Multi-Hazard Mitigation Plan Update - 2009

August 2009

Flanagan & Associates, LLC
Planning Consultants

CITY OF Tulsa
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ENGINEERING SERVICES

July 31, 2009

Mr. Bill Penka, State Hazard Mitigation Officer
Oklahoma Department of Civil Emergency Management
P.O. Box 53365
Oklahoma City, OK 73152

RE: City of Tulsa Multi-Hazard Mitigation Plan – 2009 Update

We are pleased to submit this *City of Tulsa Multi-Hazard Mitigation Plan-2009 Update*, as fulfillment of the requirements of the Pre-Disaster Hazard Mitigation Grant (PDMC-PJ-06-OK-2007-004).

This Multi-Hazard Mitigation Plan, prepared in accordance with State and Federal guidance, addresses floodplain management, dam and levee failures, tornadoes, high winds, hailstorms, lightning, winter storms, extreme heat, drought, expansive soils, wild fires, and earthquakes.

We look forward to implementing this plan to enhance protection of the lives and property of our citizens from natural hazards and hazard materials incidents. If we can answer any questions or be of further assistance, please do not hesitate to contact me at 918-596-9475.

CITY OF TULSA, DEPARTMENT OF PUBLIC WORKS

Sincerely,

Bill Robison

Bill Robison, P.E., CFM
Senior Special Projects Engineer
Stormwater Planning

Executive Summary

In the 1970's and early 1980s Tulsa was identified in a national study as one of the nation's most disaster-prone areas, having been declared a federal disaster area nine times in only fifteen years. Oklahoma's location at the intersection of the hot arid zone to the west, the temperate zone to the northeast, and the hot humid zone to the southeast makes it subject to a wide variety of potentially violent weather and natural hazards.

Citizen Advisory Committee meeting at Tulsa City Hall

This City of Tulsa Multi-Hazard Mitigation Plan 2009 Update of the original 2003 Mitigation Plan is a strategic planning guide developed in fulfillment of the Hazard Mitigation Grant Program requirements of the Federal Emergency Management Agency (FEMA), according to the *Stafford Disaster Relief and Emergency Assistance Act*. This plan Update is developed in accordance with, and fulfills requirements for, the Pre-Disaster Mitigation Grant (PDM) and Hazard Mitigation Grant (HMGP). It also fulfills requirements for the Flood Mitigation Assistance Program (FMA), Severe Repetitive Loss Program (SRL), and the Community Rating System Plan (CRS) from the Federal Emergency Management Agency (FEMA).

In December 2005, the Multihazard Mitigation Council of the National Institute of Building Sciences completed a study to assess future savings from mitigation activities. Their findings reflected the fact that mitigation activities in general produced over $4 in savings for every $1 invested in mitigation actions, with the greatest savings in the areas of flood-related events (5:1) and wind-related events (3.9:1). In addition, the report concludes, *"Mitigation is most effective when carried out on a comprehensive, community-wide, and long-term basis. Single …activities can help, but carrying out a slate of coordinated mitigation activities over time is the best way to ensure that communities will be physically, socially, and economically resilient to future hazard impacts."*

Approval of this plan will qualify the City of Tulsa to apply for PDM funds, as well as HMGP funds following a federal disaster declaration, as required under Section 322 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 2000.

Background

Virtually every area of the city is vulnerable to natural and man-made hazards. The Tulsa Hazard Mitigation Citizen Advisory Committee (THMCAC) has identified 12 hazards affecting the City of Tulsa, including floods, tornadoes, high winds, lightning, hailstorms, severe winter storms, extreme heat, drought, expansive soils, wildfires, earthquakes, and dam and levee failures.

Purpose

The purpose of this plan is to:

- Assess the progress on the previously identified mitigation measures;
- Assess the ongoing mitigation activities in the community;
- Identify and assess the hazards that pose a threat to citizens and property;
- Evaluate additional mitigation measures that should be undertaken;
- Outline a strategy for implementation of mitigation projects.

The objective of this plan is to provide guidance for community activities for the next five years. It will ensure that the city and other partners implement activities that are most effective and appropriate for mitigating natural hazards and hazardous materials incidents.

Hazard Mitigation Citizens Advisory Committee

Citizens and professionals active in disasters provided important input in the development of the plan and recommended goals and objectives, mitigation measures, and priorities for actions. The THMCAC is comprised of the members of the City of Tulsa Stormwater Drainage and Hazard Mitigation Advisory Board. Members are listed above.

The Planning Process

Planning for the City of Tulsa Multi-Hazard Mitigation Plan followed a ten-step process, based on guidance and requirements of FEMA for the PDM grant program, HMGP, the Flood Mitigation Assistance (FMA) program, and the Community Rating System (CRS).:

1. Organize to prepare the plan
2. Involve the public
3. Coordinate with other agencies and organizations
4. Assess the hazard
5. Assess the problem
6. Set goals
7. Review possible activities
8. Draft the action plan
9. Adopt the plan
10. Implement, evaluate, and revise

Plan Summary

The City of Tulsa Multi-Hazard Mitigation Plan provides guidance to help citizens protect life and property from natural hazards. The plan identifies the hazards that are most likely to strike each jurisdiction, provides a profile and risk assessment of each hazard, identifies mitigation measures for each hazard, and presents an action plan for the implementation of the mitigation measures.

Chapter 1- Introduction provides a profile of the City of Tulsa. This chapter includes a community description including demographics, lifelines, and critical facilities.

Chapter 2- Existing Mitigation Strategies provides an overview and discussion of existing resources and hazard mitigation programs.

Chapter 3- The Planning Process presents detailed information documenting the planning process including citizen and agency involvement, a table describing how and why each hazard was identified, and methodologies used in the plan for damage estimates and risk assessments.

Chapter 4- Natural and Man-Made Hazards provides an assessment of 12 natural hazards. Each assessment includes a hazard profile, catalogs historical events, identifies the vulnerable populations, and presents a conclusion.

Chapter 5- Mitigation Goals and Objectives sets disaster-specific goals and objectives and organizes proposed mitigation strategies under six mitigation categories: public information and education, preventive activities, structural projects, property protection, emergency services, and natural resource protection.

Chapter 6- Action Plan outlines an action plan for the implementation of high priority mitigation projects, including a description of the project, the responsible party, anticipated cost, funding sources, and timelines for implementation.

Chapter 7- Plan Adoption and Maintenance provides a discussion of the plan documentation of the adoption resolutions, and the Plan maintenance process. Plan maintenance includes monitoring, evaluating, and updating the plan with involvement of the public.

Appendix A- Glossary provides a glossary of terms commonly used in disaster management and hazard mitigation.

Appendix B- Mitigation Measures provides a more detailed discussion of possible Mitigation Measures outlined in Chapter 6, organized by category.

Appendix C- Mitigation Committee Meetings provides the agendas and sign-in sheets from the Citizens Advisory Committee and the Technical Advisory Committee meetings.

Appendix D: 2003 Mitigation Measures provides a report on the current status of all Mitigation Measures included in the 2003 plan – whether completed, in process, continuing in 2009 plan, or incomplete.

Appendix E- Plan Update Changes provides an overview of changes made in the plan update from the original City of Tulsa Hazard Mitigation Plan of 2003.

Appendix F- Capital Improvement Projects provides an overview of currently ongoing mitigation programs under the City of Tulsa Capital Improvements Plan.

Appendix G- Critical Facilities provides a more comprehensive list of all critical facilities within the City of Tulsa. The basic list is included in Chapter 1, Section 1.2.9.

Appendix H- Repetitive Loss Properties provides a complete list of all identified repetitive loss properties in the City under the National Flood Insurance Program guidelines.

Mitigation Measures

The following are the high priority mitigation measures defined by the Tulsa Hazard Mitigation Technical Advisory and Citizens Advisory Committees:

Mitigation Measure Description	***Hazards Addressed***
1. Incorporate an Emergency Telephone Notification System (ETNS) into the Tulsa Emergency Communications Center	Floods, Extreme, Heat, Wildfires, Winter Storms, Dam/Levee Failure
2. Construct a new Emergency Operations Center	Floods, Tornadoes, High Winds, Lightning, Hail, Winter Storms, Wildfires, Earthquakes, Dam/Levee Failure
3. Develop a Master Generator Plan for the City of Tulsa	Floods, Tornadoes, High Winds, Lightning, Winter Storms, Earthquakes, Dam/Levee Failure
4. Develop a SafeRoom plan for City of Tulsa facilities	Tornadoes, High Winds
5. Individual SafeRoom rebate program	Tornadoes, High Winds
6. Install Lightning Warning & Alert Systems in public recreation areas	Lightning
7. Public Education & Information Program Development	Floods, Tornadoes, High Winds, Lightning, Hail, Winter Storms, Extreme Heat, Drought, Expansive Soil, Wildfires, Earthquakes, Dam/Levee Failure
8. Develop a Special Needs registry through the 9-1-1 databases to assist with educating, alerting, evacuating, or responding to vulnerable populations during disaster	Floods, Tornadoes, High Winds, Hail, Winter Storms, Extreme Heat, Wildfires, Earthquakes, Dam/Levee Failure
9. Provide for back-up power sources for City water treatment plants to avoid water shortages during extended power outages	Floods, Tornadoes, High Winds, Lightning, Winter Storms, Earthquakes, Dam/Levee Failure
10. Provide backup power generators to five additional city fueling facilities	Winter Storms, High Winds, Tornadoes, Earthquakes
11. Implement structural and non-structural flood mitigation measures for flood-prone properties, as recommended in the basin-wide master drainage plans	Floods, Dam/Levee Failures
12. Develop enhanced Emergency Planning for Special Needs populations in the City of Tulsa Emergency Operations Plan and other planning documents	Floods, tornadoes, High Winds, Lightning, Hail, Winter Storms, Heat, Wildfires, Earthquakes, Dam/Levee Failure

Mitigation Measure Description	*Hazards Addressed*
13. Acquire and remove Repetitive Loss Properties and repeatedly flooded properties where the City's Repetitive Loss and master drainage plans identify acquisition to be the most cost effective and desirable mitigation measure	Floods, Dam/Levee failure
14. Develop a Comprehensive Levee evaluation and repair Plan	Floods, Dam/Levee failure
15. Develop a Levee Public Education and Evacuation Plan for at-risk areas of the community	Floods, Dam/Levee failure
16. Disaster Resistant Business Program	Floods, Tornadoes, High Winds, Lightning, Hail, Winter Storms, Extreme Heat, Wildfires, Earthquakes, Dam/Levee Failure
17. Consider establishing an administrative procedure or change in City codes for requiring builders to check for expansive soils when they apply for permits for new residential construction and for using foundations that mitigate expansive soil damages when in a moderate or high-risk area	Expansive Soils
18. Continue to update and revise basin-wide master drainage plans where changed conditions warrant	Floods, Dam/Levee Failure
19. Develop multi-lingual Disaster Education PSA's and educational videos	Floods, Tornadoes, High Winds, Lightning, Hail, Winter Storms, Extreme Heat, Drought, Expansive Soil, Wildfires, Earthquakes, Dam/Levee Failure
20. Develop a separate "public safety" information area in all public libraries and public recreation facilities to disseminate disaster safety information appropriate to the area and the season	Floods, Tornadoes, High Winds, Lightning, Winter Storms, Extreme Heat, Wildfires, Earthquakes, Dam/Levee Failures
21. Educate residents, building professionals and SafeRoom vendors on the ICC/NSSA "Standard for the Design and Construction of Storm Shelters" and consider incorporating into current regulatory measures	Tornadoes, High Winds
22. Train builders, developers, architects and engineers in techniques of disaster-resistant homebuilding	Floods, Tornadoes, High Winds, Lightning, Hail, Winter Storms, Extreme Heat, Drought, Expansive Soil, Wildfires, Earthquakes
23. Develop a comprehensive public education program on the dangers of carbon monoxide during extended power outages	Winter Storms, Tornadoes, High Winds

Mitigation Measure Description	*Hazards Addressed*
24. Develop a model SafeRoom project for a Mobile Home Park in Tulsa	Tornadoes, High Winds
25. Supplement the current Heat Coalition program to loan window air conditioners to an extremely medically vulnerable population during the summer months	Extreme Heat
26. Review the safety of Playground materials during extreme heat events	Extreme Heat
27. Implement a Firewise Community Education and Information Program	Wildfire
28. Provide stricter floodplain regulations along the Arkansas River corridor	Floods, Dam/Levee Failure
29. Consider establishing an administrative procedure or change in City codes for requiring builders to develop a drainage plan ensuring "no adverse impact" when they apply for permits for new residential construction	Floods, Dam/Levee Failure
30. Continue National Flood Insurance Program (NFIP) and Community Rating System (CRS) Participation	Floods, Dam/Levee Failure

Mitigation Action Plan

The mitigation action plan includes strategies for implementing the mitigation measures, including information on the responsible agency, time frame, cost estimate, funding sources, and a statement of the measurable results.

For further information, contact:

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Chapter 1: Introduction

1.1 About the Plan

This City of Tulsa Multi-Hazard Mitigation Plan 2009 Update is a strategic planning guide developed in fulfillment of the Pre-Disaster Mitigation Grant Program requirements of the Federal Emergency Management Agency (FEMA), according to the *Stafford Disaster Relief and Emergency Assistance Act*. This act provides federal assistance to state and local governments to alleviate suffering and damage from disasters. It broadens existing relief programs to encourage disaster preparedness plans and programs, coordination and responsiveness, insurance coverage, and hazard mitigation measures.

This plan Update is developed in accordance with, and fulfills requirements for, the Pre-Disaster Mitigation Grant (PDM) and Hazard Mitigation Grant (HMGP). It also fulfills requirements for the Flood Mitigation Assistance Program (FMA), Severe Repetitive Loss Program (SRL), and the Community Rating System Plan (CRS) from the Federal Emergency Management Agency (FEMA). While this plan addresses 12 natural hazards, the City of Tulsa completed a separate Phase II Hazard Mitigation Plan that addressed technological and man-made hazards, such as water quality emergencies, power failures, civil unrest and terrorism issues.

Included in this Chapter:

1.1.1 Purpose

The purpose of this plan is to:

- Provide a description of the planning area (Chapter 1).
- Assess the ongoing mitigation activities in the City of Tulsa (Chapter 2).
- Describe the planning process used to develop the mitigation plan (Chapter 3).
- Identify and assess the hazards that pose a threat to citizens, businesses and property (Chapter 4).
- Establish Goals and Objectives for community mitigation measures (Chapter 5)
- Evaluate Mitigation Measures that should be undertaken to protect citizens, businesses and property (Appendix B).
- Identify and recommend an Action Plan for implementation of mitigation projects (Chapter 6).
- Develop a strategy for the adoption, maintenance, upkeep, and revision of the City of *Tulsa Multi-Hazard Mitigation Plan* (Chapter 7).

In December 2005, the Multihazard Mitigation Council of the National Institute of Building Sciences completed a study to assess future savings from mitigation activities. Their findings reflect the fact that mitigation activities in general produced over $4 in savings for every $1 invested in mitigation actions, with the greatest savings in the areas of flood-related events (5:1) and wind-related events (3.9:1). In addition, the report concludes, *"Mitigation is most effective when carried out on a comprehensive, community-wide, and long-term basis. Single activities can help, but carrying out a slate of coordinated mitigation activities over time is the best way to ensure that communities will be physically, socially, and economically resilient to future hazard impacts."*

The objective of this plan is to provide guidance for mitigation activities for the next five years. It will ensure that the City of Tulsa implements hazard mitigation activities that are most effective and appropriate for the natural hazards that threaten the community.

1.1.2 Scope

The scope of the *City of Tulsa Multi-Hazard Mitigation Plan* is citywide. It addresses 12 natural hazards deemed a threat to the citizens of Tulsa. Both short-term and long-term hazard mitigation opportunities are addressed beyond existing federal, state, and local funding programs.

1.1.3 Authority

Section 322 of the Robert T. Stafford Disaster Assistance and Emergency Relief Act, 42 USC 5165, enacted under Section 104 the Disaster Mitigation Act of 2000, P.L. 106-390, provides new and revitalized approaches to mitigation planning. A major requirement of the law is the development of a local hazard mitigation plan. Section 322, in concert with other sections of the Act, provides a significant opportunity to reduce the Nation's disaster losses through mitigation planning.

Chapter 4: Natural Hazards

Introduction

Included in this Chapter:

According to the Federal Emergency Management Agency (FEMA), a hazard is defined as an event or physical condition that has the potential to cause fatalities, injuries, property damage, infrastructure damage, or agricultural loss, among other types of loss or harm. Hazards are generally defined as one of two categories based on their source: natural hazards and man-made hazards. Each hazard has its own defining characteristics, such as time of year and geographic area of probable occurrence, severity, and risk level.

Natural phenomena, such as floods, tornadoes, severe drought, and wildfires, are natural hazards because they have the potential to destructively impact human settlements and activities. When damages from a natural hazard occur, the event is generally called a natural disaster.

Man-made hazards are broadly defined as a hazard that originates from accidental or intentional human activity. They can affect localized or widespread areas and are frequently unpredictable. This category of hazard includes such events as dam breaks and hazardous material events.

While Oklahoma communities can expect disaster-related losses, hazard assessments can be used to create proactive measures against likely events, and thereby significantly decrease or eliminate their impacts. Therefore, this chapter contains a risk identification and assessment for 12 hazards. The hazards addressed are those deemed most likely to impact the City of Tulsa. The hazards include:

1. Floods
2. Tornadoes
3. High Winds
4. Lightning
5. Hail
6. Severe Winter Storms
7. Extreme Heat
8. Drought
9. Expansive Soils
10. Wildfires
11. Earthquakes
12. Dam & Levee Failures

4.9 Expansive Soils

Soils and soft rock that tend to swell or shrink due to changes in moisture content are commonly known as expansive soils. Expansive soils, also called shrink/swell soils, are sometimes referred to as swelling clays because clay materials attract and absorb water. Dry clays will increase in volume as water is absorbed and, conversely, decrease as they dry.

Measurements

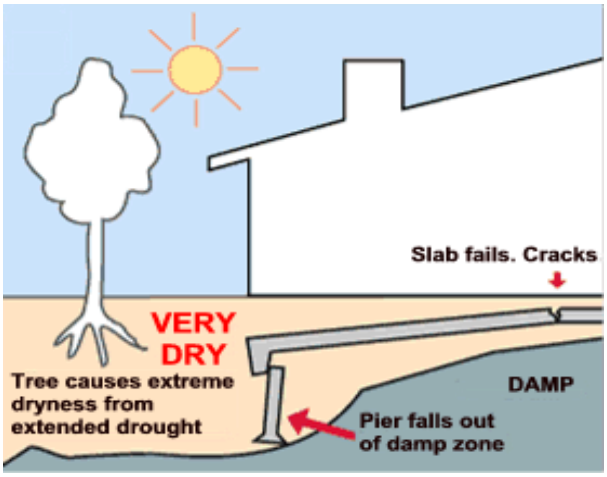
The risk associated with expansive soil is related to shrink/swell potential in a qualitative manner: very high, high, moderate and low.

The National Resource Conservation Service (NRCS), in its Soil Survey Geographic Database (SSURGO), identified expansive soils for the City of Tulsa as shown in Figure 4–16. SSURGO map units were classified from "low" to "very high" based on the weighted average of the Coefficient of Linear Extensibility (COLE) percent for the soils within the identified map units to depths between 0 inches and 60 inches, the depths at which damage to improvements from expansive soils is most likely to occur. Soil samples are dehydrated either through air-drying or oven drying for a predetermined length of time under a constant temperature. Bulk density, particle density, overall volume, and porosity are then plugged into a formula to obtain the above-mentioned COLE. In addition, the Oklahoma Department of Transportation has a program to evaluate the expansive tendencies of soils and shale formations in the state.

4.9.1 Hazard Profile

Changes in soil volume present a hazard primarily to buildings or infrastructure built on top of expansive soils. Most often, these volume changes involve swelling clays beneath areas covered by buildings and slabs or layers of concrete and asphalt.

Property damage can vary greatly across a jurisdiction, based on soils types, long-term weather conditions, the type and quality of construction, and materials used in construction. Other cases of damage involve increases of moisture volume from broken or leaking water



Tulsa is underlain by soils with shrink-swell potentials ranging from low to very high.

and sewer lines, over-watering of lawns and landscape, and modifications of the surface that produce ponding.

The effects of expansive soils are most prevalent in regions of moderate to high precipitation, where prolonged periods of drought are followed by long periods of rainfall. The most problematic soil type for expansive soils is found in the semiarid west-central United States.

The extent of damage from expansive soils can be reduced by mapping the soils in the jurisdiction and by notifying property owners and prospective buyers and builders of potential soil hazards and the techniques that can be used to limit their impacts.

4.9.1.1 Location

Based on surveys of underlying soils, Figure 4–16 shows a generalized map of the areas of Tulsa where soils have low to very high expansive qualities.

Generally, many Tulsa lowlands along the river and waterways have low shrink-swell soils. Many higher elevations have moderate to high potential, including large areas of central and east Tulsa. Localized sites with very highly expansive soils have been identified in North Tulsa and in smaller areas south and west. High shrink/swell soils predominate in future growth areas to the east and west of the city. Low and medium soils are most common in much of the far south and north, along with localized areas of very high expansive qualities.

4.9.1.2 Extent

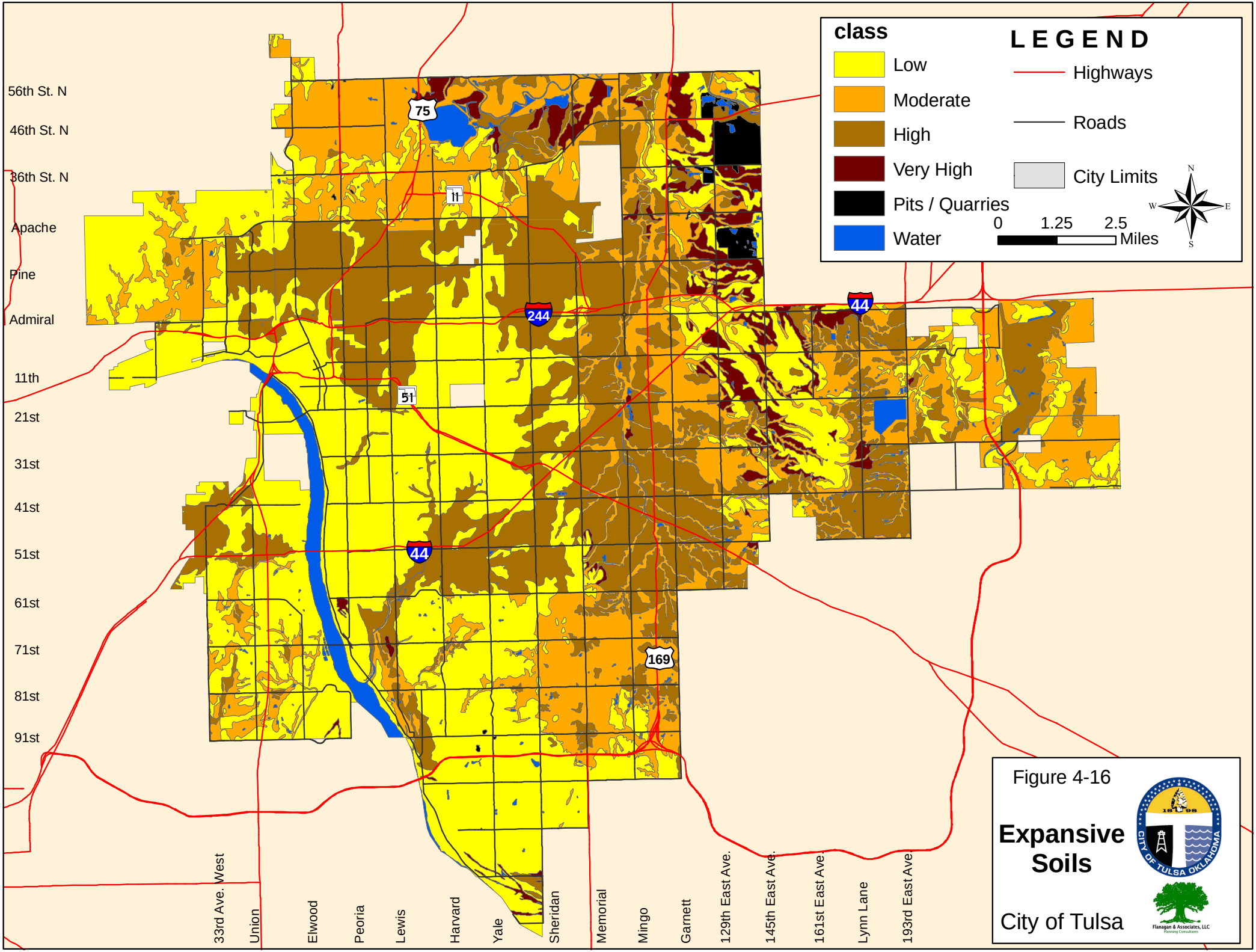
More than half the soils in Tulsa rank in the moderate to very high classification for expansive potential. Specifically, soils classified with “low” shrink/swell properties cover 41.5% of the Tulsa land area. Soils classified as “high” and “moderate” rank second and third, covering 27.12% and 24.45% respectively. Soils with a “very high” classification are the least common in Tulsa, as they cover 3.66% of the total land area. Overall, the City of Tulsa has a “moderate-high” vulnerability to the damaging effects of expansive soils.

Table 4–30: City of Tulsa Expansive Soils

Expansion Potential	Area (mi²)	% of Total City Limits
Very High	7.34	3.66
High	54.37	27.12
Moderate	49.1	24.45
Low	83.2	41.5
Water	4.9	2.44

4.9.1.3 Frequency

Local frequency analyses have not been prepared because of the nature of this hazard, which is consistent with other geologic hazards that occur rarely or slowly over time.


class
Low
Moderate
High
Very High
Pits / Quarries
Water
LEGEND
Highways
Roads
City Limits
0 1.25 2.5
Miles
N
W
E
S
56th St. N
46th St. N
36th St. N
Apache
Pine
Admiral
11th
21st
31st
41st
51st
61st
71st
81st
91st
75
11
244
44
51
44
169
33rd Ave. West
Union
Elwood
Peoria
Lewis
Harvard
Yale
Sheridan
Memorial
Mingo
Garnett
129th East Ave.
145th East Ave.
161st East Ave.
Lynn Lane
193rd East Ave
Figure 4-16
Expansive Soils
City of Tulsa
CITY OF TULSA OKLAHOMA
Flanagan & Associates, LLC

4.9.1.4 Historical Events

In Oklahoma, numerous foundation failures and pipeline breaks have resulted from soil shrinkage during the unusually hot and dry summers of 1998 and 2005-2006. During the drought of 2005-2006, soil shrinkage led to water main and sewer pipe breaks and leaks in many Oklahoma cities, including Holdenville, Okmulgee, Muskogee, and Ada.

For example, expansive soils are having a serious impact on Ada's aging water infrastructure, particularly during the drought and high temperature conditions of 2006. In July 2006, Ada lost about 2.5 MGD (million gallons a day) from its water distribution system due to breaks, leaks, and unmonitored (but authorized) use. Similar problems have plagued Okmulgee's water distribution system. Both cities have instituted aggressive pipeline maintenance programs to counter the effects of soil shrinkage during periods of prolonged drought.

Cracks in exterior walls caused by soil expansion

The only City of Tulsa structure with recorded damage from expansive soils is the motorcycle3 shop at 1720 W. Newblock. Damage was significant enough that retrofitting piering under the building was required. Since the City does not routinely list damage as having been caused by expansive soils, it is likely there has been other damage, but not to the extent that piering was required.

4.9.1.5 Probability/Future Events

There are shrink-swell soils in Tulsa that have a high probability of continuing to cause localized problems in areas of high to moderate expansive soils, similar to those experienced in the past.

4.9.2 Existing Vulnerability

Many researchers show that expansive soil is one of the most costly hazards in the United States, in terms of property damage caused by shifting soils.

For example, national studies have shown that expansive soils cause pervasive problems. Out of the 250,000 homes built each year on expansive soils, 10% sustain significant damage during their useful lives, some damaged beyond repair, and 60% sustain minor damage. For all types of building construction, annual losses of $740 million are estimated.

Despite its costly effects, expansive soil presents, in many ways, a silent hazard. Because the hazard develops gradually and seldom presents a threat to life, expansive soils have received limited attention. Many problems are not recognized as being related to expansive soils or may be considered only nuisances and therefore never repaired.

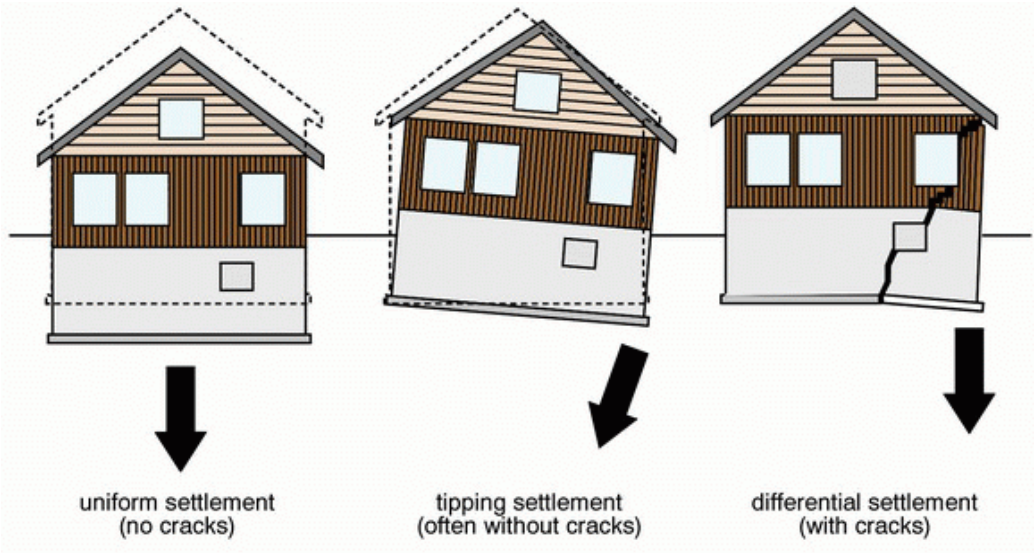
The total annual cost of expansive soil-related damage and preventive design of moderate- to high-risk structures throughout the United States has been conservatively estimated at between $2.5 billion and $10 billion (in1995 dollars).

4.9.2.1 Population

Direct threats to life or personal injury have not generally been documented for expansive soils, due to the nature of the hazard.

4.9.2.2 Structures, Buildings

The increase in soil volume can cause damage to foundations. 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.



Types of Expansive soil damage

It does not take much movement to damage buildings. As little as a differential movement of 0.25 inches between adjacent columns can cause cracking in load-bearing walls of a 2-foot wide bay.

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 greatest damage occurs when small buildings are constructed when clays are dry, such as during a drought, and then subsequent soaking rains swell the clay. Other cases of damage involve increases of moisture volume from broken or leaking water and sewer lines, over-watering of lawns and landscape, and modifications of the surface that produce ponding.

4.9.2.3 Critical Facilities

Sixty-nine of Tulsa's critical facilities, identified in Table 4–31 are built upon soils classified as having "high" or "very high" shrink/swell potential.

Table 4–31: Critical Facilities Vulnerable to Expansive Soils

ID	Name
FD5	Tulsa Fire Station #10
FD7	Tulsa Fire Station #12
FD11	Tulsa Fire Station #16
FD12	Tulsa Fire Station #17
FD17	Tulsa Fire Station #22
FD18	Tulsa Fire Station #23
FD22	Tulsa Fire Station #27
FD25	Tulsa Fire Station #3
FD33	Tulsa Fire Station #7
FG2	USPS – Whittier Post Office
FG3	USPS – Northside Post Office
FG6	USPS – Northeast Post Office
FG8	USPS – Westside Post Office
FG11	USPS – Robert Jenkins Post Office
FG12	USPS – Sheridan Post Office
FG13	USPS – Southeast Post Office
FG16	NOAA – NWS
FG17	USACE
FG18	IRS
FG19	USPS – Postage Handling Facility
LF2	American TrustCor
PD7	Tulsa Police Station (East Division)
PW2	Equipment Maintenance
PW7	Satellite Fuel Station
PW9	Street Dept. Garage / Offices
PW16	Water District Office / Warehouse
UV1	Oklahoma State University – Tulsa
VT7	Tulsa Technology Center – Lemley Campus

4.9.2.4 Infrastructure

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 feet is enough to pose an engineering problem if high standards for fast travel are to be maintained.

4.9.3 Expansive Soils Scenario

Since specific cost data is not available for the average damages per property incurred from Expansive Soils, it is not possible to include a realistic Expansive Soils Scenario. (Reference Sections 4.9.5 and 4.9.5.1 below). In future versions of this plan, it is possible that research data will have been developed and made available that allows such a scenario to be constructed.

4.9.4 Future Trends

Soils in Tulsa's identified future-development areas are primarily classed as "Low" and "Moderate", but soils with a "High" shrink-swell potential are also present, along with a few areas that are "Very High." Of particular concern, more than 23% of the land in areas zoned for future industrial development in the north and northeast quadrants of the city are classed as "Very High." With 55% of the soils within the city limits being categorized as having "moderate" to "very high" shrink/swell potential, the City of Tulsa will continue to have moderate to high vulnerability to the damaging effects of expansive soils. It is important to note that Tulsa's future industrial development areas are also on soils with a "high" shrink-swell potential. Expansive Soils in the Future Growth Areas are shown in Figure 4-17.

Table 4–32: City of Tulsa Expansive Soils – SE Osage Co. FGA

Expansion Potential	Area (mi^2)	% of Total FGA
Very High	0.0	0.0
High	.02	2.83
Moderate	.21	28.86
Low	.50	68.22
Water	.0004	.07

Table 4–33: City of Tulsa Expansive Soils – Tulsa Industrial Area FGA

Expansion Potential	Area (mi^2)	% of Total FGA
Very High	1.48	23.12
High	1.52	23.62
Moderate	1.95	30.45
Low	1.42	22.16
Water	0.04	0.65

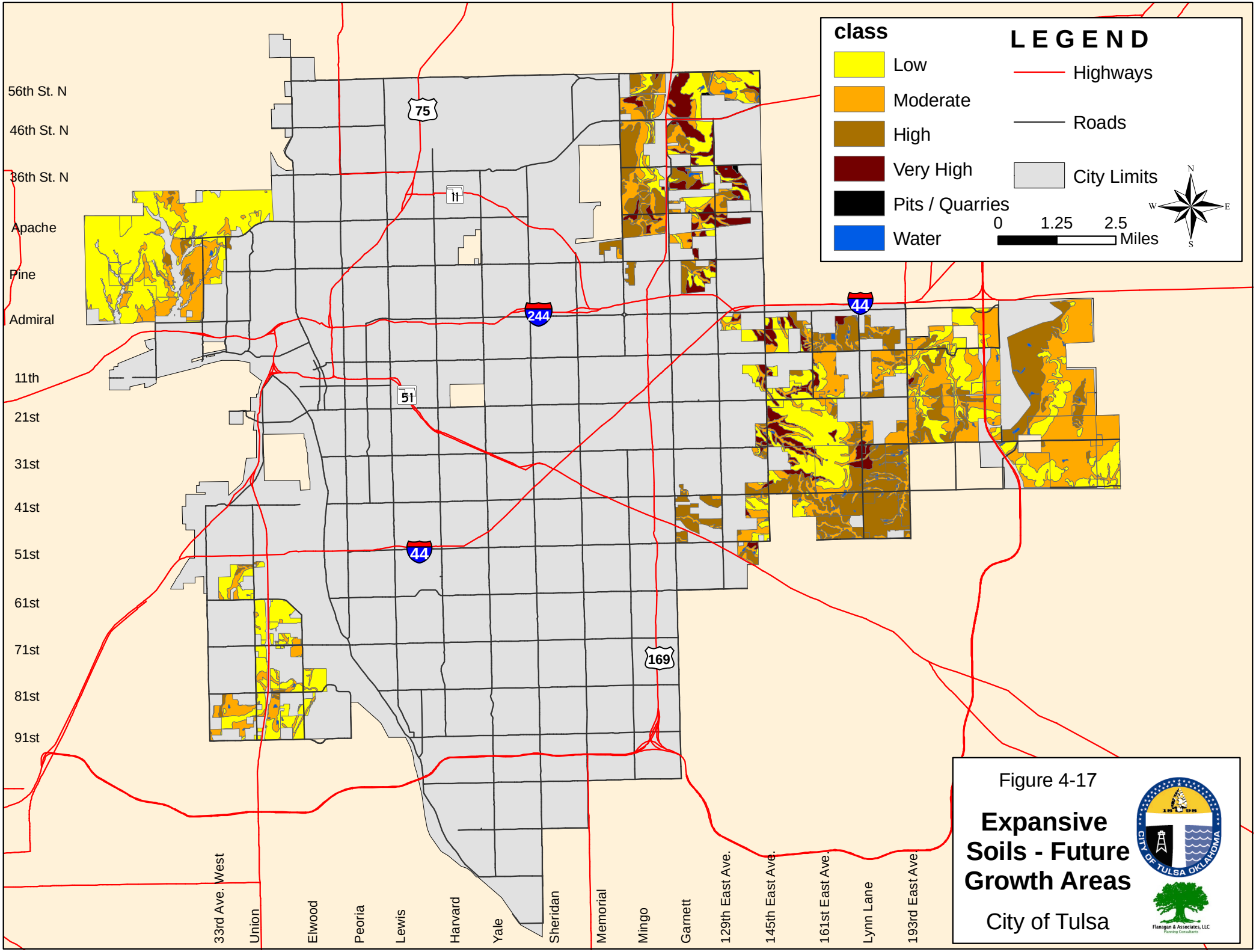


Figure 4-17

Expansive Soils - Future Growth Areas

City of Tulsa

Table 4–34: City of Tulsa Expansive Soils – SW Tulsa FGA

Expansion Potential	Area (mi²)	% of Total FGA
Very High	0.0	0.0
High	0.12	2.96
Moderate	1	25.79
Low	2.77	70.74
Water	.02	0.51

Table 4–35: City of Tulsa Expansive Soils – Wagoner County FGA

Expansion Potential	Area (mi²)	% of Total FGA
Very High	.02	0.11
High	2.94	21.88
Moderate	6.84	50.85
Low	3.53	26.24
Water	0.12	0.91

Table 4–36: City of Tulsa Expansive Soils – East Tulsa FGA

Expansion Potential	Area (mi²)	% of Total FGA
Very High	1.13	9.41
High	4.05	33.70
Moderate	3.58	29.81
Low	3.16	26.29
Water	.09	0.79

4.9.4.1 Population

Direct threats to life or personal injury have not generally been documented or projected for expansive soils because of the nature of the hazard. The primary threat is economic.

4.9.4.2 Structures / Buildings

Damage to structures in Tulsa can be expected during and following any period of extended drought. This is especially true of structures built during a period of a drought followed by soaking rains that cause swelling of clays.

4.9.4.3 Critical Facilities

As Tulsa is developed, expansive soils could cause considerable damage to new critical facilities if built without structural mitigation strategies in mind. While this will not be an immediate impact to the ability of the City of Tulsa to respond, it could shorten the effective lifespan of such facilities, thereby requiring expenditures in the future to replace these structures. In addition, long-term structural damage to buildings housing vulnerable populations – schools, long-term care facilities, childcare centers – could place the residents at risk when the building is exposed to a natural hazard event in a sub-standard condition.

4.9.4.4 Infrastructure

Long referred to as the "unknown hazard," expansive soils may be a hazard with more of a future than a past. As Tulsa's infrastructure continues to age – particularly water and sewer lines built at the beginning of the last century with materials and techniques that would not meet today's codes – a prolonged period of drought could significantly speed and intensify infrastructure deterioration. For example, aging gas and water pipelines, especially when originally constructed in wet soil, can rupture during periods of extended drought. The rehabilitation of roads and aging central business districts will likely include the replacement of much of the city's infrastructure that lies underground, especially if located in expansive soils. The use of the more flexible PVC or HDPE piping could reduce the impact of expansive soils.

4.9.5 Conclusions

The history of Tulsa's expansive soil hazard is difficult to track. Neither the City nor Insurance Companies monitor damage to structures from expansive soils as the impact of a specific natural hazard. The City treats all such damage as a maintenance issue. According to City Engineers, the expansive soil hazard is routinely taken into account in engineering studies and construction practices for infrastructure projects, but not specifically documented.

Expansive soils develop gradually and are seldom a threat to the population, but can cause severe damage to improvements built upon them. With 51.5% of the soils within the city limits classified as having moderate to high shrink/swell potential and less than 4% in the "very high" category, the City of Tulsa has a moderate to high vulnerability to the damaging effects of expansive soils. Increased damage to structures could be expected during and following a period of extended drought, particularly for structures built during a drought.

4.9.5.1 Data Limitations

Data are limited for Tulsa-specific hazard risk, vulnerability, impacts, preventive measures, costs, and benefits for damage to buildings, critical facilities, and infrastructure due to a lack of specific record keeping, as referenced in Section 4.9.5.

4.9.5.2 Update Changes

Identified significant changes made from the 2003 City of Tulsa Multi-Hazard Mitigation Plan are outlined in Appendix E. Changes are based on criteria outlined for Plan Updates in the ***Local Multi-Hazard Mitigation Planning Guidance*** document of July 1, 2008.

4.9.5.3 Sources

Extreme Weather and Climate Events at National Climatic Data Center website: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms.

FEMA Flood Insurance Statistics at Website: www.fema.gov/cis/OK.pdf.

Landslides and Expansive Soils in Oklahoma, at Web address: www.ou.edu/special/ogs-pttc/earthsci/landsl.htm. Oklahoma Geological Survey, Earth Sciences, October, 1998.

Multi-Hazard Identification and Risk Assessment, p. 122–125. Federal Emergency Management Agency, 1997.

Soil Surveys of Tulsa County, Oklahoma, U.S. Department of Agriculture, Soil Conservation Service, 1977.

Tulsa's Physical Environment, Bennison, A.P., et al. Tulsa Geological Society, 1973.

Cat	ID	NAME	ADDRESS	CITY	ZIP	PHONE #
SRHSG	IL65	The Broadmoor Retirement Community	8205 E 22nd St	Tulsa	74129	622-2151
SRHSG	NH20	The Cottage Extended Care	2552 E 21st St	Tulsa	74114	742-7080
SRHSG	NH27	The Health Care Centers @ Montereau - Memory Support	6800 S Granite	Tulsa	74136	491-5250
SRHSG	NH28	The Health Care Centers @ Montereau - Skilled Nursing	6800 S Granite	Tulsa	74136	491-5250
SRHSG	AL5	The Health Centers @ Montereau - The Villa	6800 S Granite Ave	Tulsa	74136	491-5250
SRHSG	NH30	The Mayfair Nursing Center	7707 S Memorial Dr	Tulsa	74133	250-8571
SRHSG	ML26	The Montereau in Warren Woods	6800 S Granite	Tulsa	74136	491-5200
SRHSG	AL10	The Parke Senior Living	7821 E 76th St	Tulsa	74133	249-1262
SRHSG	IL80	The Scandia	3510 E 32nd St	Tulsa	74135	747-4478
SRHSG	IL92	Town Village	8222 S Yale Ave	Tulsa	74137	493-1200
SRHSG	AL13	Tulsa Jewish Retirement & Health Care Center	2025 E 71st St	Tulsa	74136	496-8300
SRHSG	ML31	Tulsa Jewish Retirement & Health Care Center	2025 E 71st St	Tulsa	74136	496-8300
SRHSG	NH49	Tulsa Jewish Retirement & Health Care Center	2025 E 71st St	Tulsa	74136	496-8300
SRHSG	IL93	Tulsa Jewish Retirement & Health Care Center	2025 E 71st St	Tulsa	74136	496-8300
SRHSG	NH44	Tulsa Nursing Center	10912 E 14th St	Tulsa	74135	622-3430
SRHSG	IL71	Tulsa Pythian Manor	6568 E 21st Pl	Tulsa	74129	836-2710
SRHSG	IL78	Tulsa Pythian Manor West	1700 Riverside Dr	Tulsa	74119	583-4401
SRHSG	AL14	University Village Retirement Community	8555 S Lewis Ave	Tulsa	74137	299-2661
SRHSG	NH46	University Village Retirement Community	8555 S Lewis Ave	Tulsa	74137	299-2661
SRHSG	ML47	University Village Retirement Community	8555 S Lewis Ave	Tulsa	74137	299-2661
SRHSG	IL94	University Village Retirement Community	8555 S Lewis Ave	Tulsa	74137	299-2661
SRHSG	IL86	Versailles Apartments	4816 S Sheridan	Tulsa	74145	627-6116
SRHSG	RC16	Vintage Heights	1 W 36th St North	Tulsa	74106	428-4412
SRHSG	IL62	West Edison Plaza	570 N 39th West Ave	Tulsa	74127	584-4224
SRHSG	NH45	Wildwood Care Center	3333 E 28th St	Tulsa	74114	747-8008
SRHSG	IL87	Woodland Manor	8641 E 61st St	Tulsa	74133	461-1929
SRHSG	ML53	Woodland Terrace	9524 E 71st St	Tulsa	74133	250-3631
SRHSG	IL88	Woodland Terrace	9524 E 71st St	Tulsa	74133	250-3631