 to 7, 1962	
As much as 11 in. of rain fell Sept. 7 on upper Big Fossil Creek Basin. During the afternoon Sept. 7, the recording rain gage near Justin, about 13 mi northeast of Big Fossil Creek Basin, measured 5 in. during 1 hour and 2 in. more the following hour.	
Deaths and Damage:	Unknown
Max. Precipitation:	11.00 in.
Severity:	Major Storm
Storm Center(s):	**Tarrant Co., Fort Worth**
References:	Rostvedt and others, 1968a, p. 99-101

White Rock Creek Basin	
October 8, 1962	
During early morning Oct. 8, an intense storm of short duration centered over Cottonwood Creek in the upper White Rock Creek Basin. An average 4.6 in. of rain fell on the basin during about 3 hours. Rainfall on Cottonwood Creek Basin ranged from about 4 in. on the upper basin to 7 in. on the lower basin.	
Deaths and Damage:	Unknown
Max. Precipitation:	4.60 in.
Severity:	Major Storm
Storm Center(s):	**Dallas Co., Dallas**
References:	Rostvedt and others, 1968a, p. 99

South-Central and Northeast Texas	
September 15 to 30, 1964	
The rain produced historically significant peak discharges at two streamflow-gaging stations. As much as 12.5 in. of rain fell during the night Sept. 15 in Dimmit County between Carrizo Springs and Encinal. As much as 15 in. fell on the Devils River Basin during 24 hours, and as much as 17 in. fell on the upper Nueces River Basin. As much as 20.33 in. was measured Sept. 15-30. During the first 8 hours of Sept. 21, more than 12 in. fell in northeastern Tarrant County, eastward over Dallas, and in Collin County. The heaviest rain fell on an area north of Dallas.	
Deaths and Damage:	Unknown
Max. Precipitation:	20.33 in.
Severity:	Major Storm
Storm Center(s):	**Dallas Co., Dallas**
References:	Rostvedt and others, 1970a, p. 82-90

Collin, Grayson, Dallas, and Tarrant Counties	
September 20 to 21, 1964	
The storm began about midnight Sept. 20 and continued until about 8:00 a.m. Sept. 21. McKinney in Collin County reported 12.10 in. of rain from 1:15 to 7:00 a.m. on Sept. 21. Flooding was severe in McKinney, Fort Worth, and north Dallas.	
Deaths and Damage:	Two drownings occurred, and property damage was about $3 million.
Max. Precipitation:	12.10 in.
Severity:	Major Storm
Storm Center(s):	**Collin Co., McKinney**
References:	Soil Conservation Service, 1964

Navarro, Hill, Ellis, and Johnson Counties	
April 20 to May 2, 1966	
A series of flood-producing rains of 8-15 in. fell on Chambers Creek watershed Apr. 20-May 2. Rainfall of 7.91-14.75 in. was recorded. Unofficial reports of rainfall indicate that isolated areas of the watershed had as much as 17 in. The greatest rainfall was reported for the area immediately west of Corsicana.	
Deaths and Damage:	Storm damage was estimated at $441,000.
Max. Precipitation:	17.00 in.
Severity:	Major Storm
Storm Center(s):	**Navarro Co., Corsicana**
References:	Soil Conservation Service, 1966a

North Dallas	
April 28, 1966	
As much as 6.7 in. fell during a 6-hour period; 4.9 in. fell during 1 hour. Almost 8 in. of rain had fallen during the preceding 2 weeks, resulting in a well-saturated basin in which all storage areas were full.	
Deaths and Damage:	Flooding resulted in 14 deaths and damage estimated at $15 million.
Max. Precipitation:	6.70 in.
Severity:	Major Storm
Storm Center(s):	**Dallas Co., Dallas**
References:	Mills and Schroeder, 1969

Central and East Texas	
June 23 to 28, 1968	
During the afternoon June 23, Tropical Storm Candy moved inland over the middle Texas coast. The storm weakened slowly as it moved north toward the Dallas-Fort Worth area. Rainfall totals of 3-4 in. were common throughout central and eastern Texas, with numerous locations reporting 5 in. or more.	
Deaths and Damage:	No deaths or injuries resulted from this storm; however, estimates placed crop losses at $2.1 million and property losses at $625,000.
Max. Precipitation:	5.00 in.
Severity:	Major Storm
Storm Center(s):	**Dallas Co., Dallas** **Tarrant Co., Ft. Worth**
References:	Rostvedt and others, 1972, p. 42

Cleburne	
May 6 to 7, 1969	
Rainfall exceeded 8 in. during the storm. Most of this rain fell during the evening of May 6th and early morning May 7th.	
Deaths and Damage:	Damage in Johnson County was estimated at $400,000.
Max. Precipitation:	8.00 in.
Severity:	Major Storm
Storm Center(s):	**Johnson Co., Cleburne**
References:	Reid and others, 1975

North-Central Texas	
March 27, 1977	
Heavy rain fell in Tarrant, Somervell, and Dallas Counties.	
Deaths and Damage:	There were 5 drownings and $1 million in property damages.
Max. Precipitation:	Unknown
Severity:	Major Storm
Storm Center(s):	**Tarrant Co.** **Somervell Co.** **Dallas Co.**
References:	Dallas Morning News, 1999

North-Central Texas and Oklahoma	
October 10 to 14, 1981	
The storm extended in a southwest-to-northeast direction from near Abilene to near McAlester, Okla. Maximum recorded rainfall was 23 in. during 34 hours about 5 mi north of Clyde, Tex. Numerous areas reported rains exceeding 10 in.	
Deaths and Damage:	Six lives were lost, and damage was about $115 million.
Max. Precipitation:	23.00 in.
Severity:	Catastrophic
Storm Center(s):	Callahan Co., Clyde
References:	Buckner and Kurklin, 1984

North and East Texas	
May 11 to 14, 1982	
Rainfall totals for a 24-hour period ending May 13 were 13.02 in. at Trenton in Fannin County, 13.00 in. at Pilot Point in Denton County, and 12.60 in. at Bonham in Fannin County.	
Deaths and Damage:	Millions of dollars in damage were sustained.
Max. Precipitation:	13.00 in. (Denton Co.) 12.60 in. (Fannin Co.)
Severity:	Major Storm
Storm Center(s):	**Denton Co., Pilot Point** **Fannin Co., Bonham**
References:	Bomar, 1983b, p. 24

North Texas	
April 27 to 28, 1985	
Intense thunderstorms covered most of North Texas during the late evening Apr. 27 and early morning Apr. 28. About 10 in. of rain fell 9:00 to 11:00 p.m. near Rockwall in Rockwall County.	
Deaths and Damage:	Eight people drowned as a result of driving into high waters.
Max. Precipitation:	10.00 in.
Severity:	Major Storm
Storm Center(s):	**Rockwall Co., Rockwall**
References:	Moody and others, 1986

Fort Worth	
May 24, 1986	
The storm produced winds as strong as 95 miles per hour, hail as large as 3-in. in diameter, and about 4 in. of rain during an hour.	
Deaths and Damage:	Two people drowned when swept from their car after driving into a flooded underpass. Wind, rain, and flood damages were estimated at about $2 million.
Max. Precipitation:	4.77 in.
Severity:	Major Storm
Storm Center(s):	**Wise Co., Bridgeport**
References:	Moody and others, 1988, p. 22

Upper Coast and North Texas	
May 16 to 19, 1989	
Houston Intercontinental Airport recorded 10.28 in. May 17-18. Spring recorded more than 15 in. during a 24-hour period May 17-18.	
Deaths and Damage:	Widespread rains caused flooding that resulted in five deaths and total damages of about $50 million.
Max. Precipitation:	15.00 in. (Harris Co.) 10.28 in. (Harris Co.)
Severity:	Catastrophic
Storm Center(s):	Harris Co., Spring Harris Co., Houston Intercontinental Airport
References:	Griffiths and others, 1990, p. 38-40

North Texas	
May 1 to 7, 1990	
Heavy rainfall May 1-4 produced major flooding in North Texas during early May. Rainfall was 5-9 in. on north-central sections of North Texas and 2-5 in. elsewhere.	
Deaths and Damage:	Unknown
Max. Precipitation:	6.91 in. (Dallas Co.) 6.36 in. (Dallas Co.)
Severity:	Major Storm
Storm Center(s):	**Dallas Co., Dallas Naval Air Station** **Dallas Co., Dallas Love Field**
References:	National Oceanic and Atmospheric Administration, 1990

Dallas and Tarrant Counties	
May 5, 1995	
Damage caused by wind speeds up to 70 miles per hour, softball-size hail, and high-intensity rain caused this storm to be deemed the "costliest thunderstorm event in history" by the National Weather Service. The maximum rainfall intensity was almost 3 in. in 30 minutes. 109 people were injured by hail.	
Deaths and Damage:	20 lives were lost, and $2 billion in damage was reported.
Max. Precipitation:	4.96 in.
Severity:	Major Storm
Storm Center(s):	**Dallas Co., Dallas** **Tarrant Co.**
References:	None

Repetitive Loss Properties

Presently, one of FEMA's highest priorities is to break the cycle of repetitive losses on structures insured by the National Flood Insurance Program (NFIP). Through hazard mitigation planning, FEMA is strongly encouraging local communities to mitigate repetitive loss properties. When the term “repetitive loss” is used, FEMA defines it as those properties insured by the National Flood Insurance Program (NFIP) that have experienced at least 2 paid losses of more than $1,000 each in any 10-year period. At the national level, FEMA has identified over 10,000 high priority repetitive loss properties, out of a total of about 48,000 such properties. To see the NCTCOG region’s share of this list, go to HazMAP **map 18-6**. On this list, there are properties in the NCTCOG region, and the sum of all projected future flood damages that would be mitigated in the region would be about $2.3 million. The fact that the NCTCOG region has an extremely limited representation on this national Top 10,000 list is a testament to the great strides made by the region over the last 20 years within the realm of floodplain management. To see spatial representations of the repetitive loss properties for each of the counties that have them, go to HazMAP **map 18-7** (Dallas County), **map 18-8** (Denton County), **map 18-9** (Hood and Somervell Counties), **map 18-10** (Johnson County), **map 18-11** (Kaufman County), **map 18-12** (Palo Pinto County), and **map 18-13** (Tarrant County).

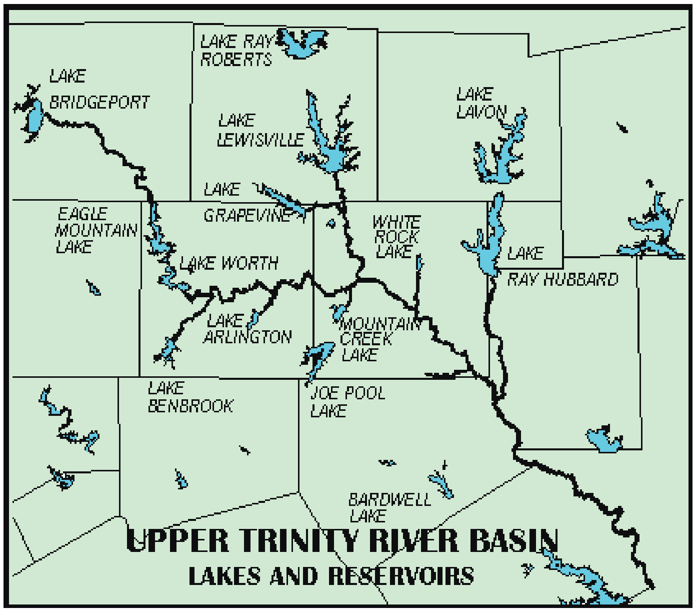
Critical Facilities in Flood Hazard Areas

FEMA also encourages the identification of critical facilities that currently lie in flood hazard areas. For the counties that have digital Q3 flood zones available, NCTCOG staff has intersected the digital Essential Facilities layer (as described in Chapter 2) with the Q3 100-year and 500-year flood zones. See HazMAP **map 18-14** (Tarrant County), **map 18-15** (Johnson County), **map 18-16** (Denton County), **map 18-17** (Dallas County), and **map 18-18** (Collin County).

Managing Flood Hazards in North Central Texas

In 1846, when A.W. Moore first saw the Trinity River near present-day Dallas he described it as “a little narrow deep stinking affair." For most of the next 150 years, many civic leaders believed that the economic future of the region depended upon navigation of the "deep stinking affair" from Fort Worth and Dallas southward more than 300 miles to the Gulf. Thus, the ultimate use of the river in the urban area was envisioned to be barge traffic with heavy industry along its banks.

When that dream died in 1981 because of changing federal priorities, it was replaced by unrelated requests for federal permits to reclaim portions of the Trinity floodplain for commercial and residential development. These requests led to studies by the U.S. Army Corps of Engineers (USACE) that showed that the cumulative effects of the various development scenarios would bring massive new flooding. In response, officials from 14 affected jurisdictions, working under the auspices of the North Central Texas Council of Governments (NCTCOG), came together in 1989 to declare their support for a cooperative,



A map of the Trinity River Corridor. Source: USACE Fort Worth District

regional approach to manage the Trinity River Corridor, one that aimed to create a safe, clean, enjoyable, natural, and diverse river corridor for the benefit of all North Central Texas. And thus began the **Trinity River COMMON VISION** program.

With a population of 5.7 million, the Dallas/Fort Worth Metroplex is the nation's largest inland metropolitan area. To assure an adequate long-term drinking water supply, each of the major branches in the upper watershed has been impounded with manmade reservoirs. Thus, the Trinity River as it flows through the urban core faces great extremes, with low flows composed almost totally of treated wastewater to massive floods with the potential for billions of dollars in damages and untold loss of life across its 240 square mile floodplain.

The cooperative regional effort to manage the Trinity River Corridor began in the early 1980's when the USACE began working on a *Regional Environmental Impact Statement* (*Regional EIS*) to address the cumulative impacts of individual permitting decisions. A working group of staff from the affected local governments and NCTCOG provided input. The draft of the *Regional EIS* first compared the cumulative impacts of two opposite philosophical approaches for utilizing the river corridor—maximum environmental quality versus maximum development—and found that maximum development would result in flood flows that would overtop existing levees in Dallas and Irving. Given the seriousness of these preliminary findings, a special Strategy Committee of elected local government officials was formed to assist in the development of the *Regional EIS*.

As expected, local involvement in USACE's preparation of the final *Regional EIS* was much more intense, with many meetings and several new development scenarios crafted between the two extremes. The final *Regional EIS* found that these more moderate development scenarios would not only result in the Dallas Floodway levees still being overtopped with catastrophic results, but that properties in upstream cities would also sustain considerable flood damages. Thus, no city could assure adequate flood protection for itself by itself—only a common approach could be successful.

Although no proof was required, Mother Nature stepped in anyway. Major floods occurred in May/June 1989 in the Upper Trinity River. Over a dozen lives were lost as a result of the floods within the Metroplex and hundreds of millions of dollars of damages were sustained.

In 1989 NCTCOG adopted a *Regional Policy Position on Trinity River Corridor* that affirmed, among other key points, that local governments must be the stewards of the Trinity River Corridor because individual goals can only be achieved through cooperative management and a comprehensive approach addressing flood damage reduction, recreation, and environmental quality must be pursued.

Upon request of the affected local governments, Congress authorized the USACE to undertake a *Reconnaissance Study* to determine if a feasible flood protection plan(s) could be identified to reduce the risk of flooding, as well as address water quality, recreation, environmental enhancements, and other allied purposes. The USACE studied a variety of flood control options and found at least a dozen with positive benefit-cost ratios that merited further attention in the *Feasibility Study* phase.

It was now time for local governments to act. In 1990, each of the nine cities (Arlington, Carrollton, Coppell, Dallas, Farmers Branch, Fort Worth, Grand Prairie, Irving, and Lewisville), three counties (Dallas, Denton, and Tarrant), and two special districts (Tarrant Regional Water District and Trinity River Authority) with development and regulatory authority for the Trinity River Corridor executed interlocal agreements with NCTCOG to establish a formal structure for cooperative planning. A Steering Committee of elected officials was formally appointed to provide policy guidance, along with a staff task force for technical support.

NCTCOG, on behalf of the local governments, was identified as the administrative agent to enter into a cost-sharing agreement with the USACE for the *Upper Trinity River Feasibility Study*. Even at this stage it was recognized that a more comprehensive COMMON VISION was needed and would be pursued not only with the Corps but other local, state, and federal partners.

In 1990, the first phase of the *Upper Trinity River Feasibility Study* began as an $8 million six-year effort, with NCTCOG responsible for providing the $4 million non-federal match. In turn, NCTCOG negotiated and administered a $2 million grant from the Texas Water Development Board and obtained the $2 million of local funds on a pro-rata annual formula based on the jurisdiction's land area within the corridor. NCTCOG's funding support came from a portion of the local share.

During the early 1990's and as part of the *Upper Trinity River Feasibility Study*, NCTCOG and the USACE undertook a massive project to map the 240-square-mile Trinity River Corridor. Aerial photography and comprehensive ground surveys were used to develop engineering scale base maps, and these base maps led to the development of a computer floodplain model. To see flooding scenarios produced by this computer model for the 25-year, 100-year, 500-year, and Standard Project Flood flooding events, go to HazMAP **map 18-2**, **map 18-3**, **map 18-4**, and **map 18-5**.

The purpose of the *Upper Trinity River Feasibility Study* is to seek potentially feasible alternatives for implementation by the participating local governments to address flood damage reduction, water quality, environmental enhancement, recreation, and other related needs throughout the Trinity River Corridor.

The Phase I Information Paper released in early 1995 identified potential projects with a preliminary positive benefit-cost ratio. The paper concluded that seven of the 14 structural flood control measures were economically viable, and a total of 11 water quality improvement and 20 environmental enhancement measures warranted further study. In addition, 38 recreational development measures were also found to be feasible, as well as cooperative approaches to watershed management. In all, more than 100 projects were identified that could justify federal cost-share participation.

The second phase of the *Upper Trinity River Feasibility Study* is currently in progress. This phase identifies implementable projects through Project Management Plans to reduce flood risks, restore environmental values, and meet other study purposes.

Since 1996, projects totaling more than $12 million have been or are being implemented. For a project to be initiated the local entity with jurisdiction must determine its interest and willingness to share in the cost of the project.

The projects currently underway include:

Arlington Johnson Creek Buyouts: The project includes the demolition of 140 structures, mostly homes, that have experienced repeated flooding along Johnson Creek. As of spring 2003, most have been demolished and native habitat restoration has begun.

Dallas Floodway/Elm Fork Project: As part of the larger city efforts, several floodway initiatives are being investigated by the USACE, including: raising the existing levees, lake development, channel meandering, modification of a bridge, and recreation facilities.

Clear Fork/West Fork Project: Tarrant Regional Water District with Fort Worth Stream & Valleys, Inc. is developing a comprehensive master plan to preserve and enhance over 70 miles of river corridor. Recent developments in this project are the announcements by Pier 1 Imports and RadioShack Corporation of plans to build new headquarters on the edge of the Trinity River in downtown Fort Worth, with possible river realignment under study.

Big Fossil Creek Watershed Project: The nine local governments in this fast growing, 73 square-mile watershed are together evaluating flood damage reduction, ecosystem restoration, water quality, and recreational opportunities.

Lake Worth Project: Fort Worth is seeking solutions to water quality and sedimentation problems in Lake Worth.

Trinity Trails System: In 1996 the Trinity Trails Advisory Committee adopted a proposed alignment for the 250-mile "spine" of the regional Trinity Trails System. The project is working to create a continuous recreation corridor with a multi-use trail along the Trinity River Corridor in North Central Texas and northward to the Red River. Significant segments have already been built or are under development.

Corridor Development Certificate Process: The studies called for stricter regulation of development within the corridor to stabilize the flood risks. After several years of detailed discussions, an innovative Corridor Development Certificate (CDC) process emerged in the early 1990's. Local governments still issue the development permit under the National Flood Insurance Program, but common requirements have been added (and adopted by each city in its floodplain ordinance). The CDC process includes USACE review of every CDC request for its flood impact and gives other participating local governments along the corridor 30 days to review and comment upon the development request. While the individual city still makes the final call, it is well understood that a bad decision will land it in court with other cities.

Unprecedented cooperation, combined with state-of-the-art technical tools and on-the-ground implementation projects have produced a decade of stunning achievements—recognized in 1998 by the Trinity River COMMON VISION being named as one of the top 20 Innovations in American Government by the Ford Foundation.

One key to the success of the Trinity River COMMON VISION program has been meaningful intergovernmental partnerships—among local governments themselves and with federal and state agencies. Whatever is done to reclaim or preserve a river corridor in an urban region requires local government action—zoning, permits, capital expenditures, maintenance. While the USACE and other federal and state agencies have important roles, local governments are responsible for the overall health, safety, and welfare of their own citizens. But local governments cannot and should not act alone; thus, the importance of partnerships.

The 1990's were a decade of almost unbelievable progress—cooperation on a scale unmatched elsewhere in the nation. Yet, our local governments and their federal and state partners recognize that there are incredible opportunities still ahead.

In fact, NCTCOG has established a vision of success for watershed management across all four major watersheds of the Upper Trinity. This vision has taken the shape of the broad **Sustainable Environmental Excellence (SEE)** initiative that, among other things, aims to translate the Trinity River COMMON VISION values of safe, clean, enjoyable, natural & diverse into **Safe Clean & Green** regional environmental corridors. While many environmental corridor planning strategies tend to focus primarily on green space issues, the **SEE Safe Clean & Green** initiative takes an integrated approach and examines not only regional greenway issues but also the flooding safety and water quality challenges and opportunities of our region's environmental corridors.

The shared vision of success for 2025 is that all regional environmental corridors are **Safe Clean & Green**. There are more than 2,400 miles of regional environmental corridors in the MPA -Trinity spread through its four watersheds. Local governments, as stewards of those corridors, must take the lead in implementing actions that enhance the health, safety, and welfare of their citizens throughout the corridors. Municipalities acting alone cannot successfully isolate and resolve flooding and water quality problems, which respect no political boundary. The multi-jurisdictional nature of regional corridors calls for cooperation with upstream and downstream neighbors.

Summary

A qualitative analysis of historical flooding events and a quantitative analysis of National Flood Insurance Program data (located in Appendix C of this document) clearly demonstrate that flooding hazards (either in the form of riverine floods, flash floods, or localized drainage problems) affect nearly every community in the region.

Continuing growth and development in the region has resulted in increasing storm water and drainage issues, challenging communities to further stabilize flood risks and minimize future flood losses. As the region comes together to address these issues, essential steps can be taken to protect citizens and property from flood loss. In order to move the region closer to achieving the vision of SAFE regional environmental corridors by 2025, flooding hazards must receive mitigation consideration in the 2003-2004 planning cycle and beyond.

References:

Federal Emergency Management Agency (FEMA). (1997). *Multi Hazard Identification and Risk Assessment.* Hydrologic Hazards Chapter 12.

North Central Texas Council of Governments (NCTCOG). (2002). *SEE Safe Clean & Green Regional Environmental Corridors: a strategic plan for 2003-2007.*

Slade, Raymond and John Patton (2003). *Major and Catastrophic Storms and Floods in Texas*. U.S. Geological Survey Open File Report 03-193

U.S. Army Corps of Engineers (USACE) Fort Worth District. (1989). *Report on Flooding May – June 1989*.

HazMAP

Chapter 19 Selected Hydrologic Hazards: Stream Bank Erosion

Hazard Identification

Stream channels are eroded by the energy of flowing water. The two types of stream bank erosion are the surface erosion of channel bank material and mass wasting. Surface erosion is the removal of individual soil particles due to the tractive force of water. Mass wasting is defined as a structural failure of a section of the stream bank, which can be caused by undercutting due to surface erosion.

Surface erosion occurs when the energy of the water exceeds the shear strength of the soil and particles are removed. The strength of the tractive force of water increases proportionally to the velocity and depth of flow. There are many factors which affect the ability of water to erode. Larger size particles weigh more and are more resistant to the force of water; for example, gravel size particles are more resistant than sand sized particles. Cohesive soils such as clays are more resistant to particle removal than soils consisting of non-cohesive silt-sized materials. Inclusions of silt or other non-cohesive particles can also make clayey soil layers more susceptible to erosion. Another factor affecting erodibility is soil cover. Vegetative cover reduces the velocity of water and tractive force on soil particles compared to bare soil conditions. Different types of vegetation as well as their location on the stream bank provide varying amounts of resistance to soil particle removal.

There are several phenomena that cause the surface erosion of stream banks. Flow hydraulics, rainfall, groundwater seepage, overbank drainage, wave attack, freeze-thaw and wet-dry cycles, and land use all have an effect, both individually and in concert. The purpose of this analysis is to identify areas in which mitigation activities may be needed in the coming years. Therefore, instead of detailed descriptions of each of these causes, this assessment focuses on the identification of potential hazard areas based on existing and available digital data. In addition, this assessment provides guidance for compiling additional data for extended analysis in future planning cycles.

Natural channels of all types are constantly changing. However, most eventually reach a point of relative stability or equilibrium. Development of the contributing watershed of a stream often results in increased impervious area, reduced infiltration, increased runoff, increased flood peaks and sometimes velocity, and increased flood frequencies. These subsequent higher peak flows and velocities impart a greater tractive force on the stream bank, which results in higher erosion rates than the pre-development state of relative equilibrium. It is a generally accepted rule of thumb that development of a watershed will cause a stream to roughly double its channel area. This process occurs over a long period of time, and many geomorphologists think it may take from 50 to 100 years for a channel to reach this new state of stability (Halff 1998). The subsequent erosion can endanger nearby structures, cause massive failures of large areas of bank material, and increase the silt load of the stream.

Risk Assessment

Stream bank erosion hazards are a very important problem in North Central Texas. Throughout the region, communities face critical problems stemming from severe stream bank erosion. Residential and commercial structures, as well as public infrastructure, are impacted. Recently, several local communities in the region have been battling some high-profile stream bank erosion situations (such as Cottonwood Creek in Richardson, Big Fossil Creek in Haltom City, Kirby Creek in Grand Prairie, and the West Fork Trinity River in Arlington). In situations like these, local communities are dealing with bridge scour, exposed utility lines, loss of backyards, and endangerment of homes and citizens. Local governments are also trying to cope with the sedimentation problems caused by severe stream bank erosion. High rates of sedimentation are reducing the storage capacity of ponds and lakes, thereby making the floodplain management and storm water management responsibilities of local governments even more difficult. The costs of stream bank repair, stream bank stabilization, and sediment removal are often difficult for local governments to address. When associated with large rainfall events or flooding, the issue can be impossible for local governments to deal with without massive state or federal assistance. Although stream bank erosion is a natural process, the impact of severe stream bank erosion on bridges, water lines, sewer mains and structures can quickly result in immediate public safety concerns.

According to NCTCOG population data, the Dallas/Fort Worth area is already the ninth-largest metropolitan area in the United States, with a population of 5.7 million people. NCTCOG has developed population growth projections out to the year 2030 for a large portion of the 16-county planning area, projecting a growth of more than 3.4 million additional people. By identifying streams that will be impacted by this large increase in development over the next 30 years, the affected communities can adopt planning and development measures to mitigate stream bank erosion hazards.

In addition to the growth projection data, there are several other data sources that are readily available to help identify areas potentially at risk for stream bank erosion. Most notably among these is the soil type that makes up the stream channel. The U. S. Department of Agriculture produces soil surveys and provides the map data in a digital spatial format, which has been overlaid with the stream channel layer as well as the population growth layer for analysis. Further potential hazard zones may be identified by using the stream layer itself, identifying areas of extreme sinuosity or meandering. By looking at the ratio of the length of the stream to the valley length, the stream can be classified as relatively straight, having moderate meanders, or pronounced meanders (Halff 1998). Although they will not be analyzed here, there are many other factors which can cause or contribute to stream bank erosion. These factors include, but are not limited to: impact force of intense rainfall, groundwater seepage, overbank drainage, changes in land use, freeze/thaw and wet/dry cycles, and wave attack. Analysis of these hazards can be done by individual communities, most likely in areas where bank erosion is known to occur or in areas which are identified by this analysis as being susceptible to erosion.

Digital Geographic Information System (GIS) data was used to perform the hazard analysis. Since NCTCOG's growth projection data is only available for 10 counties in the 16-county region, analysis was focused on this area for this planning cycle. The growth projection data contains growth of persons, households, and employees for every five years (2005, 2010, and so on) through the year 2030. For this analysis, the growth between the present time and 2030 was used in order to show long-term planning needs. However, the analysis could be performed using the same methodology described here to do a shorter-term analysis with any of the other growth parameters.

The population growth data is divided spatially into grid blocks, each approximately 280 acres. Initially, these grid blocks were displayed on a map of the area and shaded according to the degree of population growth. To make this growth data more meaningful, it was overlaid on the map by the individual hydrologic units at the watershed level, a total of 97 watersheds. By combining these two data layers digitally, a new layer was created, breaking the population growth grid blocks into their respective watersheds. Assuming that the population growth occurs in a uniform manner across the grid block, the growth totals were adjusted by the percentage of each block that falls in each certain watershed according to the following formula:

(Population Growth) x (new area / original area of grid block)

These new growth values were summed for each of the watersheds and added to a shapefile called *watersheds_growth*, which represents the projected growth for the study area broken down on a watershed-by-watershed basis. In HazMAP **map 19-1**, the darker colors are areas of greater population growth and are, therefore, more susceptible to increased rates of stream bank erosion as a consequence of population growth and associated new construction.

The U.S. Department of Agriculture's Natural Resource Conservation Service (NRCS) publishes soil survey reports for each county. Many of these soil reports are available digitally for download from the USDA-NRCS Soil Survey Division's National SSURGO (soil survey geographic) Database. The soil survey shapefiles (digital layers representing soil types) were added to a map showing streams and watersheds. By classifying the different soil types according to their susceptibility to erosion, areas with the potential for erosion due to wind and water have been further identified in HazMAP **map 19-2**. This map is color coded based on the Highly Erodable Lands (HEL) Classification found in the NRCS SSURGO data set.

HazMAP **map 19-3** estimates the local 30-year potential for erosion based on soil characteristics (from map 19-2) as well as the forecasted population growth (from map 19-1) within each soil parcel. Areas in red indicated soils with a high physical potential for erosion; orange areas indicate a probable high erosion potential; green areas indicate lower erosion potential. Darker shades of these colors indicate areas of relatively heavy growth through 2030, and lighter shades indicate lower population growth areas. Taken together, these two data sets offer an estimate of the geographic erosion potential in the watersheds of the MPA-Trinity.

For potential future analysis of this hazard, several different factors can be considered. Sinuosity could be analyzed by digitizing the approximate valley length of streams. A sinuosity index could then be computed by comparing the stream length to the valley length according to the following formula and scale:

Sinuosity Index (SI) = Stream Length / Valley Length

Pronounced Meanders: SI > 1.5 (higher hazard)
Moderate Meanders: 1.5 > SI > 1.26
Relatively Straight: 1.25 > SI > 1.0 (lowest hazard)

This analysis is most useful in determining areas of additional susceptibility for specific project areas. A minimum of 500 feet of stream should be used, centered on the project site in question.

Areas of high velocity are at greater risk of stream bank erosion than other areas. Velocities at FEMA Flood Insurance Study cross sections are published in the Floodway Data Table of each FIS. Specific areas can be analyzed for specific projects or developments, or individual communities may incorporate the velocities into a GIS stream shapefile and indicate high velocity areas graphically. Traditionally, velocities of less than 5 ft/sec are considered low velocity, while those exceeding 8 ft/sec are classified as high velocity reaches. This can also be overlaid with the soil type and population growth layers to further evaluate the hazard.

In the Population Growth portion of the risk assessment, the growth-watershed data were normalized by dividing the projected growth per watershed by the area of the watershed in acres. This way, each area could be compared on a growth density basis. The average value of this growth per area factor was close to 1.5 persons per acre. There were 30 out of the 97 watersheds which fall above this average, with 19 of those being above 2.0 and 4 of those being above 3.0. Most of the growth is concentrated in several areas: South of Fort Worth (Burleson area), Eagle Mountain/Saginaw area, Arlington/Grand Prairie, Denton, Central and Northwest Dallas (inside IH-635), and the Plano/Allen/Frisco area of Northern Dallas and Southern Collin Counties. There are several other areas, generally south of the Dallas and Fort Worth metro areas, Northeast Tarrant County, and East of Dallas and Lake Ray Hubbard, which are predicted to experience more moderate growth and will also be impacted by this hazard. No watershed within the designated Metropolitan Planning Area is predicted to have a decline in population, although there are 19 watersheds which are only predicted to experience growth of 0.5 persons per acre or less, most of which are areas that have been largely developed for some time.

Summary Based on a qualitative analysis of the impacts that stream bank erosion hazards are having on the NCTCOG region and based on a quantitative analysis of potential watershed susceptibility to stream bank erosion, the risk of stream bank erosion hazards is sufficient enough to merit mitigation consideration.

References:

Halff Associates, Inc. (June 1998). *Stream Bank Stabilization Manual for the Cities of Plano, Garland, McKinney, and Allen.*

HazMAP

Chapter 20 Selected Hydrologic Hazards: Dam Failures

Hazard Identification

Just because a dam has been in place for over 50 years does not mean that its continued existence can be taken for granted. Troubles from dam failures can occur anytime, without warning, and with catastrophic results.

A dam is defined as a barrier constructed across a watercourse for the purpose of storage, control, or diversion of water. Dams typically are constructed of earth, rock, concrete, or mine tailings. A dam failure is an accidental or unintentional collapse, breach, or other failure of an impoundment structure that results in downstream flooding. Because dams are man-made structures, dam failures are usually considered technological hazards. However, since most dam failures result from prolonged periods of rainfall, they are often cited as secondary or cascading effects of natural flooding disasters and are not named as the primary hazard that causes disaster declarations.

A dam impounds water in the upstream area, referred to as the reservoir. The amount of water impounded is measured in acre-feet. An acre-foot is the volume of water that covers an acre of land to a depth of one foot. As a function of upstream topography, even a very small dam may impound many acre-feet of water. Two factors influence the potential severity of a full or partial dam failure: (1) the amount of water impounded, and (2) the density, type, and value of development and infrastructure located downstream.

Dam failures can result from any one or a combination of the following causes:

- prolonged periods of rainfall and flooding, which cause most failures
- inadequate spillway capacity, resulting in excess overtopping flows
- internal erosion caused by embankment or foundation leakage or piping
- improper design
- improper maintenance
- negligent operation
- failure of upstream dams on the same waterway

Risk Assessment

People, property, and infrastructure downstream of dams could be subject to devastating damage in the event of failure. Exposure is compounded in communities experiencing growth because the typical dam-break floodplain is more extensive than the floodplain used for regulatory purposes. Therefore, new development is likely occurring without full recognition of the potential hazard. Few states and local jurisdictions consider the hazard classification of upstream dams when permitting development. Roads and linear infrastructure such as electric, gas, cable, water lines, and sewer lines that cross waterways are exposed to scour and damage during dam failures.

In 1972, a privately owned mine-tailings dam on Buffalo Creek in West Virginia failed. The reservoir was filled with water and mining debris, and, when the dam broke, a mass of fluid resembling mush went rushing down the valley, killing 125 people and leaving more than 3,000 homeless. Public concern stirred by the devastating Buffalo Creek dam failure prompted the U.S. Congress to adopt the National Dam Inspection Act in 1972 (Public Law 92-367). The U.S. Army Corps of Engineers (USACE) was authorized to inventory and inspect all non-Federal dams. In Texas, the Texas Water Commission (now the Texas Commission on Environmental Quality) contracted with the USACE to accomplish the Texas portion of the *National Inventory of Dams*. In 1989, FEMA and the USACE signed a Memorandum of Agreement in which FEMA accepted responsibility for updating the *National Inventory of Dams* with USACE funds. FEMA coordinates with the Association of State Dam Safety Officials, which brings together various State agencies responsible for dam safety. In Texas, dam safety is a joint function of two State agencies—the Dam Safety Unit within the Commission on Environmental Quality (TCEQ) and the Division of Emergency Management (DEM) within the Department of Public Safety.

Historically, Texas has had over 50 documented dam failures, and at least two of those failures have resulted in loss of life. In 1900, the Lake Austin Dam on the Colorado River in Austin failed, killing 25 people. In 1989, the Nix Lake Dam in Rusk County failed, killing one person.

Each dam in the *National Inventory of Dams* is assigned a downstream hazard classification based on the potential for loss of life and damage to property should the dam fail. The classification has nothing to do with the condition or structure of the dam or whether the dam is about to collapse. The hazard classifications are as follows:

Hazard Classification 1: High Hazard: dam failure would probably result in loss of life and major damage to property.

Hazard Classification 2: Significant Hazard: dam failure could possibly cause some loss of life and property damage.

Hazard Classification 3: Low Hazard: dam failure would be unlikely to cause loss of life or property damage.

Texas has more dams listed in the *National Inventory of Dams* than any other state. As of 2001, there were 6,838 dams listed in the *National Inventory of Dams*, and 1,111 of those dams were located within the NCTCOG region. See Table 20-1 for a breakdown of hazard classifications:

Table 20-1

Dams Included in the *National Inventory of Dams* and Located Within the NCTCOG Region	
High Hazard Classification	168 dams
Significant Hazard Classification	81 dams
Low Hazard Classification	842 dams

According to the *National Inventory of Dams*, of the 168 High-Hazard dams in the NCTCOG region, only 18 (10.7%) have had Emergency Action Plans (EAPs) prepared to evaluate and delineate downstream areas that would be inundated by failure of these dams. In other words, 150 (almost 90%) of the High-Hazard dams in the NCTCOG region do not have Emergency Action Plans. See HazMAP **map 20-1**.

Also according to the *National Inventory of Dams*, 250 (almost 23%) of all the dams in the NCTCOG region have not been inspected since 1993. See HazMAP **map 20-2**. In other words, 795 (almost 72%) of all dams in the NCTCOG region have no recorded inspection date. As of September 2002, only 67 (6%) of all dams had been inspected within the last 10 years.

In addition to the dams listed in the *National Inventory of Dams*, Texas also has many more dams that are inventoried by the Natural Resources Conservation Service (NRCS). As part of the federal Flood Control Act of 1944 and the Watershed Protection and Flood Prevention Act of 1954, the NRCS (previously the Soil Conservation Service) has provided federal assistance for the construction of small flood control and sediment control dams on rural agricultural lands. Local sponsorship of these dams has most often been provided by Soil and Water Conservation Districts (SWCD). As depicted in Table 20-2, there are 653 NRCS dams in the NCTCOG study area, and nearly a quarter of them are over 40 years old.

Table 20-2

NRCS Dams by Decade of Construction for the NCTCOG Region (1950-1999)*

Years	# of Dams Built
1950-1959	154
1960-1969	311
1970-1979	124
1980-1989	58
1990-1999	6
Total	653

Source: NRCS, August 2003
*NCTCOG received no data for Tarrant County

Since most of the NRCS dams were originally constructed to provide flood protection and sediment control for agricultural lands, they were designated as low hazard projects because there was not much development in the downstream areas. However, over the past 40 to 50 years, as the population of the NCTCOG region has drastically increased, the once rural areas downstream of many of these structures have been converted from agricultural uses into residential, commercial, and industrial developments.

Development of the downstream areas necessitates the original low hazard classifications to be changed to higher hazard classifications because the dams are no longer adequate for the increased downstream risks. As depicted in Table 20-3, NRCS data show there are 55 NRCS dams in the NCTCOG region that are no longer adequate for increased downstream risks, representing nearly 10% of all the NRCS dams in the region. This percentage could actually be higher because detailed current evaluations of NRCS dams have not been conducted due to resource limitations. In addition, many of these inadequate dams have not been updated because many of the legally responsible entities of these dams do not have sufficient mechanisms to provide funding for updates, or even adequate maintenance, in some cases. SWCDs do not have any statutory funding capability of their own, and counties, especially those with small populations and multiple dams, are not able to generate the resources needed to sustain a consistent and comprehensive effort to upgrade these structures.

Table 20-3

Number of NRCS Dams in the NCTCOG Region Which Are No Longer Adequate For Increased Downstream Risks*

County	# of Dams
Collin	6
Dallas	1
Denton	2
Ellis	10
Erath	4
Hood	0
Hunt	1
Johnson	6
Kaufman	11
Navarro	1
Palo Pinto	1
Parker	2
Rockwall	6
Somervell	0
Wise	4
Total	55

Source: NRCS, August 2003
*NCTCOG received no data for Tarrant County

Summary While no record could be found of any previous dam failures in the NCTCOG region, three things are clear: (1) many of the dams in the NCTCOG region are nearing the end of their designed project lives, (2) many of these dams are in desperate need of detailed evaluations and consistent maintenance, and (3) increased development downstream of these dams has put more people, property, and infrastructure at risk. Based on a quantitative analysis of the dams currently in place in the NCTCOG region and a qualitative analysis of the potential impacts that dam failures would have on the social, economic, and environmental components of the NCTCOG region, the risk of a dam failure hazard is sufficient enough for mitigation consideration.

A reliable funding mechanism needs to be developed if these structures are to remain public assets and not become liabilities. It should be noted that, in many cases, the downstream beneficiaries of the dams are located outside of the funding entity's jurisdictional boundaries and, therefore, do not pay for the flood control/sediment control benefits of the these dams. For this reason, mitigation efforts for dam failure hazards require a multi-jurisdictional approach. To their credit, some jurisdictions in the NCTCOG study area, such as the city of McKinney, have already recognized this point and are exploring multi-jurisdictional actions.

References:

Bickerstaff, Heath, Smiley, Pollan, Kever & McDaniel, L.L.P. (2000) *Rehabilitation of Soil and Water Conservation District Dams.* http://www.bickerstaff.com/articles/billlgs.pdf

Federal Emergency Management Agency (FEMA). (1997) *Multi Hazard Identification and Risk Assessment.* Technological Hazards, Chapter 20.

Salisbury, David. (March 11, 1998). Stanford Online Report. *$20 Billion Needed to Ensure Safety of Nation's Dams, Engineer Estimates.* Retrieved on September 17, 2003 from http://news-service.stanford.edu/news/march11/damsafety.html

State of Texas—Division of Emergency Management. (2000) *Hazard Analysis*. Dam/Levee Failure, Section 11.

Task Committee of the Association of State Dam Safety Officials. (2002) *The Cost of Rehabilitating Our Nation's Dams: A Methodology, Estimate & Proposed Funding Mechanisms*.

HazMAP

Chapter 21 Selected Hydrologic Hazards: Levee Failures

Hazard Identification Levees are earthen embankments whose primary purpose is to furnish flood protection from seasonal high water for a few days or weeks a year. Levees are broadly classified as either urban or agricultural because of the different requirements for each. Urban levees provide protection from flooding in communities, including their industrial, commercial, and residential facilities. Agricultural levees provide protection from flooding in lands used for agricultural purposes. There are five main types of levees:

- Mainline and Tributary levees: generally parallel the main channel and/or its tributaries.
- Ring levees: completely encircle or "ring" an area from all directions.
- Setback levees: generally built as a backup to an existing levee that has become endangered due to such actions as river migration.
- Sublevees: constructed for the purpose of underseepage control. Sublevees encircle areas landward of the main levee that are flooded, generally by capturing seepage water, during high-water stages thus counterbalancing the hydrostatic pressures beneath the top stratum.
- Spur levees: project from the main levee and provide protection to the main levee by directing erosive river currents riverward.

High levels of precipitation can cause levees to fail because the soil remains saturated and as a result, becomes sensitive to erosion. Animal burrows can aggravate the situation because the burrow created gives water a direct route into the levee. The high water moves through the saturated levee, softening and weakening its foundation and creates a tremendous force against the levee. The erosion of the foundation of the levee results in a "boil." A boil is an area on the side that begins to slide away from the base. If the levee is not maintained, it will collapse as the process continues. Sandbags are often used to slow down the erosion process by holding the boil in place. In extreme cases, water is pooled with sandbags to equalize the pressure and slow the water down.

Levee failures occur throughout the United States, most commonly near river basins. When levees fail, surrounding areas are subject to flooding, which can cause substantial, often devastating damage to homes, structures, and agricultural areas. Levee failures have caused a great number of livestock deaths and human casualties.

Risk Assessment Based on information contained in the Corps of Engineers reports; "Upper Trinity River Reconnaissance Report" and 1995 Information Paper – A Benefit-Cost Analysis, Upper Trinity River Basin, Texas, "Natural Disaster Procedures Under PL 84-99 (Supplement A to ER 500-1-1), and various FEMA "Flood Insurance Study" reports, there are numerous flood protection systems located in the 16-county NCTCOG region. The Trinity River is formed at the confluence of the West Fork and Elm Fork, just to the west of downtown Dallas, and the majority of the levees are located on these conveyances or their major tributaries. The Trinity River Basin has a total length of about 260 miles and a maximum width of about 100 miles near its upper end. The river meanders a great deal throughout its course, a distance of almost 1.5 times the length of the valley. Gage records indicate that approximately 60 days is required for passage of a major flood. These characteristics, combined with the small capacities of its tributary stream channels and the considerable development throughout the watershed, indicate the importance of levees in the NCTCOG region as a flood protection measure.

The Code of Federal Regulations, 44 CFR Section 65.10, outlines the requirements for mapping areas protected by levee systems. For the purposes of the National Flood Insurance Program (NFIP), FEMA will only recognize in its flood hazard and risk mapping effort those levee systems that meet, and continue to meet, minimum design, operation, and maintenance standards that are consistent with the level of protection from the base flood. FEMA levee requirements also include the following:

Freeboard: Riverine levees must provide a minimum freeboard of three feet above the water-surface level of the base flood. An additional one foot above the minimum is required within 100 feet in either side of structures (such as bridges) riverward of the levee or wherever the flow is constricted. An additional one-half foot above the minimum at the upstream end of the levee, tapering to not less than the minimum at the downstream end of the levee, is also required.

Closures: All openings must be provided with closure devices that are structural parts of the system during operation and design according to sound engineering practice.

Embankment Protection: FEMA requires that an engineering analysis be performed on the levee system demonstrating that no appreciable erosion of the levee embankment can be expected during the base flood.

Embankment and Foundation Stability: FEMA requires that the levee be designed and constructed for stability against loading conditions for Case IV as defined in the U. S. Army Corps of Engineers (COE) Manual, “Design and Construction of Levees”, (EM 1110-2-1913) or other engineering methods approved by FEMA.

Settlement: FEMA requires that an engineering analysis be conducted that assess the potential and magnitude of future losses of freeboard as a result of levee settlement.

Interior Drainage: FEMA requires an engineering analysis be conducted that identifies the source(s) of such flooding, the extent of the flooded area, and, if the average depth is greater than one foot, the water-surface elevation(s) of the base flood.

Operation and Maintenance: FEMA will not recognize a levee system as providing flood protection unless the system is under the jurisdiction of a Federal or State agency, an agency created by Federal or State law, or an agency of a community participating in the NFIP. Such agency must submit an officially adopted operation manual and maintenance plan to FEMA for approval.

Certification: FEMA requires that data must be submitted to support that a given levee system complies with the structural requirements specified in 44 CFR Section 65 and certified by a registered professional engineer. The certification must include a statement that the works are designed in accordance with sound engineering practices to provide protection from the base flood. In lieu of these structural requirements, a Federal agency with responsibility for levee design may certify that the levee has been adequately designed and constructed to provide protection from the base flood.

Table 21-1, *Flood Protection Levee Systems in the NCTCOG Region*, is based on information shown on FEMA published Flood Insurance Studies and described on Flood Insurance Rate Maps (FIRM’s) published for the NCTCOG planning area. FEMA requires that levee systems must be designed, constructed and maintained to the minimum standards of the National Flood Insurance Program and protect to the 100-year flood event before that can be mapped as providing flood protection. See HazMAP map 21-1 for a spatial representation of the levee systems in the NCTCOG region.

Flood Protection Levee Systems in the NCTCOG Region

Table 21-1

Levee System	County	Community
West Fork Levee System	Tarrant and Dallas	Numerous
Clear Fork Levee System	Tarrant	City of Fort Worth
Johnson Creek TRA-WWTP Levee	Tarrant	Arlington
Dallas Floodway (Trinity River)	Dallas	City of Dallas
Irving Flood Control Dist. Section I (Elm Fork)	Dallas	City of Irving
Irving Flood Control District Section III (Grapevine Creek and Elm Fork)	Dallas	City of Irving
Farmers Branch-Carrollton Flood Control District (Cooks Branch and Hutton Branch)	Dallas	Cities of Carrollton and Farmers Branch
Valwood Improvement Authority	Dallas	City of Irving
Denton County Reclamation and Road District (Elm Fork and Indian Creek)	Denton	Numerous
Denton County Levee Improvement District #1	Denton	Numerous
Grand Prairie Municipal Utility and Reclamation District (West Fork)	Dallas	City of Grand Prairie
City of Dallas Levees (Trinity River and Fivemile Creek)	Dallas	City of Dallas
Dallas County Flood Control District #1	Dallas	City of Dallas
Big Fossil Creek Flood Control Project (levees and channelization)	Tarrant	Numerous
Denton Creek Levee	Denton	Lewisville
Elm Fork Levees	Denton	Lewisville

The risk of levee failure from the base flood event is minimal for the levee systems listed above. However, there is a greater risk of levee failure or levee systems being overtopped for flood events that exceed the base flood event. The three foot freeboard required by FEMA provides a greater safety factor, but major floods of long duration such as the 1993 Mississippi River Flood can result in major damage and potential loss of life.

The Information Paper – "A Benefit-Cost Analysis, Upper Trinity River Basin, Texas", 1995, prepared by the US Army Corps of Engineers Fort Worth District states that if the Standard Project Flood were to occur (1995) more than 22,000 homes and more than 140 million square feet of commercial property would be damaged, resulting in over $4 billion in flood damages and untold loss of life.

Summary While no record could be found of any previous major levee failures in the NCTCOG region, the point must be made that increasing development both upstream and downstream of the region's existing levees are likely to be reducing the flood protection capabilities of these levees even for the base flood event. As a result of recent studies modeling the devastating impacts of the Standard Project Flood and because development has likely resulted in incremental reductions in base flood protection capabilities, the risk of a levee failure hazard is sufficient enough to merit mitigation consideration.

References:

Federal Insurance Administration/Federal Emergency Management Agency. Flood Insurance Studies and Flood Insurance Rate Maps Published for Individual Communities and County-wide for Communities within the NCTCOG Region.

The Hawk Eye. *The Anatomy of a Levee.* Retrieved September 17, 2003 from http://www.thehawkeye.com/features/1998/93flood/

Williams, Lance. (January 12, 1997). San Francisco Examiner, Page C1. *Collapse of levee no surprise, expert says*. Retrieved on September 17, 2003 from http://www.stanford.edu/~meehan/flood/sfexam.html

U.S. Army Corps of Engineers, Memphis District. (July 1999). *Levees*. Retrieved on September 17, 2003 from http://www.mvm.usace.army.mil/floodcontrol/Levees

U.S. Army Corps of Engineers, Fort Worth District. (March 1990). *Upper Trinity River Basin Reconnaissance Report.*

U.S. Army Corps of Engineers, Fort Worth District and the North Central Texas Council of Governments. (February 1995). *Upper Trinity River Basin Information Paper "A Benefit - Cost Analysis."*

HazMAP

Chapter 22 Hazards Ahead

We simply turn on the radio or television every day to learn what the weather will be. Sometimes the forecasters are right, often they are wrong. Will it rain? Will it snow? Will anything prevent me from doing what I want to do today?

If a particular weather hazard is possible, i.e., conditions are more favorable than usual for its occurrence, the National Weather Service will issue a "watch" for that particular hazard. A watch is a recommendation for near-term planning and increased awareness – be alert for changing weather, listen for further information and think about what to do if danger materializes.

As conditions change, the NWS may issue a "warning" that a particular weather hazard is either imminent or has been reported. A warning indicates the need to take action to protect life and property from that hazard – tornado warning, flood flash warning.

This Multi-Hazard Risk Assessment has analyzed, synthesized, and summarized hundreds of thousands of pieces of historical data on what has happened in the past. We have had tornadoes. We have had floods and droughts. We have had wildfires and lightening and ice storms and hail and many other natural catastrophes in our region. Properties have been damaged. Lives have been lost.

In this chapter we are introducing a new word into our glossary of risk assessment for the DFW region – **forewarning**. In the dictionary, a forewarning is an early warning about a future event. It is to tell someone that something unpleasant is going to happen. It is to warn in advance.

Over the next 30 years, the North Central Texas region is expected to add 4 million new residents, 1.5 million new households, and 2.3 million jobs. That means a lot more people, houses, apartments, businesses and infrastructure to get in the way of natural hazards.

Just like the meteorologists, we can never be certain where or when a severe weather event will occur. Yet from the detailed historical analyses presented in this risk assessment, we can make forewarnings of what is likely to occur assuming these patterns continue.

Forewarnings for Tornadoes, Hail, High Winds and Other Severe Weather Hazards

Our region is on the southern edge of "Tornado Alley", a zone that stretches from northern Texas through Oklahoma and into Nebraska. According to NOAA, the North Central Texas area is only one of two hot spots in the entire United States where there have been more than 15 recorded tornadoes per 1,000 square miles. There is no reason to believe this will not continue, along with other severe weather hazards.

- **A Large, Violent Long-Track Tornado could cause more than $4.5 billion in damages and put more than 150,000 people at risk in North Central Texas.** As presented in Chapter 9, more than 55 tornado damage path scenarios have been analyzed using GIS technology to estimate structures, property, residents, employees, and traffic impacts. For example, if a mile-wide portion of the Moore tornado were to move into downtown Dallas, over 100,000 employees and nearly $3 billion dollars of property would be inside of the tornado simultaneously.

- **More than 200 Tornadoes of Various Sizes Across the Region Over the Next 30 years.** Based on the last 50 years of data collected within this region, it is very likely that at least 200 tornados will occur by 2030. The typical or average "unit" tornado will have a straight 10-mile long continuous path about 1/6 mile wide, impacting about 960 acres (Chapter 9). As the region extends outward on the fringes and densifies within the urbanized area, more structures and property will become targets to the potential devastation from tornadoes. To see visual comparisons of expected tornado impacts between 2000 and 2030, see HazMAP **map 22-4**, **map 22-5**, **map 22-6**, and **map 22-7**. To see a case study showing visual comparison of 2000 and 2030 structural land use if the "unit" tornado were to strike a medium structural growth area, see HazMAP **map 22-8**. To see a case study showing visual comparison of 2000 and 2030 structural land use if the "unit" tornado were to strike a high structural growth area, see HazMAP **map 22-9**.

- **More than 2,000 Hail Events Across the Region Over the Next 30 Years.** Over the 16-county region, more than 3,000 storm events with hail sizes greater than 0.75 inches were recorded or observed since 1955 as discussed in Chapter 10. Extrapolating this historical data to 2030 suggests that more than 2,000 hail events are very likely and would be fairly uniformly distributed over the entire region.

- **More than 100 Significant Wind Storms Across the Region Over the Next 30 Years**. Straight-line winds are often responsible for most of the wind damage associated with a thunderstorm. Since 1955 over 160 windstorms with wind speeds exceeding 70 mph have been recorded in the NCTCOG region as discussed in Chapter 11. It is reasonable to expect that more than 100 such high wind events will occur over the next 30 years, with the risk fairly uniform across the region.

- **All Communities At Risk From Severe Winter Ice Storms.** While snowstorms are not frequent in Texas, ice storms create dangerous driving conditions, may freeze pipes and down power lines (Chapter 12). Using TxDOT road advisory data, it is clear that all communities in the region are at risk from winter ice storm hazards.

Forewarnings for Floods, Levee Failures and Other Hydrologic Hazards

In any given year, damaging floods are likely to occur on at least one major river or stream in Texas, affecting thousands of homes and businesses, and often, resulting in the loss of life. Floods in Texas killed more people between 1989 and 1998 than in any other state—145 out of a national total of 957 people killed in floods. On the average, Texas suffers $254 million in losses (direct crop and property damage) each year from flooding. Continuing growth and development in the region has resulted in increasing storm water and drainage problems, challenging communities to further stabilize flood risks and minimize otherwise likely future flood losses.

- **A Standard Project Flood Along the Trinity River Would Damage More Than 22,000 Homes and 140 Million Square Feet of Business Property, With More Than $4 Billion in Impacts and Untold Loss of Life.** These are the findings from the Trinity River COMMON VISION program, a cooperative initiative among NCTCOG, 14 local governments, the U.S. Army Corps of Engineers and other partners. (http://www.dfwinfo.com/envir/trin/index.html). (Chapter 18).

- **More Than 2,300 Miles of Regional Environmental Corridors, Much of Which Subject to Flash Flooding and Stream Bank Erosion.** In its SEE Safe Clean and Green regional plan, NCTCOG identifies more than 2,300 miles of streams as regional corridors, and discusses the range of impacts from urbanization that are occurring. (http://www.dfwenvironment.com/). (Chapter 18).

- **Many Smaller Dams Nearing the End of Their Design Lives.** While no record could be found of any previous dam failures in the NCTCOG region, three things are clear: (1) many of the dams in the NCTCOG region are nearing the end of their designed project lives, (2) many of these dams are in desperate need of detailed evaluations and consistent maintenance, and (3) increased development downstream of these dams has put more people, property, and infrastructure at risk (Chapter 20).

Forewarnings for Landslides, Expansive Soils and Other Geologic Hazards

While it's impossible to assign probabilities to future occurrences, one thing is certain: geologic hazards will always be an issue that lingers without much attention from the popular media. Although longer in time scale and often less apparent, North Central Texas should remain cognizant of geologic hazards both directly and indirectly associated with the character of the physical lands making up the greater region.

As development and city build-out occurs throughout the region, the unforeseen consequences of dense construction activities on shrinking and swelling soils, unconsolidated fill, and in previously untested areas are having both economic and quality-of-life impacts on the region. In addition, public works such as electric transmission lines, telephone poles, and roadways are often the victims of various forms of mass wasting, which causes over 2 billion dollars in damage each year nationwide.

- **Soil Expansion Poses Risks for Existing and Future Infrastructure.** Transportation and utility public works, including electrical, communications and water infrastructure, as well as many structural foundations are susceptible to damage by slow, continuous soil movements. (Chapter 7).

- **Landslides occur in all 50 states, causing $1-2 billion in damages and more than 25 fatalities on average each year**. Due to the densification of populations in untested, lower stability areas of the region, such as on the Mountain Creek Escarpment, the risk of landslides in the region may become more evident for utilities as well as for home owners. (Chapter 6).

- **90% Improbable Means 10% Probable**. A major, distant-focus earthquake could generate sufficient peak ground acceleration to cause damage to some sensitive facilities in the region. Although impossible to predict in a stable geologic region such as North Texas, the presence of major and minor fault systems within 1000 miles of the region presents some remote, yet viable, risk of damage to sensitive facilities. (Chapter 8).

Forewarnings for Droughts, Heat, Wildland Fires and Other Climatic Hazards

Over time, the prevailing conditions of North Central Texas with respect to temperature, precipitation, and wind result in different types of climatic hazards. For instance, during the summer months, the NCTCOG region is frequently affected by severe heat-related hazards. Persistent domes of high pressure establish themselves over the region, which set up hot and dry conditions. This high pressure prevents other weather features such as cool fronts or rain events from moving into the area and providing necessary relief. Without relief for an extended period of time, other associated conditions such as wildfires, droughts, and poor air quality become hazards.

- **Several Droughts Of 1-2 Years Duration or More**. Since 1892, North Central Texas has had 12 drought years, consisting of eight 1-year droughts and two 2-year droughts for a total of 10 drought events. Assuming this long-term pattern continues, the region can expect to experience several droughts by 2030 (Chapter 15). There is growing speculation among climatologists that, during the next few decades, Texas could see even more frequent droughts, of longer duration, than the ones it has experienced since the great drought of the 1950's.

- **Region Frequently Affected by Severe Summer Heat Hazards**. Severe summer heat is an invisible killer. Although a heat wave does not happen with the spectacle of other hazards such as tornadoes and floods, the National Center for Environmental Health reports that, from 1979 to 1999, excessive heat exposure caused 8,015 deaths in the United States. In other words, during this period, more people in the U.S. died from severe summer heat than from hurricanes, lightning, tornadoes, floods, and earthquakes combined. And, according to a recent study, the number of heat waves has tripled over the last 50 years. The study contends that the steady rise in temperatures is a result of global warming caused by human pollution. (Chapter 14).

- **As the Region Grows, So Grows the Wildland/Urban Interface**. In recent years, many areas of the NCTCOG region have experienced serious wildland fires. As the region continues to grow and spread further out into the hinterland, the possibility for more serious wildfires in the wildland/urban interface will also increase. (Chapter 16).

NCTCOG 2030 Demographic Forecasts

NCTCOG's 2030 Demographic Forecasts for population, employment, and households are used to identify areas of projected growth over the next three decades in the NCTCOG region. Areas identified for future growth are also areas of future vulnerability. And, those areas are given special consideration because they also represent opportunities for mitigation strategies to make the most difference for new development and redevelopment.

NCTCOG 2030 Demographic Forecast			
Population			
2000	**2030**	**Total Change**	**Percent Change**
5,067,400	9,107,200	4,039,800	80%

See HazMAP **map 22-1** for a spatial representation of the population forecast.

NCTCOG 2030 Demographic Forecast			
Households			
2000	**2030**	**Total Change**	**Percent Change**
1,886,700	3,395,900	1,509,200	80%

See HazMAP **map 22-2** for a spatial representation of the households forecast.

NCTCOG 2030 Demographic Forecast			
Employment			
2000	**2030**	**Total Change**	**Percent Change**
3,158,200	5,416,700	2,258,500	72%

See HazMAP **map 22-3** for a spatial representation of the employment forecast.

NCTCOG's 2030 Demographic Forecast has a 30-year time horizon, with 2000 as the base year and 2030 as the end year. The NCTCOG Executive Board adopted the regional projections in May 2002 upon recommendation by the Demographic Methodologies Task Force, a working group of local officials from city, county, and transportation entities that acted as a governing body for the process.

These forecasts show North Central Texas with a 2030 population of 9.1 million persons in 3.4 million households, and non-construction employment of 5.4 million jobs. These projections represent 30-year increases of 4.0 million residents, 1.5 million households, and 2.3 million jobs. The rate of growth projected through the three decades represented in this forecast is at a magnitude never before experienced in the North Central Texas region.

The 2030 regional forecasts differ from earlier projections for North Central Texas in several significant ways. The 2030 rate of growth for population and households is noticeably higher. This growth may seem extreme, given the current economic conditions in the region; however, North Central Texas continues to be a destination for job seekers and international immigrants, citing the region's quick recovery from the recession of the early 1990's and the low cost of living.

Employment growth is not projected to increase at the same rate as population, but the 72 percent increase is very similar to previous forecasts. This results in an almost 5 percent increase of the population-to-employment ratio (P/E). This directly correlates to the departure of many baby boomers from the labor force, as the region's share of the over-60 population will double during the term of this forecast.

Previous forecasts have shown declining household sizes as we move toward the end of the forecast period. National research has indicated similar patterns throughout other regions in the United States. However, the 2000 Census actually showed increasing household sizes in the region. Although, we do not expect continued climbs in the household sizes, it would seem that a decline in North Central Texas would be very gradual, if one occurs at all. The increase in immigration population that has historically held on to higher household sizes is expected to offset declines that would be attributed to an aging population. Therefore, using the 2000 Census data as the base, the household sizes in this forecast stay relatively constant through 2030 at about 2.7 persons per household.

Forecasts are available both at the "district" level and at the "traffic survey zone" level. There are 478 districts that are generally based on Census tracts. Because the district forecasts show the magnitude and direction of residential and commercial growth expected both across and within the ten counties of North Central Texas, they can be used in regional infrastructure planning, such as in the Mobility 2030 Plan. The traffic survey zone (tsz) data allow planners to focus in on small areas of the region such as neighborhoods and business centers. There are 8,071 traffic survey zones.

Forecasts have been provided by NCTCOG's Research and Information Services Department (http://www.dfwinfo.com/ris/forecast/). The mission of NCTCOG's Research and Information Services Department is to provide objective, consistent, and timely information and analysis on the development of the region. These data are used in the planning and economic development activities of local governments in North Central Texas.