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University of Tennessee, Knoxville Multi-Hazard Mitigation Disaster Resistant University Plan

A Thesis Presented for the
Master of Civil Engineering Degree
The University of Tennessee, Knoxville

Kelli Dawn Taylor
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ABSTRACT

The purpose of creating this Multi-Hazard Mitigation Disaster Resistant University Plan is to meet the requirements of the Disaster Mitigation Act of 2000. This hazard mitigation plan documents the process of creating a plan for the University of Tennessee, Knoxville, including identifying hazards and risks associated with UTK and identifying a hazard mitigation strategy specific to UTK that will lessen the campus' vulnerability and make it more resistant to disaster and more sustainable. This plan identifies goals for hazard mitigation and risk reduction of natural and man-made hazards to UTK's campus by following the planning guidelines and requirements as included in FEMA's *Multi-Hazard Mitigation Planning Guidance Under the Disaster Mitigation Act of 2000* (March 2004; Revised November 2006). This plan was created using these FEMA-recommended guidelines of organizing resources, identifying hazards and assessing risks, developing a mitigation plan, and adopting and implementing the plan.

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Executive Summary

The University of Tennessee, Knoxville (UTK) has assembled this Multi-Hazard Mitigation Disaster Resistant University (DRU) Plan to meet the requirements of the Disaster Mitigation Act of 2000. This plan documents the process of creating this plan including identifying hazards and risks associated with UTK and identifying a hazard mitigation strategy specific to UTK that will lessen the campus' vulnerability and make it more resistant to disaster and more sustainable.

Hazard mitigation is defined as action(s) taken to lessen or eliminate risk to life and property from hazards, natural or man-made. This hazard mitigation plan was created through the process of identifying which hazards threaten UTK, what these hazards' effects on campus would be, how to mitigate these effects, and strategizing and prioritizing plans to mitigate these effects. Hazard mitigation planning is beneficial to UTK in two ways. It helps the University become less vulnerable to future disaster losses and is necessary in order for the University to maintain its eligibility for FEMA Pre-Disaster Mitigation and Hazard Mitigation Grant Programs.

The Executive Summary section of this report provides a summary of the mitigation planning process and is organized in the following way:

1. Background, Methodology & Process
2. Risk Assessment Findings
3. Mitigation Strategy & Action Plan
4. Plan Adoption and Implementation

BACKGROUND, METHODOLOGY & PROCESS

University of Tennessee, Knoxville Profile

The UTK campus has grown from 40-acres in 1826 to 556 acres today, which are comprised of both the main campus and agriculture campus. The campus is located in East Tennessee 35 miles northwest of the Great Smoky Mountains on hilly land. The campus currently consists of 26,400 students, 8,300 faculty and staff, and over 300,000 alumni (University of Tennessee, Knoxville, 2007).

Scope

UTK's DRU Plan is a plan that identifies goals for hazard mitigation and risk reduction of natural and man-made hazards to UTK's campus, including the main campus, agriculture campus, and various properties located near to these two campuses. This plan follows the planning guidelines and requirements as included in FEMA's *Multi-Hazard Mitigation Planning Guidance Under the Disaster Mitigation Act of 2000* (March 2004; Revised November 2006).

Planning Process

The need was recognized for a hazard mitigation plan for UTK and was, subsequently, primarily funded by a grant from FEMA. An advisory committee was created, which helped contribute to this plan by attending meetings, providing information sources, gathering data, and managing administrative details. The hazard mitigation plan for UTK was created using FEMA's recommended guidelines and consisted of the following four phases:

1. Organize Resources
2. Identify Hazards and Assess Risks
3. Develop Mitigation Plan
4. Adopt and Implement Plan

RISK ASSESSMENT FINDINGS

The risk assessment for the UTK campus was completed using the guidelines provided in the FEMA publication 386-2 *Understanding Your Risks: Identifying Hazards and Estimating Losses*. This publication states that risk assessment should be completed based on the following four-step process:

1. Identify Hazards
2. Profile Hazard Events
3. Inventory Assets
4. Estimate Losses

Identify Hazards

A hazard identification study was completed in order to determine what hazards affect UTK's campus. These hazards were identified as follows:

- Dam Failure
- Drought
- Earthquake
- Expansive Soils
- Extreme Heat
- Flood
- Hurricane
- Land Subsidence
- Landslide
- Radiation Fallout
- Severe Storm
 - Hailstorm
 - Heavy Rains
 - Lightning
 - Windstorm
- Severe Winter Storm
- Terrorists
- Tornado
- Toxic Chemical Release
- Wildfire

Profile Hazard Events

In order to profile the severity of hazard events a frequency scale was created in order to establish likelihood of occurrence of each of these hazard events. Each event was given a likelihood of occurrence based on estimations of documented past occurrences of these events obtained from previously documented local, state, and federally declared disasters, as well as insurance claims made by UTK. This frequency scale is shown as follows:

Highly Likely: Near 100% chance of occurrence in next year, or happens every year.

Likely: Between 10 and 100% chance of occurrence in next year, or has a recurrence interval of 10 years or less.

Occasional: Between 1 and 10% chance of occurrence in the next year, or has a recurrence interval of 11 to 100 years.

Unlikely: Less than 1% chance of occurrence in next 100 years, or has a recurrence interval of greater than every 100 years.

Inventory Assets

Campus properties were gathered for each building in order to quantify the value of buildings on campus. These values included monetary, life, and cultural or historical values. Some of these properties specifically include building replacement values, content values, occupancy, hazardous materials locations, and criticality of facilities.

Estimate Losses

A vulnerability assessment was conducted in order to estimate the impact each hazard may have on the UTK campus. The vulnerability that each hazard may have on campus was estimated based on the impact of past occurrences to the campus, the extent of the campus that could be affected, and the possible monetary damage and life loss potential. A vulnerability scale was created in order to quantify the vulnerability for each event and is shown as follows:

Extremely High: Very widespread and catastrophic impact.

High: Widespread potential impact. This ranking carries a high threat to the general population and/or built environment. The potential for damage is widespread. Hazards in this category may have already occurred in the past.

Medium: Moderate potential impact. This ranking carries a moderate threat level to the general population and/or built environment. Here the potential damage is more isolated and less costly than a more widespread disaster.

Low: Minimal potential impact. The occurrence and potential cost of damage to life and property is minimal.

Extremely Low: The occurrence and potential cost of damage to life and property is very minimal to non-existent.

Table 1 summarizes the results of the risk assessment portion of this plan and includes whether the hazard was deemed critical or non-critical. A critical hazard is one that is addressed in the mitigation strategy portion of this plan due to either a combination of high risk and vulnerability rating and/or no plan currently being in existence for UTK for that specific event.

MITIGATION STRATEGY & ACTION PLAN

This section illustrates the mitigation strategy process and action plan for UTK's DRU Plan. The development of this mitigation strategy was completed by following Phase 3 of FEMA's four-phase plan and includes the following steps:

- Set Planning Goals
- Draft an Action Plan

Set Planning Goals

Goals and mitigation actions were developed based on the results of the risk and vulnerability assessments and existence of current mitigation policies. Analyzing these three areas provided the opportunity for identifying areas where improvements could be made on current mitigation policies. These goals were to protect lives from hazards, improve the university to mitigate losses, and maintain FEMA eligibility for grant funding.

Draft an Action Plan

Creating a final action plan, or mitigation strategy, was able to be completed after reviewing the planning process, risk and vulnerability assessment, and planning goals. This action plan consists of the following projects:

Severe Storm

- Put up lightning rods in certain critical locations, specifically the electrical substation and possibly the fiber optics vault, Steam Plant Turbine Building, Steam Plant Gear Switching Building, and Steam Plant and Addition
- Devise a different plan in order to allow for redundancy of campus power supply so that the electrical substation, or any other location, is not the primary source of power

Table 1: Summary of Risk Assessment

Event	Likelihood of Occurrence	Vulnerability	Critical/Non-Critical Hazard
Dam Failure	Unlikely	Medium	Critical
Drought	Occasional	Extremely Low	Non-Critical
Earthquake (M_w of 4-5)	Occasional	High	Critical
Earthquake (M_w of 5-6)	Unlikely	High	Critical
Expansive Soils	Unlikely	Extremely Low	Non-Critical
Extreme Heat	Occasional	Extremely Low	Non-Critical
Flood	Unlikely	Extremely Low	Non-Critical
Hurricane	Occasional	Extremely Low	Non-Critical
Land Subsidence	Occasional	Extremely Low	Non-Critical
Landslide	Unlikely	Extremely Low	Non-Critical
Radiation Fallout	Unlikely	Low	Non-Critical
Severe Storm (Hail, High Winds)	Occasional	Medium	Critical
Severe Storm (Lightning, Heavy Rains)	Highly Likely	Medium	Critical
Severe Winter Storm	Occasional	Low	Non-Critical
Terrorists	Unlikely	Medium	Non-Critical
Tornado	Unlikely	Medium	Critical
Toxic Chemical Release	Occasional	Low	Non-Critical
Wildfire	Unlikely	Low	Non-Critical

Earthquake

- Design all new buildings on campus to the most current seismic code
- Secure and/or protect all important utilities and mechanical equipment as best as possible in the Hoskins Library Chiller Building, Music Chiller Building, Reese Hall Chiller Building, and Facilities Services Maintenance Shops and Warehouse
- For all other facilities vulnerable to an earthquake (as listed in section 5.0 Mitigation Strategy), do not store any items deemed valuable in these buildings or secure these items to a wall or floor in order to minimize movement during an earthquake that would damage valuables
- Anchor all cabinets containing toxic chemicals to walls and/or floors so that during an earthquake, movement of these chemicals is minimized and the likelihood of spillage is decreased in the Veterinary Teaching Hospital, Plant Sciences Biotechnology Building, Dabney-Buehler Hall, Dougherty Engineering Building, Science and Engineering Building, Walters Life Sciences Building, Hesler Biology Building and Greenhouse, Perkins Hall, Jessie Harris Building, Neyland Drive Biology Annex, and the Engineering Annex
- Conduct a further, more detailed analysis of possible earthquake scenarios and how they would affect each building on campus

Dam Failure

- Give alert via text message of dam failure in order to warn those people located in lower elevation areas to quickly move to higher elevations away from the Tennessee River.
- Send emergency personnel to broadcast warning by vehicle over a loudspeaker in areas closest to river for those people who do not have access to text messaging.

Tornado

- Identify “safe” locations in highly populated buildings, such as residence halls, student centers, and buildings containing large numbers of offices and classrooms and then educate faculty, staff, and students on the whereabouts of these locations and emphasize the necessity to go to them in the event of a tornado

PLAN ADOPTION AND IMPLEMENTATION

After the development of the mitigation plan, it is ready to be formally adopted, implemented, evaluated and revised as necessary. The purpose of adopting this Multi-Hazard Mitigation DRU Plan is for the University to maintain its eligibility for FEMA Pre-Disaster Mitigation and Hazard Mitigation Grant Programs, raise awareness of the plan, and formalize the plan’s implementation. Implementing this plan and maintaining its goals is necessary for success of the hazard mitigation planning process. This involves taking various actions based on priority. Plan maintenance involves updates, which should include, if applicable, the following subjects:

- Changes in vulnerability due to project implementation
- Documentation of effective and/or non-effective mitigation actions

- Documentation of new hazards
- Incorporation of new data on hazards and campus risk
- Incorporation of new mitigation plans and policies
- Incorporation of growth and developmental changes to UTK

The update process provides an opportunity to make successes of the plan public and to allow for public input and comments.

1.0 Introduction

The University of Tennessee, Knoxville has prepared this Multi-Hazard Mitigation Disaster Resistant University Plan in ordinance with the Disaster Mitigation Act of 2000. This plan documents the planning process, identifies natural hazards and risks/vulnerabilities of these hazards, and creates a hazard mitigation strategy to make UTK less vulnerable to disasters. This plan can also be used to aid in future land use and local policy decisions.

Hazard mitigation is defined as action(s) taken to lessen or eliminate risk to life and property from hazards, natural or man-made. This hazard mitigation plan was created through the process of identifying which hazards threaten UTK, what these hazards' effects on campus would be, how to mitigate these effects, and strategizing and prioritizing plans to mitigate these effects. Hazard mitigation planning is beneficial to UTK in two ways. It helps the University become less vulnerable to future disaster losses and is necessary in order for the University to maintain its eligibility for FEMA Pre-Disaster Mitigation and Hazard Mitigation Grant Programs.

PURPOSE AND NEED

Natural and man-made disasters are the cause of hundreds of deaths and thousands of injuries in the United States every year. These disasters also cause billions of dollars-worth of damage. Many of the effects of a disaster are expected and can be predicted. Being able to predict these effects leads the way for eliminating some of the life loss and monetary damages through mitigation.

The Federal Emergency Management Agency (FEMA) has defined reducing losses from natural disasters as one of its principle goals. Reducing these losses is done through hazard mitigation planning and implementation of this planning. Mitigation planning has proven effective in many areas of the United States.

The Disaster Mitigation Act of 2000 requires that state and local governments develop hazard mitigation plans in order to maintain eligibility for federal disaster assistance and hazard mitigation funding. Completion of this plan will provide UTK with both of these benefits, as well as reducing costs of disasters to the University and minimizing impacts to daily activities on campus.

SCOPE

UTK's Multi-Hazard Mitigation DRU Plan identifies goals for hazard mitigation and risk reduction of natural and man-made hazards. This plan covers the UTK campus, which includes the main campus, agriculture campus, and various UTK-owned properties located in close proximity to the main and agriculture campuses. This plan follows the

Disaster Mitigation Act of 2000 requirements and FEMA's *Multi-Hazard Mitigation Planning Guidance Under the Disaster Mitigation Act of 2000*.

2.0 University Profile

LOCATION AND SETTING

The University of Tennessee, Knoxville campus is located in the city of Knoxville in east Tennessee. The campus is adjacent to Knoxville's downtown district. The campus included for this plan includes the main campus and the agriculture campus, which are separated by the CSX railroad. These two campuses are profiled in the following paragraphs and are shown in Figure 1.

Main Campus

The University of Tennessee began as Blount College in 1794. The present Main Campus originated in 1826 as a 40-acre tract known as "The Hill." The Morrill Act was passed by Congress in 1862, which granted federally owned lands to states in order to create public agricultural and mechanical colleges. The main campus has grown from 40 acres to 556 acres. The Main Campus is bordered by Volunteer Boulevard on the West, the Tennessee River on the south, 11th Street on the east, and roughly by Cumberland Avenue on the north. The main campus includes facilities such as administrative, dining, housing, mechanical, medical care, parking, police, utilities, athletics/physical education, classrooms, laboratories, offices, data systems, radio stations, student centers, a guest house, and libraries.

Agriculture Campus

The University of Tennessee's Agriculture Campus is located directly to the west of the Main Campus and is bordered by Alcoa Highway on the north, Third Creek on the east, and the Tennessee River on the south and west. The Morrill Act passed in 1862 later provided \$400,000 worth of real estate (262 acres) to the University of Tennessee in 1869 known then as UT Farm, now referred to as the Ag Campus. It has now grown to a size of 298 acres. The Agriculture Campus includes facilities such as classrooms, laboratories, offices, and farm buildings (University of Tennessee, Knoxville, 2007).

Other Properties

In addition to the previous two properties, The University of Tennessee owns several other properties included in this hazard mitigation plan. These consist of:

- The Welcome Center located northwest of the Agriculture Campus on Neyland Drive used primarily for administration and banquet purposes.
- Kingston Apartments and Parking Garage located directly north of the Agriculture Campus at 2521 Kingston Pike used for housing and parking.
- Tyson Park located also directly north of the Agriculture Campus used for athletics.
- Fulton Bottoms and Storage Shed located west of the Main Campus and northeast of the Agriculture Campus used for athletics.

- Properties directly north of Cumberland Avenue (or the Main Campus) including Laurel Avenue Apartments, Pool House, and Parking Garage; Child Development Center; White Avenue Parking Garage; Clement Hall; Strong Hall; Panhellenic; Law Complexes; White Avenue Building; White Avenue Biology Annex; Hoskins Library; TANDEC; Jessie Harris Building; and 11th Street Parking Garage. These properties include facilities such as housing, parking, classrooms, laboratories, offices, dining, police, libraries, and a student center.

NATURAL SETTING

All of the campus properties are located in East Tennessee about 35 miles northwest of the Great Smoky Mountains. The campus is located on very hilly land, which is characteristic of East Tennessee. The subsurface conditions of the campus consist mostly of siliceous dolomite (which is similar to limestone), some limestone, and a little shale and sandstone. Due to the dissolution of limestone with water, karst also occurs quite frequently across campus resulting in underground caves and the occurrence of sinkholes appearing on the surface. Most new construction is performed using drilled shafts or piling to the bedrock to avoid problems arising from constructing on karst (Drumm, 2007).

HISTORY

A brief history of the University of Tennessee, Knoxville written by University Historian Milton M. Klein follows.

Blount College, the University of Tennessee's forerunner, was established in Knoxville in 1794, two years before Tennessee became a state. Located near the center of Knoxville's present business district, Blount College was nonsectarian in character, which was unusual for an institution of higher education in that day. The university has remained nondenominational and is said to be the oldest such institution west of the Appalachian Divide.

From the outset, Blount College was all-male, as were most colleges at the time. The restriction was ended in 1892 when the first women students were admitted. The University of Tennessee thereafter was fully coeducational.

In 1807 the state legislature changed the name to East Tennessee College, and in 1826 the present site at Knoxville, the 40-acre tract known as "The Hill," was acquired. The college's name changed again in 1840—to East Tennessee University.

The Civil War forced the institution to close, and its buildings were used as a hospital for Confederate troops and later occupied by Union troops.



Figure 1: Map of UTK Campus

East Tennessee University reopened after the war, and in 1869 the state legislature selected the university as the state's federal land-grant institution, under terms of the Morrill Act passed by Congress in 1862. This enabled the university to broaden its offerings by adding agricultural and engineering courses to its curriculum, as well as military science, which the Morrill Act required.

The university has grown almost constantly since then. The medical campus, founded in Nashville and acquired by the university in 1879, moved to Memphis in 1911. The University of Tennessee at Martin, established in 1900 as a private institution, became part of the University of Tennessee in 1927. The University of Tennessee at Chattanooga was established in 1969 when the private University of Chattanooga merged with the University of Tennessee.

The Space Institute, a graduate research and education center near Tullahoma, opened in 1964. The Institute of Agriculture, headquartered in Knoxville, traces its beginnings to 1869 when UT became Tennessee's land-grant institution, and the Institute for Public Service was founded and brought together several government and industrial outreach programs in 1971.

Today the University of Tennessee, Knoxville has grown to a size of 550 acres with approximately 220 buildings. Last year (2006) the university received \$127 million in research grants. The campus now has 26,400 students enrolled, 8,300 faculty and staff working, and boasts more than 300,000 alumni.

3.0 Planning Process

Dr. James E. Beavers and Dr. Richard Bennett, both faculty of the University of Tennessee, were the initiators of this Multi-Hazard Mitigation Disaster Resistant University (DRU) Plan for the University of Tennessee, Knoxville. Dr. Beavers holds a Ph.D. in Civil Engineering with a minor in Probability and Statistics. He held various senior positions at the Department of Energy in Oak Ridge, Tennessee from 1972 to 1994 and was a director at the Center for Natural Phenomenon Engineering from 1990 to 1994. He has chaired more than 20 national engineering committees for various organizations, served as a member or chair on more than 80 such committees, authored or coauthored more than 200 publications and testified before the United States Congress on eight occasions. He is considered an international expert in earthquake engineering. Dr. Bennett also holds a Ph.D. in Civil Engineering and has been teaching at the University of Tennessee, Knoxville since 1983. He currently teaches for the freshman engineering program as well as various graduate level classes including Masonry Design, Structural Dynamics, and Finite Element Applications in Structural Engineering. He has written 38 journal articles, 27 conference proceedings, and been published in over 40 other publications. He has been involved in numerous areas of research including Structural Safety and Reliability, Subsidence Damage Mitigation, Masonry, and other miscellaneous areas of research. The funding for the development of this plan was provided by Federal Emergency Management Agency (FEMA).

The hazard mitigation plan for UTK was created using FEMA's recommended guidelines and consisted of the following four phases:

1. Organize Resources
2. Identify Hazards and Assess Risks
3. Develop Mitigation Plan
4. Adopt and Implement Plan

FOUR PHASE PLANNING PROCESS

The four-phase planning process suggested by FEMA was used and is described in more detail as follows:

Phase 1: Organize Resources

During this phase, the development of the plan involved assessing community support, building the planning team (advisory committee), and engaging the public. This plan also required involvement from many resources including university and government. The research and organization of data was primarily done by Structural Engineering graduate student Kelli Taylor under the guidance of Dr. James E. Beavers (Research Director, Construction Industry Research & Policy Center) and Dr. Richard Bennett (Professor and

Associate Head, Department of Civil and Environmental Engineering). The advisory committee and other resources of importance are shown in Tables 2 and 3.

Many meetings were held during the planning process to accomplish various tasks. These meetings and their purposes along with other various important dates are shown in Table 4.

Phase 2: Identify Hazards and Assess Risks

Phase 2 consisted of identifying hazards, profiling hazard events, assessing vulnerability of assets, and estimating potential losses. Dr. James E. Beavers and Dr. Richard Bennett decided which hazards, natural as well as human-caused, were applicable to UTK's campus by using FEMA Bluebook 386-2, their knowledge of East Tennessee's most common hazard occurrences, and their combined expertise in hazard mitigation. In order to assess the risks, a very thorough and exhaustive set of data was gathered for the purpose of comparing various aspects of each of the campus buildings. Different aspects of hazardous events and effects during these events were compared, such as building fragility, monetary loss, life loss, and location of hazardous materials in order to determine which buildings were the most critical and which events were the most destructive to campus. After comparing this data, potential losses were able to be quantified, as well as the importance of these various losses. A more detailed account of Phase 2 can be viewed in Sections 4.0—Risk Assessment, 4.1—Hazard Identification, and 4.2—Vulnerability Assessment.

Phase 3: Develop Mitigation Plan

Phase 3 consisted of developing mitigation goals and objectives, identifying and prioritizing mitigation actions, preparing an implementation strategy, and documenting

Table 2: Advisory Committee

Name	Organization	Title
Denise Barlow	UTK Finance and Administration	Vice Chancellor
Dr. James E. Beavers	UTK Construction Industry Research & Policy Center	Research Director
Dr. Richard Bennett	UTK Department of Civil and Environmental Engineering	Professor and Associate Head
Brian Browning	UTK Finance and Administration	Business Manager
Dr. Tim Ezzell	UTK Community Partnership Center	Director
Ken Fritts	East Tennessee TEMA	Coordinator
Alan Lawson	Knox County and Knoxville City Emergency Management	Director
Jeff Maples	UTK Finance and Administration	Senior Associate Vice Chancellor
Mike Sherrell	UTK Facilities Services	Executive Director

Table 3: Additional Public Resources

Name	Organization	Title
Andrew Shafer	UTK Dean of Students	Interim Fraternity Affairs Advisor
Mark Smith	UTK Environmental Health & Safety	Director
Pam Diehl	UTK University Housing	Assistant Director for Finance
Amy Howard	UTK Dining Services	Employee
Jim Dietrich	UTK University Center	Employee
Bill Myers	UTK Men's Athletic Business Office	Budget Director
Jane Taylor	UTK Department of Civil and Environmental Engineering	Business Manager
George Chris	UTK Facilities Planning	Employee
Tim MacKenzie	UTK Office of Information & Technology	Information Security Official
George Lecrone	UTK Telephone Services	Employee
Will Fontanez	UTK Cartographic Services Laboratory	Director
Judy McGee	UTK Office of Risk Management	Director
Betsey Creekmore	UTK Space & Facilities Services	Employee
Cris Hughes	Tennessee Valley Authority	Dam Safety & Engineering Employee
Tom Cloud	Tennessee Emergency Management Agency, East	Emergency Management Planner
Dr. Eric Drumm	UTK Civil & Environmental Engineering	Professor
Dr. George Flanagan	Oak Ridge National Laboratory	Advanced Reactor System and Safety Group
David Clarke	UTK Tennessee Transportation Assistance Program	Director
Roger Byrd	Knox County Fire Department	Fire Marshall

Table 4: Important Dates During Planning Process

Date	Topic/Purpose
5/4/2005	UT Research Office submits grant proposal to TEMA
8/8/2005	TEMA submits grant proposal to FEMA
10/25/2005	FEMA signs grant to approve project
1/4/2006	UTK receives official grant from FEMA
3/28/2006	Dr. Beavers and Dr. Bennett have first meeting with UTK Facilities Services.
4/26/2006	Members of Advisory Committee established
8/1/2006	Graduate student, Kelli Taylor begins working on project
10/2/2006	Dr. Beavers, Dr. Bennett and Kelli Taylor meet with Brian Browning from Facilities Services to discuss good sources where Kelli Taylor should look for information needed about campus buildings.
10/3/2006	Dr. Beavers, Dr. Bennett and Kelli Taylor meet to inspect progress of information gathered about UTK campus so far and discuss future goals
10/17/2006	Dr. Beavers, Dr. Bennett and Kelli Taylor meet to inspect progress of information gathered about UTK campus so far and discuss future goals
10/31/2006	Dr. Beavers, Dr. Bennett and Kelli Taylor meet to inspect progress of information gathered about UTK campus so far and discuss future goals
11/28/2006	Kelli Taylor gives first presentation to Advisory Committee on status of project
3/22/2007	Meeting with Advisory Committee occurs in which committee is updated on status of project and asked questions about uncertainties. Identification of all campus buildings and their properties is 95% complete. Hazard assessment is begun.
5/1/2007	Hazard assessment process is begun.
9/15/2007	Hazard assessment process is completed. Vulnerability assessment process is begun.
9/26/2007	Meeting with Advisory Committee occurs in which committee is updated on status of project and asked questions about uncertainties.
11/29/2007	Report is completed by Kelli Taylor; submitted to Dr. Beavers and Dr. Bennett for review.
12/10/2007	Final report is presented to advisory board

the mitigation planning process. The University of Tennessee Knoxville's current and in-use mitigation plans for various events were gathered and assessed in order to see what events are being mitigated and if they are being mitigated suitably. For those events that were either not being mitigated suitably or not at all, mitigation goals were determined to lessen the effects of these hazards should they occur.

Phase 4: Adopt and Implement Plan

Phase 4 consisted of adopting and putting the Plan into practice, while monitoring and evaluating its successfulness and progress. The strategy of implement is described in more detail in Section 7.0—Implementation and Plan Maintenance.

4.0 Risk Assessment

As stated by the FEMA Bluebook 386-2:

Risk assessment is the process of measuring the potential loss of life, personal injury, economic injury, and property damage resulting from natural hazards by assessing the vulnerability of people, buildings, and infrastructure to natural hazards. Risk assessment provides the foundation for the rest of the mitigation planning process. The risk assessment process focuses your attention on areas most in need by evaluating which populations and facilities are most vulnerable to natural hazards and to what extent injuries and damages may occur. It tells you:

- The hazards to which your state or community is susceptible
- What these hazards can do to physical, social, and economic assets
- Which areas are most vulnerable to damage from these hazards
- The resulting cost of damages or costs avoided through future mitigation projects

In addition to benefiting mitigation planning, risk assessment information also allows emergency management personnel to establish early response priorities by identifying potential hazards and vulnerable assets.

This risk assessment follows FEMA-generated guidelines for Phase 2: Identifying Hazards and Assessing Risks.

4.1 Hazard Identification

The two primary coordinators for this project, Dr. James E. Beavers and Dr. Richard Bennett, determined which natural and man-made hazards were most likely to occur based on previous occurrences shown by historical data, geographical location of the campus, and input from the advisory board during scheduled meetings. A complete list of existing hazards in the United States was compiled using the FEMA *State and Local Mitigation Planning How-to Guide: Understanding Your Risks*, as well as personal knowledge of possible modern events that may occur. A complete list of these hazards can be seen in Table 5. From this complete list of hazards, those chosen to be included in the Multi-Hazard Mitigation DRU Plan for UTK were determined during various meetings after thoroughly examining the frequency of past events occurring in the East Tennessee region as well as future events that may possibly occur, but that have not yet occurred.

This collection of hazards that are specific and significant to UTK's campus was selected based on the knowledge of past frequencies of each event, as well as how damaging the event was in terms of life, property, and monetary loss. Events that have occurred infrequently or never, such as land subsidence and radiation fallout, were included in this study because a real possibility exists that they may occur sometime in the future, however unlikely the possibility. Events that are considered completely inapplicable to UTK's campus such as avalanche, tsunami, volcano, etc. due to geographical location were not considered, and, therefore, were not included in the list of hazards to be analyzed. While a pandemic (West Nile Virus, bird flu, etc.) is an applicable event to UTK it will not be included in the applicable hazards for this report because the University has developed an independent plan for this event. It is included as a subset of the *Campus Emergency Preparedness Plan*.

TEMA's *Hazard Mitigation Plan for the State of Tennessee* states, "...windstorms may be considered as part of a symbiotic relationship or concurrent events with Severe Storms. Consequently, it is relatively impossible to discern or define where one begins and the other ends. Therefore, the State of Tennessee, while clearly understanding windstorms may be a separate hazard, elected to consider windstorms and the historical significance of such events along with priority hazards." The same is true of lightning and hailstorms in Tennessee—they almost never occur without the existence of a severe storm. Therefore, the same approach is taken with UTK's Multi-Hazard Mitigation DRU Plan. It is impractical to consider a hailstorm, lightning, or windstorm event as a separate, singular event to be analyzed, therefore, all of these events are grouped together in a category along with heavy rains called Severe Storm. A final, complete list of hazards considered for UTK's project follows.

Table 5: List of Hazards

Hazard	Applicable/Not Applicable to UTK
Avalanche	Not Applicable
Coastal Erosion	Not Applicable
Coastal Storm	Not Applicable
Dam Failure	Applicable
Drought	Applicable
Earthquake	Applicable
Expansive Soils	Applicable
Extreme Heat	Applicable
Flood	Applicable
Hailstorm	Applicable
Hurricane	Applicable
Land Subsidence	Applicable
Landslide	Applicable
Lightning	Applicable
Pandemic	Applicable
Radiation Fallout	Applicable
Severe Winter Storm	Applicable
Terrorists	Applicable
Tornado	Applicable
Toxic Chemical Release	Applicable
Tsunami	Not Applicable
Volcano	Not Applicable
Wildfire	Applicable
Windstorm	Applicable

- Dam Failure
- Drought
- Earthquake
- Expansive Soils
- Extreme Heat
- Flood
- Hurricane
- Land Subsidence
- Landslide
- Radiation Fallout
- Severe Storm
 - Hailstorm
 - Heavy Rains
 - Lightning
 - Windstorm
- Severe Winter Storm
- Terrorists
- Tornado
- Toxic Chemical Release
- Wildfire

A frequency scale, or scale for likelihood of occurrence, was established in order to evaluate the likelihood of future occurrences of each of these hazard events. The estimated frequency of a hazard event is classified into one of the following categories: (It should be noted that the same scale has been used by the University of Colorado, Boulder's Multi-Hazard Mitigation DRU Plan.)

Highly Likely: Near 100% chance of occurrence in next year, or happens every year.

Likely: Between 10 and 100% chance of occurrence in next year, or has a recurrence interval of 10 years or less.

Occasional: Between 1 and 10% chance of occurrence in the next year, or has a recurrence interval of 11 to 100 years.

Unlikely: Less than 1% chance of occurrence in next 100 years, or has a recurrence interval of greater than every 100 years.

Each hazardous event analyzed in this project was classified into one of these frequency categories based on estimations of documented past occurrences of these events. These documented frequencies were obtained from previously documented local, state, and federally declared disasters, as well as insurance claims made by UTK for various reasons.

DISASTER DECLARATION/INSURANCE CLAIMS

This section contains information regarding Disaster Declarations and Insurance Claims for the University of Tennessee, Knoxville campus and surrounding areas.

Disaster Declarations

The state of Tennessee has experienced 20 federally declared disasters since 1991. A list of these disasters is shown in Table 6. The total cost of each of these disasters is shown along with the funds granted by the U.S. government in parentheses. Also, Figure 2

shows the percentage of these disasters since 1991 involved in federal disaster declarations, with severe storms and flooding being the greatest majority of disaster causes in Tennessee.

Knox County specifically was a part of the May 8, 2003 event disaster declaration and the June 12, 2000 event. For the May 8, 2003 event Knox County received individual assistance, which is government assistance to individuals and homes. For the June 12, 2000 event Knox County received public assistance, which is government assistance to State and local governments for damaged public facilities.

Disaster declarations are made by county, so it is not possible to state whether or not UTK has specifically made a disaster declaration. However, in Knoxville there is usually one disaster declaration about every other year due to flooding, ice and snowstorms, and/or tornadoes. However, in all the disaster declarations for Knox County, UTK has not been involved in any of damage claims (Tennessee Emergency Management Agency, 2004).

Insurance Claims

In order to better evaluate the severity of past hazard events to estimate the severity and likelihood of future hazard events, insurance claims made by UTK were gathered and compared. A table containing insurance claims made by UTK over the past ten years is shown in Table 7. This information was obtained from the UTK Risk Assessment Office and includes where and when the disaster occurred, as well as what the disaster was and how much insurance was paid out for the event. UTK has a deductible of \$25,000, so some events costing less than \$25,000 were not reported. In these cases the University took care of them independently.

Shown in Figure 3 is an illustration of the number of different types of damage claims made by UTK. Water and fire are the most frequently occurring causes of damage for the campus. Figure 4 shows the monetary damages caused by these different types of disasters. These monetary figures do not include claims not yet completed, claims under the \$25,000 deductible, or damages handled by other outside resources such as a contractor or water company. This figure shows that water and fire have been the most expensive types of damage for the university (McGhee, 2007).

The following sections contain more detailed discussions of the hazard events chosen to be evaluated for UTK's hazard mitigation plan.

Table 6: Federal Disaster Declarations in Tennessee Since 1991

Declaration Date	Event	Cost (\$ million)
April 6, 2006	Severe Storms and Tornadoes	Not Available
October 7, 2004	Severe Storms and Flooding	Not Available
July 29, 2003	Heavy Rains, High Winds, Severe Storms	36.8 (5.0)
May 8, 2003	Flooding, Severe Storm, Tornado	38.5 (6.2)
March 20, 2003	Winter Storm, Flooding	5.9 (0.45)
November 13, 2002	Flooding, Severe Storm, Tornado	4.1 (0.75)
April 5, 2002	Flooding, Severe Storm	8.7 (1.7)
August 15, 2001	Severe Storm, Flooding	3.5 (0.9)
June 12, 2000	Flooding, Severe, Storm, Tornado	3.7 (0.53)
May 12, 1999	Severe Storm, Tornado, Flooding	5.6 (1.2)
January 19, 1999	Severe Storm, Tornado, High Winds	17.4 (1.8)
January 15, 1999	Ice Storm	12.3 (2.4)
July 23, 1998	Severe Storm	4.2 (0.82)
April 20, 1998	Tornadoes	36.2 (4.0)
January 13, 1998	Flooding	28.5 (4.1)
April 2, 1997	Severe Storms, Tornadoes	1.4 (0.4)
March 7, 1997	Severe Storms, Flooding	7.4 (1.1)
June 14, 1995	Tornadoes, Floods	1.0 (0.19)
April 14, 1994	Storms, Floods	4.6 (0.98)
February 28, 1994	Winter Storm	64.7 (9.4)
June 21, 1991	Severe Storms, Flooding	4.8 (0.6)
January 4, 1991	Severe Storms, Flooding	4.7 (0.7)
Total		294.0 (43.22)

Federally Declared Disasters in TN

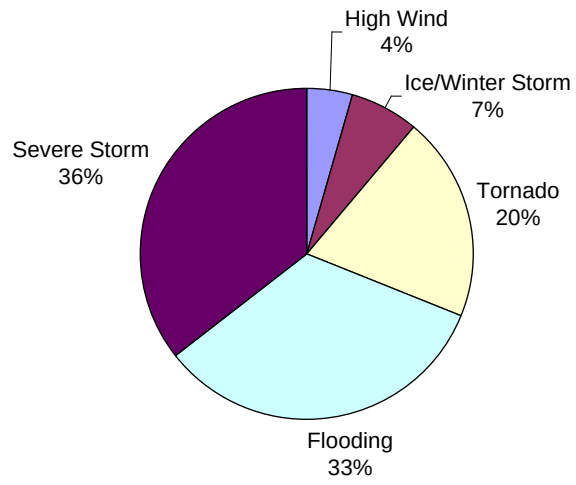


Figure 2: Federal Disasters in Tennessee

Table 7: UTK Insurance Claims

Building	Disaster	Loss Date	Insurance Paid
Dougherty Engineering Building	Flood caused by water line burst	5/9/2007	Claim still open
White Avenue Parking Garage	Building damage due to automobile accident	10/29/2006	\$5,115.88
Dougherty Engineering Building	Fire loss	10/17/2006	Claim still open
UTK Botany Research (Gatlinburg)	Windstorm damage-trees down on building	10/16/2006	\$19,000.00
Various Buildings	Flood-storm damage	8/4/2006	Claim still open
Dougherty Engineering Building	Small roof fire (caused by contractor)	7/12/2006	\$900.00 (paid by contractor)
Reese Hall	Flood standpipe turned on	5/28/2006	\$80,515.55
Clement Hall	Contractor left water faucet on causing flood	5/25/2006	\$81,392.58
Plant Sciences Biotechnology Building	Steam release malfunction	4/17/2006	\$191,034.55
Presidential Court Building	Bakery fire	7/4/2005	\$108,761.23
Carolyn Brown University Center (Smokey's Cafeteria)	Water damage to mural	5/20/2005	Under \$25,000 deductible
Alumni Memorial Building	Ceiling collapsed	5/9/2005	\$17,385.00
Humanities and Social Sciences Building	Heating coil in air handler burst	12/15/2004	Under \$25,000 deductible
Alpha Gamma Rho Fraternity House	Storm damage water & roof	6/17/2004	Handled by fraternity's insurance
Student Recreational and Fitness Center	Sprinkler head malfunction	3/21/2004	\$144,482.00
Alumni Memorial Building	Water main burst	7/16/2003	Handled by Knoxville Utilities Board (KUB)

Table 7, cont.

Building	Disaster	Loss Date	Insurance Paid
Walters Life Sciences Building	Contents loss in cold room	7/1/2003	\$7,175.28
Sigma Phi Epsilon Fraternity House	Fire damage to contents	6/12/2003	Handled by fraternity's insurance
Transportation Services (Motor Pool)	Water damage due to contractor	10/2/2002	Handled by contractor
Carriage House	Fire loss	8/2/2002	\$525,839.18
Dabney-Buehler Hall	Fire loss	7/20/2002	\$55,393.84
Health, Physical Education, and Recreation Building	Computer theft	11/4/2000	\$13,587.00
Sutherland Avenue Apartments (Storage Shed)	Fire loss	9/5/2000	\$13,444.00
Dabney-Buehler Hall	Water damage	5/13/1999	\$1,000.00
Stokely Management Center	Fire loss	10/29/1998	\$3,591.24
Pasqua Nuclear Engineering Building	Theft	6/14/1998	\$1,914.00
Married Student Housing	Flood damage due to storm	5/21/1998	\$98,405.56
Dabney-Buehler Hall	Fire loss	3/30/1998	\$120,852.59
Dougherty Engineering Building	Chemical Engineering theft	8/24/1997	\$16,409.20

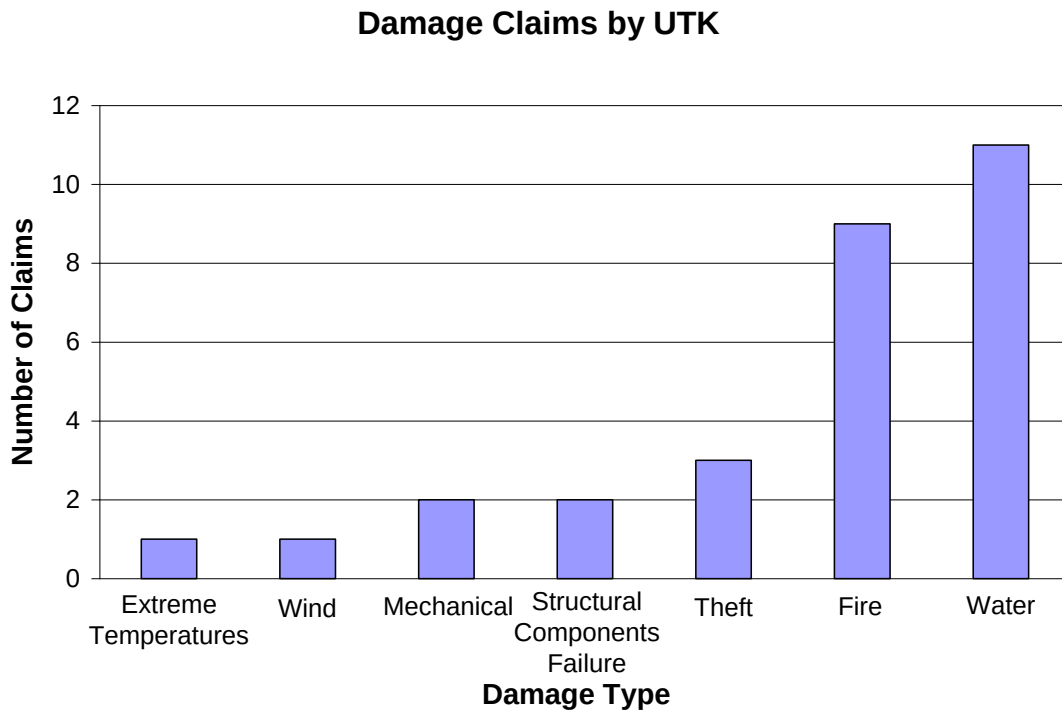


Figure 3: Types of Insurance Claims Made by UTK

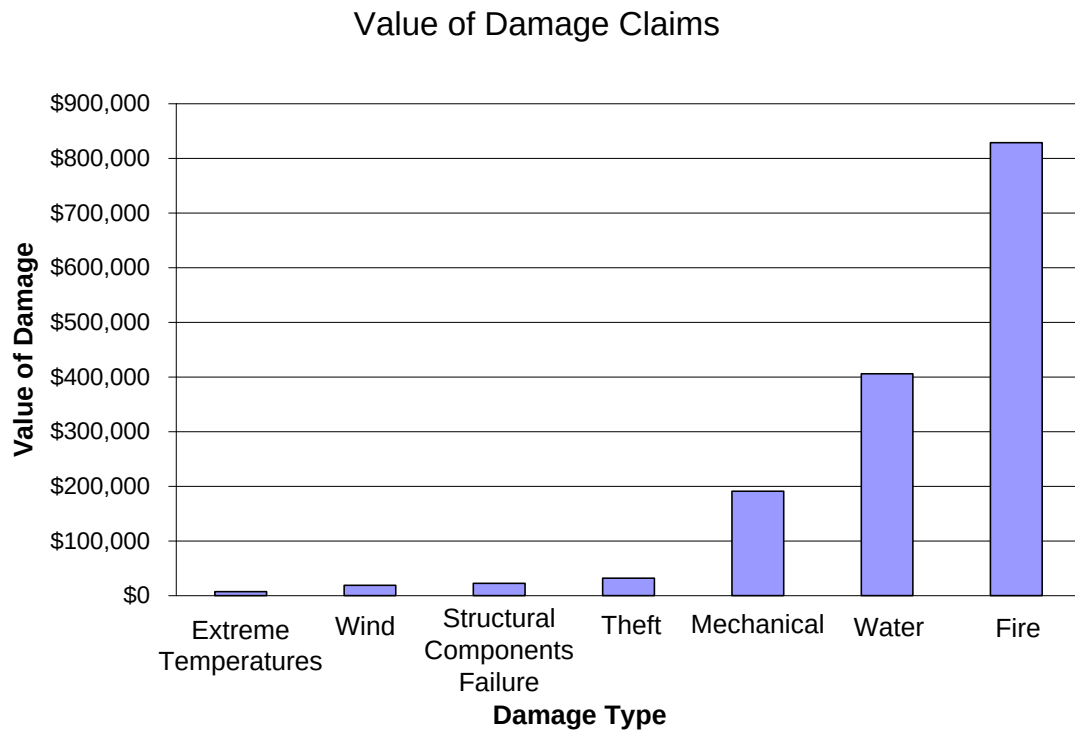


Figure 4: Monetary Worth of Insurance Claims

DAM FAILURE

A total of 76 major dams exist in the Tennessee and Cumberland watersheds. Of these dams, 49 are owned and operated by the Tennessee Valley Authority (TVA), 11 of which are located upstream from Knoxville. The six largest of these dams were the only ones considered of the TVA-operated dams because they are the only ones that have the potential to affect the UT campus in Knoxville under certain failure scenarios. One other major non-TVA-regulated dam in close proximity to the UTK campus was also considered (the only non-TVA-regulated dam upstream and near to Knoxville). All of the dams taken into account are shown in Table 8 (Hughes, 2007).

Tom Cloud, an Emergency Management Planner with TEMA East stated, “There are no state regulated dams or unregulated farm ponds that pose a risk to UTK;” as well as, “There are no US Army Corps of Engineers (USACE) projects that directly affect UTK.” Tom Cloud also stated, “There is only one Federal Energy Regulatory Commission (FERC) regulated dam that is distantly upstream from UTK (Walters Dam on the Pigeon River operated by Progress Energy), and it does not pose any significant risk to UTK.”

With regard to the TVA maintained dams, six do have the potential to affect UTK under certain scenarios. Exact flood inundation maps exist for these varying failure scenarios; however, TVA considers these maps to be highly sensitive and not for public distribution of any sort, including this report. However, a description of the effects on the campus is permitted (Hughes).

TVA divided the flood inundation areas into two zones—Zone A and Zone B. For flood waters to reach the levels shown by the different zones on the map, different scenarios would have to occur. The water levels would reach the extents of Zone A if only one event included in its possible scenarios were to occur. The water levels would reach the

Table 8: Dams Upstream from Knoxville

Dam	River	City	Regulated By
Cherokee Dam	Holston River	Jefferson City, TN	TVA
Douglas Dam	French Broad River	Sevierville, TN	TVA
Fort Patrick Henry Dam	South Fork Holston River	Kingsport, TN	TVA
Boone Dam	South Fork Holston River	Kingsport, TN	TVA
South Holston Dam	South Fork Holston River	Bristol, TN	TVA
Watauga Dam	Watauga River	Elizabethton, TN	TVA
Walters Dam	Pigeon River	Waterville, NC	FERC

extents of Zone B also if only one event included in its possible scenarios were to occur. The extents of Zone A reach out farther than Zone B because it is the most severe flooding due to dam failure that can ever possibly occur. Flooding into Zone A has an extreme unlikelihood of ever occurring, and flooding into Zone B has a moderate unlikelihood of occurring. These scenarios are described as follows:

Zone A:

- Douglas failure in Possible Maximum Flood (PMF)
- Douglas PMF without dam failure
- Cherokee failure in PMF
- Watauga failure in PMF
- South Holston failure in PMF

Zone B:

- Douglas failure—nonflood condition
- Cherokee failure—nonflood condition
- Cherokee PMF without dam failure
- Watauga PMF without dam failure
- South Holston PMF without dam failure
- Boone & Fort Pat. failure in PMF
- Boone & Fort Pat. PMF without dam failure

A Possible Maximum Flood, or PMF, is the largest flood that can ever possibly occur in the future, which is highly unlikely (having about a 1 in a million chance of occurring), but is still considered to ensure that structures designed for the PMF will also withstand all other lesser floods. Of all of the campus buildings considered for this project, 14% of these buildings are located within flood Zone B. Zone A (which contains the buildings of Zone B also) contains 37% of campus buildings. Although this is a significant percentage of buildings, the majority of these buildings are either smaller in size than others on campus or do not have high value in terms of money and life loss. A few select buildings that fall within these flood zones, however, are quite important in the logistics and research (content values) areas. A more detailed discussion of how dam failure could affect these specific buildings is located within Section 4.2—Vulnerability Assessment.

Past Occurrences

Floods occurred in the in the 1920s and 1930s, but these were before TVA's dam projects upstream and immediately downstream from Knoxville were completed in the late 1930s and 1940s. These dam projects have prevented any subsequent flooding to affect Knoxville. Also, there has never been a failure of any of the TVA dams located upstream from Knoxville and the UT campus (Hughes 2007).

In conclusion to the information obtained regarding the magnitudes of any of the seven dams failing, if any of the non-TVA dams were to fail, water levels would not rise enough to flood the UTK campus. As far as the TVA dams are concerned, if one or some were to fail according to the TVA scenarios, buildings on campus would be affected.

However, as stated previously, the chances of any of these scenarios occurring is highly, highly unlikely.

Likelihood of Future Occurrences: Unlikely

DROUGHT

Extreme or severe droughts occur in Tennessee approximately once every 15 years (Tennessee Emergency Management Agency, 2002). Other varying degrees of droughts do occur throughout the year. Their varying degrees created and used by the National Weather Service's Climate Prediction Center are as follows:

- Extreme Drought
- Severe Drought
- Moderate Drought
- Near Normal Conditions
- Unusual Moist Spell
- Very Moist Spell
- Extremely Moist

Extreme drought is the driest condition and extremely moist is the wettest.

Past Occurrences

The National Weather Service's Climate Prediction Center gives weekly drought information since 1998 for various divisions in the United States. Gathering information from this database gives past drought occurrences in Knoxville since 1998 shown in Figure 5. The drought raw data can be viewed in the appendix. As shown in the figure, Knoxville experienced either near normal conditions or above average moisture 84% of the last 11 years that the data was gathered. Of the other 16%, which were times of drought conditions, only 5% were extreme or severe droughts (United States National Weather Service Climate Prediction Center, 2007).

It should be noted that the most recent drought of 2007 has been one of the longest and most severe droughts in recent history. As shown in the drought raw data in the appendix, in 2007 no unusual moist spell, very moist spell, or extremely moist conditions existed for any week in 2007. Only near normal conditions or varying degrees of drought existed throughout the entire year.

With Tennessee having an average of about one extreme or severe drought every 15 years, this puts a drought event in the "occasional" category. This may seem like an area of high concern due to the small recurrence interval. However, TVA has water storage in case of this event occurring, and the effects of a drought are not likely to be life-threatening.

Likelihood of Future Occurrences: Occasional

EARTHQUAKE

FEMA's *State and Local Mitigation Planning How-to Guide: Understanding Your Risks* states to determine if UTK is located in an area of high seismic risk. An area with any seismic risk is defined in the handbook as an area with 3% g peak acceleration or more. Using a map acquired from USGS, shown in Figure 6, it was determined that Knoxville, shown as a black dot in the map is located in a region of 8-16% g, which is an area of medium seismic risk. Therefore, an earthquake event was considered to be an event of interest, due to the level of seismic risk.

To determine a more precise measurement of hazard for the UTK campus, a Peak Ground Acceleration (PGA) value was found for a 10% chance of being exceeded over 50 years using the USGS website and latitude/longitude of the center of UTK's campus. A peak ground acceleration is a measure of the ground movements during an earthquake, and finding this value for a probability of 10% that this event will occur in 50 years is a commonly used earthquake measurement and is recommended by FEMA for mitigation planning. The USGS website gave a value of 8.81% g, which gives a more precise

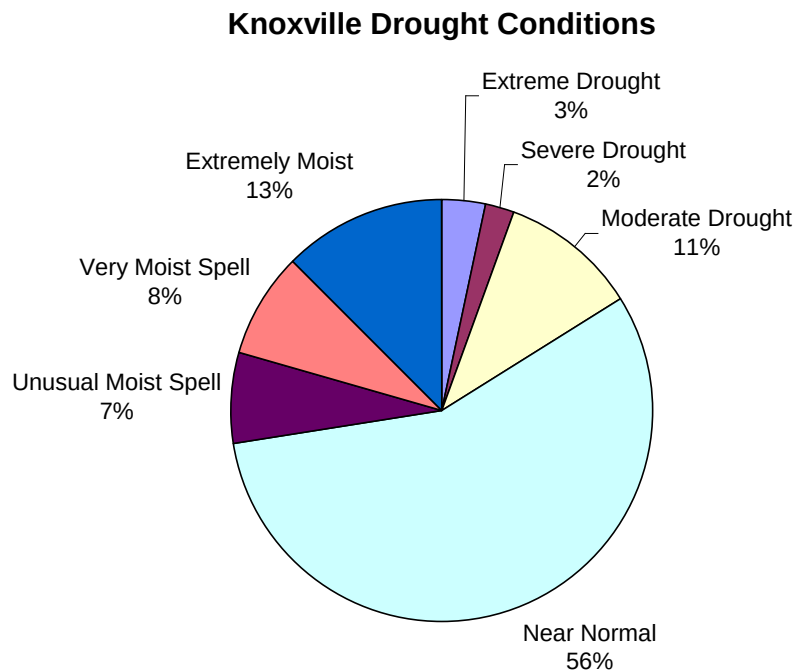


Figure 5: Knoxville Drought Data Since 1998

number than the range of 8-16% g determined from Figure 6. This shows that UTK is on the lower end of the medium risk spectrum.

It was determined that different magnitudes of earthquakes have varying degrees of likelihood of occurrence; therefore, earthquake events were divided into two categories— M_w of 4 to 5 and M_w of 5 to 6, where M_w is the moment magnitude.

Past Occurrences

Over twenty-five earthquakes are known to have been felt in Knox County over the past 200 years. Table 9 shows a historical list of earthquakes, which are listed with the estimated intensity (using the Modified Mercalli Intensity scale shown in Table 10) that was actually felt in Knox County—not at the origin of the earthquake. Of these 25 earthquakes, only 6 have been strong enough to cause structural damage (those over an intensity of V). The earthquakes that did cause some damage, only caused mild damage in most cases as seen from the Modified Mercalli Intensity scale. Significant earthquake events denoted with an asterisk (*) in Table 9 are described in greater detail later in the report (McClain and Myers, 1970).

- **November 28, 1844**-In Knoxville bricks were thrown from the top of a chimney, and one chimney in the county was thrown down. In Blount County (an adjacent Tennessee county), bricks were displaced from several chimneys and houses.
- **May 31, 1897**-This Giles County, Virginia earthquake was the largest recorded earthquake in the Appalachian region. The intensity at the epicenter was estimated to be VIII, but this was over a small region. The intensity was reduced to VII outside the epicenter and inside an 8000 square mile area. The intensity in Knoxville was reduced further to a V. The Knoxville Journal and Tribune reported that the only damage in the city was the toppling of a chimney in West Knoxville. The paper said “This will amount to but a few dollars.”
- **March 28, 1913**-In Knoxville bricks to fell from chimneys, pictures to fell to the floor, heavy furniture was overturned, and fire alarms were activated. The Knoxville Journal and Tribune read as follows:

A few bricks were shaken from the top of the home of W.P. Chandler on Second Street, falling into a neighboring yard. It was also reported that two or three chimneys in North Knoxville had toppled over. At Sterchi Bros. store on Gay Street, several pieces of shelving toppled over, and out on Richards Street, a chimney gave way, the bricks tumbling down. It was also reported that the shock wave was unusually severe out on the Sevierville pike, at Shook’s Gap, and that at several homes in that vicinity chimneys had tumbled down. Also two or three are said to have fallen at homes just beyond the end of the Sevierville Pike car line. Constable W. A. Chanaaberry reported that two feet of the chimney at his residence at 715 East Cumberland Avenue had toppled off and his horse, in the barn, had been knocked down. The iron bars of a sign on Union Avenue were bent and much of the plastering in the

auditorium fell off. Pictures fell from the walls of the home of Dr. Harrill, dentist, on Union Avenue. A stovepipe in the home of Chas. H. Smith, on West Clinch Avenue, fell, and several ladies, guests of Mrs. Smith at the time, were given a severe fright.

This excerpt just gives a firsthand account showing that the only damages encountered were bent bars, toppled chimneys, shelving, pictures, a stovepipe and a horse. No structural damage occurred.

- **January 16, 1918**-Hundreds of dollars worth of pane glass were shattered, as reported by The Knoxville Journal and Tribune. The newspaper attributed the earthquake to using 100 sticks of dynamite to break up an ice jam in the river. No damage besides the loss of window panes was reported.
- **September 7, 1956**-This earthquake was one of the largest earthquakes in Knox County. Chimneys were thrown down, plaster was knocked from walls, and windows were shattered. Broken window glass and shattered dishes were reported from Asheville to Middlesboro, Tennessee. No major damage was reported, however.
- **April 15, 1960**-People were awakened as this earthquake occurred at 5:12 a.m. The Knoxville News-Sentinel tells of people who described the earthquake as jolting their house and causing their windows to quiver. No damage was reported.
-
- **November 30, 1973**- Small cracks were formed in walls in Knoxville. A horizontal crack near the base of a wall at the University Hospital emergency room was created. People reported items being overturned in their homes. One resident said the earthquake knocked a picture off the wall, a vase off a table, and turned over an alarm clock. Another resident said the earthquake knocked the plug to a water heater out of its socket, caused her wardrobe doors to fly open, and knocked bricks out of the chimneys of two houses. There was a report by a resident of their foundation being cracked and cinder blocks (sic) being loosened in the basement wall. Two earthquake related injuries were reported—one by a woman who fell down the stairs during the earthquake and broke her leg and another by a man who suffered a foot injury when he ran into a door while going to check on his children during the earthquake. *The Knoxville News Sentinel* summarized the earthquake by saying “Chimneys were cracked, dishes broken, but no major damage was reported.” Also, during the time of this earthquake, Dr. Beavers (initiator and committee member of UTK’s Multi-Hazard Mitigation DRU Plan) was in charge of strong motion monitoring at the Department of Energy complex in Oak Ridge, Tennessee. At the Y-12 Security Complex one instrument recorded 0.025 g of motion on the second floor of one building indicating that the peak ground motion was at least 0.01g 25 miles from the

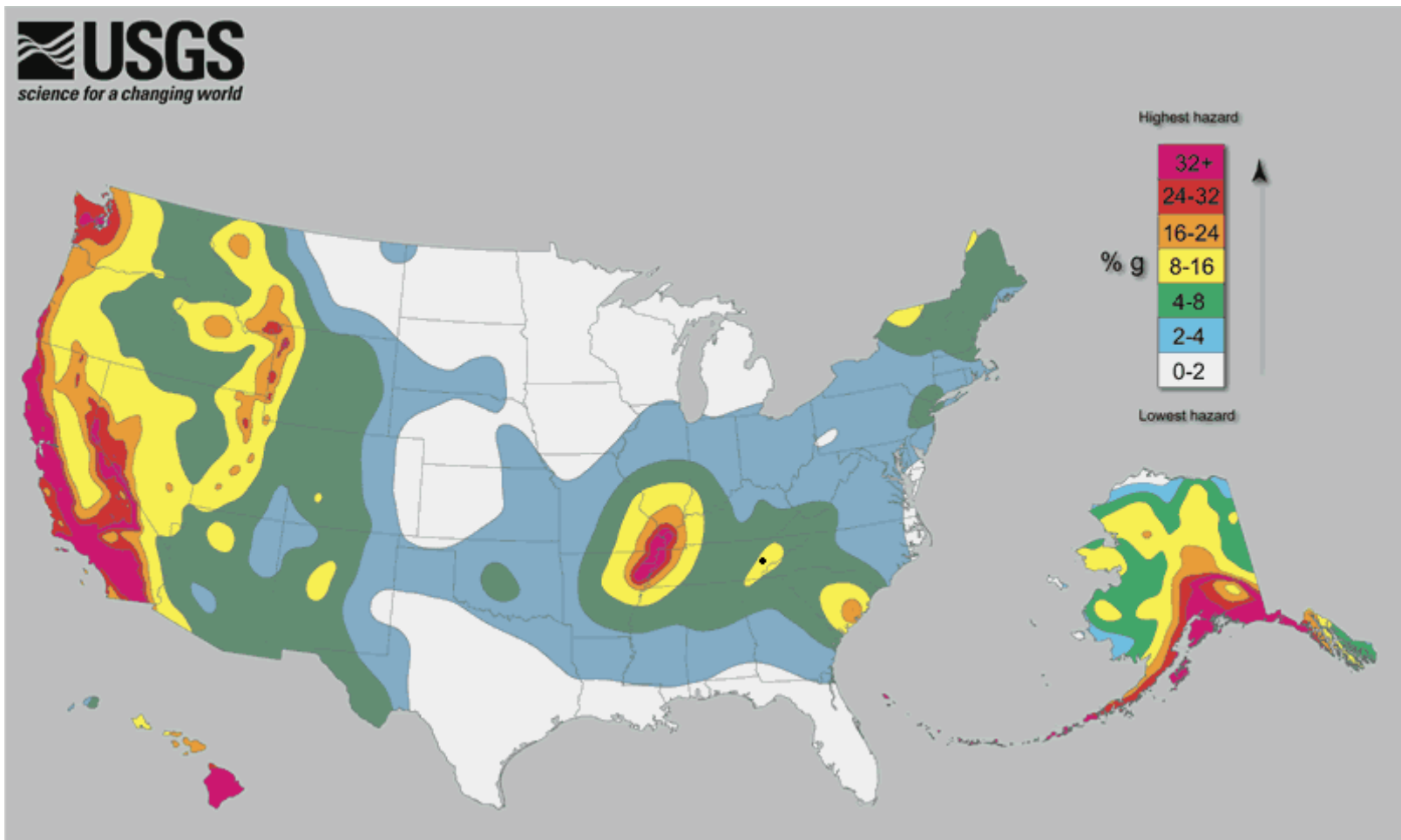


Figure 6: Seismic Risk Map
(Source: United States Geological Survey)

Table 9: Earthquakes Felt in Knox County

Date	Location	Intensity
1811 and 1812	New Madrid, Missouri	Unknown
Nov 28, 1844*	Knoxville	VI
Nov 12, 1875	Knoxville	III-IV
May 25, 1877	Knoxville	III-IV
Nov 16, 1877	Western NC and East TN; felt at Knoxville and Murphy, NC	III-IV
Aug 25, 1884	Knoxville	IV
May 31, 1897*	Giles County, Virginia	V
Mar 5, 1904	Maryville	V
Mar 28, 1913*	Knoxville	VII
Aug 3, 1913	Knoxville	IV
Mar 5, 1917	Knoxville	III
Jan 16, 1918*	Knoxville	V
Jun 22, 1918	Near Lenoir City	IV-V
Oct 16, 1930	Knoxville	III-IV
Mar 4, 1941	Knoxville	III
Jun 6, 1947	Knoxville	III
Jun 19, 1950	Alcoa; felt in Knoxville	IV
Jan 6, 1955	Bristol; felt by few on upper floor of tall buildings in Knoxville	IV
Jan 12, 1955	Blount and Knox counties; felt at Blue Grass and Maryville	IV
Jan 25, 1955	Knoxville	IV
Sep 7, 1956*	Knoxville	VI
Apr 15, 1960*	Near Knoxville	V
Aug 24, 1966	Knoxville	IV
Nov 30, 1973*	Alcoa-Maryville	VI
Feb 14, 1984*	Knoxville	VI
Mar 27, 1987*	Greenback, Loudon County	VI

Table 10: Modified Mercalli Intensity Scale

Intensity	Effects
I	Not felt except by a very few under especially favorable circumstances.
II	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
III	Felt quite noticeably indoors, but many people do not recognize it as an earthquake. Vibration like passing of truck. Duration estimated.
IV	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing cars rocked noticeably.
V	Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks stop, start, change rate.
VI	Felt by all, many frightened and run outdoors; persons walk unsteadily. Small bells ring. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.
VII	Everyone runs outdoors; difficult to stand. Noticed by persons driving cars. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken.
VIII	Steering of cars affected. Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water.
IX	General panic. Damage considerable in specially designed structures; well designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed over banks.
XI	Few, if any, masonry structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
XII	Damage total. Practically all works of construction are damaged greatly or destroyed. Waves seen on ground surface. Line of sight and level are distorted. Objects are thrown into the air.

epicenter, which is an amount of shaking to cause objects to rattle and people to get scared. Usually 0.15 g of motion is the amount needed to cause structural damage, so the 0.025 g is not destructive enough for structural damage (Beavers 9 Aug 2007).

- **February 14, 1984**-This earthquake was one of the most recent and largest intensities felt in Knoxville—a VI. Windows were broken in Blaine and New Market (20 miles and 25 miles, respectively, northeast of Knoxville). No structural damaged occurred.
- **March 27, 1987**-This earthquake, also an intensity of VI, caused cracks in chimneys and foundations at Greenback, Friendsville, Louisville, and Tallassee. This earthquake occurred at 2:29 a.m. and resulted in about 150 calls to the new 911 center, with most callers just curious as to what had happened. No severe structural damage was reported.

Thus, in over 150 years of recorded history in Knox County, there has been no significant structural damage from an earthquake. Reported injuries have been limited to two minor injuries. Some chimneys have fallen over, windows have been broken, things have fallen off shelves, pictures have fallen off of walls, but the earthquakes have caused more panic than actual damage. All of these earthquakes occurred when there were no seismic design requirements, and the damages were all still minor (Stover and Coffman, 1993).

One earthquake scenario of concern, however unlikely, that must be mentioned is an earthquake originating in the New Madrid fault zone. This fault zone is located near the Mississippi River in Missouri, Arkansas, and Tennessee. Any earthquake originating here is likely to be extremely powerful, and its effects will most likely reach Knoxville. The largest recorded earthquake from this fault line was a series of four large earthquakes occurring in 1811 and 1812 at a distance of 320 miles from the UTK campus. These earthquakes were the strongest ever to occur in North America, estimated to be a XII on the Modified Mercalli Intensity Scale. Damage was reported as far away as Washington, DC. The shaking caused church bells in Boston to ring. Land rolled in visible waves. The Mississippi River was forced to change its course. Reelfoot Lake was formed. Other earthquakes in the zone of lesser magnitude occurred in 1843 and 1895. In 1843 the intensity VIII earthquake caused considerable shock to be felt in Knoxville, but no damage occurred. In 1895 the intensity VI earthquake caused shock to again be felt in Knoxville, but no damage was sustained (United States Geological Survey, 2007).

As shown in Figure 7 an earthquake affects a much larger area around the New Madrid fault zone than an earthquake of a similar magnitude on the west coast. This is due to the differences in the geology on the eastern part of the country. In Figure 7 the area near the epicenters represents damage to buildings, while the surrounding area represents shaking felt, but little damage to objects.

Scientists estimate with a probability of over 90% that a magnitude 6 to 7 earthquake will occur sometime in the next 50 years in the New Madrid zone. When this does occur, many more structures will be damaged than have been in the earthquakes out west

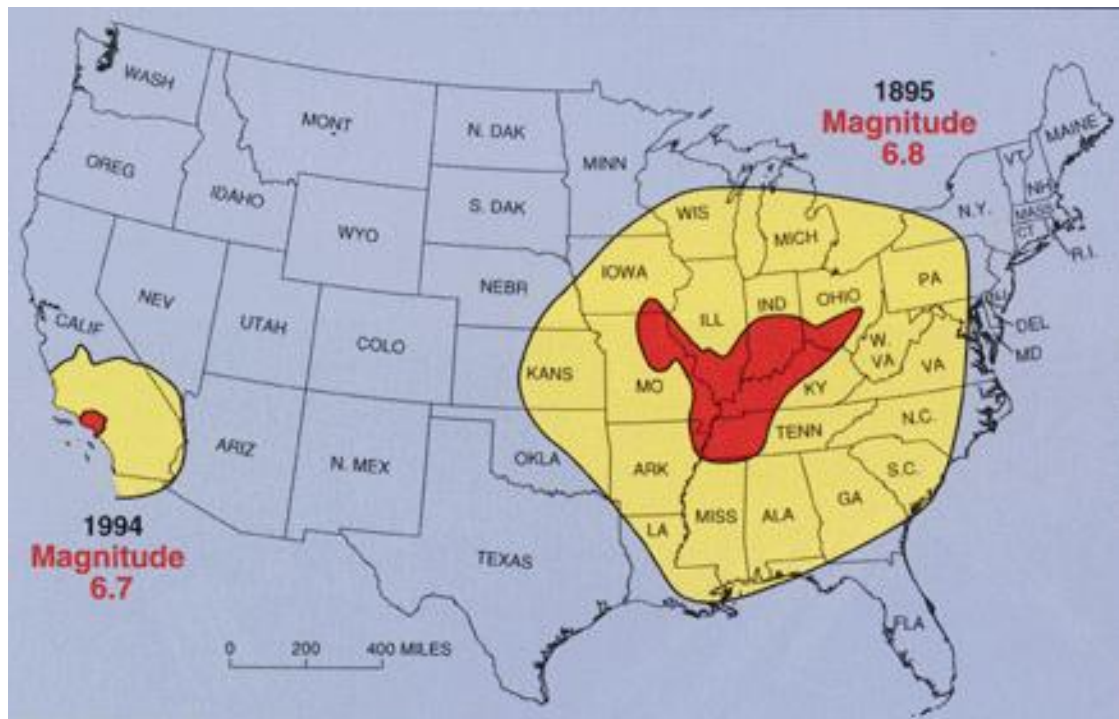


Figure 7: Variances in Earthquake Effects Across United States
(Source: United States Geological Survey)

because the structures around the New Madrid fault zone are not designed to withstand earthquakes, while the ones out west are. If a greater magnitude earthquake occurs, structural damage could be caused in Knoxville and, thus, the UTK campus. Also, since the earthquake waves will travel underground for such a long distance, the period of the waves would become quite long (meaning the oscillations would occur at greater time intervals apart) because they would have a longer time to dissipate and would probably be between 1.5 and 2 seconds. For periods of this length, taller buildings are most affected and would definitely cause swaying of some of UTK's taller buildings. While an earthquake in the New Madrid fault zone with a magnitude greater than 7 is not likely to occur soon, it will probably occur one day, and the campus must be prepared to deal with its results (United States Geological Survey, 2007).

Likelihood of Future Occurrences: M_w of 4-5, Occasional; M_w of 5-6, Unlikely

EXPANSIVE SOILS

Expansive soils are those that have a volume increase when they get wet and shrink when they dry. They can cause damage to foundations, slabs, roads, sidewalks, pipelines and sometimes cause buildings and their components to crack. Expansive soils usually contain high amounts of clay, which is not usually the case in East Tennessee. The subsurface conditions of East Tennessee primarily consist of limestone, dolomite, shale,

and sandstone. Figure 8 shows a map of the United States depicting areas containing varying degrees of expansive soils. Knoxville is located in the category of “Nonexpansive: The Occurrence of Expansive Materials Is Extremely Limited.”

Past Occurrences

No occurrences of damages due to expansive soils have occurred at the University of Tennessee, Knoxville.

Likelihood of Future Occurrences: Unlikely

EXTREME HEAT

Episodes of extreme heat are most detrimental to the elderly, children, and people who have no access to a cooling source during this episode. Prolonged periods of extreme heat are rare in Tennessee, typically occurring only about once every 20 years. However, they do occur at times, so the University must be prepared to handle these periods when they do arise.

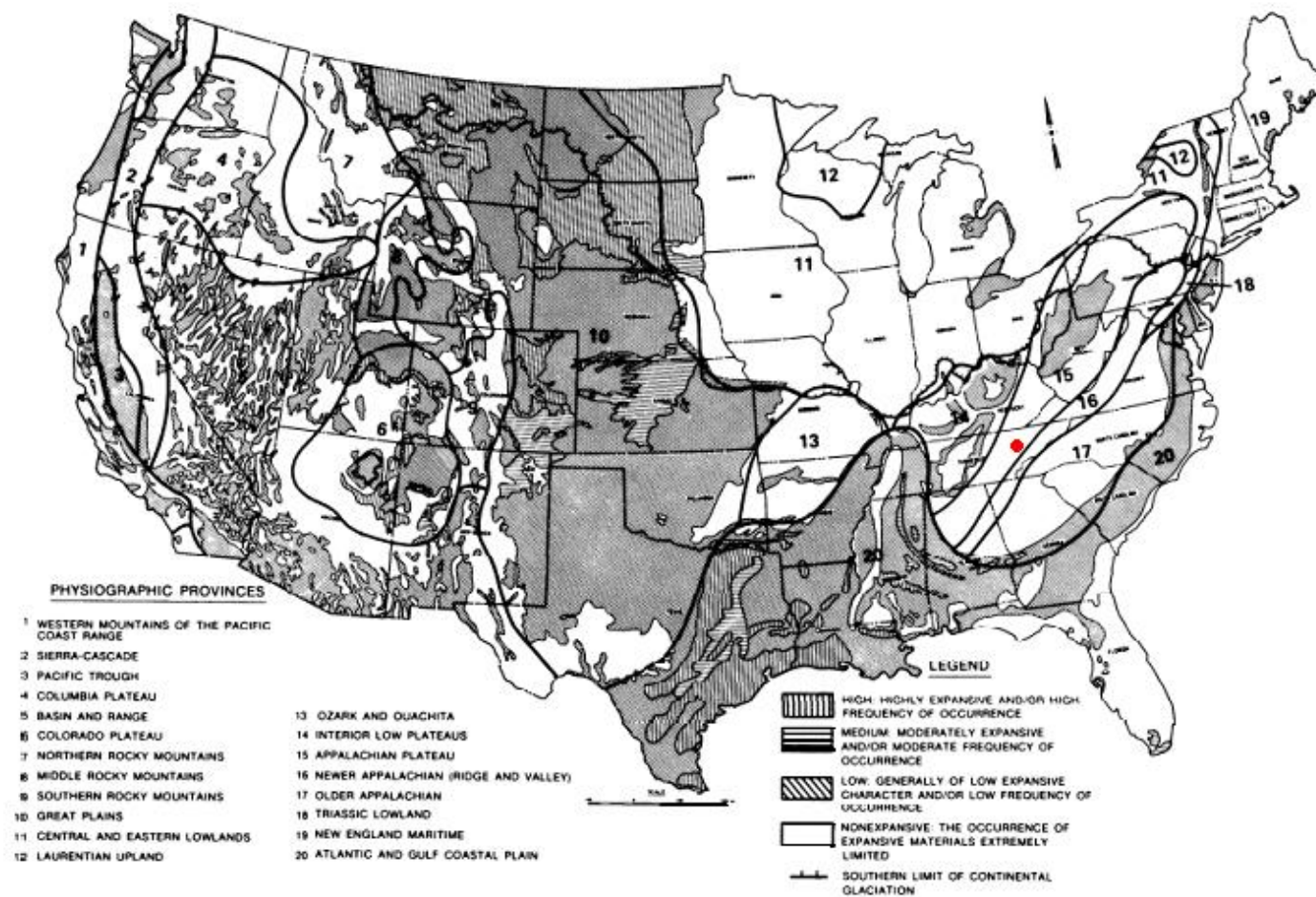
Past Occurrences

Some major historical occurrences of extreme heat events in Tennessee follow:

- **1980**-A severe heat wave resulted in a total of 156 heat-related deaths. Ten were in Nashville, 16 in Chattanooga, 88 in Memphis and 42 in other cities. During the most extreme time of the heat wave, Memphis exceeded 100°F for 33 days. On July 13 the temperature was at its worst, reaching 108°F.
- **1952**-During three different occasions throughout the year, the temperature exceeded 100°F, resulting in 38 heat-related deaths. During each of these three occasions, each one consisted of three to eight consecutive days of severe heat.
- **1930**-In Decatur County on the dates of July 29th and August 9th of this year the temperature reached 113°F, which is the highest temperature ever recorded in Tennessee (Tennessee Emergency Management Agency, 2004).

Some more recently occurring events involving extreme heat in Knox County are as follows:

- **July 16, 1995**-One homeless man died as a result of the extreme temperatures in Knoxville.
- **June 27, 1998**-Neighbors discovered one man deceased on this morning in his home in a low-income, high-crime area. He lived on a fixed income and thus did not turn on the air conditioning for fear of not being able to pay the electric bill. He also did not open the windows out of fear of living in a high-crime area. He was discovered in his house with no windows open and a small fan blowing.



U. S. Army Corps of Engineers

Figure 8: United States Areas of Expansive Soils
(Source: Army Corps of Engineers)

- **June 28, 1998**-Neighbors discovered a deceased woman on this afternoon in her home in a low-income, high-crime area. She also lived on a fixed income and thus did not turn on the air conditioning or open any windows (National Climatic Data Center, 2 Aug 2007).

Likelihood of Future Occurrences: Occasional

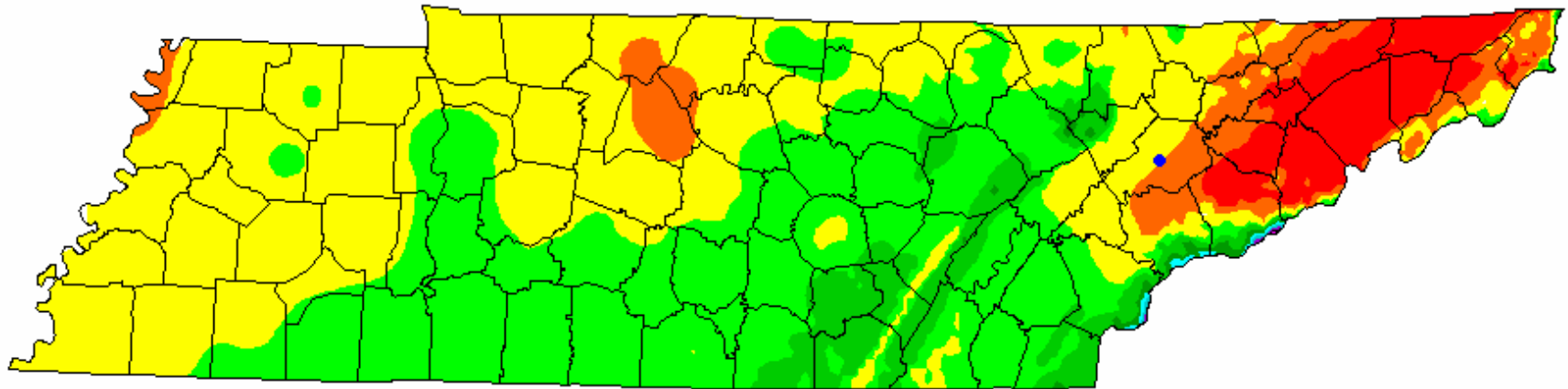
FLOOD

Some of the worst disasters in Tennessee history have been due to flooding (over 50% of Tennessee's federally declared disasters since 1991 involve flooding), so this hazard event was initially an area of priority. The University of Tennessee, Knoxville campus is located directly north of the Tennessee River; therefore, this close proximity to the river, as well as several creeks, warranted consideration of the possibility of flooding, primarily due to heavy rain or snowmelt. The UTK campus does have a chance of flooding, due to its location, but it is not likely because Knoxville is located in a region of lower annual precipitation than other areas of Tennessee shown in Figure 9. Knoxville is denoted by the dot.

In order to determine if the UTK campus is in an area of risk of flooding from the base flood (also known as the 100-year flood, which is a flood that has a 1% chance of occurring in any one year) a Flood Insurance Rate Map (FIRM) was obtained from FEMA and is shown in two separate figures. The eastern side of campus is shown on the left half of Figure 10 and is the portion of the map to the north of the Tennessee River. The western side of campus is shown on the right half of Figure 11 and comprises of the area to the right of the northern-most tip of the Tennessee River. This map mostly just shows the Agriculture campus. The various levels of flooding are broken down into Flood Zones designated by FEMA. Descriptions of these various flood zones are shown in Table 11.

As seen in the FIRM all areas of flooding for the UTK campus lie within the categories X or AE. As shown by the legend on the maps, category AE includes the extents that the base flood would reach and is a high-risk area. However, zone AE does not reach hardly any campus buildings, so if it was to occur (which it probably will, having a 26% chance of occurring in 30 years), not much would be affected. The other flooding areas are encompassed by the shaded and unshaded portions of zone X. The shaded portions of zone X show areas of either 0.2% chance of flooding per year, areas of 1% chance of flooding per year with the flood depth being less than 1 foot or drainage area less than 1 square mile, or areas protected by levees. The unshaded portions of zone X show areas that are outside the 0.2% annual chance of flooding, meaning that they have an even lower likelihood of occurring than the shaded zone X portions. All of this means that floods in zone X have either a low likelihood of occurring if they even occur at all, and if they do occur, their extents are not severe. These areas in zone X are moderate- to low-risk areas and also do not reach hardly any campus buildings. The estimated extents of

Average Annual Precipitation Tennessee



Legend (in inches)	
Under 46	62 to 66
46 to 50	66 to 70
50 to 54	70 to 74
54 to 58	74 to 78
58 to 62	Above 78

Period: 1961-1990

This map is a plot of 1961-1990 annual average precipitation contours from NOAA Cooperative stations and (where appropriate) USDA-NRCS SNOTEL stations. Christopher Daly used the PRISM model to generate the gridded estimates from which this map was derived; the modeled grid was approximately 4x4 km latitude/longitude, and was resampled to 2x2 km using a Gaussian filter. Mapping was performed by Jenny Weisburg. Funding was provided by USDA-NRCS National Water and Climate Center.

Figure 9: Average Annual Precipitation in Tennessee
(Source: Tennessee Emergency Management Agency)

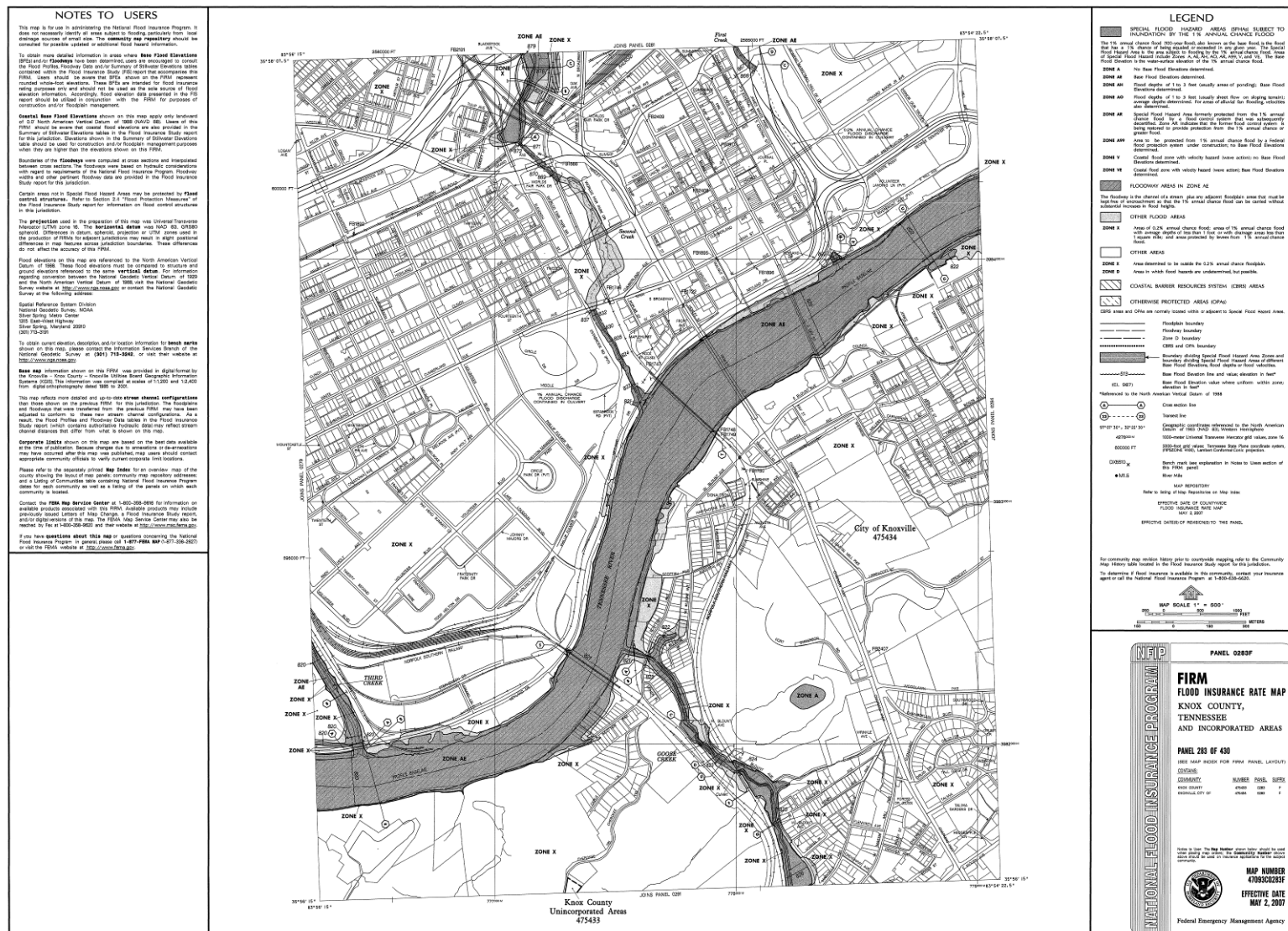


Figure 10: FIRM for Eastern Part of UTK Campus
(Source: Federal Emergency Management Agency)

Table 11: FEMA Flood Zone Designations

Risk	Zone	Description
Moderate to Low Risk Areas	B, C, and X	Areas outside the 1-percent annual chance floodplain, areas of 1% annual chance sheet flow flooding where average depths are less than 1 foot, areas of 1% annual chance stream flooding where the contributing drainage area is less than 1 square mile, or areas protected from the 1% annual chance flood by levees. No Base Flood Elevations or depths are shown within this zone. Insurance purchase is not required in these zones.
High Risk Areas	A	Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. Because detailed analyses are not performed for such areas; no depths or base flood elevations are shown within these zones.
	AE, A1-A30	Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. In most instances, base flood elevations derived from detailed analyses are shown at selected intervals within these zones.
	AH	Areas with a 1% annual chance of shallow flooding, usually in the form of a pond, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.
	AO	River or stream flood hazard areas, and areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Average flood depths derived from detailed analyses are shown within these zones.
	AR	Areas with a temporarily increased flood risk due to the building or restoration of a flood control system (such as a levee or a dam). Mandatory flood insurance purchase requirements will apply, but rates will not exceed the rates for unnumbered A zones if the structure is built or restored in compliance with Zone AR floodplain management regulations.

Table 11, cont.

Risk	Zone	Description
	A99	Areas with a 1% annual chance of flooding that will be protected by a Federal flood control system where construction has reached specified legal requirements. No depths or base flood elevations are shown within these zones.
High Risk-Coastal Areas	V	Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. No base flood elevations are shown within these zones.
	VE, V1 - 30	Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.
Undetermined Risk Areas	D	Areas with possible but undetermined flood hazards. No flood hazard analysis has been conducted. Flood insurance rates are commensurate with the uncertainty of the flood risk.

flooding based on the FIRMs shows that flooding overall is not a high-probability occurrence, and the areas affected if flooding does occur are not large.

Past Occurrences

During the past 146 years, severe floods have occurred in Tennessee for 51 of these years. Some of the floods occurring in Tennessee are described as follows:

- **December 19, 1990 to January 4, 1991**-Six people were killed, and the President signed a federal disaster declaration for Tennessee to provide disaster assistance to 22 counties.
- **February 15-20, 1990**-The Tennessee cities of Copperhill (in Polk County) and Chattanooga (Hamilton County) were damaged by the floods. Several deaths occurred and thousands were forced to evacuate their homes.
- **1989**-The high rainfall during this year caused damage to Rhea County. No deaths or injuries occurred from this flooding. Also during this year there was flooding in East Tennessee from the rainfall effects of Hurricane Hugo.
- **Mid-March 1973**-This was the most destructive flood on the Tennessee River, as well as its tributaries. Few deaths occurred, but evacuations were necessary, and damages were great, estimated at \$50 million.
- **March 4-19, 1963**-Three different storms occurred over the Appalachian Mountains as far south as Alabama to as far north as West Virginia, causing flooding all along its path. Fifty counties in Tennessee sustained damages including 1,000 damaged bridges, 500,000 damaged acres of cropland, 100,000 damaged acres of winter crops, 1,500 killed livestock, and 3,000 damaged or destroyed homes.
- **August 4-5, 1938**-Around Webb Mountain (near Sevier County) about 11 inches of rainfall over a 27 square mile area in 3 to 4 hours caused a flash flood. Extreme runoff and erosion were created, killing eight people.
- **January 18, 1935**-Heavy rain along the Obion River in West Tennessee caused water to rise rapidly, quickly breaking levees. The swiftness of the storm caused many families to be unable to escape the rising water, and they were forced to climb to roofs and trees. Later that day, the temperature dropped, causing four inches of snow and deaths from exposure. A total of 19 fatalities occurred from the mentioned exposure as well as drowning. Sixty-one people sustained ailments due to the exposure, such as frostbite. Property loss, such as livestock, animal food, and household items, was hundreds of thousands of dollars, which would be millions of dollars in today's inflated dollars.
- **March 21-23, 1929**-This flooding of the Emory River at Harriman was one of the harshest floods of its size ever in the east United States. In 3½ hours the water levels in the river rose 22 feet. Every stream in the area flooded, and every town along the river was flooded. Forty people were killed, and property loss was over \$10 million, which would exceed \$100 million in today's dollars.
- **1927**-The flood on the Ohio, Mississippi, and Cumberland rivers, along with their tributaries, was one of the worst floods in United States history and was the second worst flood in Tennessee history. Some areas in the region received over

24 inches of rain over nine days. Before this rainfall, the ground was already saturated due to rains late in the previous year, so this extra rain just exacerbated the flooding. Levees long the Mississippi River broke in 45 locations. The damages included 162,017 damaged houses, 41,487 destroyed buildings, 200 to 500 fatalities, and \$124,648,545 in agricultural losses.

- **June 1924**-Flash flooding occurred in Carter County over a total 150 square mile area. Rainfall reached 15 inches, which created an 8-10 foot high wall of water. When this water wall plunged down a narrow valley, two homes were completely destroyed and nine people were killed, contributing to 11 total fatalities (Tennessee Emergency Management Agency, 2004).

Knox County specifically has experienced two major floods since 1950. Knoxville also experienced significant floods in 1808, 1867, and 1939 when the Tennessee River flooded.

Some more recent floods, while less severe, have occurred in Knoxville and are listed in Table 12. The descriptions of each flood are as described by the National Climatic Data Center (NCDC).

The University of Tennessee experiences some flooding every year. An area of particular concern from flooding is Third Creek. The campus does not have a high likelihood of flooding from this creek, however, it may be impacted. Storm water runoff is most likely to cause flooding of the campus. Lake Avenue on campus has had some serious problems from flooding in the past due to stopped up storm drains and subsequently has caused the University to lose money. Some of the total monetary losses each year for UTK due to flooding are shown in Table 13 (National Climatic Data Center, 19 July 2007).

Likelihood of Future Occurrences: Unlikely

HURRICANE

As defined by FEMA, a hurricane is a category of tropical cyclone characterized by thunderstorms and defined surface wind circulation. Hurricanes develop over warm waters and are caused by the atmospheric instability created by the collision of warm air with cooler air. Two types of hurricanes exist—wet and dry. Wet hurricanes comprise mostly of rain and flooding and generally affect both coastal and inland areas, while dry hurricanes consist of mostly wind and usually affect only coastal areas.

Knoxville is not located directly on a coastline. The closest distance from Knoxville to the Atlantic Ocean (the nearest coastline) is approximately 315 miles. However, a hurricane can reach inland as far as 400 miles. Knoxville is located within the reaches of a hurricane, but at this distant range the effects of the hurricane would likely be very weakened. Since Knoxville is quite far inland, the majority of these weakened effects

Table 12: Reported Floods in Knox County

Date	Type	Damage	Description
8/20/93	Flash Flood	\$5K	2 inches of rain flooded a few roads and underpasses.
12/4/93	Flash Flood	\$1K	Several roads were flooded.
2/10/94	Flash Flood	\$5K	Not Available
2/11/94	Flash Flood	\$1K	Not Available
3/27/94	Flash Flood	\$50K	Not Available
4/15/94	Flash Flood	\$50K	Heavy rainfall produced flash flooding across the southeast corner of Tennessee. Numerous roads were closed because of the flash flooding. Some rock and mud slides occurred as well. An apartment complex was flooded in Knox County.
5/9/95	Flash Flood	\$5K	Several roads were closed due to flooding. One family was trapped in their car on one of these roads.
4/21/97	Flash Flood	\$0K	Heavy rain over several hours resulted in flash flooding. Parts of I-40 were underwater.
7/1/97	Flash Flood	\$0K	Flash flooding in the Shipetown area resulted in a tractor trailer and several cars stalling in flooding from Flat Creek along Mine Road. Several individuals, including the tractor trailer driver, had to be rescued from their vehicles.
4/17/98	Flood	\$0K	Long-lived heavy rain event caused evacuations of apartments throughout the county. Numerous roads underwater and impassable throughout county.
4/18/98	Urban/Small Stream Flood	\$0K	Road near West Town Mall flooded. 2 inches of rain per hour near Karns.
5/7/98	Urban/Small Stream Flood	\$0K	Flooding on Emory Road and Norris Freeway.
5/21/98	Urban/Small Stream Flood	\$0K	TV meteorologist reported flooding in Duck Pond area of Fountain City. Storm spotters reported 10 inches of water on Merchant Drive near Red Lobster. Broadway and Dutch Valley Road flooded. Water across I-275 near Baxter.

Table 12, cont.

Date	Type	Damage	Description
5/21/98	Urban/Small Stream Flood	\$0K	Storm spotter reported junction of John Sevier and Asheville Highway was flooded up to car bumpers.
6/1/98	Urban/Small Stream Flood	\$0K	Several roads still flooded and impassable.
6/1/98	Urban/Small Stream Flood	\$0K	Alcoa Highway near the Navy/Marine Corps Reserve Center was impassable due to water across the road.
6/2/98	Urban/Small Stream Flood	\$0K	Numerous streets closed due to flooding.
6/2/98	Urban/Small Stream Flood	\$0K	Apartment building evacuated due to flooding at Knox Lane and Fair Drive.
7/11/99	Flood	\$0K	Widespread showers and thunderstorms with heavy rain caused flooding problems throughout much of East Tennessee. In Knox County many cars were stranded in flooded underpasses.
4/4/00	Flood	\$0K	Many roads impassable.
8/30/01	Urban/Small Stream Flood	\$0K	Many roads in the Cedar Bluff, Cross Park and Bridgewater areas were flooded and closed. Several persons had to be evacuated from cars.
1/23/02	Flood	\$0K	Prolonged heavy rain throughout the day resulted in numerous road closings across much of central East Tennessee.
3/17/02	Flood	\$5M	Widespread flooding occurred across most of East Tennessee with the hardest hit counties in central East Tennessee including Bledsoe, Meigs, Roane, Rhea, Loudon, Blount, Knox, and Sevier Counties. Rainfall totals between five and eight inches were reported in 36 hours. Numerous major rivers flooded including the Clinch, Powell, Sequatchie, and Pigeon Rivers.

Table 12, cont.

Date	Type	Damage	Description
3/17/02	Flash Flood	\$0K	Widespread flooding occurred across most of East Tennessee. Rainfall totals between five and eight inches were reported in 36 hours. Total damage estimates were calculated to be over 5 million dollars.
2/14/03	Flood	\$18.1M	Four day rainfall totals of two to eight inches fell across east Tennessee, with the highest amounts occurring across the Cumberland Plateau and adjacent valleys areas. This rainfall combined with a melting snowpack (reports of up to a foot in the higher elevations) to produce widespread flooding of rivers and streams with numerous mudslides also reported (one notable mudslide pushed an apartment complex off its foundation in Knox County). The Powell, Clinch and Holston rivers measured the most significant rises with Claiborne, Rhea and Knox counties reporting the most significant damage.
2/16/03	Flash Flood	\$0K	Seventy roads reported to be flooded with some closed. One injury reported in an apartment complex which was destroyed by a mudslide.
2/21/03	Flood	\$0K	With the ground already saturated from the previous week's rainfall, three day rainfall totals of one to three inches created some flooding of streams and rivers as well as several mudslides across east Tennessee. Rivers which rose above their flood stages included the South Chickamauga, Clinch, Powell, Holston, Pigeon, French Broad and Sequatchie rivers.
4/10/03	Flood	\$0K	Seven day rainfall totals of three to five inches were reported across central east Tennessee and northeast Tennessee, with one to three inches occurring on the 10th. Several secondary roads across the area were flooded with several rivers experiencing some minor flooding including the Clinch, French Broad, Holston, Pigeon and Powell rivers.

Table 12, cont.

Date	Type	Damage	Description
5/5/03	Flash Flood	\$2.8M	Kingston Pike and Gleason Road flooded and closed. Some sinkholes filled to overflowing, minor mudslides.
6/14/04	Flash Flood	\$10K	Car submerged on Kingston Pike as flash flood waters invaded area.
6/17/04	Flash Flood	\$300K	"Shoulder deep" water covered the parking of an apartment complex in Bearden, covering some vehicles and invading several units. Also, water filled the parking of a popular restaurant in Bearden, completely submerging several vehicles.
7/6/05	Flash Flood	\$0K	Three feet of water on Interstate 40 at Papermill Road.
8/4/06	Flash Flood	\$0K	Thunderstorm rains produced four feet of water at the intersection of Cumberland and Poplar Streets in Knoxville.
9/23/06	Flash Flood	\$0K	Water ran into basements in the Cedar Bluff area from thunderstorms with extremely heavy rain.
9/23/06	Flash Flood	\$0K	A stationary thunderstorm complex produced over two inches of rain on one hour, creating flooding which made several roads impassable in the Cedar Bluff area.
9/23/06	Flash Flood	\$0K	Flooding from stationary thunderstorms caused flooding of streets in downtown Knoxville and in the west end of the county.

Table 13: Dollar Loss for University of Tennessee Due to Flooding

Year	Gross Dollar Loss
1994	\$113,034
1995	\$315,887
1996	\$118,417
1997	\$148,683
1998	\$270,364
1999	\$286,078
2000	\$80,824
2001	\$117,106
2002	\$55,334
2003	\$1,133,691
Average	\$263,942

would be rain. The worst effects that this increased rain would likely have on the UTK campus would be flooding of existing bodies of water. This event would essentially be the same as a flood event for the campus. For a more detailed discussion on the possible flooding effects, refer to the “Flood” section of this report.

Also, some of the high winds from the coast of the storm could reach Knoxville if the storm was severe enough. The wind effects from a dry hurricane are comparable to a windstorm event. For a more detailed discussion on the effects of this wind, refer to the “Tornado” section of this report.

Past Occurrences

Information from the National Hurricane Center’s website reported that there have been 35 hurricanes to affect Knox County since 1896, which is an average of about one hurricane every three years. The details of these hurricanes are displayed in Table 14. Notable is the fact that the highest wind speed Knox County has experienced due to a hurricane is 55 mph, which is lower than ASCE 7 Building Standard’s requirement that buildings be designed for wind speeds of 90 mph.

Some of the most damaging hurricanes to affect Knoxville include Hurricanes Ivan, Andrew and Katrina. In Tennessee these hurricanes did not cause any casualties, but they did produce monetary damage. A more detailed history and profile of these hurricanes follows.

Hurricane Ivan was a Category 5 (the most extreme) hurricane and is the strongest hurricane recorded to affect Knoxville. Hurricane Ivan passed as close as 45 miles to the east of Knoxville as displayed in Figure 12. This hurricane generated 3-7 inches of rain throughout the eastern Tennessee Valley (containing Knoxville), causing flash floods and power outages. Around 15,000 people were left without power in the state of Tennessee, which is only 0.5% of the 2.9 million people who normally have electricity. However, 15,000 is a significant number of people to be without power. Ivan also damaged a 26-

inch natural gas pipeline operated by Tennessee Gas Pipeline Co.. The hurricane caused tornado damage all throughout the Southeastern United States, although none actually occurred in Tennessee. Ivan was responsible for 124 deaths, again, none in Tennessee (United States Department of Energy, 2004).

Hurricane Andrew was a Category 4 hurricane, and has been recorded as the second most expensive natural disaster in United States history, causing nearly \$25 billion in damages. It produced about 3 inches of rain in Tennessee and also caused tornadoes throughout the Southeast, although none occurred in Tennessee. Hurricane Andrew caused 65 deaths (none in Tennessee) (National Hurricane Center, 24 June 2007).

Also affecting Knoxville was Hurricane Katrina, causing total damages throughout the country of \$200 billion. This hurricane was one of the most devastating natural disasters in the history of the United States. Tennessee was not affected nearly as much as other states, such as Louisiana, Alabama, and Mississippi. The path of Hurricane Katrina was more in Middle and Western Tennessee rather than East Tennessee where Knoxville is located. However, some effects were felt in Tennessee. Rainfall of 4 to 8 inches fell over parts of the Tennessee Valley and wind gusts of up to almost 50 mph were measured in East Tennessee. Aside from the meteorological effects the hurricane had on Tennessee, it also affected the population. Over 16,000 refugees evacuated southern states to relocate into Tennessee, and UTK housed a number of student refugees from other universities forced to close due to the hurricane (National Hurricane Center, 25 June 2007).

All of these systems described did not produce the damage anywhere near seen in coastal areas because of the distance of Knoxville from the coast. By the time the storms had reached Knoxville, they were weakened; however, while they did not produce excessive amounts of damaging winds, they did all bring above average amounts of rain, which caused some flooding. This flooding due to hurricane events was distinguished as an area of concern, which is why hurricane events were included in the list of hazard events for the UTK campus.

Likelihood of Future Occurrences: Occasional

LAND SUBSIDENCE/KARST

Karst is a common underground condition in East Tennessee resulting in ground fissures, sinkholes, underground streams, and caverns. Most of Tennessee's geography contains some karst, but East Tennessee is one of the areas in Tennessee containing more karst than others. East Tennessee also suffers more sinkholes than other parts of the state. Sinkholes are the main area of concern regarding the effects of karst because they are what cause structural damage. The prevalence of sinkholes in East Tennessee is illustrated in Figure 13, with a lower sinkhole index indicating more sinkholes. Boring logs specifically taken from the UTK campus indicate that it is constructed on underground caves.

Table 14: Hurricanes Affecting Knox County

Name	Date	Wind Speed in Knox County (mph)
None	July 8, 1896	30
None	July 9, 1896	30
None	October 10, 1905	25
None	October 11, 1905	25
None	September 18, 1906	30
None	September 5, 1915	45
None	September 5, 1915	30
None	August 15, 1928	30
None	August 16, 1928	30
None	October 17, 1932	20
None	October 18, 1932	20
None	October 18, 1932	15
None	June 18, 1934	35
None	August 18, 1939	25
None	August 13, 1940	35
None	August 14, 1940	35
Eloise	September 23, 1975	55
Eloise	September 24, 1975	30
Eloise	September 24, 1975	20
Danny	August 17, 1985	30
Danny	August 18, 1985	25
Andrew	August 28, 1992	20
Opal	October 5, 1995	30
Bill	July 2, 2003	20
Frances	September 8, 2004	25
Ivan	September 17, 2004	25
Ivan	September 17, 2004	20
Katrina	August 30, 2005	≈50 in Monroe County (nearby county)

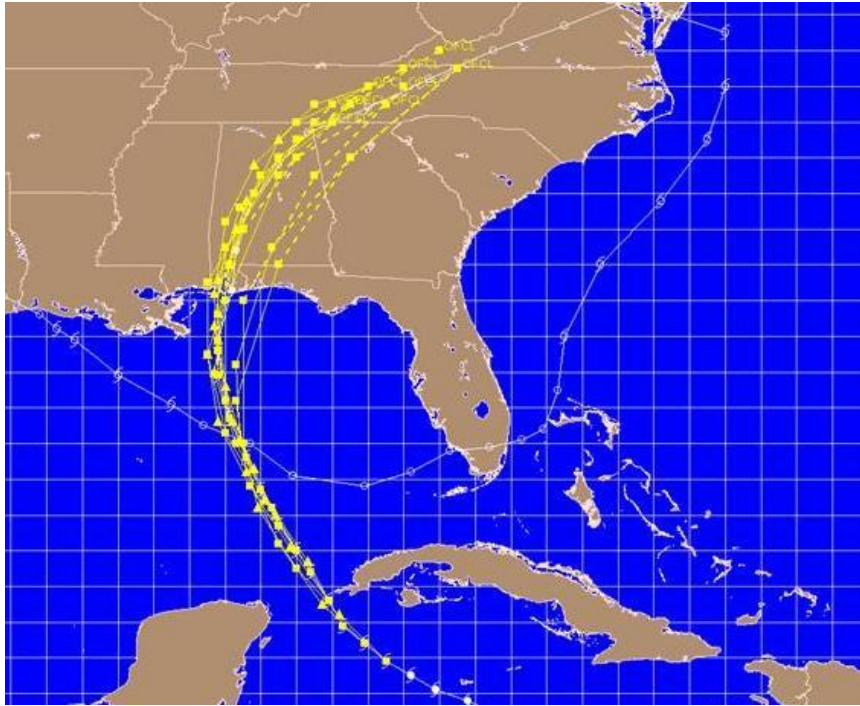


Figure 12: Hurricane Ivan Path
 (Source: National Hurricane Center)



Figure 13: Sinkholes Throughout Tennessee
 (Source: Shofner, Mills, and Duke)

Past Occurrences

There have been numerous incidents of damage due to karst on the UTK campus. Some noteworthy past land subsidence events and preventative measures are as follows:

- Outdoor Pool at the Aquatic Center—A void opened up under an older pool, tearing the bottom of the pool out and completely emptying the entire pool. Tens of thousands of gallons of pool water were dumped into the ground, but it was never determined where this water went. The pool had to be totally replaced with the pool that is currently at the Aquatic Center
- ROTC Building—This was an old building, which used to be beside a football practice field. It was a rectangular shaped building built over the tip of a ridge of underlying rock. Since this building's middle coincided with the ridge of the rock, the edges of the building settled differentially and the building cracked down middle.
- Intersection of Henley and Main Street—In 1936 a massive sinkhole opened up and engulfed a car. The same hole has reopened in 1951, 1962, and 1998, causing broken pipe lines.
- Neyland Stadium—During the replacement of some artificial turf here, several rainstorms came and eroded soil (unprotected from the artificial turf) in the northwest corner of the stadium into an underground void. The rainwater essentially cleaned off the soil on top of the underlying rock. After this event, the void was filled up with a soil and concrete mixture.
- 11th Street Parking Garage—During construction at least three instances of soil being completely washed away from bedrock into a cave occurred in the same manner as the incident in Neyland Stadium.
- Circle Park—During construction of this building a cave was discovered lying underneath the future building's footprint. The top of the cave was blown off with dynamite and filled with concrete to prevent any collapses.
- Thompson Boling Arena—A significantly-sized cave was discovered on the southern side of this building that could have possibly sunk in sometime in the future and was repaired before any damage occurred.
- Andy Holt Avenue—Various sinkholes in the past have opened up and caused busted pipes. Knoxville is an old city and has lots of old pipes that are likely to break due to the stress of a sinkhole.
- Cumberland Avenue—Various sinkholes here also have caused broken pipes. (Berry, 2007)
- Hoskins Library—Extensive settlement due to a five year drought occurred in the shrinking soil underlying the Kefauver wing of this building, causing very large cracks in walls and ceilings. The area of the building that is experiencing cracking, including one elevator, was closed to students. The building is currently being repaired with the \$1.5 million that UTK has budgeted for the project (Dunlap, 2007).

No significant damages have occurred to anything on campus from land subsidence. All of the damages have been minor, such as building cracks or pipe bustings, as opposed to

building collapses. Underground cave-ins will definitely occur in the future, as the campus is filled with them. However, the underground caves that underlay UTK's campus are smaller in diameter compared to others over the country, usually being only 4 to 5 feet in diameter. (Berry, 2007)

Likelihood of Future Occurrences: Occasional

LANDSLIDE

The UTK campus is located in the mountainous and hilly East Tennessee region, where landslides are prone to occur due to the inclines of the topography. For this reason, a landslide event was included in the list of possible events that could affect UTK. Although the campus is located in a region of widely sloping topography, the campus itself does not contain many areas of steeply sloping soil. The primary areas on campus with the greatest slope include a 45° natural slope beside the Pasqua Nuclear Engineering Building and some steep fill soil slopes (also approximately 45°) on the west side of campus near the tennis courts, which are included in the topographic map of campus in Figure 14. However, these primary areas and most other lesser sloping areas are underlain by rock and are very stable (Drumm, 2007).

Past Occurrences

There have been no past occurrences of landslides on the UTK campus.

Likelihood of Future Occurrences: Unlikely

RADIATION FALLOUT

Radiation fallout is not an event of high occurrence anywhere in the United States, however, it was considered due to the fact that the UTK campus is located about 30 miles to the east of the Department of Energy's largest science and energy laboratory, Oak Ridge National Laboratory (ORNL). In 1943 ORNL was the location for the separation of plutonium for the Manhattan Project during World War II to essentially create the world's first atomic bomb. It currently has an annual budget of \$1.06 billion (Oak Ridge National Laboratory, 2007).

One location of particular interest is the Y-12 National Security Complex, which is a United States Department of Energy National Nuclear Security Administration facility located near ORNL. This facility manufactures nuclear weapons components, performs reliability and maintenance testing on existing nuclear weapons, and also contains highly enriched uranium. Therefore, the possibility of radiation fallout on the UTK campus was considered a possible event due to the close proximity of the Y-12 nuclear facility.

Another location considered was the Watts Bar Nuclear Plant, a TVA-owned and -operated plant. This nuclear plant has a 50 mile radius "planning zone" surrounding it,

UTK Topographic Map

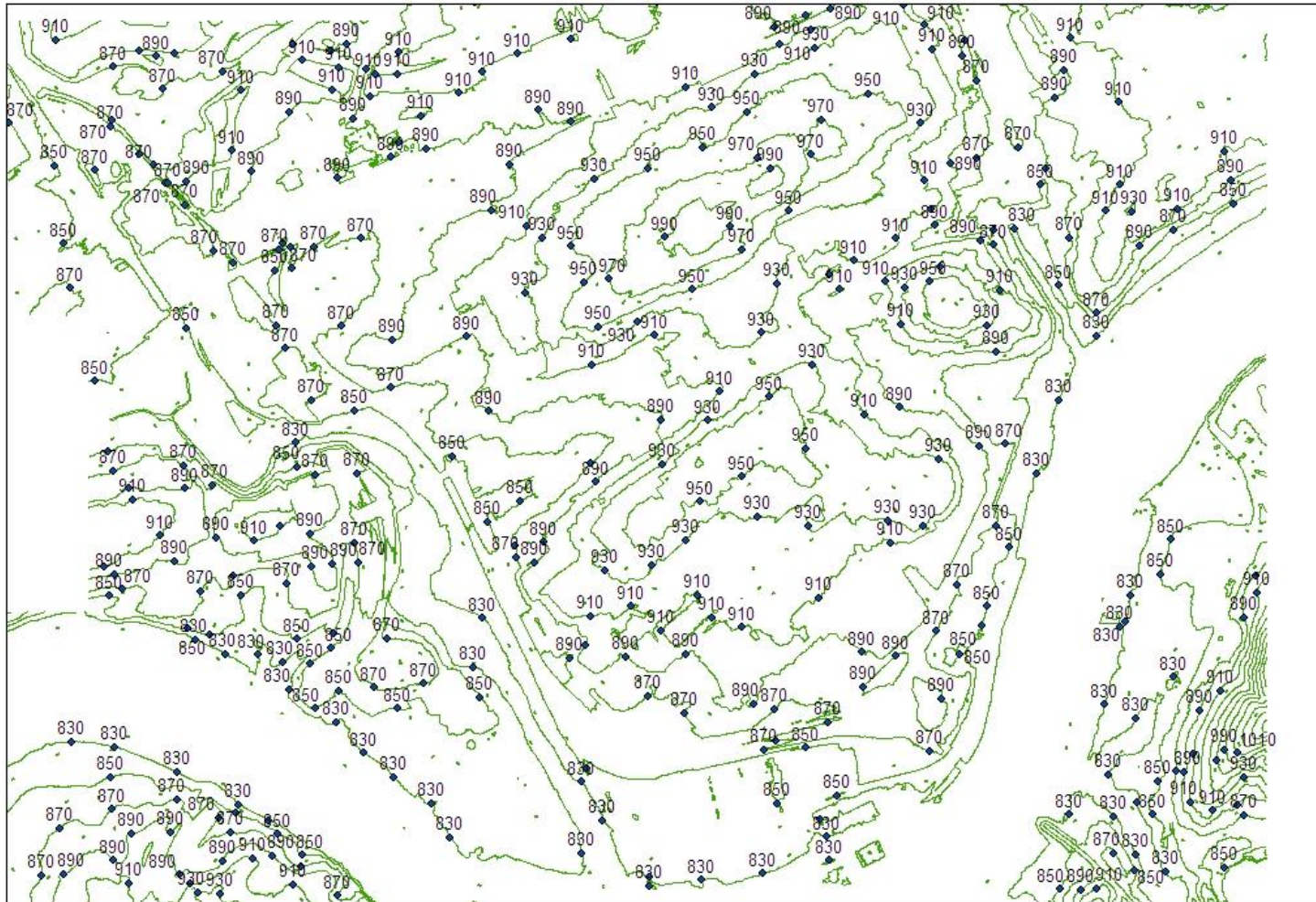


Figure 14: Topographic Map of UTK Campus

which contains all areas that might be affected by radiation release. UTK is outside this 50 mile planning zone, therefore, effects from an event at Watts Bar would be negligible in Knoxville.

Other threats from radiation release could be at locations other than nuclear plants, including “dirty” bombs created from a radiological theft and then released at any location on campus. However, all radioactive material is accounted for by a Nuclear Regulatory Commission (NRC) license and any loss of stolen material would be reported immediately. Another threat for radiation release would be the transport of radiological materials on an Interstate or other road in which the vehicle was involved in an accidental crash, releasing harmful materials. However, before most radiological transports, an accidental release scenario is usually taken into account, and the material is packaged very resiliently, thus probably not affecting the campus. Both of these threats are very unlikely to occur because they have such rigid restrictions around them (Flanagan, 2007).

Past Occurrences

There have only been several past occurrences of radiation releases at ORNL—most of them minor and contained on the ORNL or Y-12 sites. However, in two events, this was not the case. On May 15, 2004 radiation was released into an area not contained by ORNL and out in the public. On June 16, 1958 an even worse event occurred. This event was a criticality accident, which is caused when a nuclear chain reaction accidentally occurs, releasing highly dangerous neutron radiation. These events along with other less serious events are described more in detail as follows:

- June 16, 1958—At Y-12 a criticality accident occurred, caused from highly enriched uranium being mixed in an unsafe container. Eight men were hospitalized, some having acute radiation sickness characterized by nausea, vomiting, skin burns, bleeding gums, and fatigue. All but two of the victims are now deceased, many from cancer, neurological disorders and other ailments they claimed (though not officially proven) to have been caused by their radiation exposure. The radiation did not leave the area of the plant. This is the only criticality event ever to occur at Y-12 (Munger, 2006).
- 1970s-Radioactive material was released into the White Oak Creek, which runs through ORNL burial grounds for radioactive waste. This creek eventually connects with the Clinch River and then empties into Watts Bar Lake, a source of drinking water. Current testing shows that radioactivity levels are too low to affect anyone who lives near or uses these water sources (Flanagan, 2007).
- September 7, 1993—At ORNL several tubes containing iridium (a radioactive material) ruptured releasing radioactive material. The radiation was contained and exposure to workers was very low (Munger, 1993).
- December 8, 1999—At Y-12 a chemical explosion of sodium potassium liquid occurred, injuring 11 workers including one who was severely burned. Lockheed Martin Energy Systems, the manager of Y-12, was blamed with failing to correctly identify the hazards of explosion of the sodium potassium and also did

not correctly train workers on how to clean up a chemical spill. For these reasons, Lockheed Martin was fined \$1 million (Munger, 2000).

- October 6, 2003—In Building 2026 of ORNL, nuclear materials were spilled when a clogged waste drain overflowed. Two workers were exposed to radiation when they rushed to clean up the mess before assessing the hazard of the situation. They also did not regard radiation alarms by leaving. They were not exposed to high levels of radiation and also were not exposed for long. UT-Battelle (manager of ORNL) paid \$55,000 in fines for this safety blunder (Munger, 2004).
- May 15, 2004—A truck hauling radioactive waste to its disposal site leaked several drops of this liquid material (strontium 90) over a 25-foot stretch of Highway 95. This section of highway was shut down and the radioactive sections of pavement were torn up and repaved with new, non-radioactive asphalt. About 150 people had to work continuously to test the radiation, determine contaminated areas, and repave the road to clean up this spill. The estimated cost of cleanup of this spill is between \$1 million and \$2.5 million. No negative health effects or injuries due to this spill have been reported. The contractor at fault from this spill, Bechtel Jacobs Co., was fined \$250,000 (Mitchell and Munger, 2004).

Despite all of these occurrences of radiation release in Oak Ridge, no known radiation or nuclear waste has affected the UTK campus in the past. The chances of an event occurring that could harm the UTK campus are extremely small. In order for radiation to be released to affect the campus, a sabotage event would most likely have to occur to intentionally release large amounts of nuclear material from the Y-12 facility. For this material to reach the campus, wind conditions would have to be precise. If the material finally did reach campus, no negative health effects would be present because the radioactive material would likely be dispersed as it approached Knoxville, making the radiation levels only slightly above what is already present. The threat of a radiation event affecting UTK is extremely low (Flanagan, 2007).

Likelihood of Future Occurrences: Unlikely

SEVERE STORM

A severe storm for the purposes of this report is defined to be a storm that contains any or all of the following:

- Hail
- Heavy Rains
- High winds
- Lightning

While it is impractical to consider any of these event as a separate, singular event to be analyzed (excluding heavy rains, for which the effects are described more in detail in the Flooding section of this report), for the sake of illustrating the level at which any of these

events specifically can affect Knoxville, a discussion of past occurrences is provided in the following section.

Also, a more extensive paper on the specific event of hailstorms throughout the United States has been developed by State Farm Insurance Company. It is published by the American Society of Civil Engineers (ASCE)-2008.

Past Occurrences

A total of 203 severe thunderstorms and accompanying high winds have been reported by the NCDC to affect Knox County since 1950. This is an average of almost 4 severe storms per year, which is a high frequency of occurrence. It would be impractical to list all 203 of these storms, but a listing of some of the stronger and more damaging storms as obtained from the NCDC website follow. The monetary damages listed are not exclusive to Knox County. They include total damages throughout the extents of the storm.

- **\$2 million in damages (October 5, 1995)**-A large part of East Tennessee experienced high winds from the remnants of Hurricane Opal. Wind speeds at the higher elevations of the Appalachians were measured at 70 mph while 40-50 mph gusts were common at the lower elevations. Trees and power lines were down over much of the region. The greatest damage occurred in Hamilton County where damage was estimated in excess of \$1 million. Over 20 thousand homes were without power as a result of the storm. Over 70 miles of the Appalachian Trail was closed due to trees being down.
- **\$610,000 in damages (December 1, 2006)**-Wind speeds measured at 77 mph caused numerous trees and power lines to go down throughout East Tennessee.
- **\$500,000 in damages (May 24, 1996)**-Trees and power lines went down and some very minor injuries were reported. The stage set and lighting equipment of a county music singer was severely damaged. Hail the size of ping pong balls was reported.
- **\$500,000 in damages (January 28, 1994)**-Numerous trees were blown down and roofs were blown off all throughout southeast corner of the Tennessee. A building containing 6 helicopters was destroyed in Maryville, which is in very close proximity to Knoxville.
- **\$75,000 in damages (July 4, 1997)**-Trees were blown down from the Concord area to Chapman Highway, which contains the UTK campus. A section of roof was blown off a building at Baptist Hospital (National Climatic Data Center, 3 Aug 2007).

A total of 83 hail events have been reported in Knox County since 1950. A breakdown of the decade in which these events occurred is shown in Figure 15. These hail events produced hail with an average diameter of 1.15 inches (29.2 mm) and caused reported damages of over \$56,000 dollars since 1950 (National Climatic Data Center, 19 July 2007).

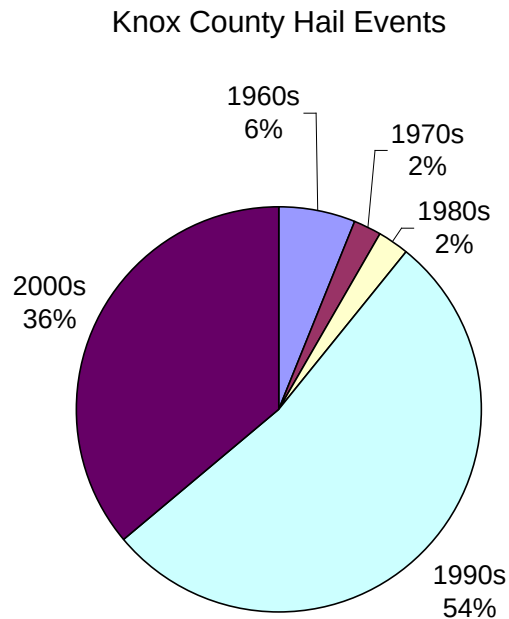


Figure 15: Knox County Hail Events

An average of 62 people are killed every year by lightning in the United States (National Weather Service, 2007). The most recent major lightning events reported in Knox County were on September 1, 1995 and August 4, 2006. During the 1995 event lightning struck a house at 11:30 pm and caused \$40,000 worth of damage. During the 2006 event, lightning struck an apartment building on Middlebrook Pike at 2:50 pm and caught the roof on fire. Several units were damaged, and one was destroyed causing \$25,000 worth of damage (National Climatic Data Center, 19 July 2007).

For a detailed discussion of the effects of high winds on the UTK campus, refer to both the “Tornado” and “Hurricane” sections of this report. Also, for a detailed discussion of heavy rains on the campus, refer to the “Flooding.”

While the likelihood for a severe storm is at least one storm per year (making it a highly likely event), some of its effects, hail and high winds, only have an occasional likelihood of occurrence. Heavy rains and lightning, on the other hand, have a highly likelihood of occurrence.

Likelihood of Future Occurrences: Occasional (Hail and High Winds); Highly Likely (Heavy Rains and Lightning)

SEVERE WINTER STORM

A severe winter storm consists of an assortment of events, including snowstorms and ice storms. Snowstorms can be hazardous due to limited visibility and maneuverability while driving, people being trapped in buildings and cars, inability of emergency services to respond to emergencies due to road blockage, and caving of roofs and power lines. Ice storms can impede driving, as well as cause above-ground power and telephone lines to collapse, leaving the campus or parts of campus with no electricity or phone service. Figure 16 shows the drastic effects ice can have on power lines.

Past Occurrences

On average, one winter storm has occurred every five years in Tennessee. In 1993 a winter storm occurred in Eastern Tennessee, causing 18 fatalities and \$18 million in damages. In 1994 a winter storm covered two-thirds of Tennessee, causing \$100 million in damages.

Twenty-five snow and ice storms have been reported for Knox County since 1950. These storms have caused a total of \$501,000 worth of damage in the county, but caused no



Figure 16: Power Lines During Ice Storm
(Source: National Oceanic and Atmospheric Administration)

reported deaths or injuries. A list of these storms can be seen in Table 15 (Tennessee Emergency Management Agency, 1 July 2007).

One ice storm and one snowstorm have affected the UTK campus in the past 25 years. The ice storm occurred in February of 1994 causing a total of \$500 million worth of damages, 1 death and 770,000 people without electricity in various southeastern states. The damage was the 2nd worst in the country (behind Mississippi) (Lott and Sittel, 2007). The snowstorm affecting campus occurred March 12-13, 1993. Snow depths averaged 15 inches in Knoxville and as much as 30 inches in the nearby Great Smoky Mountains. Forty-thousand people were without power for several days in Knoxville (the largest power outage in Knoxville's history), and all the major interstates north of Atlanta were closed. The total number of people killed by the storm was 270, five of those being in Knoxville (Brown, 2003).

Likelihood of Future Occurrences: Occasional

TERRORISTS

While terrorism events throughout the majority of the United States are quite unlikely, they must be considered due to their random and unpredictable nature. The risk is always present for various extremist individuals to be displeased with university research, policies, or happenings and to show this displeasure with violence. Various specific terrorist acts of concern for UTK include plane crashes into buildings, bombings on large congregations of people (such as sporting events, residence halls, large office buildings, large auditoriums, and student centers), gunfire, and chemical releases.

Past Occurrences

Most acts of terrorism in the United States are directed towards government buildings and officials. The most notable of these terrorist acts would be the terrorist attacks on September 11, 2001, otherwise known as the "9/11 attacks," in which about 3,000 people were killed when four airline jets were hijacked. Two planes were intentionally crashed into the twin towers of the World Trade Center, one crashed into the Pentagon, and the last plane was unintentionally crashed into a field in Pennsylvania. While most terrorism acts are not this severe and are focused on government, some have occurred in schools and universities. There have been 23 shootings in colleges and universities throughout the United States. Some of the more damaging school shootings in U.S. history are as follows:

- University of Texas-On August 1, 1966 Charles Whitman killed 14 people and wounded 31, while shooting a rifle from an observation deck. He killed his wife and mother before going on his shooting rampage, which ended in him being killed by police. During his autopsy it was discovered that he had a brain tumor,

: Severe Winter Storms in Knox County

Date	Type	Description
12/20/1993	Snow	Much of East Tennessee received snow. The mountains were the hardest hit areas with up to 20 inches of snow reported. Several roads were closed due to the snow.
1/14/1994	Snow	Up to 2 inches of snow fell on parts of Northeast Tennessee.
2/9/1994	Ice Storm	A major ice storm hit much of Tennessee. Numerous trees were knocked down. Many of these trees took down power lines as well. About 770,000 people in the state lost power for some period of time.
1/6/1996	Winter Storm	A strong low pressure system from the Gulf Coast region brought up to one foot of snow to parts of East Tennessee. Numerous trees and power lines fell. Many roads became impassable shutting down schools and businesses across the area. Numerous auto accidents occurred. There were also isolated incidents of collapsed roofs.
1/11/1996	Winter Storm	Heavy snow accumulations of 4-8 inches caused numerous power outages and car accidents. Numerous trees fell as well. Schools and businesses were closed.
2/2/1996	Winter Storm	Snowfall amounts across Knox County were 6-8 inches. Numerous minor traffic accidents were reported though no major accidents. Some specific snow amounts reported were: West Knox Marina, Hamblen County Boat Dock, and Rhea County Boat Dock reported collapsed roofs due to the weight of the snow and a number of boats were damaged or sunk.
12/18/1996	Winter Storm	A strong upper level disturbance brought heavy snow showers to the area resulting in widespread icy roads and hazardous driving conditions. Across northeast Tennessee, amounts were generally from 1-2½ inches.
1/10/1997	Winter Storm	An arctic cold front and associated upper level disturbance swept through the southern Appalachians. Snowfall amounts were 1-3 inches in southeast Tennessee, 2-4 inches across the northern Cumberland plateau and central east Tennessee, and 3-5 inches in northeast Tennessee.

Table 15, cont.

Date	Type	Description
12/30/1997	Winter Storm	A series of fast-moving upper level disturbances caused heavy snow shower activity across East Tennessee. Amounts were generally 2-5 inches, with locally higher amounts in higher elevations.
2/4/1998	Winter Storm	A strong storm system over the southeast dumped generally 2-5 inches across the southern Cumberland Plateau. Across the northern part of the Plateau, 6-12 inches fell. As many as 50,000 customers were without power.
12/22/1998	Ice Storm	The ice storm left minor accumulations of ice in valley locations due to warm ground temperatures. Most of the ice was on trees and bridges. Most roads were only wet. In higher elevations, the ice was much heavier.
1/6/1999	Winter Storm	Generally less than 2 inches of snow fell across East Tennessee, resulting in numerous school closings and traffic accidents.
3/13/1999	Winter Storm	A very wet weather system brought heavy amounts of rain to East Tennessee. Heavy rain began early Saturday morning, changed to heavy snow in some places during the day Saturday, back to rain Saturday night, then finally to snow Sunday night. There were also isolated reports of freezing rain. Rainfall amounts across much of East Tennessee was 1-2 inches. Snowfall amounts in northeast Tennessee averaged 1-3 inches.
1/22/2000	Winter Storm	Generally 2-4 inches of snow fell across central and northeast portions of East Tennessee, with only a few reports of amounts in the 1-2 inch range and 4-5 inch range. In southeast sections of East Tennessee, generally a mixture of sleet and freezing rain fell, with ice accumulation around 1/8 of an inch.
12/2/2000	Winter Storm	Widespread snow fell across East Tennessee. Amounts varied widely. In northeast Tennessee, snowfall amounts averaged 1-3 inches, with a few spots in the mountains reporting 2-4 inches. In central East Tennessee, amounts ranged from 1-3 inches, with a few isolated reports of 3-5 inches. In southeast Tennessee, amounts were a bit heavier. Snowfall amounts averaged 2-4 inches, with a few places reporting 3-5 inches.

Table 16, cont.

Date	Type	Description
12/18/2000	Winter Storm	Widespread light snow fell across East Tennessee. Amounts in counties in the valley generally ranged from 1-2 inches. In the higher mountain elevations, amounts were a bit higher, averaging 2-4 inches.
1/20/2001	Winter Storm	Low pressure moved northeast across the southern Appalachians, bringing light snow to the region. Across most of East Tennessee, amounts were under 1 inch.
1/5/2002	Winter Storm	Winter storm brought a wide range of amounts to East Tennessee. In central East Tennessee, amounts were generally 2-4 inches, with a few spots receiving as much as 5 inches, and as little as a half inch.
1/16/2003	Winter Storm	A storm system moved from the southern plains across the Tennessee Valley of Alabama into the southern Appalachians bringing snowfall amounts ranging from 2-8 inches across eastern Tennessee. The higher accumulations were concentrated across extreme northeast sections of the state.
1/22/2003	Winter Storm	A strong upper level disturbance moved southeast from the northern plains and Midwest states across eastern Tennessee producing significant snowfall amounts. Snowfall amounts ranged from 2-5 inches in the lower elevations while higher elevations across the region picked up totals ranging from 5-8 inches.
2/9/2003	Heavy Snow	Three to six inches of snow was reported across most of the Cumberland Plateau, with up to 4 inches of snow reported across portions of the far eastern Tennessee mountains.
1/9/2004	Winter Storm	The storm produced snowfall amounts ranging from 1-4 inches. Most of East Tennessee averaged 2-3 inches of snow.
2/26/2004	Heavy Snow	3-6 inches of snow.
1/29/2005	Ice Storm	A mixture of freezing rain and sleet across the lower elevations and a mixture of sleet and snow across the higher terrain. Much of the region ended up with ice accumulation around one quarter inch with some locations measuring as much as one half inch of ice. Trees and power lines were downed across parts of the region due to ice accumulation.

which some believe caused his mental instability. This incident led a movement toward the creation of modern SWAT teams.

- Oak Ridge, Tennessee—On November 12, 1972 three men hijacked a Southern Airlines plane and demanded \$10 million. They threatened to crash the plane into one of the nuclear facilities in Oak Ridge if their demands weren't met. They ended up departing to Cuba after being promised \$2 million. In Cuba they were arrested and convicted of their crime. No one was hurt and no damage was done from this event (Beavers 7 Aug 2007).
- University of North Carolina, Chapel Hill—On January 26, 1995 a schizophrenic law student killed two and injured two others with a rifle.
- Columbine High School—On April 20, 1999 two students went on a shooting rampage in Colorado, killing 13 people and wounding 24 others before both committing suicide. They used various shotguns, handguns, rifles, and bombs during their massacre. The cause of the rampage is thought to be due to many things including feelings of isolation, being outcasts and bullied, depression, and previous violent natures.
- University of Arizona—On October 28, 2002 a 41-year-old nursing student who was failing the nursing program shot and killed three nursing professors before committing suicide.
- West Nickel Mines Amish School—On October 2, 2006 a 32-year old milk-tank truck driver went on a shooting rampage in this one-room school house. He injured 5 girls and killed 5 more girls between the ages of 7 and 13 and then committed suicide. He was thought to have had mental problems and have been a sexual deviant.
- Virginia Tech University—On April 16, 2007 23-year-old South Korean immigrant and Virginia Tech student Seung-Hui Cho killed 32 people and wounded 25 others before committing suicide while on a shooting massacre. This was the deadliest shooting in modern U.S. history. It is unclear as to why Cho went on his killing rampage, but some speculate his tendency to be a loner, his hatred of the wealthy, and his past occurrences of mental illness (he had undergone psychiatric treatment previously) contributed to his decision to go on a killing rampage.

School shootings that have occurred in Tennessee are as follows:

- Richland High School—On November 15, 1995 in Lynnville a 17-year-old male student went on a shooting rampage which resulted in 2 dead and 1 injured.
- Campbell County Comprehensive High School—In Jacksboro on November 8, 2005 a 15-year-old student killed 1 and injured 2 others ("List of School-Related Attacks," 2007).

No past occurrences of terrorism exist for the University of Tennessee, Knoxville.

Likelihood of Future Occurrences: Unlikely

TORNADO

Since tornadoes are most prevalent in the Midwest, Southeast (region containing UTK), and Southwest United States, as stated in the FEMA *State and Local Mitigation Planning how-to guide: Understanding Your Risks*, tornadoes were considered as an event to explore more.

The design wind speed for Knoxville was found using FEMA's Design Wind Speed Map for Community Shelters, which is based on design wind speeds created by the American Society of Civil Engineers (ASCE). This wind speed map is shown in Figure 17. On this map, Knoxville is symbolized by the dot. It can be seen from this map that Knoxville is located within Zone III, meaning that community shelters should be designed for 200 mph winds.

Also, shown in Figure 18 is a map of tornado activity and frequency in the United States. Knoxville is located within the region of 1 to 5 tornadoes per 1,000 square miles, which is on the lower end of the frequency spectrum. Knoxville is not located within the boundaries of "Tornado Alley," which is an area in the United States that gets proportionately more tornadoes than anywhere else besides Florida. Tornadoes within "Tornado Alley" can reach Category F3 and above on the Fujita Tornado Measurement Scale, which are considered to be strong to violent tornadoes. The ridges and valleys characteristic of East Tennessee minimize the risk from tornadoes in Knoxville. Since Knoxville is not located within "Tornado Alley," its tornadoes can generally be assumed to be anywhere from Category F0 to F2 on the Fujita Scale (shown in Table 16). In the United States, 80% of all tornadoes are Category F0 or F1, so the likelihood of a higher intensity tornado occurring in Knoxville is not high. Category F0 to F2 tornadoes range from causing light damage to considerable damage ("Tornado," 2007).

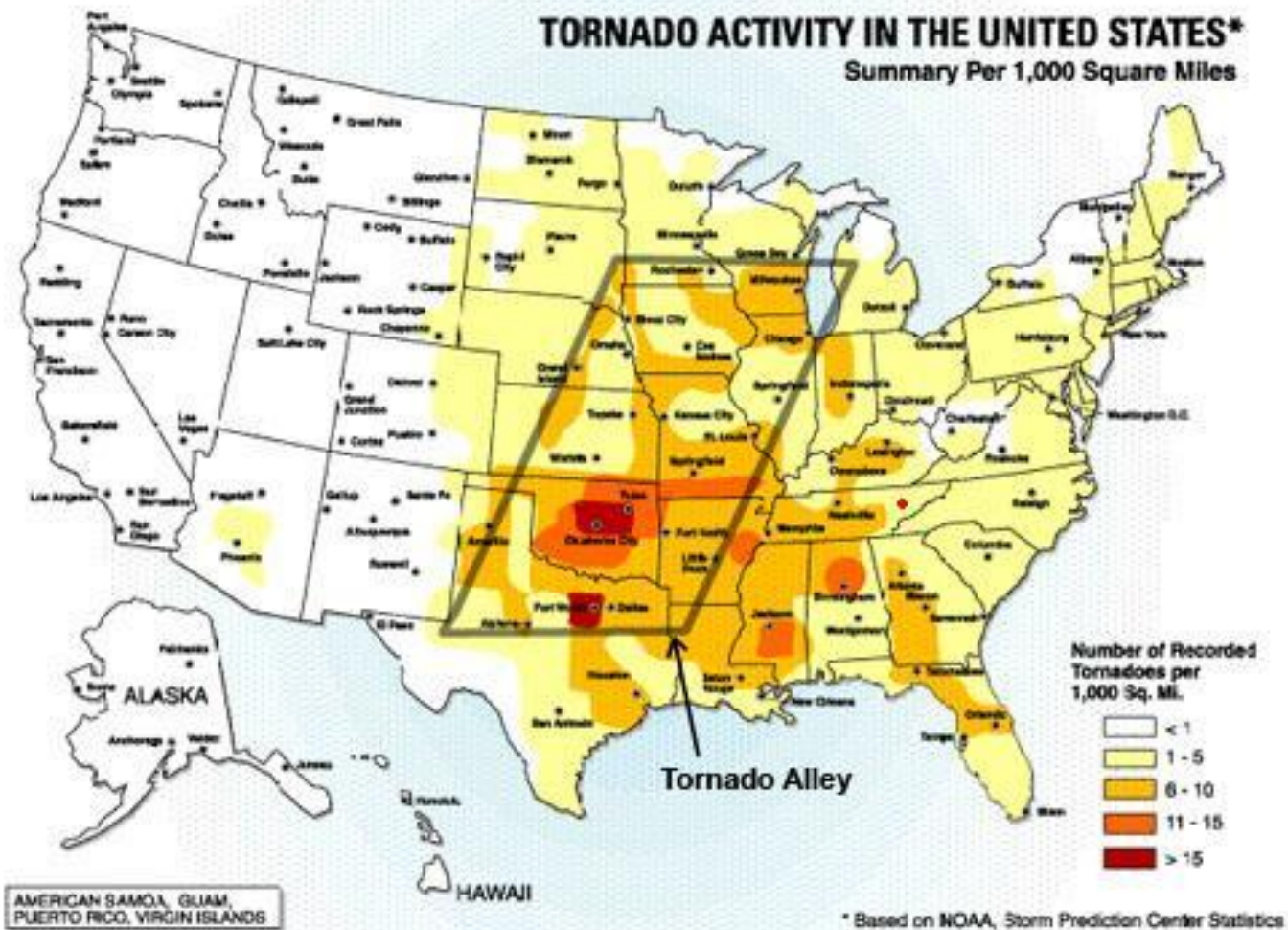
It should be noted that while the Fujita Scale is used for tornado measurement in this report, the Enhanced Fujita Scale (EF-Scale) has currently been adopted in order to improve tornado measurements and provide a more consistent measurement of tornado damage. This scale was only recently adopted; therefore, all measurements previously made and included in this report were done using the Fujita Scale and were kept that way for practicality and accuracy purposes. The EF-Scale and its relation to the Fujita Scale can be seen in the appendix.

Past Occurrences

A list of all tornadoes occurrences in Knox County (the county where Knoxville and the UTK campus are located) occurring for the years 1950 to 1995 can be found in Table 17. As seen from this table, only seven tornadoes occurred in Knox County for that 45 year interval, which is not a significant amount. Of these tornadoes, most caused only light to moderate damage, and hardly any fatalities occurred (Tornado Project Online, 2007 and National Climatic Data Center, 3 Aug 2007).



Figure 17: Design Wind Speed Map
(Source: Federal Emergency Management Agency)



The number of tornadoes recorded per 1,000 square miles

Figure 18: Tornado Activity in the United States
(Source: National Oceanic and Atmospheric Administration)

Table 17: Fujita Tornado Measurement Scale

Tornado Category	Maximum Wind Speeds	Typical Effects
F0	40-72 mph (35-62 kt)	Gale Tornado. Light Damage: Some damage to chimneys; breaks twigs and branches off trees; pushes over shallow-rooted trees; damages signboards; some windows broken; hurricane wind speed begins at 73 mph.
F1	73-112 mph (63-97 kt)	Moderate Tornado. Moderate damage: Peels surfaces off roofs; mobile homes pushed off foundations or overturned; outbuildings demolished; moving autos pushed off the roads; trees snapped or broken.
F2	113-157 mph (98-136 kt)	Significant Tornado. Considerable damage: Roofs torn off frame houses; mobile homes demolished; frame houses with weak foundations lifted and moved; boxcars pushed over; large trees snapped or uprooted; light-object missiles generated.
F3	158-206 mph (137-179 kt)	Severe Tornado. Severe damage: Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forests uprooted; heavy cars lifted off the ground and thrown; weak pavement blown off roads.
F4	207-260 mph (180-226 kt)	Devastating Tornado. Devastating damage: Well constructed homes leveled; structures with weak foundations blown off some distance; cars thrown and disintegrated; large missiles generated; trees in forest uprooted and carried some distance away.
F5	261-318 mph (227-276 kt)	Incredible Tornado. Incredible damage: Strong frame houses lifted off foundations and carried considerable distance to disintegrate; automobile-sized missiles fly through the air in excess of 300 ft (100 m); trees debarked; incredible phenomena will occur.
F6-F12	Gtr than 319 mph (277 kt)	The maximum wind speeds of tornadoes are not expected to reach the F6 wind speeds.

Table 18: Knox County Tornado Occurrences

Date	Time	# Dead	# Injured	Fujita Scale	Damage
April 15, 1965	5:30 pm	0	6	F2	\$2.5 million; concrete block house and church destroyed; metal roofing blown off.
April 3, 1974	11:30 pm	2	21	F1	\$25,000; mobile homes destroyed
May 27, 1981	6:40 pm	0	0	F0	\$25,000
February 21, 1993	4:05 pm	0	3	F3	\$5 million; 50 houses and 10 businesses damaged; 6 mobile homes and 2 businesses destroyed
June 30, 1993	6:00 pm	0	1	F0	---
June 30, 1993	6:45 pm	0	0	F0	---
May 18, 1995	8:00 pm	0	0	F1	Parts of houses blown off; at least a dozen homes damaged; many trees and power lines down
May 23, 2000	4:05 pm	0	1	F1	Mobile home was ripped off its foundation. Winds estimated to be 75-80 mph
May 15, 2003	4:10 pm	0	0	F1	\$150,000; Many power lines and about 100 trees down; parts of a country club damaged
May 15, 2003	4:15 pm	0	0	F1	\$200,000; Many power lines and traffic signals down; several buildings including 6 condos damaged

The entire state of Tennessee has an average of five tornadoes per year; however, the likelihood of a tornado occurring exactly inside the area of the UTK campus is a 1×10^{-4} % chance or once every 10,000 years (Beavers, 12 June 2007).

Likelihood of Future Occurrences: Unlikely

TOXIC CHEMICAL RELEASE

Toxic chemical release is an event of concern due to the various quantities of chemicals stored in the many research and engineering buildings throughout campus, as well as the existence of several railroads located on the perimeter of campus used to haul chemicals and dangerous substances.

The chemicals stored in the buildings throughout campus mostly consist of flammable liquids and gases. This type of chemical is the most hazardous because it consists of the largest volume of chemicals stored in the buildings. The second most hazardous type of chemicals stored in the buildings are corrosives, which are chemicals with very high or very low pHs (strong acids or bases). The third most hazardous type is toxics, which are any chemicals that could be harmful to the human body if they were to come into contact. These types of contact might be inhalation (causing lung irritation or neurological disorders), dermal contact (causing skin or eye irritations) or ingestion (causing liver failure or other internal organ dysfunctions). The least hazardous type of chemicals on campus include reactives, which are explosive or react in some other negative way when exposed to certain things, such as water or air. Some reactives on campus consist of radionuclides and biohazards, but relatively low levels of these substances are present on campus.

Chemical spills are usually categorized by three severities and taken care of differently according to the circumstances. Small spills are usually contained and the lab workers clean up the spill on their own. These types of spills are not reported. Larger spills are reported to the Office of Environmental Health & Safety and are handled by their personnel. The largest types of spills are reported to and handled by the local Hazardous-Materials squad.

As far as chemicals in transport are concerned, most of the chemicals coming through Knoxville are hauled by railroad instead of truck because railroads are much safer than vehicles. Railroad cars are less likely to experience collisions (due to built in signals for that purpose) and are traveling at much lower speeds (usually a maximum of 40 mph through campus, but generally closer to 10 or 15 mph) than a vehicle on the interstate. Also, many precautions are taken to safely package dangerous materials for transport in the event that a railcar is accidentally derailed, so even if a train were to derail the contents would not likely be punctured. However, the quantities hauled on railroads are quite large and would be very dangerous if a mishap were to occur. Chemicals hauled on the railroads are widely varying, but the ones hauled in close proximity to the UTK campus are inhalation hazards, explosive hazards, and other freight.

The toxic inhalation hazards are generally spilled liquid chemicals. Most of the liquid chemicals hauled around Knoxville are chlorine and a little sulfuric acid. Chlorine is very dangerous to humans. If any of chlorine was to be released and wind conditions were just right, the campus would probably have to be evacuated because exposure to this toxic inhalation hazards can be fatal, and university officials would most likely not want to take any chances. If sulfuric acid was spilled, it could also form toxic vapors, but the effects would not be as bad as those of chlorine. The Knoxville and Holston River Railroad runs from North Knoxville around the UTK campus and out to Forks of the River. This railroad mostly picks up and delivers railcars to local rail customers, and operates only a couple of trains a day. It also serves KUB's wastewater treatment plant and travels along Neyland Drive to do so, as well as a wastewater treatment plant east of the South Knoxville Bridge. The Knoxville and Holston River Railroad may or may not carry chlorine to and from these plants at any given time. This railroad also serves Holston Gases in South Knoxville, which also receives hazardous materials. The Norfolk Southern Railroad to the north of campus also hauls chlorine to a paper plant in Bowater, but chlorine does not comprise the majority of the chemicals hauled on this railroad. Other inhalation hazards of concern that may be hauled on these trains include hydrogen fluoride, anhydrous ammonia, sulfur dioxide, and ethylene oxide. These chemicals are a small fraction of the hazardous materials traffic in Knoxville, but they are dangerous in the event of an accident.

Far more commonly hauled on Knoxville railroads are explosive hazards rather than inhalation hazards. Explosive hazards are generally solid chemicals. The Norfolk Southern railroad, which runs along the north side of campus, has a very large amount of chemical traffic because it serves Kingsport, which is where the Eastman chemical plant is located, as well as Chattanooga, which is where a Dupont chemical plant is located. It generally has 14 to 16 freight trains a day that could carry hazardous materials. One specific solid chemical of concern hauled on this rail is ammonium nitrate. This chemical is a huge explosive if ignited and is generally used to make bombs. If a railcar full of ammonium nitrate was to explode, buildings within a half a mile (which includes campus) would be damaged, the very least being broken windows. However, this act would have to be deliberate, which has an even lower likelihood of occurrence than an accident. The CSX railroad, which runs between the main and Agricultural campuses, handles 18 to 22 trains per day, 8 to 10 of which could carry hazardous flammable and explosive materials. The most common of these explosives are ethanol, propane, and ammonium nitrate, and are also hauled on the Norfolk Southern Railroad.

Other freight hauled on the railroads around campus consists of generally non-hazardous materials, such as asphalt, coal, metal scraps and grain.

Past Occurrences

Not many major chemical spills originating in the campus buildings have ever occurred. An average of one or two minor chemical spills a month occur, minor meaning the spill is small and well-contained. The usual cause of chemical releases is accidental lab fires. Also, the usual result of a chemical spill is a lab fire, since most of the chemicals on

campus are flammable liquids and gases. Most of these chemical spills (occurring once or twice a month) are small and do not cause any personal injuries. However, a few past occurrences of chemical spills in campus buildings have been noteworthy. Some of the more recent spills are as follows:

- Dougherty Engineering Building-A fuel line failed, which spread gasoline throughout a lab, creating a large fire. This in itself was a chemical spill, but also thousands of gallons of water were dumped on the building (which has the third largest supply of chemicals on campus). Dumping all of this water in the building inevitably caused some chemicals to spill. No injuries were reported, but evacuations of the building for days were necessary, and property damage was caused.
- A researcher blew away part of his hand about 10 years ago with an accidental chemical reaction.
- Walters Life Sciences Building-A student spilled alcohol, which ignited near a Bunsen burner. The student sustained minor burns to the hands.
- Dabney-Buehler Hall-3-5 years ago the building was evacuated.

All past toxic chemical releases in buildings have been accidental and were caused by students and researchers being clumsy or neglectful, such as knocking things over or discarding of chemicals in trash cans, down drains, and not following safety guidelines. Almost no injuries have occurred from the majority of the spills due to the fact that most of the chemicals on campus are stored in small containers so spills won't be as disastrous if they were to happen.

In the future it is expected that the current trend of one to two minor spills a month along with a 50% chance of a major spill occurring in 5 years will continue to be the case, unless an unexpected event, such as an earthquake, was to occur. Not enough chemicals are present in any of the buildings to possibly cause a need for evacuation of the dormitories. The only area that might have to be evacuated in the event of intentional chemical release would be "The Hill," which is an area of campus classrooms, labs, and offices located next to the majority of chemical locations.

Railroad spills are even rarer on and around the campus. The only time a major railroad spill has occurred in Knoxville was on September 16, 2002 in Farragut. A 141-car train derailed causing 10,600 gallons of oleum, a type of sulfuric acid, to spew into the air. About 3,000 people were forced to be evacuated from their homes for two days, and an area of contaminated soil measuring 6 feet deep by 25 feet wide was dug up and disposed of. The only damages were some skin and eye irritations to people.

No events of toxic chemical release from railroad cars have ever occurred on campus in the past.

The railroad system is difficult to secure due to the number of people available to guard and check railroad cars. People are currently on duty to keep an eye on idle railroad cars

to keep people from tampering with them and releasing chemicals, but there aren't enough personnel to spend their time guarding railroad cars when an event of sabotage has a low likelihood of occurrence. They mostly spend their time concentrating on theft because that is what most often happens to sitting railroad cars. Railroads could be very dangerous if terrorists were to use them, but are less dangerous if an accident were to occur. Currently, precautions are taken to discourage terrorist sabotage during UT football games. This is a tempting target, considering around 110,000 people are located in the concentrated area of the stadium at one time, and a railroad runs directly next to it. Rail traffic is discouraged from moving during any of these football games. Railroads have a higher likelihood of experiencing an unintentional accident rather than terrorist activity, but both of these events have quite an unlikelihood of occurrence (Clarke, 2007).

Likelihood of Future Occurrences: Occasional

WILDFIRE

A wildfire is a large, rapidly spreading fire that is difficult to extinguish. It destroys the vegetation that fuels it and exposes and possibly destroys structures as well. FEMA states that areas most likely to experience wildfires are those that contain large amounts of wooded, brush, and grassy areas. The states most at risk for wildfires due to these factors are California, Colorado, New Mexico, Montana, Kansas, Mississippi, Louisiana, Georgia, Florida, the Carolinas, Tennessee, Massachusetts, and the national forests of the western United States. Since FEMA declared that Tennessee is a state of high risk for wildfires, this hazard event was included in the Multi-Hazard Mitigation DRU Plan for UTK. Predicting whether a wildfire is likely to occur or not is problematic because wildfires depend on several factors—available fuel (vegetation), topography, and weather and wind conditions.

What can be predicted is the general type of vegetation covering the area of interest, and then determining if this is considered heavy, medium, or light fuel for a wildfire. Using the fuel model key from the National Fire Danger Rating (NFDR) System, 1978, U.S. Department of Agriculture (USDA) Forest Service the fuel model type was estimated to be Model F based on the campus consisting of predominately brush, shrubs, tree reproduction or dwarf tree species, average height of woody plants being 6 feet or greater, and woody plants occupying less than two-thirds of the site. Table 18 shows fuel models based on the fuel model key and type of fuel for each fuel model. The UTK campus has Model F, or medium fuel.

The topography of the campus also plays a role in whether the campus is more encouraging for a wildfire spread. The steeper the slope of land, the faster a fire will usually spread. Slopes and their defined risk are in Table 19.

Table 19: Fuel Models

Fuel Model	Fuel Type	Fuel Description
G, I, J, K, U	Heavy	Vegetation consisting of round wood 3 to 8 inches in diameter
B, D, F, H, O, Q, T	Medium	Vegetation consisting of round wood 1/3 to 3 inches in diameter
A, C, E, L, N, P, R, S	Light	Vegetation consisting of herbaceous plants and round wood less than ¼ inch in diameter

Table 20: Slopes and Corresponding Wildfire Spread Risk

Slope	Wildfire Spread Risk
< 40%	Low
41% - 60%	Moderate
> 61%	High

Most areas on campus have a low slope being less than 40%. As discussed in the “Landslide” section of this report, the campus mainly consists of areas with a low slope. Two primary areas on campus that do have moderate slopes include a natural slope beside the Pasqua Nuclear Engineering Building (45°) and some steep fill soil slopes on the west side of campus near the tennis courts (45°). These areas of steep slope can, again, be seen in the “Landslide Vulnerability” section of this report as circles on the topographic map of the UTK campus in Figure 28.

Using the current weather and fuel (vegetation) conditions, the National Interagency Fire Center provides an up-to-date map of Fire Danger Class. For the date of July 9, 2007, the Wildfire Danger Class for Knoxville is shown by Figure 19 to be low.

Past Occurrences

Small wildfires occur in the Knoxville area at least once a year. Usually at least one fire per year occurs in Sharps Ridge (North Knoxville) and sometimes in South Knoxville, but these do not cause extensive damage like wildfires in western states. However, wildfires have never occurred on the UTK campus. Since the campus has a medium fuel type, mostly low sloping landscapes, and also is about halfway surrounded by a river (which will prevent any surrounding wildfires from that direction to enter the campus) the Knoxville Fire Marshal states that the campus area is considered a low risk area for wildfires (Byrd, 2007).

Likelihood of Future Occurrences: Unlikely

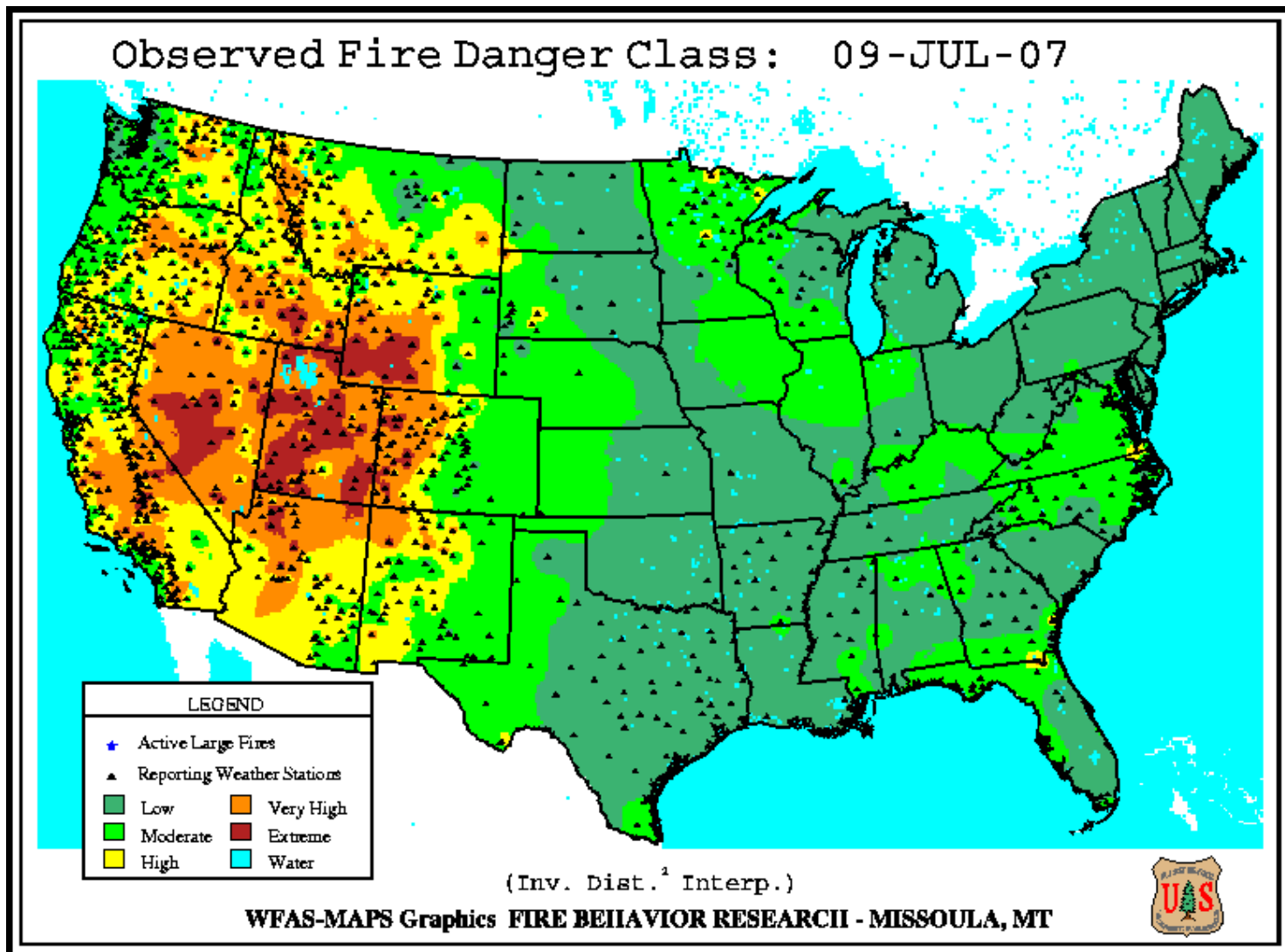


Figure 19: Wildfire Danger Class
 (Source: United States Department of Agriculture Forest Service)

HAZARD PROFILING SUMMARY

A summary of all the events and their estimated likelihood of future occurrences are in Table 20.

Table 21: Estimated Frequency of Likelihood Occurrence of Hazard Events

Event	Likelihood of Occurrence
Severe Storm (Lightning, Heavy Rains)	Highly Likely
Drought	Occasional
Earthquake (M_w of 4-5)	Occasional
Extreme Heat	Occasional
Hurricane	Occasional
Land Subsidence	Occasional
Severe Storm (Hail, High Winds)	Occasional
Severe Winter Storm	Occasional
Toxic Chemical Release	Occasional
Dam Failure	Unlikely
Earthquake (M_w of 5-6)	Unlikely
Expansive Soils	Unlikely
Flood	Unlikely
Landslide	Unlikely
Tornado	Unlikely
Wildfire	Unlikely
Radiation Fallout	Unlikely
Terrorists	Unlikely

4.2 Vulnerability Assessment

An assessment for campus vulnerability due to the various hazards identified in Section 4.1—Hazard Identification was completed in order to determine a hazard’s potential for damage to buildings and life. Vulnerability is defined for this report as how daily life and processes on campus would be impacted if a hazard event were hypothetically to occur. As a summary, these hazards are as follows:

- Dam Failure
- Drought
- Earthquake
- Expansive Soils
- Extreme Heat
- Flood
- Hurricane
- Land Subsidence
- Landslide
- Radiation Fallout
- Severe Storm
 - Hailstorm
 - Heavy Rains
 - Lightning
 - Windstorm
- Severe Winter Storm
- Terrorists
- Tornado
- Toxic Chemical Release
- Wildfire

A scale used in quantifying the possible vulnerabilities of each of these hazard events follows. (The same scale has been used by the University of Colorado, Boulder’s Multi-Hazard Mitigation DRU Plan).

Extremely High: Very widespread and catastrophic impact.

High: Widespread potential impact. This ranking carries a high threat to the general population and/or built environment. The potential for damage is widespread. Hazards in this category may have already occurred in the past.

Medium: Moderate potential impact. This ranking carries a moderate threat level to the general population and/or built environment. Here the potential damage is more isolated and less costly than a more widespread disaster.

Low: Minimal potential impact. The occurrence and potential cost of damage to life and property is minimal.

Extremely Low: The occurrence and potential cost of damage to life and property is very minimal to non-existent.

CAMPUS PROPERTIES AND LIVES AT RISK

Various values to be considered are at risk on the UTK campus. These values were broken down into the following categories:

- **Total Values of Structures Based on Use Type**-Includes structure replacement cost and contents value of various categories of building uses.
- **Critical Facility Values**-Includes structure replacement cost and contents value for those facilities deemed critical to the campus' daily operation.
- **Life Values of Structures Based on Use Type**-Includes quantities of populations at risk in various categories of building uses.

Total Values of Structures Based on Use Type

The various categories of building uses, or use type, were created based on the uses that buildings at UTK are primarily used for. These categories for use type include:

- Administration
- Athletics/Physical Education
- Class/Lab/Office
- Communications
- Dining
- Farm Buildings
- Housing
- Library
- Mechanical
- Medical Care
- Office
- Parking
- Physical Plant
- Student Center

A summary of the different usages of buildings along with how much they are worth is shown in Table 21. The replacement values of the buildings are as estimated by UTK's Space & Facilities Services. The content values are the value of the insurable contents in the buildings. Shown in Figure 20 is a summary of the percent of total values each building type is worth. One can see that Class/Lab/Office facilities comprise almost half the total value for buildings and contents values on campus. This is followed by

Athletics/Physical Education facilities and then Library and Housing facilities at about the same percentage.

Critical Facility Values

Those facilities deemed critical were classified into various categories depending on their reason for criticality. These various reasons for criticality include:

- Emergency Operations
 - Medical Care
 - Police
- Information Storage
 - Student Records
 - Student Services
 - Accounts Payable Offices
 - Payroll Offices
- Communications
 - Landline Communications
 - Radio Station
 - Internet Facilities
 - Mail Services
- Utilities
- Cultural Resources
 - Irreplaceable Collections
- Historic

A more detailed discussion of the critical facilities on campus can be viewed in the following section *Critical, Cultural, & Historical Resources Inventory*. A figure depicting the various critical facilities broken down into Type of Use categories including how much each type is worth is shown in Figure 21. It should be noted that these values are also included in the table for Total Values of Structures Based on Use Type. One can see from this figure that the most monetarily valuable critical structures are Class/Lab/Office facilities and Athletic facilities, accounting for almost 75% of the total value of critical structures on campus and over \$1.2 billion.

Life Values of Structures Based on Use Type

Using the same “Use Type” categories as used previously, the amount of people at risk in each one of these categories was determined using the average occupancy during the peak hour of each building. This information was tabulated both with and without populations from sporting events. This was done because the inclusion of populations during sporting events significantly skews the data to show that a massive amount of people occupy Athletics/Physical Education facilities compared to the other types when this is only true during a sporting event. The data not including populations from sporting events gives more realistic data for every day populations on campus. Data for both of these situations can be seen in Table 22, and corresponding graphs are shown in Figures

Table 22: Total Values of Structures Based on Use Type

Type of Building	# on Campus	% on Campus	Replacement Value	Contents Value	Total Building Value	% of Total Value
Administration	2	0.9	\$8,385,980.00	\$334,288.00	\$8,720,268.00	0.3
Athletics/Physical Education	29	13.7	\$519,060,055.00	\$19,805,596.00	\$538,865,651.00	18.3
Class/Lab/Office	65	30.7	\$949,499,731.00	\$273,623,500.33	\$1,223,123,231.33	41.5
Communications	5	2.4	\$76,577,819.00	\$36,193,057.00	\$112,770,876.00	3.8
Dining	2	0.9	\$23,530,333.33	\$1,674,551.67	\$25,204,885.00	0.9
Farm Buildings	20	9.4	\$7,147,332.00	\$1,122,330.00	\$8,269,662.00	0.3
Housing	31	14.6	\$277,248,606.00	\$10,291,838.00	\$287,540,444.00	9.8
Library	3	1.4	\$125,505,500.67	\$211,431,455.00	\$336,936,955.67	11.4
Mechanical	4	1.9	\$801,900.00	\$5,500,000.00	\$6,301,900.00	0.2
Medical Care	1	0.5	\$1,912,500.00	\$543,099.00	\$2,455,599.00	0.1
Office	21	9.9	\$89,285,030.00	\$27,351,112.00	\$116,636,142.00	4.0
Parking	10	4.7	\$95,545,799.50	\$1,496,000.00	\$97,041,799.50	3.3
Physical Plant	9	4.2	\$100,922,800.00	\$12,621,870.00	\$113,544,670.00	3.9
Student Center	10	4.7	\$63,075,900.00	\$4,655,163.00	\$67,731,063.00	2.3
Totals	212	100.0	\$2,338,499,286.50	\$606,643,860.00	\$2,945,143,146.50	100.0

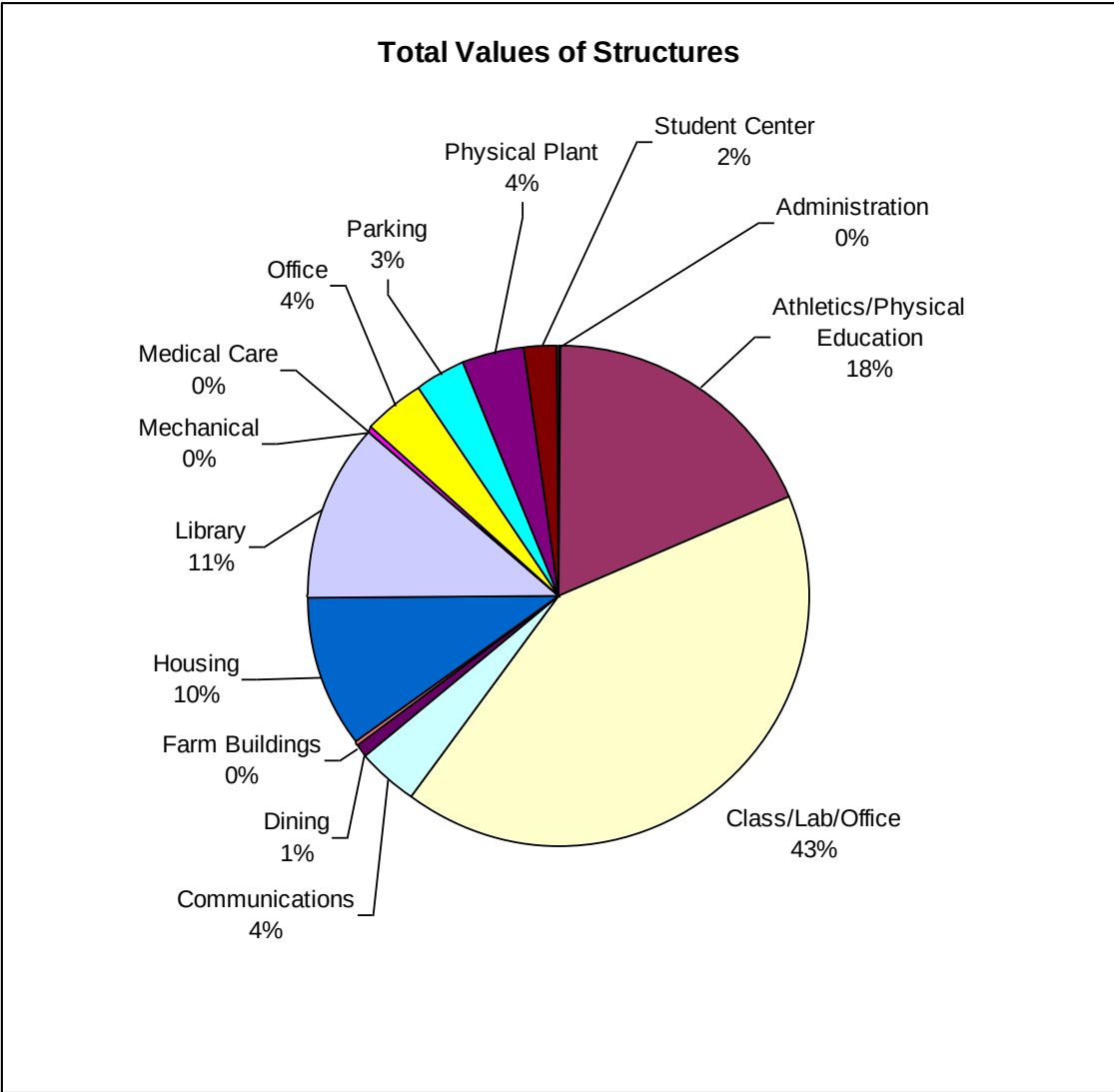


Figure 20: Total Value of Structures

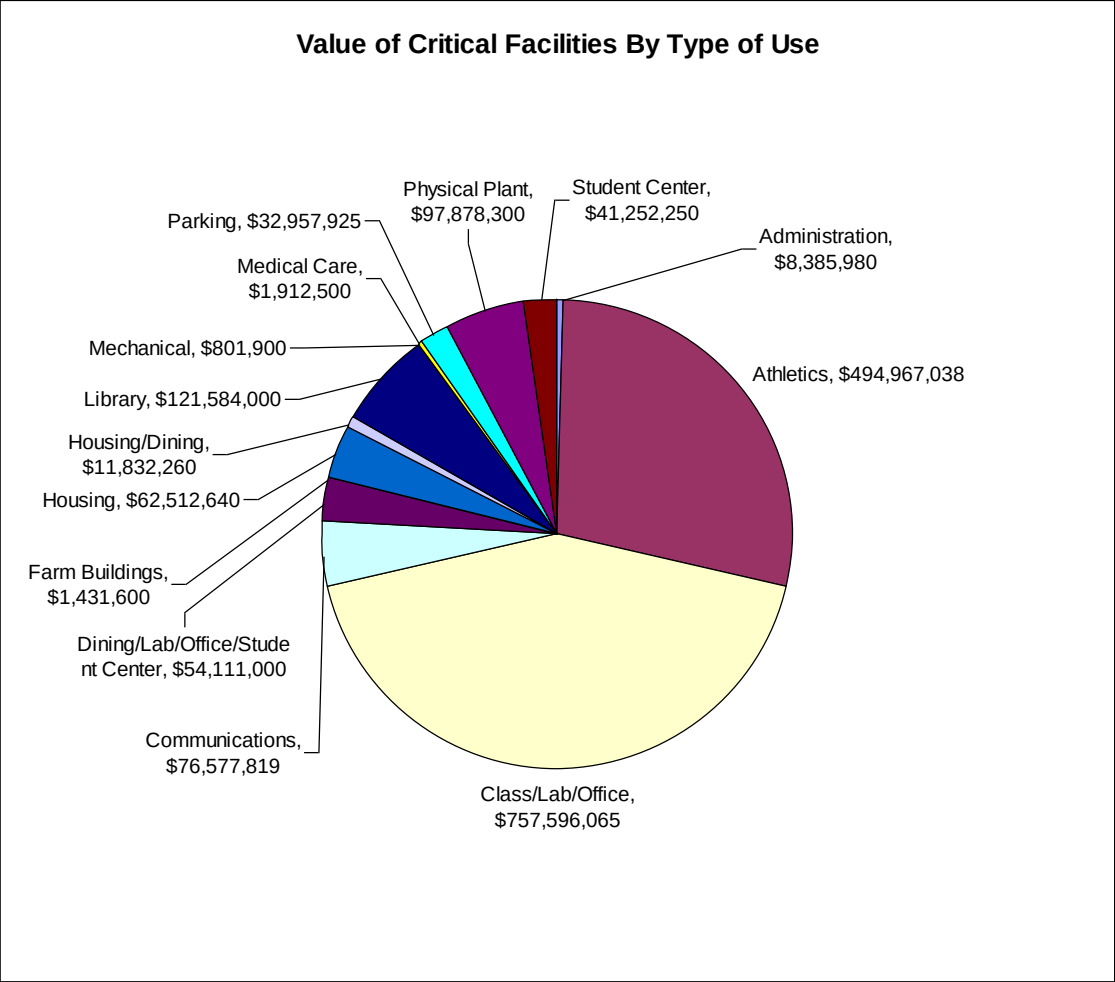


Figure 21: Critical Facility Values By Type of Use

22 and 23. As shown in these graphs, during a sporting event, particularly a football game when Neyland Stadium is occupied, Athletics/Physical Education facilities comprise the vast majority of populations at UTK. If sporting events are not considered, a more realistic breakdown of occupancies shows that Class/Lab/Office facilities, followed by Housing and then Athletics/Physical Education comprise the top three building types for occupancies, which is almost the same as the top three highest total values of building types.

CRITICAL, CULTURAL, & HISTORICAL RESOURCES INVENTORY

In order to better assess the approximate vulnerability for various hazard events, it is helpful to know which buildings are considered the most important (meaning being critical, cultural, or historical resources) and where these buildings are located in order to determine if they would be affected by any of the hazard events, thus making the vulnerability of the event higher. A list of these buildings considered critical, culturally important, or historically important is shown as follows along with the reason for being critical:

- | | |
|--|---|
| • 11th Street Parking Garage (Emergency Operations) | • Carriage House (Historic) |
| • 907/909 21st St Duplex (Historic) | • Ceramics Annex (Historic) |
| • 908 21st Street (Historic) | • Child Development Center (Historic) |
| • Administration Parking Garage (Information Storage and Communications) | • Claxton Education Building (Historic) |
| • Alpha Tau Omega Fraternity House (Historic) | • Communications and University Extension Building (Communications) |
| • Andy Holt Tower (Information Storage, Communications, and Historic) | • Conference Center Building (Information Storage and Historic) |
| • Animal Science Laboratory (Historic) | • Crops Genetic Laboratory (Historic) |
| • Art and Architecture Building (Historic) | • Dabney-Buehler Hall (Historic) |
| • Austin Peay Building (Historic) | • Dougherty Engineering Building (Historic) |
| • Auxiliary Services Building (Communications and Historic) | • Dunford Hall (Historic) |
| • Ayres Hall (Historic) | • Earth and Planetary Sciences Building (Historic) |
| • Berry Hall (Historic) | • English Language Institute-2019 Terrace (Historic) |
| • Brehm Animal Sciences Building (Historic) | • English Language Institute-907 Mountcastle (Historic) |
| • Carolyn Brown University Center (Information Storage and Historic) | • Environment and Landscape Laboratory (Historic) |
| | • Environmental Health and Safety-2111 Terrace (Historic) |

Table 23: Life Values of Structures Based on Use Type

	Including Populations at Sporting Events		Not Including Populations at Sporting Events	
Type of Building	Occupancy During Peak Hours	% of Total Occupancy	Occupancy During Peak Hours	% of Total Occupancy
Administration	56	0	6	0
Athletics/Physical Education	144,910	85	3,509	12
Class/Lab/Office	10,810	6	10,810	38
Communications	2,682	2	2,682	9
Dining	2,400	1	2,400	8
Farm Buildings	5	0	5	0
Housing	6,238	4	6,238	22
Library	387	0	387	1
Mechanical	3	0	3	0
Medical Care	42	0	42	0
Office	788	0	788	3
Parking	53	0	53	0
Physical Plant	390	0	390	1
Student Center	1,328	1	1,328	5
Totals	170,092	100.0	28,641	100.0

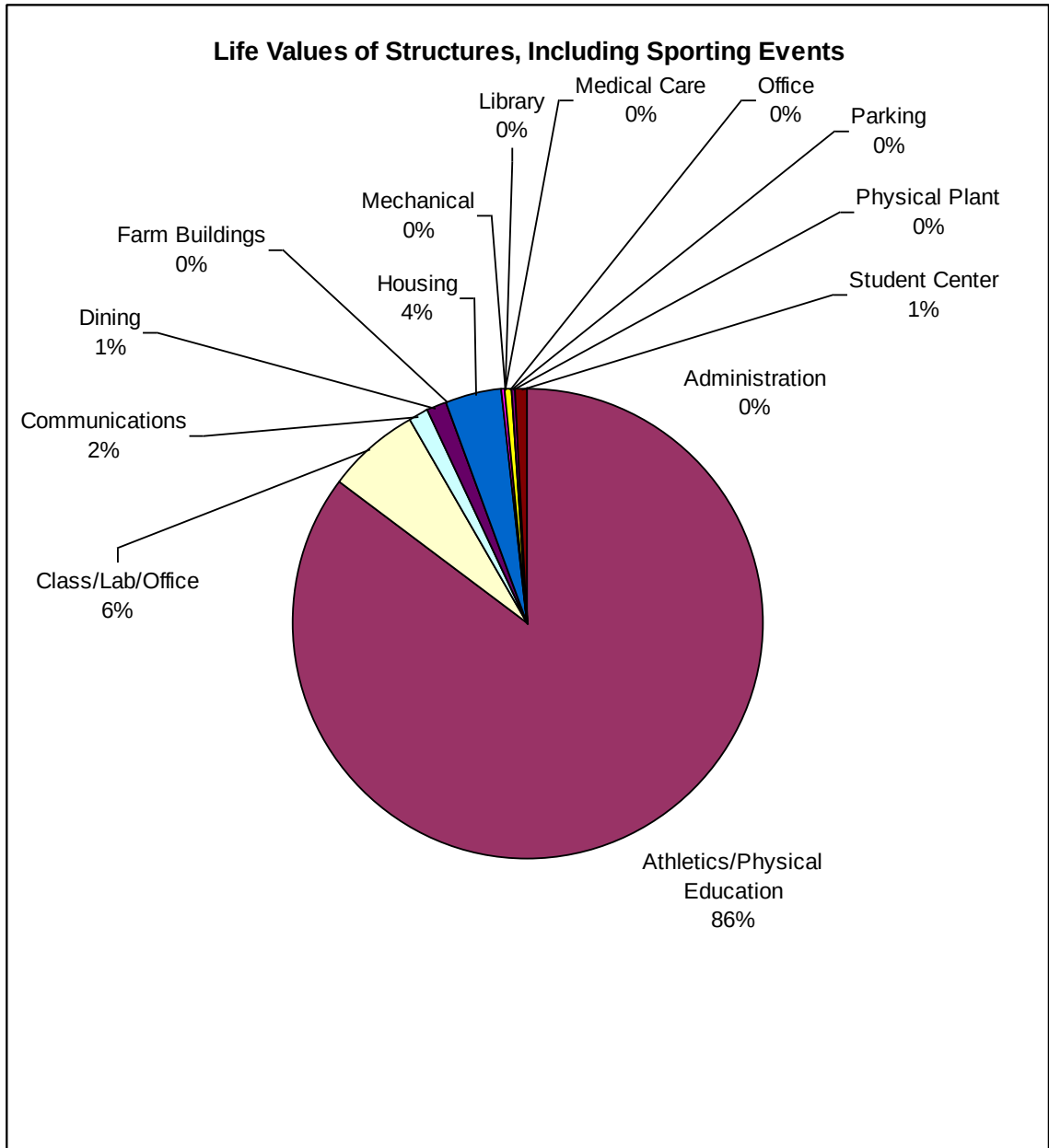


Figure 22: Life Values of Structures, Including Sporting Events

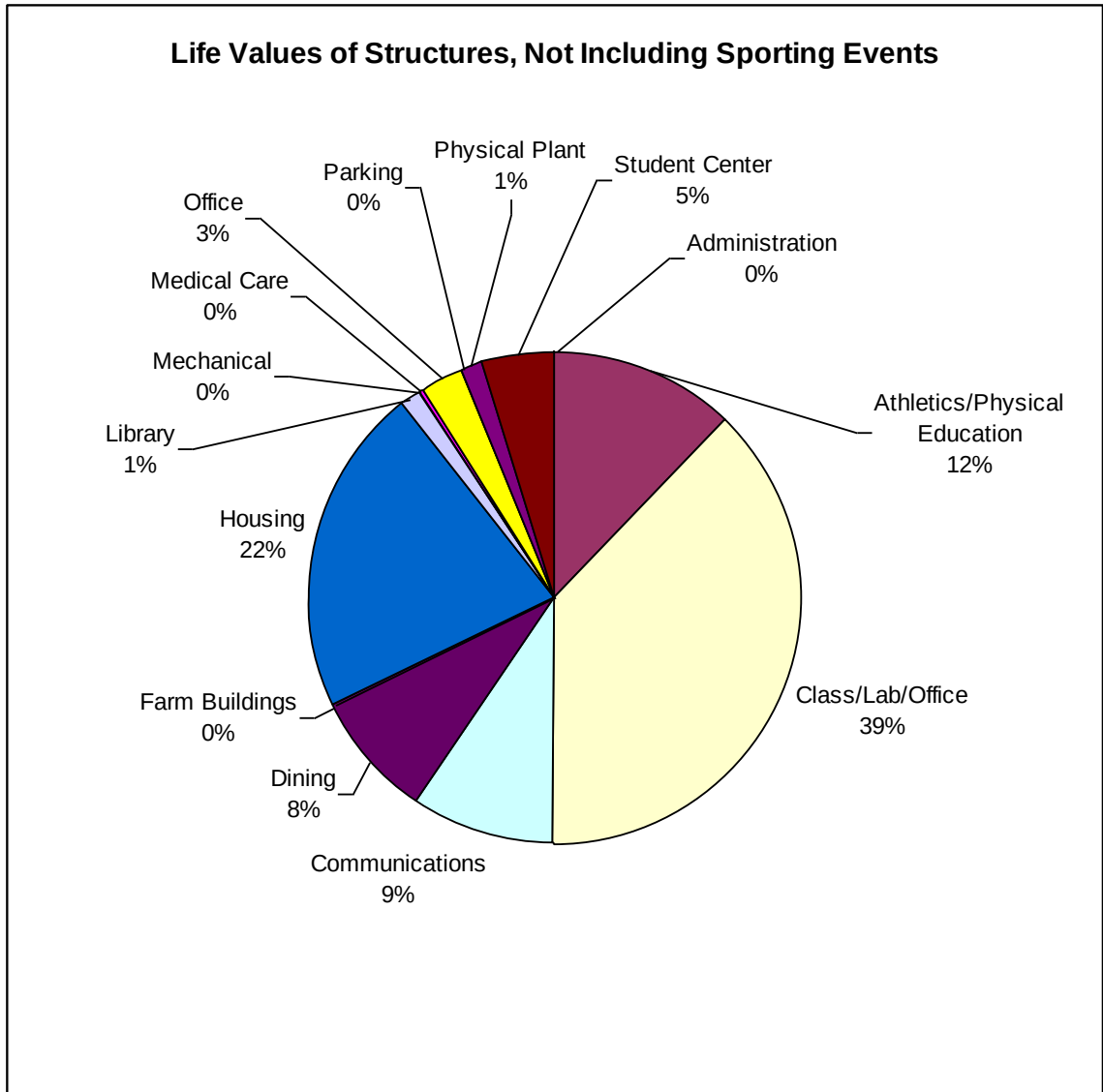


Figure 23: Life Values of Structures, Not Including Sporting Events

- Environmental Health and Safety- 22nd Street (Historic)
- Estabrook Hall (Historic)
- Facilities Services and Operations Building (Utilities and Historic)
- Facilities Services Maintenance Shops and Warehouse (Utilities)
- Facilities Services Utilities Maintenance Building (Utilities)
- Ferris Hall (Historic)
- Fiber Optics (Communications)
- Food Safety and Processing Building (Historic)
- Forestry Fertilizer Storage Building (Historic)
- Glocker Business Administration (Historic)
- Greenhouse TVA (Historic)
- Greve Hall (Historic)
- Henson Hall (Historic)
- Hesler Biology Building and Greenhouse (Historic)
- Hess Hall (Historic)
- Hopecote (Historic)
- Hoskins Library Chiller Building (Utilities)
- Humanities and Social Sciences Building (Communications)
- Humanities and Social Sciences Parking Garage (Communications)
- Interior Design Resource Center (Historic)
- James D Hoskins Library (Cultural Resources and Historic)
- Jessie Harris Building (Historic)
- John C Hodges Library (Cultural Resources)
- Knoxville W.A.V.E. (Historic)
- Law Complex: George C Taylor Wing (Historic)
- Law Complex: Law Library and Classroom Addition (Cultural Resources)
- Massey Hall (Historic)
- McClung Museum (Cultural Resources and Historic)
- McClung Tower and Plaza (Communications)
- McCord Hall (Historic)
- Mcleod Food Sciences Building (Historic)
- Melrose Hall (Historic)
- Metron Building (Communications)
- Morgan Hall (Historic)
- Music Building (Cultural Resources)
- Music Chiller Building (Utilities)
- Music Department Annex (Historic)
- Neyland Stadium (Historic)
- Nielsen Physics Building (Historic)
- Office of Equity and Diversity (Historic)
- Panhellenic Building (Historic)
- Parking and Transit Services (Information Storage)
- Pasqua Nuclear Engineering Building (Historic)
- Pediatric Language Clinic (Historic)
- Perkins Hall (Historic)
- Plant Sciences Biotechnology Building (Historic)
- Radiological Safety (Historic)
- Reese Hall Chiller (Utilities)
- Sophronia Strong Hall and Cafeteria (Historic)
- South College (Historic)
- Steam Plant and Addition (Utilities)
- Steam Plant Gear Switching Building (Utilities)
- Steam Plant Turbine Building (Utilities)
- Stokely Athletics Center (Historic)
- Stokely Management Center (Communications)
- Student Counseling Services (Historic)
- Student Health Clinic (Emergency Operations)

- Student Services Building (Information Storage)
- Student Success Center (Historic)
- Temple Court (Historic)
- Thornton Athletics Student Life Center (Cultural Resources)
- Tyson Alumni Center (Historic)
- ULA Love Doughty Carousel Theatre (Historic)
- Visitors' Center (Historic)
- White Avenue Building (Information Storage)

Critical, culturally important, and historically important buildings comprise 48% by number of total buildings, 72% by monetary value of total buildings, 72% of total building occupancy taking sporting events into account, and 67% of total building occupancy not taking sporting events into account. From these numbers it can be seen that critical buildings comprise almost half of the total number of buildings on campus and over two-thirds of the monetary and life values of all the structures.

VULNERABILITY OF UTK FROM SPECIFIC HAZARDS

Vulnerability of the campus was estimated for some events based on known information and more precisely quantified for other events where more information was known. Some of the events that were more precisely quantified, for example, were dam failure for which resulting flood maps were available, as well as flooding for which FIRMs were available. In order to quantify vulnerability of various hazards, different types of information were taken into account. The different types of information included in quantifying vulnerability include:

- Number of buildings damaged
- Types of buildings damaged
- Monetary damage value (building and contents values)
- Critical resources damaged
- Cultural or historic resources damaged
- Estimated life loss

Putting an estimated figure on the extent of damages included above, if a hazard event were to occur, is an event's vulnerability or impact. An assessment of each hazard's vulnerability to the UTK campus is included in the following sections.

DAM FAILURE VULNERABILITY

As discussed in the Dam Failure component of Section 4.1—Hazard Identification, two failure scenarios exist for a dam failure event. A dam failure will create a flood in either Zone A or Zone B with Zone A reaching to farther extents than Zone B and Zone A encompassing all of the buildings in Zone B along with more buildings. The buildings that are encompassed by Zone B are listed as follows:

- Animal Science Laboratory
- Brehm Animal Sciences Building
- Ceramics Annex
- Engineering Annex

- Equine Animal Building
- Estabrook Hall
- Forest Genetics Greenhouse (17)
- Forestry Fertilizer Storage Building
- Fulton Bottoms and Storage Shed
- Greenhouse #10
- Greenhouse #11, 12, 13
- Greenhouse #14 (Plastic)
- Greenhouse #15 (Hydroponic)
- Greenhouse #16 (Plastic)
- Greenhouse #8
- Greenhouse #9
- Growth Chamber Laboratory
- Neyland Drive Biology Annex
- Pasqua Nuclear Engineering Building
- Plant Propagation Building
- Plant Sciences Annex A
- Plant Sciences Annex B
- Plant Sciences Laboratory
- Publications and Services Building
- Shade House
- Storage Building
- Tyson Field and Storage Shed
- Tyson Park-Women's Softball Dugout #1
- Tyson Park-Women's Softball Dugout #2
- Tyson Park-Women's Softball Pressbox
- Tyson Park-Women's Softball Ticket Booth
- Veterinary Teaching Hospital

A summary including the monetary and life values of the buildings encompassed by Dam Failure Zone B broken down according to Type of Use is shown in Table 23. As shown, Zone B dam failure affects 14.5% of all of the structures on campus, the majority of which are sparsely populated and non-monetarily valuable farm buildings. Also, Zone B dam failure affects 6 historically critical structures (out of a total of 102 critical facilities) and no buildings containing hazardous materials.

Zone A comprises of those buildings previously described in Zone B as well as the following buildings:

- 2111 Stephenson Dr - Warehousing Offices
- 907/909 21st St Duplex
- Alumni Memorial Building
- Auxiliary Services Building
- Berry Hall
- Biosystems Eng. And Environmental Sci Lab
- Biosystems Eng. And Environmental Sci Office Bld
- Boathouse
- Butler Building
- Construction Industry Research and Policy Center
- Crops Genetic Laboratory
- Dougherty Engineering Building
- Ellington Plant Sciences Building
- English Language Institute-907 Mountcastle
- Environment and Landscape Laboratory

Table 24: Dam Failure Zone B Assets & Populations at Risk

Type of Use	% of Total in Hazard Area			
	# of Buildings	Monetary Value of Buildings	Population Including Sporting Events	Population Not Including Sporting Events

Type of Use	% of Total in Hazard Area			
	# of Buildings	Monetary Value of Buildings	Population Including Sporting Events	Population Not Including Sporting Events
Administration	0.0%	0.0%	0.0%	0.0%
Athletics/Physical Education	2.7%	0.02%	0.08%	0.54%
Class/Lab/Office	4.1%	3.4%	0.4%	3.0%
Communications	0.0%	0.0%	0.0%	0.0%
Dining	0.0%	0.0%	0.0%	0.0%
Farm Buildings	6.8%	0.2%	0.002%	0.015%
Housing	0.0%	0.0%	0.0%	0.0%
Library	0.0%	0.0%	0.0%	0.0%
Mechanical	0.0%	0.0%	0.0%	0.0%
Medical Care	0.0%	0.0%	0.0%	0.0%
Office	0.5%	0.05%	0.00%	0.00%
Parking	0.0%	0.0%	0.0%	0.0%
Physical Plant	0.5%	0.04%	0.003%	0.019%
Student Center	0.0%	0.0%	0.0%	0.0%
Total	14.5%	3.7%	0.5%	3.5%

- Environmental Health and Safety-22nd Street
- Ferris Hall
- Food Safety and Processing Building
- Forestry Products
- Greenhouse Quonset (Plastic)
- Greenhouse TVA
- McCord Hall
- Mcleod Food Sciences Building
- Metron Building
- Morgan Hall
- Music Department Annex
- Neyland Stadium
- Office of Research and Information Technology
- Parking and Transit Services
- Perkins Hall
- Plant Sciences Biotechnology Building
- Plot Barn
- Racheff Research Building
- Science and Engineering Building
- Soccer Field Pressbox
- Soccer Field Restrooms
- Soccer Team Building
- Stadium Drive Parking Garage-G10
- Steam Plant and Addition
- Steam Plant Gear Switching Building
- Steam Plant Turbine Building
- Thompson-Boling Assembly Center and Arena
- Visitors' Center

A summary including the monetary and life values of the buildings encompassed by Dam Failure Zone A broken down according to Type of Use is shown in Table 24. As shown, Zone A dam failure affects 37.6% of all of the structures on campus, the majority of which are Class/Lab/Offices, Farm Buildings, and Athletics/Physical Education Facilities. Dam failure in this zone also affects 43.6% of all the monetary value of structures on campus as well as 78.9% of all populations on campus if sporting events are included. This is due to Neyland Stadium being flooded in this event, which comprises most of the population if sporting events are included. If sporting events are not included 17.5% of the population on campus is affected. Also, Zone A dam failure affects 38 critical structures (out of a total of 102 critical facilities) and 7 buildings containing hazardous materials. A breakdown of these critical facilities is shown in Table 25. Most of the critical buildings located within Zone A are historically important, although 3 extremely critical facilities—Steam Plant Facilities—are also affected along with 1 information storage facility and 2 communications facilities. Six buildings housing hazardous materials are affected (out of a total of 11 buildings housing hazardous materials on campus).

It should be noted that one of the most critical facilities on campus, the electrical substation, is not located in either Flood Zone A or B.

Vulnerability: Medium

DROUGHT VULNERABILITY

Drought is one of the events that is not able to be precisely quantified due to the fact that drought is a more broad occurrence that will affect the campus as a whole, rather than only specific parts. It is also an event in which the onset is gradual, rather than occurring suddenly, such as an earthquake would. Therefore, the vulnerability impact that a drought would have on campus can only be estimated based on data from past occurrences.

Data has been gathered only since 1998 for drought conditions in Knoxville. Data is gathered for every week since 1998, and from all of this data only 3% of the time did a severe or extreme drought exist. Even in the event of an extreme or severe drought occurring, TVA has surplus water storage when a drought is anticipated to remedy the potential problems. Therefore, while the effects of a drought may include cosmetic damage to campus greenery or the issuance of water restrictions, they are not likely to be life-threatening or affect campus operation in any way.

Vulnerability: Extremely Low

EARTHQUAKE VULNERABILITY

An earthquake event can affect campus in several ways including causing unreinforced masonry crumbling, cosmetic damage, broken utilities, and even structural damage or failure if severe enough. An earthquake has many variables that affect campus

Table 25: Dam Failure Zone A Assets & Populations at Risk

Type of Use	% of Total in Hazard Area			
	# of Buildings	Monetary Value of Buildings	Population Including Sporting Events	Population Not Including Sporting Events
Administration	0.9%	0.28%	0.03%	0.22%
Athletics/Physical Education	8.1%	17.90%	76.29%	0.08%
Class/Lab/Office	12.7%	20.95%	2.54%	16.72%
Communications	0.0%	0.00%	0.0%	0.0%
Dining	0.0%	0.00%	0.0%	0.0%
Farm Buildings	9.0%	0.27%	0.003%	0.02%
Housing	0.0%	0.00%	0.0%	0.0%
Library	0.0%	0.00%	0.0%	0.0%
Mechanical	0.0%	0.00%	0.0%	0.0%
Medical Care	0.0%	0.00%	0.0%	0.0%
Office	3.6%	0.17%	0.01%	0.06%
Parking	0.5%	0.74%	0.000%	0.00%
Physical Plant	2.3%	3.11%	0.03%	0.22%
Student Center	0.5%	0.19%	0.02%	0.15%
Total	37.6%	43.6%	78.9%	17.5%

Table 26: Dam Failure Zone A Critical and Hazardous Facilities

Critical Structure	Reason for Criticality	Notes	Hazardous Materials
907/909 21st St Duplex	Historical	---	---
Animal Science Laboratory	Historical	---	---
Auxiliary Services Building	Historical and Communications: Mail Services	---	---
Berry Hall	Historical	---	---
Brehm Animal Sciences Building	Historical	---	---
Ceramics Annex	Historical	---	---
Crops Genetic Laboratory	Historical	---	---
Dougherty Engineering Building	Historical	---	2nd most hazardous on main campus (chemicals)
English Language Institute-907 Mountcastle	Historical	---	---
Environment and Landscape Laboratory	Historical	---	---
Environmental Health and Safety-22nd Street	Historical	---	---
Estabrook Hall	Historical	---	---
Ferris Hall	Historical	---	---
Food Safety and Processing Building	Historical	---	---
Forestry Fertilizer Storage Building	Historical	---	---
Greenhouse TVA	Historical	---	---
McCord Hall	Historical	---	---
McLeod Food Sciences Building	Historical	---	---

Table 25, cont.

Critical Structure	Reason for Criticality	Notes	Hazardous Materials
Metron Building	Communications: Telecom-munications	Important for Logistics of Campus	---
Morgan Hall	Historical	---	---
Music Department Annex	Historical	---	---
Neyland Stadium	Historical	---	---
Parking and Transit Services	Information Storage: Records	---	---
Pasqua Nuclear Engineering Building	Historical	---	---
Perkins Hall	Historical	---	6th most hazardous on main campus (chemicals)
Plant Sciences Biotechnology Building	Historical	---	2nd most hazardous on Ag Campus (chemicals/fertilizers)
Steam Plant and Addition	Utilities	Source of almost all heat on campus; Extremely Critical Facility	---
Steam Plant Gear Switching Building	Utilities	Source of almost all heat on campus; Extremely Critical Facility	---
Steam Plant Turbine Building	Utilities	Source of almost all heat on campus; Extremely Critical Facility	---
Visitors' Center	Historical	---	---

Table 25, cont.

Critical Structure	Reason for Criticality	Notes	Hazardous Materials
Science and Engineering Building	Non-critical	---	3rd most hazardous on main campus (chemicals)
Veterinary Teaching Hospital	Non-critical	---	Most hazardous on Ag Campus (chemicals/fertilizers)
Neyland Drive Biology Annex	Non-critical	---	8th most hazardous on main campus (chemicals)

vulnerability. These variables—timing, location, intensity, depth of epicenter, geological and soil conditions,—are random and unable to be estimated. Various combinations of these variables can have varying effects on campus. For example, if an earthquake were to occur at 4 am with an epicenter in closer proximity to the campus and at a medium intensity, the structural damages and casualties might not be high due to the fact that most of the buildings are unpopulated at 4 am. If an earthquake were to occur at 1 pm with an epicenter farther away from campus and at a high intensity, more structural damage and casualties might occur due to more people being on campus at 1 pm. Three different scenarios were analyzed using HAZUS in order to achieve a variety of outcomes and estimate the damages on campus with varying conditions. HAZUS, which is an abbreviation for Hazards United States, is a GIS-based natural hazard loss estimation software package developed by FEMA. This program estimates risk using three steps—calculating exposure for a specific area, characterizing intensity of the hazard, and calculating the potential losses based on this area and intensity. HAZUS is currently widely used by emergency management organizations worldwide. These scenarios, all assuming the depth of the epicenter to be 10 km, include the following:

- Magnitude 6.0 earthquake at the location of the 1974 Alcoa earthquake at coordinates of 83.96W 35.80N (about 11 miles south of the center of UT's campus)
- Magnitude 5.0 earthquake at the location of the 1970 Alcoa earthquake of the same location
- Magnitude 6.0 earthquake at the location of Ayres Hall on the UTK campus at coordinates of 83.93W 35.96N

A HAZUS analysis of Knox County was done by Dr. James E. Beavers based on these three different scenarios and then scaled down (based on percent monetary damages and life losses) to the size of UT's campus in order to estimate the damages done solely to UT due to an earthquake.

Monetary Damages

Magnitude 6.0 Earthquake at Location of 1974 Alcoa Earthquake

For this scenario \$954.5 million in building damages (structural and non-structural) and building content damages would occur for the entirety of Knox County. This number does not include income losses (including lost wages, capital, rent, and relocation costs) because income losses were not included in the scope of the report for UTK, nor does it include damages to single family residences. Of the total building damages to Knox County, about half were damages from single family residences. This type of structure is most likely to be damaged during an earthquake due to its frailty and lack of seismic design and is not as prevalent on UT's campus as it is for Knox County. Therefore, including damages to single family residences would skew the data when scaling the values down to represent UTK, so in order to make the damage estimates more accurate single family residences were not included. The total building replacement value for Knox County, not including residential housing, is \$4.609 billion. Therefore, monetary-

wise 20.7% of building values were damaged. It was then estimated that this same percentage of building and content values would be damaged on UT's campus if this earthquake scenario were to occur, which would mean \$639.8 million would be damaged in the event of a magnitude 6.0 earthquake at the location of the 1974 Alcoa earthquake.

Magnitude 5.0 Earthquake at Location of 1974 Alcoa Earthquake

For this scenario \$118.5 million in building damages (structural and non-structural) and building content damages would occur for the entirety of Knox County, again, not including income losses or damages to single family residences. Of the total building replacement value for Knox County, not including residential housing, of \$4.609 billion, 2.6% of building values were damaged. Using this same percentage to estimate building and content values damaged on UT's campus for this earthquake scenario, gives \$80.4 million in damages in the event of a magnitude 5.0 earthquake at the location of the 1974 Alcoa earthquake.

Magnitude 6.0 Earthquake at Location of Ayres Hall on UTK Campus

For this scenario \$2.159 billion in building damages (structural and non-structural) and building content damages would occur for the entirety of Knox County, again, not including income losses or damages to single family residences. Of the total building replacement value for Knox County, not including residential housing, of \$4.609 billion, 46.9% of building values were damaged. Using this same percentage to estimate building and content values damaged on UT's campus for this earthquake scenario, gives \$1.448 billion in damages in the event of a magnitude 6.0 earthquake at the location of Ayres Hall.

Injuries and Casualties

Using HAZUS the number of people injured or killed by each earthquake scenario was done for varying times of the day, but for the purposes of this report, the analysis at 2 pm is used for this report because this is the time at which the educational, commercial, and industrial sector loads are at a maximum and would be most harmful to UTK. As is done previously in the "Monetary Damages" section, injuries and casualties in single family residences are not included in order to make the scaling of the data more applicable to UT's campus. The total population on campus was assumed to be not during a sporting event because the likelihood of an earthquake occurring during the small time frame that a sporting event is occurring is quite small.

Magnitude 6.0 Earthquake at Location of 1974 Alcoa Earthquake

Of Knoxville's total population of 382,032 (2000 Census Bureau data), an earthquake of this scenario at 2 pm causes 1399 injuries and 69 deaths, which are 0.4% of the population and 0.0002%, respectively. The total population on campus, not including sporting events, is about 25,860. This means that about 95 people will be injured and 5 killed during this earthquake scenario.

Magnitude 5.0 Earthquake at Location of 1974 Alcoa Earthquake

Of Knoxville's total population of 382,032, an earthquake of this scenario at 2 pm causes 36 injuries and 1 death, which are 0.00009% of the population and 0.000003%, respectively. Of the total population on campus of about 25,860, scaling down the data means that about 3 people will be injured and 0 killed during this earthquake scenario.

Magnitude 6.0 Earthquake at Location of Ayres Hall on UTK Campus

Of Knoxville's total population of 382,032, an earthquake of this scenario at 2 pm causes 3617 injuries and 212 deaths, which are 0.9% of the population and 0.0006%, respectively. Of the total population on campus of about 25,860, scaling down the data means that about 245 people will be injured and 14 killed during this earthquake scenario.

All of the information regarding building damages, injuries and casualties is shown in Figures 24 and 25.

While pinpointing exact buildings that will be damaged or destroyed or locations of injuries and casualties cannot be done, determining if any critical structures are safe from an earthquake can be estimated. Buildings built since 1987 have some seismic design, so buildings built before this date (about 75% of number of buildings and 84% of total value) probably have little to no seismic design and will be very vulnerable to damage from earthquakes. A list of the various types of critical structures that could possibly be vulnerable to an earthquake follows.

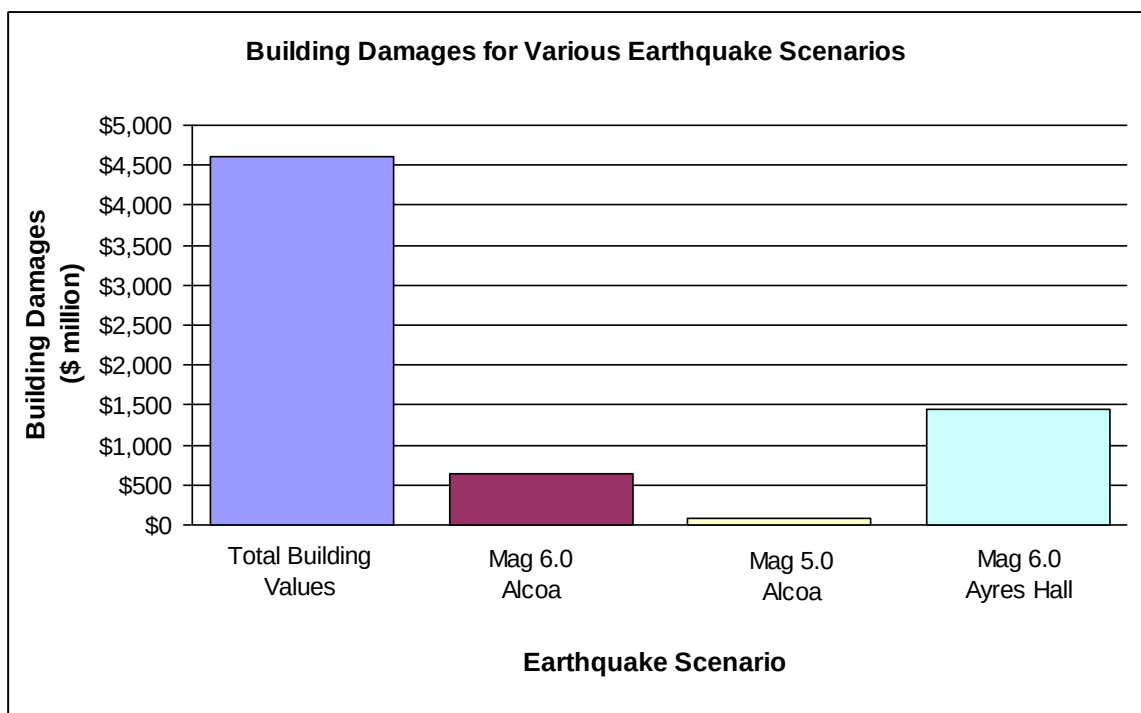


Figure 24: UTK Building Values Damaged from Earthquake

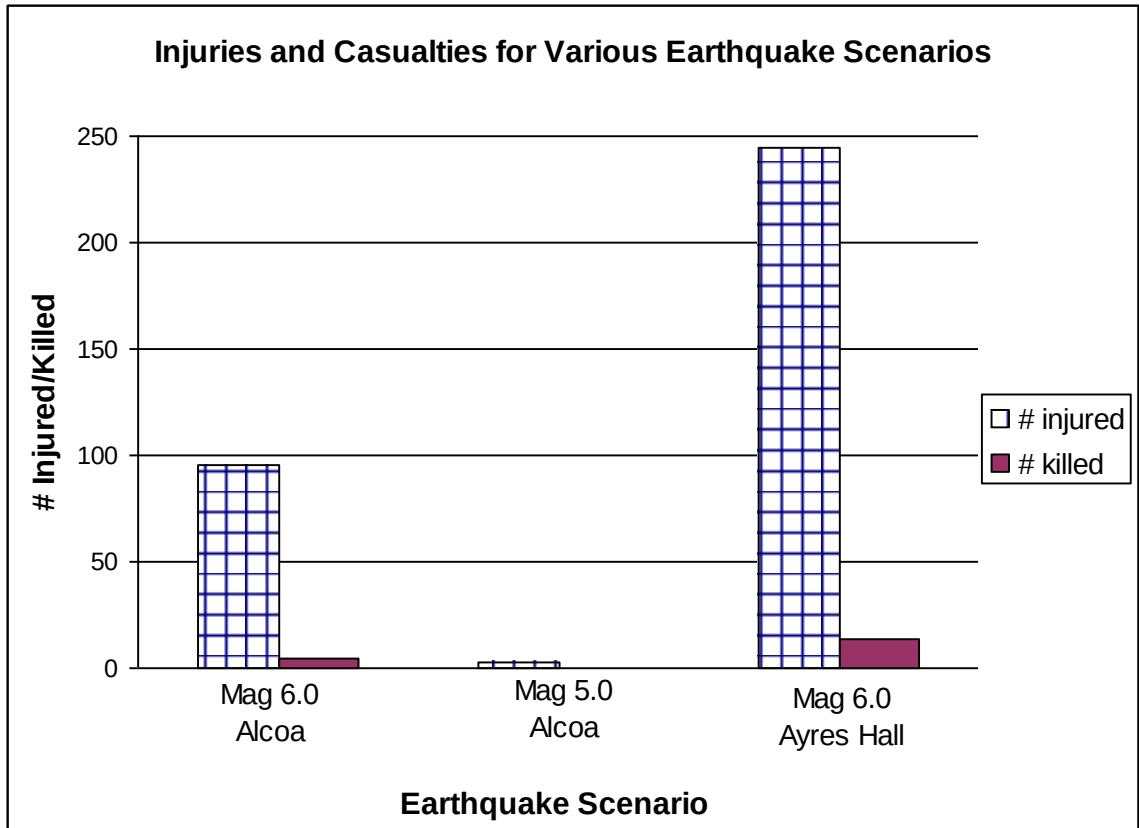


Figure 25: UTK Injuries and Casualties from Earthquake

Emergency Operations

Student Health Clinic—Medical care facility

Information Storage

White Avenue Building—Research Records

Student Services Building—Student Records

Conference Center Building—Retirement Services Records and Historic

Carolyn Brown University Center—Student Services

Andy Holt Tower—One of top 3 logistically important buildings. Payroll/Accounts Payable Offices and Communications and Historic.

Administration Parking Garage—Under Andy Holt Tower and Communications

Communications

McClung Tower and Plaza—Main server location

Stokely Management Center—One of top 3 logistically important buildings

Humanities and Social Sciences Building—One of top 3 logistically important buildings. Telephone boards located in basement.

Auxiliary Services Building—Mail Services and Historic

Metron Building—Telecommunications

Humanities and Social Sciences Parking Garage—Telecommunications
Communications and University Extension Building—Radio Satellites
Andy Holt Tower—One of top 3 logistically important buildings. WUTK radio station and Information Storage and Historic.
Administration Parking Garage—Under Andy Holt Tower and Information Storage

Utilities

Music Chiller Building—Utilities to protect irreplaceable collections in Music Building
Facilities Services Utilities Maintenance Building—Campus utilities
Facilities Services Maintenance Shops and Warehouse—Campus utilities
Steam Plant and Addition—Source of almost all heat on campus (Addition built with 1991 code, meaning it has seismic design)
Facilities Services and Operations Building—Campus utilities and Historic

Cultural Resources

John C Hodges Library—Building of high concern due to logistics and irreplaceable collections
Music Building—Irreplaceable collections
McClung Museum—Irreplaceable collections and Historic
James D Hoskins Library—Irreplaceable collections and Historic

Historic Buildings

907/909 21st St Duplex	English Language Institute-907
908 21st Street	Mountcastle
Alpha Tau Omega Fraternity House	Environmental Health and Safety-2111 Terrace
Animal Science Laboratory	Environmental Health and Safety-22nd Street
Art and Architecture Building	Estabrook Hall
Austin Peay Building	Ferris Hall
Ayres Hall	Food Safety and Processing Building
Berry Hall	Forestry Fertilizer Storage Building
Brehm Animal Sciences Building	Glocker Business Administration
Carriage House	Greenhouse TVA
Ceramics Annex	Greve Hall
Child Development Center	Henson Hall
Claxton Education Building	Hesler Biology Building and Greenhouse
Crops Genetic Laboratory	Hess Hall
Dabney-Buehler Hall	Hopecote
Dougherty Engineering Building	Interior Design Resource Center
Dunford Hall	Jessie Harris Building
Earth and Planetary Sciences Building	Knoxville W.A.V.E.
English Language Institute-2019 Terrace	Law Complex: George C Taylor Wing

Massey Hall
McCord Hall
McLeod Food Sciences Building
Melrose Hall
Morgan Hall
Music Department Annex
Neyland Stadium
Nielsen Physics Building
Office of Equity and Diversity
Panhellenic Building
Pasqua Nuclear Engineering Building
Pediatric Language Clinic

Perkins Hall
Radiological Safety
Sophonra Strong Hall and Cafeteria
South College
Stokely Athletics Center
Student Counseling Services
Student Success Center
Temple Court
Tyson Alumni Center
ULA Love Doughty Carousel Theatre
Visitors' Center

Also, three buildings containing hazardous chemicals are susceptible to damage from earthquakes and are as follows:

Veterinary Teaching Hospital—Most hazardous on Ag Campus (chemicals/fertilizers)
Walters Life Sciences Building—4th most hazardous on main campus (chemicals)
Engineering Annex—9th most hazardous on main campus (chemicals)

Of all of these buildings, the most vulnerable are unreinforced masonry structures. Reinforced concrete structures and steel structures are not as vulnerable during an earthquake as masonry. Of this list of vulnerable buildings, only 17 are masonry structures, all of which are critical for being historic except two. The Music Chiller Building is a vulnerable masonry structure that is critical for housing utilities for the music building, which houses irreplaceable collections. Also, the Facilities Services Maintenance Shops and Warehouse is a vulnerable masonry structure that is critical for housing utilities for various parts of campus. None of the masonry structures house large numbers of people, such as in a dormitory or student center.

As seen from the values of building damage, injury, and life loss due to an earthquake, this event would be the most devastating to UTK if the right conditions existed.

Vulnerability: High

EXPANSIVE SOILS VULNERABILITY

As discussed previously in the Expansive Soils component of Section 4.1—Hazard Identification, Knoxville is located within an expansive soils category of “Nonexpansive: The Occurrence of Expansive Materials Is Extremely Limited.” Therefore, since expansive soils do not generally occur in the area of the campus, there can be no effects to create campus vulnerability.

Vulnerability: Extremely Low

EXTREME HEAT VULNERABILITY

An extreme heat event would likely affect the entire campus uniformly rather than specific parts of it or in varying conditions throughout campus. Monetary damage to campus properties would most likely not occur—damage to populations would be the biggest concern. Most extreme heat events occur during the summer months, when campus population is at a low. The main effect that extreme heat would have on the campus operation would be adverse health effects to university employees and students while either in buildings or walking on campus. Extreme heat is mostly detrimental to the elderly and children, so since the vast majority of the population on campus is neither elderly nor very young, most people would not be affected. However, if some people were affected, the measures need to be taken to remedy these adverse health effects by ensuring that proper air conditioning is provided and functional.

Vulnerability: Extremely Low

FLOOD VULNERABILITY

While flooding is a significant hazard in the state of Tennessee, causing much of the state's federally declared disasters, it is not such a disastrous event at UTK. This is due to the fact that the campus is located in East Tennessee, with widely varying topography and much of the campus being built in higher elevations than its surrounding bodies of water. Flooding can cause cosmetic and structural building damage, contents damage, and even life loss, but at UTK the only effect likely to occur is building contents damage and cosmetic damage. As seen in the FIRMs of campus shown in Figures 10 and 11, the extents of flooding on campus are very minimal. The only facilities that could even be reached by flood waters would be Fulton Bottoms and Storage Shed (rugby field), Tyson Field and Storage Shed, Tyson Park Women's Softball Facilities, and possibly some various storage sheds on the agricultural campus. None of these facilities are critical or monetarily valuable, nor do they contain any people or hazardous materials. The flood zones as shown in the FIRM maps do not reach any potentially important structures near to the water's edge, such as the Steam Plant, the electrical substation, Thompson-Boling Assembly Center and Arena, or Veterinary Teaching Hospital. Flooding on campus will reach almost no facilities and none that are critical or important.

Vulnerability: Extremely Low

HURRICANE VULNERABILITY

A hurricane event would affect the UTK campus by bringing rain and flooding, along with possible high winds. The high winds would be uniformly present throughout the entire campus rather than affecting certain buildings, while the rain-induced flooding

would target specific low-lying buildings located near bodies of water. This flooding from a hurricane event would have an equal or lesser (due to the storm being weakened by distance) vulnerability as a flood event described previously. For a more detailed discussion of the flooding vulnerability due to a hurricane refer to the “Flood Vulnerability” portion of this report.

The high winds would also be lessened due to Knoxville’s distance from any hurricane’s origin, but might still be present. Figure 26 shows the National Hurricane Center’s estimation of wind speeds throughout the East Coast region for the *mildest* scenario of a hurricane storm—a Category 1 moving forward at a speed of 8 knots. For this mildest scenario, wind speeds of 0 to 35 mph may reach Knoxville. Figure 27 shows an estimation of wind speeds for a *worst* case scenario of a hurricane storm—a Category 5 moving forward at a speed of 24 knots. For this worst case scenario, wind speeds of 50 to 65 mph may reach Knoxville. ASCE 7 requires that the design wind speed for Knoxville buildings is 90 mph, so buildings designed according to the current code will be structurally sound for the worst case hurricane winds.

During a hurricane, damage to either campus properties or populations would most likely not occur from high winds, and the flooding aspect of a hurricane would be less than the effects described in the “Flood Vulnerability” section of this report.

Vulnerability: Extremely Low

LAND SUBSIDENCE VULNERABILITY

Land subsidence should not be a problem at UTK because most newer buildings are built on drilled shafts, which reach stable bedrock. Older buildings are at a potential risk since they are not built on drilled shafts; however, differential settlement is usually the failure mode to occur, giving warning signs such as cracking or tilting of the building. These are mainly cosmetic problems, not life safety problems, so karst is not a main area of concern for mitigation due to the fact that the problem is not life threatening, and the solution (drilling shafts underneath already-constructed buildings) would be quite expensive. The inclusion of this hazardous event in UTK’s hazard mitigation plan is just to make the University aware that a land subsidence event holds a small chance of occurrence, and the problem should be addressed at the time of occurrence, should it ever arise.

The worst case scenario of a karst collapse is that one of the underground caves would open up adjacent to a building column. However, one column failing would not cause significant structural damage because most buildings are designed to have redundancy, which would take care of the load not being able to be taken by the collapsed column. No buildings or even halves of buildings would be destroyed by karst collapses, and most damages due to karst on the campus are fairly easy to fix, if there is any damage at all.

Vulnerability: Extremely Low

MAX WIND= 075 KT SPEED OF MOTION= 08 KT

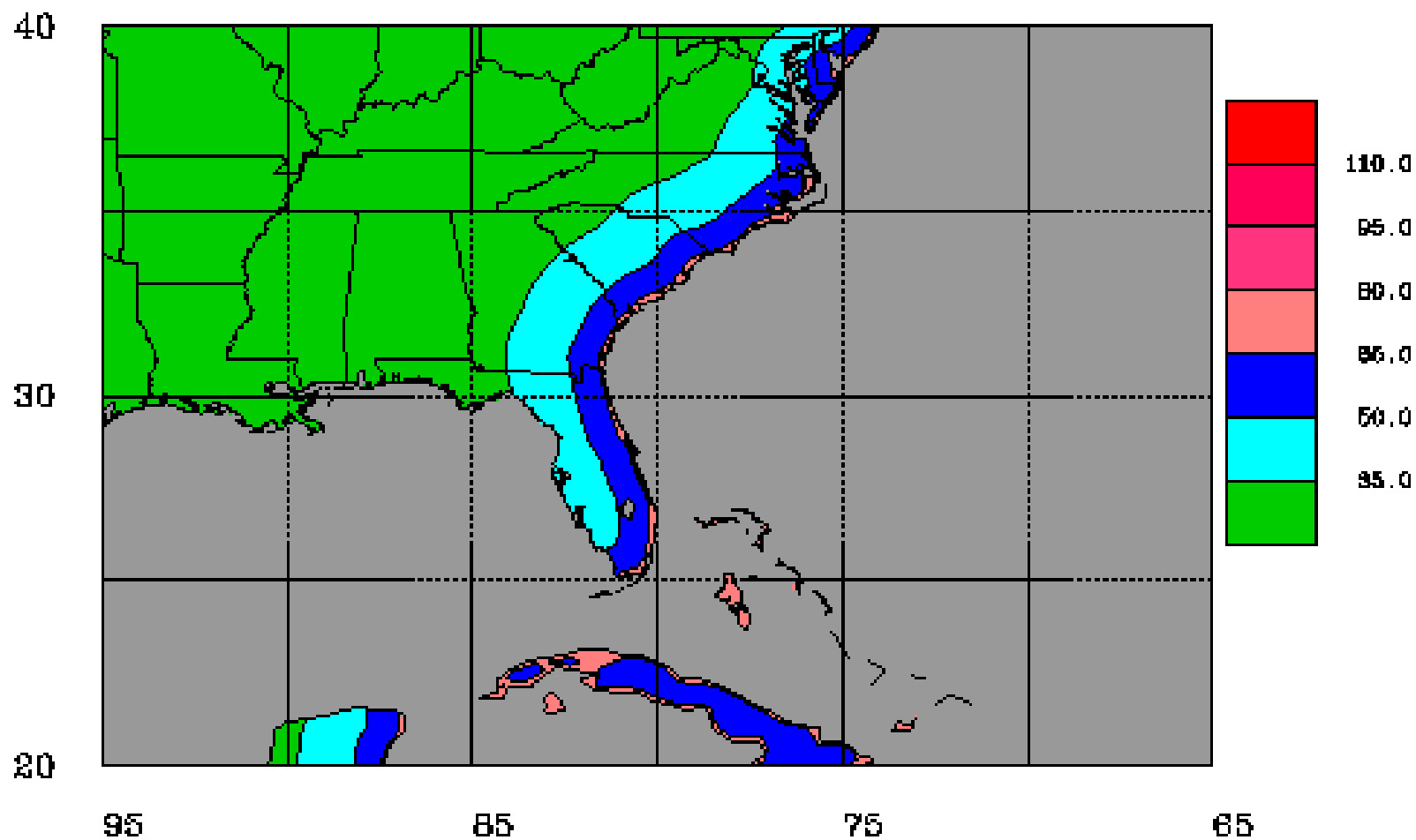


Figure 26: Lowest East Coast Hurricane Wind Speeds
(Source: National Hurricane Center)

MAX WIND= 135 KT SPEED OF MOTION= 24 KT

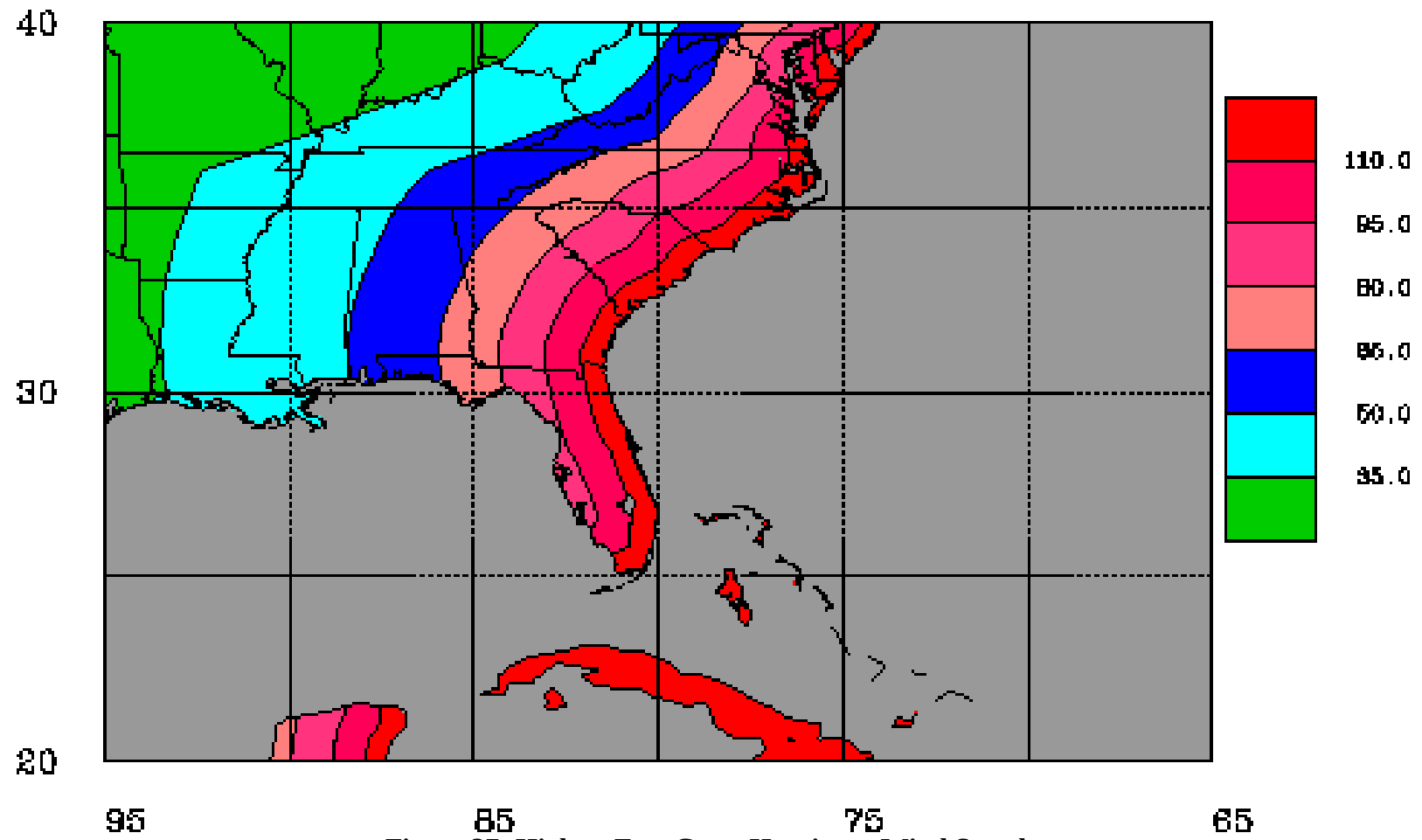


Figure 27: Highest East Coast Hurricane Wind Speeds
(Source: National Hurricane Center)

LANDSLIDE VULNERABILITY

The occurrence of a landslide can potentially cause damages to structures, utility systems, roads, and people if they are present at the time of a landslide. Only two locations on campus exist where it would even be possible for a landslide to occur—a 45° slope by the Pasqua Nuclear Engineering Building and a 45° slope on the west side of campus near the tennis courts. This degree of inclination (45°) is not very steep, so if a landslide were to occur, huge amounts of soil and material would most likely not move. However, if a landslide did occur at either of these two locations not much damage would occur. If a landslide occurred at the Pasqua Nuclear Engineering Building location, soil would slide down the slope towards the north side of the building and cause some windows and doors to be blocked. However, access to the building would still be available on the other three sides. No road blockage, utility damage, or structural damage would be present in this event. If a landslide occurred at the tennis courts location, soil would slide towards the tennis courts, covering the southern side of the courts. Soil could also slide west towards Volunteer Boulevard possibly blocking some of the road. The only damages from a landslide at the tennis courts location would be a mess on the tennis courts to clean up and possible road blockage of Volunteer Boulevard. (These locations are shown in Figure 28.) Therefore, the potential damages caused by a landslide would be minimal, causing mainly inconvenience and a necessity to clean up the displaced soil, but no life or large property and structural damages.

Vulnerability: Extremely Low

RADIATION FALLOUT VULNERABILITY

An event of a radiation release affecting the UTK campus would have effects mostly on the population of the campus, and not the structures or contents of the buildings. This event could happen either near the campus, originating at the Y-12 nuclear facility in Oak Ridge, Tennessee or could happen on the campus resulting from an accidental or intentional spill while in transport. If a radiation release occurred at the Y-12 nuclear facility, it would have to be an intentional sabotage event in order for enough radiation to reach the campus. The wind traveling from Oak Ridge generally travels in a northeasterly direction, meaning radioactive material would be transported to the north of Knoxville and probably not reach campus. Also as the wind naturally transports the radioactive material to campus, it also disperses it, making its effects to the population lessen (Logan, 2007). UTK is located about 30 miles away from the Y-12 facility, so even if the winds weren't blowing northeastward and radioactive material did actually reach Knoxville, by the time the radioactive material reached campus it would be so dispersed that it would raise radiation levels on campus only slightly higher than the background radiation level, thus not causing any adverse health effects. If a radiation release occurred closer to campus, most likely from a “dirty” bomb created from a radiological theft and planted

UTK Topographic Map

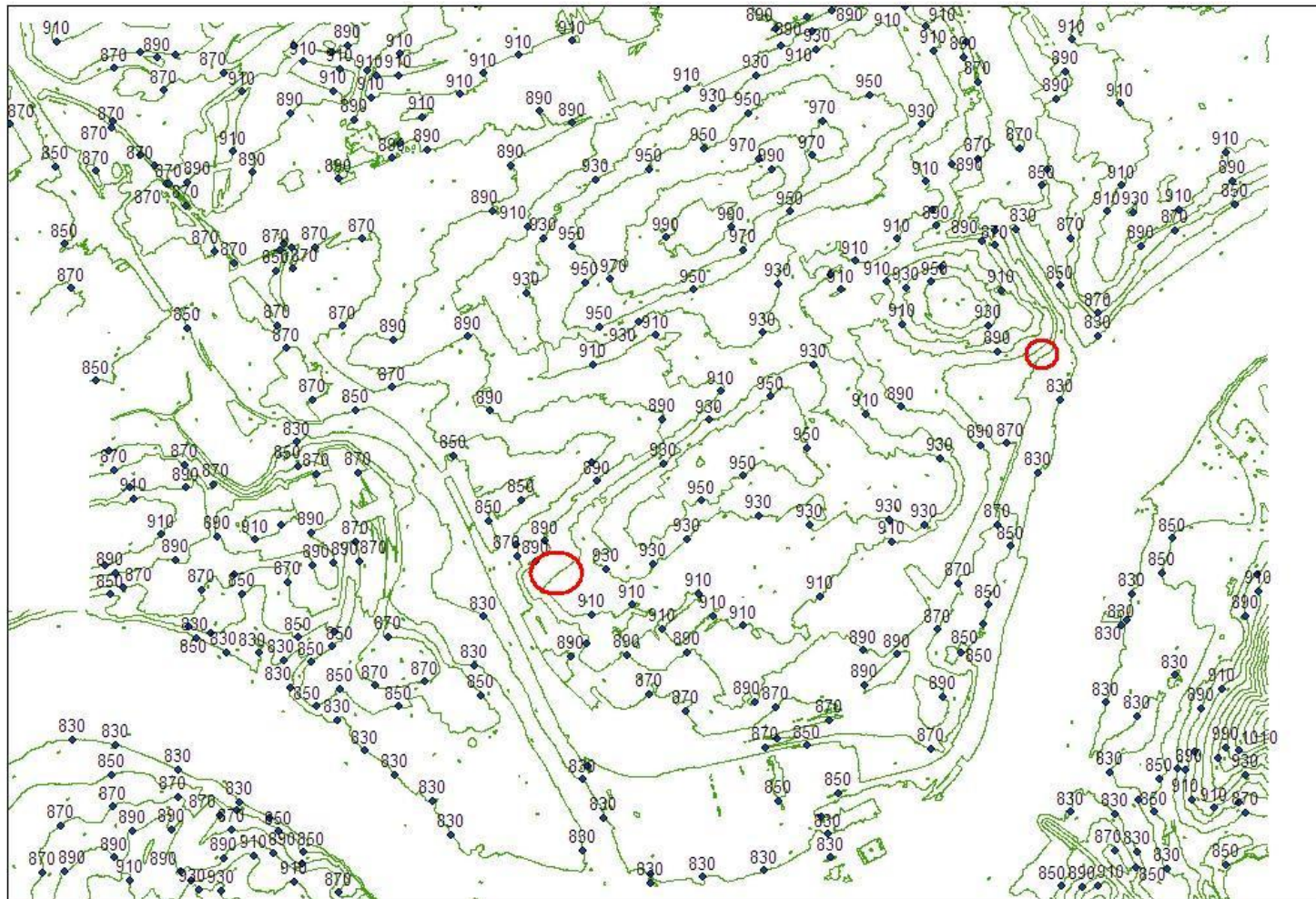


Figure 28: High Slopes at UTK

anywhere, or possibly a radiation release while radioactive material is in transport on the Interstate, more health effects on campus would be seen. An average of over 26,000 people are present on campus at any given time in the day, and an average of over 110,000 people are present on campus during a football game. A significant radiation release could affect most of these people if the event were to occur. The typical effects of radiation exposure to the human body are shown in Table 26.

The radiation doses on campus would likely be much less than 100 REM for the majority of people on campus, so the effects would likely not be noticeable, much less severe or fatal. Of course, any people located very near to ground zero would experience higher effects, but these effects would be very localized and would not drift far. During the Chernobyl nuclear accident, the only radiation doses greater than 100 rem were located directly in and around the nuclear reactor in which the explosion occurred. Any radiation release at UTK would likely not be as catastrophic as the Chernobyl accident, therefore, any radiation being accidentally or intentionally released on the campus would most likely not have the size and/or strength to cause any effects greater than those seen above a dose of 100 REM (Flanagan, 2007).

Vulnerability: Low

SEVERE STORM VULNERABILITY

The vulnerability that a severe storm could create on campus would be due to a combination of four components—hail, heavy rains, high winds, and lightning. Each of these components would have different effects on campus, and, thus, affect campus vulnerability differently. The heavy rains component of a severe storm has the same vulnerability effects as a flooding event. For a more detailed discussion of heavy rains, refer to the “Flood Vulnerability” section of this report. The same is true of high winds. High winds will have the same or lesser vulnerability effects as a tornado event. For a more detailed discussion of high winds from a severe storm, refer to the “Tornado Vulnerability” section of this report.

As far as hail during a severe storm, property damage and power outages are of concern, while population damage is not. The properties most likely to be damaged are automobiles (which are not covered in the scope of this report), glass components of structures, and cosmetic damage to paint and brick. Shown in Table 27 is a listing of various hail stone size ranges and their typical extent of damages depicted by the shaded areas. Hail as small as 11 mm (mothball) can cause damage to plastic, glass, paint, and wood of structures, but generally a hail size closer to 20 mm (cherry) is required before this occurs. Severe roof damage and risk of serious injuries occurs at hail sizes as small as 46 mm (hen’s egg), but on an average closer to 80 mm (tennis ball). Extensive structural damage and risk of fatalities do not occur unless the hail is at least 81 mm (orange), but most often it is 100 mm (grapefruit). The average size of hail in Knox County is 29.2 mm, which means that if it were moving at speeds fast enough, hail could

Table 27: Radiation Exposure Effects

Dose	Symptoms
5-20 REM	No symptoms.
20-50 REM	No noticeable symptoms. Red blood cell count decreases temporarily.
50-100 REM	Mild radiation sickness with headache and increase risk of infection due to disruption of immunity cells. Temporary male sterility is possible.
100-200 REM	Light radiation poisoning, 10% fatality after 30 days. Nausea with occasional vomiting. General illness and fatigue. The immune system is depressed with increased risk of infection. Temporary male sterility is common. Spontaneous abortion or stillbirth will occur in pregnant women.
200-300 REM	Moderate radiation poisoning, 35% fatality after 30 days. Nausea with vomiting. Loss of hair all over the body, fatigue and general illness. Massive loss of white blood cells, greatly increasing the risk of infection. Permanent female sterility is possible.
300-400 REM	Severe radiation poisoning, 50% fatality after 30 days. Uncontrollable bleeding in the mouth, under the skin and in the kidneys.
400-600 REM	Acute radiation poisoning, 60% fatality after 30 days. Female sterility is common. Primary causes of death (about 2 to 12 weeks after irradiation) are infections and internal bleeding.
600-1000 REM	Acute radiation poisoning, near 100% fatality after 14 days. Survival depends on intense medical care. Bone marrow is nearly or completely destroyed, so a bone marrow transplant is required. Gastric and intestinal tissues are severely damaged. Recovery would take several years and probably would never be complete.
1000-5000 REM	Acute radiation poisoning, 100% fatality after 7 days. Powerful fatigue and immediate nausea. Cell death in the gastric and intestinal tissue, causing massive diarrhea, intestinal bleeding and loss of water, leading to water-electrolyte imbalance. Death sets in with delirium and coma due to breakdown of circulation. Death is currently inevitable; the only treatment that can be offered is pain therapy.
>5000 REM	Acute radiation poisoning, 100% fatality after around 48 hours.

cause destruction of glass, damage to tiled roofs, pitted brick walls, and significant risk of injuries. Hail in Knox County usually causes lesser damages because it is not always falling at maximum speeds. While population harm is a possibility, it is not a concern for this report because everyone on UT's campus has access to indoor areas in the event of hail (Tornado and Storm Research Organization, 2007).

Specific properties that might be damaged from hail cannot be pinpointed—damage will most likely occur uniformly or randomly throughout campus. For this reason, it is impossible to estimate the monetary damages that might occur from this component of a severe storm. However, for the entirety of Knox County, total damages of only \$56,000 have been reported since 1950 (as given by the National Climatic Data Center's Storm Events for Tennessee website), which is only about \$980 a year (not much for an area as large as a county with a population of over 400,000). Therefore, the damages caused on an even smaller scale of the UTK campus alone can be estimated to be smaller than the county-wide damages.

As far as lightning during a severe storm goes, property damage and power outages are of concern, while, again, population damage is not. The reason for this is the same as for a hail event—all people on UT's campus have access to indoor areas in the case of a severe storm onset. The properties most likely to be damaged from a lightning strike could be any buildings or electrical facilities on campus. It is impossible to estimate which specific buildings or electrical facilities could be targeted due to the random nature of storms. However, one specific area is of great concern. If a lightning strike was to occur at UT's substation, the primary source of UT's electricity, UT could be left without power entirely. The substation is located at the southern-most end of Pat Head Summit Street near the steam plant and is the source of at least 80% of UT's power. This would be very devastating in the heat of the summer or cold of the winter. It also would cause logistical problems, and basically all operations on campus would be forced to shut down (Sherrell, 2007).

Vulnerability: Medium

SEVERE WINTER STORM VULNERABILITY

A severe winter storm can cause traffic accidents, road blockages, delays in emergency response, people to be trapped in buildings and cars, frozen pipes, caving of roofs, utility outages, and disruption of daily activities. A severe winter storm would affect the entire campus if it were to occur. Traffic accidents and road blockages are not of primary concern during a winter storm because automobiles are beyond the extent of this report, and the campus is small enough that traveling anywhere on foot is feasible. Delays in emergency response, while a concern, are not a huge concern again due to the fact that the campus is small enough that there would not be massive delays if any were to occur. People being trapped in buildings is also not of a huge concern because all buildings on campus have heat and running water, and most likely people would not be trapped for long due to the availability of emergency services.

Table 28: Hail Stone Sizes and Corresponding Damages

Diameter (mm)	Size Example	Damage Intensity										
		No damage	Slight damage to plants, crops	Significant damage to fruit, crops, vegetation	Severe damage to fruit, crops; damage to glass/plastic structures; paint and wood scored	Widespread glass damage; vehicle bodywork damage	Wholesale destruction of glass; damage to tiled roofs; significant risk of injuries	Aircraft bodywork dented; brick walls pitted	Severe roof damage; risk of serious injuries	Severe damage to aircraft bodywork	Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open	Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open
5 to 10	pea											
11 to 15	mothball, bean											
16 to 20	cherry, penny											
21 to 30	walnut											
31 to 45	golf ball, table tennis ball											
46 to 60	hen' s egg, billiard ball											
61 to 80	tennis ball, orange											
81 to 100	grapefruit, softball											
101 to 125	melon											
over 150	coconut											

More of concern during a severe winter storm would be frozen pipes, caving of roofs, and utility outages. Frozen pipes could cause running water to become unavailable to parts of campus, but the likelihood of all pipes on campus freezing is quite low. This means that water would still be available in parts of campus; people just may have to travel to another area of campus to obtain it. Lightweight roofs and awnings are most vulnerable to snow loads. Failures of lightweight roofs and awnings, however, are usually very localized failures are very small monetarily and no big risk to people. It is impossible to discern which buildings on UT's campus have lightweight roofs without extensive research, so it is impossible to determine which buildings are most vulnerable to a snow load. However, it can be stated that none of the critical structures on campus have lightweight roofs; therefore, the most imperative structures will likely not be damaged by a snowstorm. Any roof cavings that did occur would likely not harm many people or cause any severe structural or interior damage other than the need to have the roof replaced. Utility outages are of primary concern during a severe winter storm. Utility outages could occur from damaged power lines in an ice storm or from a roof caving in one of the structures that houses utilities. During a severe snow or ice storm campus would not be in operation, so the majority of people on campus would be located in the residence halls. Power outages on campus would cause inconvenience, but would likely not cause any personal injury or death because if any of the residence halls lost power, the residents would be moved to other buildings on campus that still retained power. The primary source of UT's power, the electrical substation, has not ever been damaged by ice storms, so the likelihood of the power throughout the entirety of campus going out is very slim. A severe winter storm would cause logistical problems and inconvenience, as well as cost to repair power lines, but no severe population harm or extensive structural damage would occur.

Vulnerability: Low

TERRORISTS VULNERABILITY

An event of terrorism at UTK is quite unlikely, but could have some dire consequences if it did occur. Acts of terrorism of concern at UTK include plane crashes into structures, bombings on large congregations of people (such as sporting events, residence halls, large office buildings, large auditoriums, and student centers), gunfire, and chemical releases.

Plane crashes into structures and bombings, particularly during a sporting event, could be devastating in terms of life loss. The ten most populated structures on campus and their average populations are as follows and include populations during a sporting event because an act of terrorism would not be random and planning for it to occur during a sporting event would be likely:

- **Neyland Stadium:** Over 110,000 people
- **Thompson-Boling Assembly Center and Arena:** 25,000 people
- **Tom Black Track:** 7,500 people

- **Lindsey Nelson Stadium:** 3,700 people
- **Carolyn Brown University Center:** 3,200 people
- **Intercollegiate Swim Facility:** 2250 people
- **Humanities and Social Sciences Building:** 1680 people
- **Glocker Business Administration:** 950 people
- **Alumni Memorial Building:** 930 people
- **Holt Avenue Apartments Residence Hall:** 880 people

A plane crash or bombing could also be devastating in terms of monetary loss to the campus. The ten most valuable buildings on campus, including replacement value and contents value, are shown as follows:

- **Neyland Stadium:** \$692 million
- **John C Hodges Library:** \$237 million
- **Science and Engineering Building:** \$109 million
- **James D Hoskins Library:** \$96 million
- **Steam Plant and Addition:** \$84 million
- **Dabney-Buehler Hall:** \$84 million
- **Veterinary Teaching Hospital:** \$66 million
- **Conference Center Building:** \$62 million
- **Carolyn Brown University Center:** \$57 million
- **Thompson-Boling Assembly Center and Arena:** \$57 million

A terrorist gunfire event would be more isolated and affecting less people, although no less significant. Gunfire would not cause any structural damage, but would be one of the most devastating events at UTK in terms of life loss. A terrorist-initiated chemical release could also have destructive consequences. This event, toxic chemical release, and its specific effects on campus are discussed more in detail in the “Toxic Chemical Release Vulnerability” section of this report. In conclusion, while a terrorist event is not likely, if it does occur it could have one of the most devastating effects in terms of life loss and/or monetary loss of all of the events.

Also a likely terrorist target could be the electrical substation, since it is the source of 80% of UT’s electricity. In order for the substation to be damaged enough to severely affect campus, intentional acts would have to be taken. This is very feasible since the only protection surrounding the substation is a fence. One would simply have to know the basic mechanics of a substation in order to damage it.

Vulnerability: Medium

TORNADO VULNERABILITY

Tornadoes are an event of an unpredictable and random nature, so the likelihood of it occurring at any location on campus is equal. The effects on campus due to a tornado

could include damages from winds and fallen or uprooted trees, such as cosmetic damage to buildings, damage to roofs, and damage to weaker, smaller buildings. Tornadoes occurring in Knoxville are generally a Category F0 to F2 on the Fujita Scale, as discussed in the “Tornado” section of this report. Category F0 to F2 include light damage, moderate damage, and considerable damage. The damages are described as following:

- Light Damage: some damage to chimneys, broken twigs and branches, pushed over shallow-rooted trees, damaged signboards, and some broken windows.
- Moderate Damage: peeled off roof surfaces, overturned mobile homes, demolished outbuildings, moving automobiles being pushed off the roads, and broken trees.
- Considerable Damage: torn off roofs of frame houses, demolished mobile homes, lifted and moved frame houses with weak foundations, pushed over boxcars, snapped or uprooted large trees, and light-object missiles generated.

Light damage and moderate damage are not of huge concern because mainly cosmetic damage falls into this category. Cosmetic damage is not life threatening or extremely expensive to repair, as a destroyed building would be. Also, mobile homes do not exist on campus and automobiles are not included in the scope of this report, so neither of these are of concern for moderate damage.

A tornado with considerable damage (most likely a Category F2) would be more damaging to the campus causing roofs to be torn off of some of the older frame houses, and even causing some of these older frame houses with weaker foundations to be lifted from the ground and moved. It also could cause boxcars to be pushed over, which is of concern due to the fact that many boxcars near to campus contain various toxic chemicals. For a more detailed discussion of how these toxic chemicals could affect campus refer to the “Toxic Chemical Release” and “Toxic Chemical Release Vulnerability” section of this report. A Category F2 tornado could also cause large trees to be snapped or uprooted, which would be the culprit of most structural damage on campus. Many smaller, less structurally sturdy buildings would be damaged if any large trees fell on them, while larger, more structurally sturdy buildings may be damaged less intensely. Also of concern due to uprooted trees would be damaged power lines. These snapped or uprooted trees could cause many of the power lines on campus to be damaged or destroyed, causing much of the electricity on campus to be out. This would definitely be negative and have a large impact on campus, but would not be completely disastrous.

Peak tornado season in the southern states is March through May and 3 pm through 9 pm, so if a tornado occurred it would probably occur when the temperatures aren’t at their coldest and when classes aren’t at their peak hours. This means that if the power went out people would not be in dire danger from the cold, and less people would be in the unprotected outdoors than they would be while in transit to classes. A final concern due to an F2 tornado would be light-object missiles generated by the high winds, which could be harmful to people outdoors. As stated previously, a tornado would most likely occur

during a time when the population outdoors is not at a maximum, so a lesser amount of people would be likely to be affected by projectile objects.

A picture depicting one example of damage that a Category F2 can cause is shown in Figure 29. This figure shows uprooted and overturned trees and a ripped off roof, characteristic of a Category F2 tornado, but no significant structural damage. This type of damage would be the most common structural damage on campus if a Category F2 tornado were to occur because most larger buildings are either structural frames or reinforced concrete, which would hold up during an F2 storm. Some critical, cultural, or historical wood frame or masonry buildings that might be at risk of being lifted and moved or even destroyed are shown in Table 28. All of the buildings listed are critical for being historic except the Hoskins Library Chiller Building (houses utilities to protect irreplaceable collections), Music Chiller Building (houses utilities to protect irreplaceable collections), Reese Hall Chiller Building (houses utilities for Reese Hall dormitory), Facilities Services Maintenance Shops and Warehouse (houses utilities for all of campus). All of the occupancies of these buildings are low in comparison to the other buildings on campus. Of all of the masonry and wood frame buildings on campus, including critical and non-critical buildings, none have irreplaceable collections and two contain hazardous chemicals (Engineering Annex—9th most hazardous on the Agricultural Campus; Veterinary Teaching Hospital—most hazardous on the Agricultural Campus). The total populations in all of these less sturdy buildings is only 3.5% of the total population on campus (assuming a sporting event is not taking place) and the total values consist of 5.9% of the total values on campus. This numbers show that large numbers of people and large monetary values are not present in buildings that are most likely to be damaged by a tornado on campus. However, four buildings do house utilities for various buildings on campus and two contain hazardous materials.

A facility of specific importance, the UT electrical substation, is vulnerable during a tornado or event of high winds. It has been damaged by high winds in the past, and could be damaged in the future. An F2 tornado could cause over half of the power to be out throughout campus by damaging the substation (Sherrell, 2007).

Vulnerability: Medium

TOXIC CHEMICAL RELEASE VULNERABILITY

In the event of a toxic chemical release at UTK, the main concern is adverse effects to human health and fires, rather than severe structural damage. The main concentrations of toxic chemicals are located in either various research and engineering buildings throughout campus or on various railroads around campus. Currently, chemical spills in the engineering and research buildings are either cleaned up by the lab workers, cleaned up by personnel from the Office of Environmental Health & Safety, or handled by the local Hazardous-Materials squad, depending on the severity of the spill. In the case of



Figure 29: Category F2 Tornado Damage
 (Source: National Oceanic and Atmospheric Administration)

Table 29: Critical Buildings Damaged From a Category F2 Tornado

Building	Type of Building
907/909 21st St Duplex	Masonry
Estabrook Hall	Masonry Frame
Berry Hall	Masonry Frame
Ceramics Annex	Masonry Frame
Austin Peay Building	Masonry Frame
Child Development Center	Masonry Frame
Temple Court	Masonry Frame
Carriage House	Masonry Frame
South College	Masonry Frame
Greenhouse TVA	Masonry Frame
Animal Science Laboratory	Masonry Frame
Tyson Alumni Center	Masonry Frame
Visitors' Center	Wood Frame
English Language Institute-2019 Terrace	Wood Frame

Building	Type of Building
Environmental Health and Safety-2111 Terrace	Wood Frame
Pediatric Language Clinic	Wood Frame
Hopecote	Wood Frame
Knoxville W.A.V.E.	Wood Frame
English Language Institute-907 Mountcastle	Wood Frame
Environmental Health and Safety-22nd Street	Wood Frame
Music Department Annex	Wood Frame
908 21st Street	Wood Frame
Interior Design Resource Center	Wood Frame
Office of Equity and Diversity	Wood Frame
Radiological Safety	Wood Frame
Student Counseling Services	Wood Frame
Student Success Center	Wood Frame
ULA Love Doughty Carousel Theatre	Wood Frame
Environment and Landscape Laboratory	Wood Frame/Masonry Veneer
Hoskins Library Chiller Building	Masonry Frame
Music Chiller Building	Masonry Frame
Reese Hall Chiller Building	Masonry Frame
Facilities Services Maintenance Shops and Warehouse	Masonry Frame

any of these spills the most likely effects would be burns to the skin or damage to lungs from inhalation and/or fires, due to the fact that most of the chemicals stored throughout campus buildings are flammable. In the event of a fire, the local Knoxville Fire Department would handle the situation. The various buildings throughout campus that contain hazardous chemicals are shown in Table 29. These buildings contain 12% of the total population on campus (not during a sporting event) and 16% of the total building and content values on campus. Also, over half of these buildings are critical, but they are critical for being historical buildings rather than communications or utilities (Smith, 2006).

Toxic chemicals hauled on railroads have a greater potential to do damage to the University than the chemicals stored in the buildings due to the large quantities stored and hauled on the railroads. Most of the dangerous chemicals hauled in close proximity to the campus are inhalation hazards and explosive hazards. The inhalation hazards can consist of chlorine, sulfuric acid, hydrogen fluoride, anhydrous ammonia, sulfur dioxide, and ethylene oxide. Chlorine is the most dangerous of these chemicals with the potential to be fatal. If any were to be spilled, with correct wind conditions, the campus would probably have to be evacuated. The other chemicals can also form toxic vapors, but the effects of these kinds of spills would not be as bad as those of chlorine and might call for smaller, more concentrated evacuations. The explosive hazards hauled in close proximity to the campus are more common than the inhalation hazards. One specific chemical of concern is ammonium nitrate hauled on the Norfolk Southern railroad, which is a huge explosive and common bomb material. If a railcar full of ammonium nitrate was to explode, buildings within a half a mile (which includes campus) would be damaged, the very least being broken windows. Other explosives of concern are ethanol, propane, and ammonium nitrate, also hauled on the Norfolk Southern Railroad, which would have less explosive effects than ammonium nitrate, but could still do damage to parts of campus (Clarke, 2007).

Vulnerability: Low

WILDFIRE VULNERABILITY

The University of Tennessee is located in a fairly urban area with medium fuel vegetation in areas where vegetation is present. Much of the campus is covered in non-vegetative matter, such as buildings, roads, and parking lots, which is not conducive to wildfire spread. It is very difficult to estimate which buildings would be most affected by a wildfire because the location of a wildfire's origin is unable to be predicted. However, it can be reasonably assumed that a wildfire would not approach campus from the north or east sides because both of these areas are very urbanized with little vegetation to fuel the fires. While the south and west sides of campus have quite a bit more vegetation to fuel a

Table 30: Campus Buildings Containing Toxic Chemicals

Building Name	Ranking	Critical Facilities
Veterinary Teaching Hospital	Most hazardous on Ag Campus	Non-critical
Plant Sciences Biotechnology Building	2nd most hazardous on Ag Campus	Critical (Historical Bldg)
Dabney-Buehler Hall	Most hazardous on main campus (chemicals)	Critical (Historical Bldg)
Dougherty Engineering Building	2nd most hazardous on main campus (chemicals)	Critical (Historical Bldg)
Science and Engineering Building	3rd most hazardous on main campus (chemicals)	Non-critical
Walters Life Sciences Building	4th most hazardous on main campus (chemicals)	Non-critical
Hesler Biology Building and Greenhouse	5th most hazardous on main campus (chemicals)	Critical (Historical Bldg)
Perkins Hall	6th most hazardous on main campus (chemicals)	Critical (Historical Bldg)
Jessie Harris Building	7th most hazardous on main campus (chemicals)	Critical (Historical Bldg)
Neyland Drive Biology Annex	8th most hazardous on main campus (chemicals)	Non-critical
Engineering Annex	9th most hazardous on main campus (chemicals)	Non-critical

wildfire, the Tennessee River stands between this vegetation and campus, thus blocking any wildfire spread. Wildfire spreads the most rapidly in areas of higher slopes, and the only areas of higher slopes on campus are a 45° slope by the Pasqua Nuclear Engineering Building and a 45° slope by the tennis courts. Therefore, wildfire would more likely be most damaging and uncontrollable in these areas, likely damaging the Pasqua Nuclear Engineering Building, Estabrook Hall, Berry Hall, Goodfriend Tennis Center Building, and Outdoor Tennis Center the most before the fires were able to be extinguished. Of these properties, the only ones of a critical, cultural or historic value are Estabrook Hall (historic), Pasqua Nuclear Engineering Building (historic) and Berry Hall (historic) All of the buildings together comprise of only 0.85% of the total monetary property values on campus and only 3.2% of the campus population (not during a sporting event). In the event of a wildfire it is unlikely that any buildings housing emergency operations, information storage, communications, utilities, cultural resources, large amounts of hazardous materials or irreplaceable collections would be vastly affected, therefore a wildfire would not make the campus very vulnerable.

Vulnerability: Low

VULNERABILITY SUMMARY

A summary of all the events and their vulnerability on the UTK campus are in Table 30.

Table 31: Vulnerability of Hazard Events

Event	Vulnerability
Earthquake	High
Dam Failure	Medium
Terrorists	Medium
Tornado	Medium
Severe Storm	Medium
Radiation Fallout	Low
Severe Winter Storm	Low
Toxic Chemical Release	Low
Wildfire	Low
Drought	Extremely Low
Expansive Soils	Extremely Low
Extreme Heat	Extremely Low
Flood	Extremely Low
Hurricane	Extremely Low
Land Subsidence	Extremely Low
Landslide	Extremely Low

FINAL SUMMARY

All of the events have been quantified in terms of likelihood of occurrence and vulnerability. In order to determine which events are the most important overall, a numerical rating was given to each scale category described as follows:

Likelihood of Occurrence

Highly Likely: 4

Likely: 3

Occasional: 2

Unlikely: 1

Vulnerability

High: 4

Medium: 3

Low: 2

Extremely Low: 1

Rating each event's likelihood of occurrence and vulnerability and then summing them gave an event's total (also known as impact rating) with the higher the number meaning an event was more important and will have more of an impact on UTK. This process is shown in Table 31, which also shows that the events that affect the campus the most are a severe storm and earthquake.

Table 32: Rating of Events at UTK

Event	Likelihood of Occurrence	Numerical Rating	Vulnerability	Numerical Rating	Total
Severe Storm (Lightning, Heavy Rains)	Highly Likely	4	Medium	3	7
Earthquake (M_w of 4-5)	Occasional	2	High	4	6
Severe Storm (Hail, High Winds)	Occasional	2	Medium	3	5
Earthquake (M_w of 5-6)	Unlikely	1	High	4	5
Severe Winter Storm	Occasional	2	Low	2	4
Toxic Chemical Release	Occasional	2	Low	2	4
Dam Failure	Unlikely	1	Medium	3	4
Terrorists	Unlikely	1	Medium	3	4
Tornado	Unlikely	1	Medium	3	4
Drought	Occasional	2	Extremely Low	1	3
Extreme Heat	Occasional	2	Extremely Low	1	3
Hurricane	Occasional	2	Extremely Low	1	3
Land Subsidence	Occasional	2	Extremely Low	1	3
Radiation Fallout	Unlikely	1	Low	2	3
Wildfire	Unlikely	1	Low	2	3
Expansive Soils	Unlikely	1	Extremely Low	1	2
Flood	Unlikely	1	Extremely Low	1	2
Landslide	Unlikely	1	Extremely Low	1	2

4.3 Assessment of Existing Mitigation Plans and Policies

All of the natural hazards posing a threat to UTK have been identified and quantified for both the likelihood of occurrence and vulnerability it may have on the campus. This section briefly discusses what loss prevention methods the university currently has in place. Assessing the current mitigation plans and policies helps to determine which areas in the university's mitigation plans are lacking and need to be elaborated on or entirely created. UTK's current mitigation plans exist in the university document *Campus Emergency Management Plan* in which emergency plans for critical facilities as well as specific disasters exist. For the critical facilities each plan contains basic information that would be useful in the event of an emergency, such as emergency contact numbers (those of personnel in charge of facilitated operations), evacuation procedures, options for relocations if necessary, and other details specific to each facility. These critical facilities with existing emergency plans are as follows:

- Housing
- Dining Services
- Institute of Agriculture
- Environmental Health and Safety
- Facilities Services
- Public Relations
- Student Health Services
- Office of Information Technology
- Telephone Services
- Police
- Transportation Services

Other facilities with important or special natures that aren't deemed critical are identified as "special units." These facilities also have existing emergency management plans and are as follows:

- Fraternity Affairs
- McClung Museum
- University Center
- Athletics (Have entire separate plan for athletics not included in *Campus Emergency Management Plan*)

For specific disasters contained in the *Campus Emergency Management Plan* refer to "Attachment B: Incident Commander Action Steps" within the document, which identifies different emergency events, their expected impacts and consequences to UT, and suggested action steps in the case of each.

Dam Failure

No current mitigation plan exists.

Drought

No current mitigation plan exists.

Earthquake

- After the event
 - EMP (Emergency Management Plan) Activated
 - IRT (Incident Response Team) Contacted
 - EMT (Emergency Management Team) Notified
 - Activate the EOC (Emergency Operations Center)

Expansive Soils

No current mitigation plan exists.

Extreme Heat

No current mitigation plan exists.

Flood

No current mitigation plan exists.

Hurricane

For heavy rains associated with hurricane:

- At the Alert (48-hour) Point
 - EMP Activated
 - IRT Contacted
 - EMT Notified
- At the Watch (36-hour) Point
 - Secure the campus
 - Secure building contents (flood damage)
 - Test all backup environmental equipment
- Within the Warning (24-hour) Point
 - If not already accomplished, activate the EOC
 - University Police and critical personnel take cover at secure location before situation becomes dangerous

Land Subsidence

No current mitigation plan exists.

Landslide

No current mitigation plan exists.

Radiation Fallout

For Release Inside a Building:

- After the Event
 - EMP Activated
 - IRT Contacted
 - EMT Notified
 - Activate the EOC
 - Eliminate a terrorist attack as a possibility
 - Consider evacuating campus
 - All entrances closed
 - Ventilation systems in affected buildings shutdown
 - Personnel in affected buildings are quarantined

For Release Outside a Building on Campus:

- After the Event
 - EMP Activated
 - IRT Contacted
 - EMT Notified
 - Activate the EOC
 - Eliminate a terrorist attack as a possibility
 - Campus not evacuated/everyone remains indoors
 - All entrances closed
 - All ventilation systems shutdown
 - Personnel in affected buildings are quarantined

For Release Off Campus:

- After the Event
 - EMP Activated
 - IRT Contacted
 - EMT Notified
 - Activate the EOC
 - All ventilation systems shutdown
 - Eliminate a terrorist attack as a possibility
 - All entrances and exits closed
 - All individuals may be instructed to leave the campus grounds and to seek shelter inside buildings

Note: These mitigation plans for a radiation release assume an accidental non-terrorist event.

Severe Storm (Hailstorm, Heavy Rains, Lightning, Windstorm)

For heavy rains:

- At the Alert (48-hour) Point
 - EMP Activated
 - IRT Contacted
 - EMT Notified
- At the Watch (36-hour) Point
 - Secure the campus
 - Secure building contents (flood damage)
 - Test all backup environmental equipment
- Within the Warning (24-hour) Point
 - If not already accomplished, activate the EOC
 - University Police and critical personnel take cover at secure location before situation becomes dangerous

Severe Winter Storm

For a severe winter storm including severe snow and ice conditions the following suggested action steps exist:

- At the Alert (48-hour) Point
 - EMP Activated
 - IRT Contacted
 - EMT Notified
- At the Watch (36-hour) Point
 - Activate EOC
 - Secure the campus
 - Test all backup environmental equipment
- Within the Warning (24-hour) Point
 - Close the University long before travel conditions become dangerous
 - University Police and critical personnel take cover at secure location before situation becomes dangerous

Terrorists

For Airplane Crash:

- After the Event
 - EMP Activated
 - IRT Contacted
 - EMT Notified

For Armed Hostile Intruder:

- After the Event
 - EMP Activated
 - IRT Contacted

- EMT Notified
- EOC Activated
- Eliminate a terrorist attack as a possibility
- Security establishes a perimeter around the affected areas
- Consider an emergency lockdown of the immediate area
- If the threat is outside, cancel all outdoor events

For Bomb, Chemical, Radiation, or Biological Release Inside a Building:

- During the Event
 - EMP Activated
 - IRT Contacted
 - EMT Notified
 - EOC Activated
 - Eliminate hoax as a possibility
 - Affected buildings evacuate
 - Consider a campus-wide evacuation
 - All entrances closed
 - Ventilation systems in affected buildings shut down
 - Personnel from affected buildings are quarantined

For Bomb, Chemical, Radiation, or Biological Release Outside on Campus:

- During the Event
 - EMP Activated
 - IRT Contacted
 - EMT Notified
 - EOC Activated
 - Eliminate hoax as a possibility
 - Campus not evacuated/everyone remains indoors
 - All entrances closed
 - Ventilation systems in affected buildings shut down
 - Personnel from affected buildings are quarantined

For Bomb, Chemical, Radiation, or Biological Release Off Campus:

- During the Event
 - EMP Activated
 - IRT Contacted
 - EMT Notified
 - EOC Activated
 - Eliminate hoax as a possibility
 - All entrances and exits closed
 - All individuals may be instructed to leave grounds and to seek shelter inside buildings
 - Ventilation systems may be shut down

Tornado

- At the Watch Point
 - Facilities Services assigns someone to continually monitor weather reports
- At the Warning Point

- Weather reports continually monitored
- Facilities Services assignments someone with communication equipment to observe weather conditions
- After the Storm
 - EMP Activated
 - IRT Contacted
 - EMT Notified
 - Activate the EOC

Toxic Chemical Release

For Release Inside a Building:

- After the Event
 - EMP Activated
 - IRT Contacted
 - EMT Notified
 - Activate the EOC
 - Eliminate a terrorist attack as a possibility
 - Consider evacuating campus
 - All entrances closed
 - Ventilation systems in affected buildings shutdown
 - Personnel in affected buildings are quarantined

For Release Outside a Building on Campus:

- After the Event
 - EMP Activated
 - IRT Contacted
 - EMT Notified
 - Activate the EOC
 - Eliminate a terrorist attack as a possibility
 - Campus not evacuated/everyone remains indoors
 - All entrances closed
 - All ventilation systems shutdown
 - Personnel in affected buildings are quarantined

For Release Off Campus:

- After the Event
 - EMP Activated
 - IRT Contacted
 - EMT Notified
 - Activate the EOC
 - All ventilation systems shutdown
 - Eliminate a terrorist attack as a possibility
 - All entrances and exits closed
 - All individuals may be instructed to leave the campus grounds and to seek shelter inside buildings

Note: These mitigation plans for a toxic chemical release assume an accidental non-terrorist event.

Wildfire

No current mitigation plan exists.

Also existing for each department at the University of Tennessee is a Continuity Operations Plan (COOP), which includes inter-departmental procedures for handling hazardous materials, emergency communications systems, emergency access to information and systems, mitigation strategies, schedule for annual updates, principal assignments, and recovery procedures, among other things. For an example of what each department's plan includes refer to an example of the COOP for Civil and Environmental Engineering in the appendix.

5.0 Mitigation Strategy

The University of Tennessee Mitigation Plan includes recommendations for how UTK can lessen the vulnerability of people, infrastructure, property, and cultural resources to potential disasters. For this plan, it was decided that all events with an impact rating of 4 are medium and 3 or less are low priority and are not addressed in the scope of this report due to the reality that all events will not be able to be mitigated due to lack of university funds. Focusing on those events with the most impact is a more practical way to mitigate events at UTK. Therefore, this section will include mitigation strategies for the event of a severe storm and earthquake. Shown in Table 32 is a list of all the events, their total impact rating, and if a mitigation plan in the *Campus Emergency Management Plan* exists. This table shows that for all high priority events (those with an impact rating of 5 or greater), a mitigation plan does currently exist in the *Campus Emergency Management Plan*, however, the plans are not extremely detailed. The purpose of this section is to elaborate on the existing mitigation plans.

Table 33: Summary of Mitigating Events

Event	Impact Rating	Existing Mitigation Plan
Severe Storm (Lightning, Heavy Rains)	7	Yes
Earthquake (M_w of 4-5)	6	Yes
Severe Storm (Hail, High Winds)	5	Yes
Earthquake (M_w of 5-6)	5	Yes
Severe Winter Storm	4	Yes
Toxic Chemical Release	4	Yes
Dam Failure	4	No
Terrorists	4	Yes
Tornado	4	Yes
Drought	3	No
Extreme Heat	3	No
Hurricane	3	Yes
Land Subsidence	3	No
Radiation Fallout	3	Yes
Wildfire	3	No
Expansive Soils	2	No
Flood	2	No
Landslide	2	No

SEVERE STORM MITIGATION ACTIONS

In order to mitigate potential losses to the specific aspect of lightning during a severe storm, this plan recommends that lightning rods are put up in certain critical locations, specifically the electrical substation (the source of 80% of UTK's electricity). Lightning rods could also be of use at the fiber optics vault location (the source of all computer systems, security systems, most telephones, and some heating and lighting on campus) as well as the Steam Plant Turbine Building, Steam Plant Gear Switching Building, and Steam Plant and Addition (the sources of almost all the heat on campus) (Sherrell, 2007). A lightning strike at any of these locations without a lightning rod could currently paralyze campus operation.

Also, on a more specific note of the electrical substation, a different plan needs to be devised in order to allow for redundancy of campus power supply so that the electrical substation, or any other location, is not the primary source of power. This means that if an event were to occur that did take down one of the power locations, the majority of power throughout campus would not be lost because the power would be coming from several locations, thus would have redundancy.

EARTHQUAKE MITIGATION ACTIONS

In order to mitigate potential losses to various intensities of earthquakes, several suggested actions exist. First and foremost, to prevent any future buildings from being vulnerable to earthquakes, this report recommends that all new buildings constructed on campus are designed to the most current seismic code. As far as already-existing buildings go, the buildings shown in Table 33 are the most vulnerable to seismic damage due to the fact that masonry frames and wood frames are the most vulnerable during an earthquake. Some of these buildings are critical and some are not. Those that are critical are mostly all critical for being historical, in which case not much can be done to protect the entire building from earthquake damage without extensive time and funds. However, four buildings, the Hoskins Library Chiller Building, Music Chiller Building, Reese Hall Chiller Building, and Facilities Services Maintenance Shops and Warehouse are all critical for housing utilities. It is recommended for these structures that all important utilities and mechanical equipment be secured and/or protected as best as possible so that in the event of an earthquake the equipment is not thrown, broken, or damaged in a way to disrupt utilities flow to campus. For all other facilities vulnerable to an earthquake, it is recommended that any items deemed valuable either not be stored in these buildings in the future, moved to another more secure location if they currently are stored there, or secure these items to a wall or floor in order to minimize movement during an earthquake that would damage valuables.

Table 34: Buildings Most Vulnerable to Earthquake

Building	Critical/Non-critical	Type of Construction
907/909 21st St Duplex	Critical (Historic)	Masonry Frame
Tom Black Track Facilities Building	Non-critical	Masonry Frame
Tom Black Track Pressbox	Non-critical	Masonry Frame
Tom Black Track Pressbox 2	Non-critical	Masonry Frame
Tom Black Track Storage Building	Non-critical	Masonry Frame
Fulton Bottoms and Storage Shed	Non-critical	Masonry Frame
Tyson Field and Storage Shed	Non-critical	Masonry Frame
Child Development Center	Critical (Historic)	Masonry Frame
Temple Court	Critical (Historic)	Masonry Frame
Ceramics Annex	Critical (Historic)	Masonry Frame
Austin Peay Building	Critical (Historic)	Masonry Frame
Veterinary Teaching Hospital	Non-critical	Masonry Frame
Berry Hall	Critical (Historic)	Masonry Frame
Estabrook Hall	Critical (Historic)	Masonry Frame
Biosystems Eng. And Environmental Sci Lab	Non-critical	Masonry Frame
Carriage House	Critical (Historic)	Masonry Frame
South College	Critical (Historic)	Masonry Frame
Forestry Products	Non-critical	Masonry Frame
Shade House	Non-critical	Masonry Frame
Equine Animal Building	Non-critical	Masonry Frame
Animal Science Laboratory	Critical (Historic)	Masonry Frame
Greenhouse TVA	Critical (Historic)	Masonry Frame
Forest Genetics Greenhouse (17)	Non-critical	Masonry Frame
Laurel Apts Pool House	Non-critical	Masonry Frame
Sigma Chi Fraternity House	Non-critical	Masonry Frame
Sigma Phi Epsilon Fraternity House	Non-critical	Masonry Frame
Hoskins Library Chiller Building	Critical (Utilities to protect irreplaceable collections)	Masonry Frame
Music Chiller Building	Critical (Utilities to protect irreplaceable collections)	Masonry Frame
Reese Hall Chiller	Critical (Utilities for residence hall)	Masonry Frame
Tyson Alumni Center	Critical (Historic)	Masonry Frame

Table 33, cont.

Building	Critical/Non-critical	Type of Construction
Engineering Annex	Non-critical	Masonry Frame
Lake Avenue Parking Garage	Non-critical	Masonry Frame
Publications and Services Building	Non-critical	Masonry Frame
Facilities Services Maintenance Shops and Warehouse	Critical (Utilities)	Masonry Frame
International House	Non-critical	Masonry Frame
Neyland Stadium	Critical (Historic)	Steel Braced Frame/Masonry
Visitors' Center	Critical (Historic)	Wood Frame
English Language Institute-2019 Terrace	Critical (Historic)	Wood Frame
Environmental Health and Safety-2111 Terrace	Critical (Historic)	Wood Frame
Pediatric Language Clinic	Critical (Historic)	Wood Frame
Growth Chamber Laboratory	Non-critical	Wood Frame
Hopecote	Critical (Historic)	Wood Frame
Knoxville W.A.V.E.	Critical (Historic)	Wood Frame
Radiological Safety	Critical (Historic)	Wood Frame
908 21st Street	Critical (Historic)	Wood Frame
English Language Institute-907 Mountcastle	Critical (Historic)	Wood Frame
Environmental Health and Safety-22nd Street	Critical (Historic)	Wood Frame
Interior Design Resource Center	Critical (Historic)	Wood Frame
Music Department Annex	Critical (Historic)	Wood Frame
Office of Equity and Diversity	Critical (Historic)	Wood Frame
Construction Industry Research and Policy Center	Non-critical	Wood Frame
Architecture Research Annex	Non-critical	Wood Frame
Student Success Center	Critical (Historic)	Wood Frame
Student Counseling Services	Critical (Historic)	Wood Frame
ULA Love Doughty Carousel Theatre	Critical (Historic)	Wood Frame
Associate Provost for Faculty and Student Diversity	Non-critical	Wood Frame/Masonry Veneer

Table 33, cont.

Building	Critical/Non-critical	Type of Construction
Office of Research and Information Technology	Non-critical	Wood Frame/Masonry Veneer
Phi Delta Theta	Non-critical	Wood Frame/Masonry Veneer
1821 Andy Holt Avenue	Non-critical	Wood Frame/Masonry Veneer
Environment and Landscape Laboratory	Critical (Historic)	Wood Frame/Masonry Veneer
2106 Terrace Avenue	Non-critical	Wood Frame/Masonry Veneer

Also of concern during earthquakes are toxic chemical spills in storage locations. These locations are as follows:

- Veterinary Teaching Hospital
- Plant Sciences Biotechnology Building
- Dabney-Buehler Hall
- Dougherty Engineering Building
- Science and Engineering Building
- Walters Life Sciences Building
- Hesler Biology Building and Greenhouse
- Perkins Hall
- Jessie Harris Building
- Neyland Drive Biology Annex
- Engineering Annex

It is recommended that all cabinets containing toxic chemicals be anchored to the wall and/or floor so that during an earthquake, movement of these chemicals is minimized and the likelihood of spillage is decreased.

A further, more detailed analysis of possible earthquake scenarios and how they would affect each building on campus is recommended, but is beyond the scope of this report.

DAM FAILURE MITIGATION ACTIONS

While dam failure is not an event of high impact rating, it is notable because it is of medium impact rating and does not currently have a mitigation plan. Not much can be done to protect buildings and their contents in the event of a dam failure. Measures can be taken to protect some contents and buildings from flooding due to dam failure, but these measures are not practical or economically feasible. However, one thing of most importance during dam failure is human life, which is able to be protected. In the event of a dam failure, the waters would likely take 15 to 20 minutes to reach campus from the upstream breach, giving enough time to warn those people located in lower elevation areas to quickly move to higher elevations away from the Tennessee River. This alert could be feasibly given via text message, as is done all over many campuses throughout the United States in the event of a terrorist or gunman. Also, for those people on campus who do not have access to text messages, an “in-person” warning system would be beneficial in those areas located closest to the Tennessee River, such as emergency personnel driving throughout these areas while broadcasting a warning over a loudspeaker.

TORNADO MITIGATION ACTIONS

A tornado event already has a basic mitigation plan included in the *Campus Emergency Management Plan*. However, elaborating on that basic plan, this plan suggests that in

order to better protect lives during this event, preventative educative actions should be taken. This includes identifying “safe” locations in highly populated buildings, such as residence halls, student centers, and buildings containing large numbers of offices and classrooms and then educating faculty, staff, and students on the whereabouts of these locations and emphasizing the necessity to go to them in the event of a tornado.

6.0 Plan Adoption, Implementation and Maintenance

The purpose of adopting this Multi-Hazard Mitigation DRU Plan is for the University to maintain its eligibility for FEMA Pre-Disaster Mitigation and Hazard Mitigation Grant Programs, raise public awareness of the plan, and formalize the plan's implementation. The adoption of this plan completes the Formal Plan Adoption step in the plan development process.

Implementing this plan and maintaining its goals is necessary for success of the hazard mitigation planning process. This involves taking various actions based on priority. This plan provides recommendations for actions and priorities, but the ultimate decision will be up to Facilities Services and the members of this project's advisory committee at the University of Tennessee, Knoxville. Some actions may be of higher priority due to vulnerability of campus, however, actions requiring low funding will more than likely take precedence over those requiring greater funding.

A recommended implementation mechanism is to incorporate this hazard mitigation plan's recommendations into other university plans, such as campus master plans and/or capital improvement budgeting. Along with these efforts, it is recommended to maintain a regular attempt at obtaining funds in order to accomplish some of the more expensive recommended actions.

Plan maintenance requires a continuing effort to monitor and evaluate the implementation of this plan, and to update the plan based on progress or changing circumstances. In order to better monitor the implementation of this plan UTK should review this plan yearly or after a hazard event. Evaluation of this progress can be attained by monitoring changes in vulnerability (due to implementing recommended actions, failed mitigation actions, or new development). Plan updates should include, if applicable, the following subjects:

- Changes in vulnerability due to project implementation
- Documentation of effective and/or non-effective mitigation actions
- Documentation of new hazards
- Incorporation of new data on hazards and campus risk
- Incorporation of new mitigation plans and policies
- Incorporation of growth and developmental changes to UTK

The update process provides an opportunity to make successes of the plan public and to allow for public input and comments.

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Appendix

APPENDIX A: RAW DATA

Drought Raw Data

Date	Condition		Date	Condition		Date	Condition		Date	Condition		Date	Condition
1/3/98	near normal		1/2/99	near normal		1/1/00	near normal		1/6/01	near normal		1/5/02	near normal
1/10/98	unusual moist spell		1/9/99	near normal		1/8/00	near normal		1/13/01	near normal		1/12/02	near normal
1/17/98	very moist spell		1/16/99	near normal		1/15/00	near normal		1/20/01	near normal		1/19/02	near normal
1/24/98	very moist spell		1/23/99	near normal		1/22/00	near normal		1/27/01	near normal		1/26/02	unusual moist spell
1/31/98	very moist spell		1/30/99	near normal		1/29/00	near normal		2/3/01	near normal		2/2/02	near normal
2/7/98	very moist spell		2/6/99	near normal		2/5/00	near normal		2/10/01	near normal		2/9/02	near normal
2/14/98	very moist spell		2/13/99	near normal		2/12/00	near normal		2/17/01	near normal		2/16/02	near normal
2/21/98	unusual moist spell		2/20/99	near normal		2/19/00	near normal		2/24/01	near normal		2/23/02	near normal
2/28/98	unusual moist spell		2/27/99	near normal		2/26/00	near normal		3/3/01	near normal		3/2/02	near normal
3/7/98	unusual moist spell		3/6/99	near normal		3/4/00	near normal		3/10/01	near normal		3/9/02	near normal
3/14/98	unusual moist spell		3/13/99	near normal		3/11/00	near normal		3/17/01	near normal		3/16/02	near normal
3/21/98	very moist spell		3/20/99	near normal		3/18/00	near normal		3/24/01	near normal		3/23/02	near normal
3/28/98	unusual moist spell		3/27/99	near normal		3/25/00	near normal		3/31/01	near normal		3/30/02	near normal
4/4/98	unusual moist spell		4/3/99	near normal		4/1/00	near normal		4/7/01	near normal		4/6/02	near normal
4/11/98	unusual moist spell		4/10/99	near normal		4/8/00	near normal		4/14/01	near normal		4/13/02	near normal
4/18/98	very moist		4/17/99	near		4/15/00	near normal		4/21/01	moderate		4/20/02	near

4/25/98	spell very moist spell	4/24/99	normal near normal	4/22/00	near normal	4/28/01	drought moderate drought	4/27/02	normal near normal
5/2/98	very moist spell	5/1/99	near normal	4/29/00	near normal	5/5/01	moderate drought	5/4/02	near normal
5/9/98	very moist spell	5/8/99	near normal	5/6/00	near normal	5/12/01	moderate drought	5/11/02	near normal
5/16/98	very moist spell	5/15/99	near normal	5/13/00	near normal	5/19/01	severe drought	5/18/02	near normal
5/23/98	unusual moist spell	5/22/99	near normal	5/20/00	near normal	5/26/01	moderate drought	5/25/02	near normal
5/30/98	unusual moist spell	5/29/99	near normal	5/27/00	near normal	6/2/01	moderate drought	6/1/02	near normal
6/6/98	very moist spell	6/5/99	near normal	6/3/00	near normal	6/9/01	moderate drought	6/8/02	near normal
6/13/98	very moist spell	6/12/99	moderate drought	6/10/00	near normal	6/16/01	moderate drought	6/15/02	near normal
6/20/98	very moist spell	6/19/99	moderate drought	6/17/00	near normal	6/23/01	moderate drought	6/22/02	moderate drought
6/27/98	unusual moist spell	6/26/99	near normal	6/24/00	near normal	6/30/01	moderate drought	6/29/02	moderate drought
7/4/98	unusual moist spell	7/3/99	near normal	7/1/00	near normal	7/7/01	near normal	7/6/02	moderate drought
7/11/98	near normal	7/10/99	near normal	7/8/00	near normal	7/14/01	moderate drought	7/13/02	near normal
7/18/98	near normal	7/17/99	near normal	7/15/00	near normal	7/21/01	moderate drought	7/20/02	moderate drought
7/25/98	near normal	7/24/99	near normal	7/22/00	near normal	7/28/01	near normal	7/27/02	moderate drought
8/1/98	near normal	7/31/99	near normal	7/29/00	near normal	8/4/01	near normal	8/3/02	moderate drought
8/8/98	near normal	8/7/99	near normal	8/5/00	near normal	8/11/01	near normal	8/10/02	moderate drought
8/15/98	near normal	8/14/99	near normal	8/12/00	near normal	8/18/01	near normal	8/17/02	moderate drought
8/22/98	near normal	8/21/99	near normal	8/19/00	near normal	8/25/01	near normal	8/24/02	moderate drought
8/29/98	near normal	8/28/99	near normal	8/26/00	near normal	9/1/01	near normal	8/31/02	moderate drought

9/5/98	moderate drought		9/4/99	near normal		9/2/00	near normal		9/8/01	near normal		9/7/02	severe drought
9/12/98	moderate drought		9/11/99	moderate drought		9/9/00	near normal		9/15/01	near normal		9/14/02	severe drought
9/19/98	severe drought		9/18/99	moderate drought		9/16/00	near normal		9/22/01	near normal		9/21/02	near normal
9/26/98	severe drought		9/25/99	moderate drought		9/23/00	near normal		9/29/01	near normal		9/28/02	near normal
10/3/98	severe drought		10/2/99	moderate drought		9/30/00	near normal		10/6/01	near normal		10/5/02	near normal
10/10/98	moderate drought		10/9/99	near normal		10/7/00	near normal		10/13/01	near normal		10/12/02	near normal
10/17/98	severe drought		10/16/99	near normal		10/14/00	near normal		10/20/01	near normal		10/19/02	near normal
10/24/98	severe drought		10/23/99	near normal		10/21/00	near normal		10/27/01	near normal		10/26/02	near normal
10/31/98	moderate drought		10/30/99	near normal		10/28/00	near normal		11/3/01	near normal		11/2/02	unusual moist spell
11/7/98	moderate drought		11/6/99	near normal		11/4/00	near normal		11/10/01	near normal		11/9/02	unusual moist spell
11/14/98	near normal		11/13/99	near normal		11/11/00	near normal		11/17/01	near normal		11/16/02	very moist spell
11/21/98	moderate drought		11/20/99	near normal		11/18/00	near normal		11/24/01	near normal		11/23/02	very moist spell
11/28/98	moderate drought		11/27/99	near normal		11/25/00	near normal		12/1/01	near normal		11/30/02	very moist spell
12/5/98	moderate drought		12/4/99	near normal		12/2/00	near normal		12/8/01	near normal		12/7/02	very moist spell
12/12/98	near normal		12/11/99	near normal		12/9/00	near normal		12/15/01	near normal		12/14/02	very moist spell
12/19/98	near normal		12/18/99	near normal		12/16/00	near normal		12/22/01	near normal		12/21/02	very moist spell
12/26/98	near normal		12/25/99	near normal		12/23/00	near normal		12/29/01	near normal		12/28/02	very moist spell
Date	Condition		Date	Condition		Date	Condition		Date	Condition		Date	Condition
1/4/03	very moist spell		1/3/04	extremely moist		1/1/05	extremely moist		1/7/06	near normal		1/6/07	near normal
1/11/03	unusual		1/10/04	extremely		1/8/05	extremely		1/14/06	near		1/13/07	near

	moist spell			moist			moist			normal			normal
1/18/03	unusual moist spell		1/17/04	extremely moist		1/15/05	extremely moist		1/21/06	near normal		1/20/07	near normal
1/25/03	near normal		1/24/04	extremely moist		1/22/05	extremely moist		1/28/06	near normal		1/27/07	near normal
2/1/03	unusual moist spell		1/31/04	extremely moist		1/29/05	extremely moist		2/4/06	near normal		2/3/07	near normal
2/8/03	unusual moist spell		2/7/04	extremely moist		2/5/05	very moist spell		2/11/06	near normal		2/10/07	near normal
2/15/03	very moist spell		2/14/04	extremely moist		2/12/05	very moist spell		2/18/06	near normal		2/17/07	near normal
2/22/03	extremely moist		2/21/04	extremely moist		2/19/05	very moist spell		2/25/06	near normal		2/24/07	near normal
3/1/03	extremely moist		2/28/04	extremely moist		2/26/05	very moist spell		3/4/06	near normal		3/3/07	near normal
3/8/03	extremely moist		3/6/04	extremely moist		3/5/05	very moist spell		3/11/06	near normal		3/10/07	near normal
3/15/03	very moist spell		3/13/04	extremely moist		3/12/05	very moist spell		3/18/06	near normal		3/17/07	near normal
3/22/03	very moist spell		3/20/04	extremely moist		3/19/05	unusual moist spell		3/25/06	near normal		3/24/07	near normal
3/29/03	very moist spell		3/27/04	very moist spell		3/26/05	unusual moist spell		4/1/06	near normal		3/31/07	moderate drought
4/5/03	near normal		4/3/04	unusual moist spell		4/2/05	very moist spell		4/8/06	near normal		4/7/07	moderate drought
4/12/03	very moist spell		4/10/04	unusual moist spell		4/9/05	unusual moist spell		4/15/06	near normal		4/14/07	near normal
4/19/03	very moist spell		4/17/04	unusual moist spell		4/16/05	unusual moist spell		4/22/06	near normal		4/21/07	moderate drought
4/26/03	unusual moist spell		4/24/04	near normal		4/23/05	near normal		4/29/06	near normal		4/28/07	moderate drought
5/3/03	unusual moist spell		5/1/04	near normal		4/30/05	unusual moist spell		5/6/06	near normal		5/5/07	moderate drought

5/10/03	extremely moist		5/8/04	near normal		5/7/05	near normal		5/13/06	near normal		5/12/07	moderate drought
5/17/03	extremely moist		5/15/04	near normal		5/14/05	near normal		5/20/06	near normal		5/19/07	moderate drought
5/24/03	extremely moist		5/22/04	near normal		5/21/05	near normal		5/27/06	near normal		5/26/07	severe drought
5/31/03	extremely moist		5/29/04	near normal		5/28/05	near normal		6/3/06	near normal		6/2/07	severe drought
6/7/03	extremely moist		6/5/04	near normal		6/4/05	near normal		6/10/06	near normal		6/9/07	severe drought
6/14/03	extremely moist		6/12/04	near normal		6/11/05	near normal		6/17/06	near normal		6/16/07	extreme drought
6/21/03	extremely moist		6/19/04	near normal		6/18/05	near normal		6/24/06	moderate drought		6/23/07	extreme drought
6/28/03	very moist spell		6/26/04	near normal		6/25/05	near normal		7/1/06	moderate drought		6/30/07	extreme drought
7/5/03	extremely moist		7/3/04	near normal		7/2/05	near normal		7/8/06	moderate drought		7/7/07	extreme drought
7/12/03	extremely moist		7/10/04	near normal		7/9/05	near normal		7/15/06	moderate drought			
7/19/03	extremely moist		7/17/04	near normal		7/16/05	near normal		7/22/06	moderate drought			
7/26/03	extremely moist		7/24/04	near normal		7/23/05	near normal		7/29/06	moderate drought			
8/2/03	extremely moist		7/31/04	near normal		7/30/05	near normal		8/5/06	moderate drought			
8/9/03	extremely moist		8/7/04	near normal		8/6/05	near normal		8/12/06	moderate drought			
8/16/03	extremely moist		8/14/04	near normal		8/13/05	near normal		8/19/06	moderate drought			
8/23/03	extremely moist		8/21/04	near normal		8/20/05	near normal		8/26/06	moderate drought			
8/30/03	extremely moist		8/28/04	near normal		8/27/05	near normal		9/2/06	near normal			
9/6/03	extremely moist		9/4/04	near normal		9/3/05	near normal		9/9/06	near normal			
9/13/03	extremely		9/11/04	near		9/10/05	near normal		9/16/06	near			

	moist			normal				normal				
9/20/03	extremely moist		9/18/04	extremely moist		9/17/05	near normal		9/23/06	near normal		
9/27/03	extremely moist		9/25/04	very moist spell		9/24/05	near normal		9/30/06	near normal		
10/4/03	extremely moist		10/2/04	very moist spell		10/1/05	near normal		10/7/06	near normal		
10/11/03	extremely moist		10/9/04	very moist spell		10/8/05	near normal		10/14/06	near normal		
10/18/03	extremely moist		10/16/04	very moist spell		10/15/05	near normal		10/21/06	near normal		
10/25/03	extremely moist		10/23/04	extremely moist		10/22/05	near normal		10/28/06	unusual moist spell		
11/1/03	extremely moist		10/30/04	extremely moist		10/29/05	near normal		11/4/06	unusual moist spell		
11/8/03	extremely moist		11/6/04	extremely moist		11/5/05	near normal		11/11/06	unusual moist spell		
11/15/03	extremely moist		11/13/04	extremely moist		11/12/05	moderate drought		11/18/06	unusual moist spell		
11/22/03	extremely moist		11/20/04	extremely moist		11/19/05	near normal		11/25/06	unusual moist spell		
11/29/03	extremely moist		11/27/04	extremely moist		11/26/05	near normal		12/2/06	unusual moist spell		
12/6/03	extremely moist		12/4/04	extremely moist		12/3/05	near normal		12/9/06	near normal		
12/13/03	extremely moist		12/11/04	extremely moist		12/10/05	near normal		12/16/06	near normal		

12/20/03	extremely moist		12/18/04	extremely moist		12/17/05	near normal		12/23/06	near normal			
12/27/03	extremely moist		12/25/04	extremely moist		12/24/05	near normal		12/30/06	near normal			

APPENDIX B: MISCELLANEOUS INFORMATION

Fujita Scale and EF Scale

Fujita Scale			EF Scale	
F Number	Fastest 1/4-mile (mph)	3 Second Gust (mph)	EF Number	3 Second Gust (mph)
0	40-72	45-78	0	65-85
1	73-112	79-117	1	86-110
2	113-157	118-161	2	111-135
3	158-207	162-209	3	136-165
4	208-260	210-261	4	166-200
5	261-318	262-317	5	Over 200

COOP for Civil and Environmental Engineering Department

THE UNIVERSITY *of* TENNESSEE 

KNOXVILLE

Department

of

Civil and Environmental Engineering

Head of Operations	Developer		Date Plan Finalized
	Dayakar Penumadu, (Interim Department Head) Jane Taylor (Business Manager)		October 26, 2007
	Name	Phone Number	Alt. Phone Number
	Dayakar Penumadu dpenumad@utk.edu	865-974-2503	865-974-7700
Email Address			

A. Department's Critical Functions

Critical Function:	Teaching		
	Primary	Alternate	Second Alternate
	Richard Bennett 865-974-7540	Chris Cox 865-974-7729	Dayakar Penumadu 865-974-2503
Critical Function:	Research		
	Primary	Alternate	Second Alternate
	Dayakar Penumadu 865-974-2503	Chris Cox 865-974-7729	Richard Bennett 865-974-7540

B. Department's Leadership Succession

Department Head	Name	Phone Number & Email Address	Alt Phone Number & Email Address
First Successor	Dayakar Penumadu	865-974-2503 dpenumad@utk.edu	865-974-7700
Second Successor	Richard Bennett	865-974-7540 rmbennett@utk.edu	

C. Employees with Special Skills/Knowledge

Name	Skills/Knowledge	Current Position	Contact Information
Jane Taylor	IRIS	Business Manager	865-974-7727
Marion Dills	IRIS	Accounting Spec. III	865-974-7702
Sharon Hale	Chemical Inventory	Senior Res. Assistant	865-974-7719
Ken Thomas	Ability to make emergency repairs	Electrical & Instrumentation Shop Superintendent	865-974-2329

D. Department Objectives

The mission of the Department of Civil and Environmental Engineering is three-fold: (1) to educate the engineers of tomorrow such that they are prepared to practice in a global economy; (2) to contribute to state and national economic growth through effective and visible research; and (3) to serve the public through the efforts of individual faculty and students.

E. More Contact Information

	Name	Phone Number	Address
COOP Contact	Dayakar Penumadu	865-966-4859 (H) 865-335-5980 (C)	UTK: Perkins Hall, Room 223 Home: 12800 Big Horn Lane, Knoxville, TN 37922
Email address	Richard Bennett	865-693-6550 (H)	Perkins Hall, Room 221
Dept. locations	dpenumad@utk.edu	rmbennett@utk.edu	
	Perkins Hall, Room 223		

Principal nature of department:

Instruction

Laboratory Research

Administration

Research Support

A list of hazardous chemicals and supplies stored/used in department is listed at this website: <http://www.pp.utk.edu/ChemInv/default.htm>.

V. Emergency Communication Systems

To rapidly communicate with employees in an emergency, the Department of Civil and Environmental Engineering will maintain a phone number and e-mail list and insure personnel contact information is updated in the IRIS system. The department will use the following communication systems for backup, after hours, when not on campus, or for other contingencies.

Telephone

Email

Departmental web site

A. Emergency Access to Information and Systems

Remote access to Blackboard is available to all faculty from their home computers which will give them the ability to e-mail all the students in classes being taught in our department.

The department head and associate department head has a list of all the faculty and staff e-mail addresses and have the ability to send e-mails from their homes.

The department head and associate department head has a telephone list of all the faculty and staff and have the ability to telephone from their homes.

B. Key Internal (Within UT) Dependencies

Dependency	Approval on documents	
Provider	College of Engineering	
Dependency	Research Proposal Approval	
Provider	Office of Research and Grants/Contract	
Dependency	Human Resource document approval	
Provider	Human Resources	

C. Key External Dependencies

Dependency (Product or service)	Gases for labs	
	Primary	Alternate
Supplier/Provider	Airgas	Holston Gas
Phone Numbers	865-584-6390	865-573-1917

Dependency (Product or service)	Office Supplies	
	Primary	Alternate
Supplier/Provider	Staples	Office Depot
Phone Numbers	865-560-3150	865-558-6024
Dependency (Product or service)	Computer Supplies	
	Primary	Alternate
Supplier/Provider	CompUSA	Newegg
Phone Numbers	888-782-7334	800-390-1119
Dependency (Product or service)	Laboratory Supplies	
	Primary	Alternate
Supplier/Provider	Fisher Scientific	Cole Parmer
Phone Numbers	800-766-7000	800-323-4340
Dependency (Product or service)	Miscellaneous Supplies	
	Primary	Alternate
Supplier/Provider	Lowe's	Home Depot
Phone Numbers	865-690-9770	865-691-9500

VI. Mitigation Strategies

The Department of Civil and Environmental Engineering will keep in stock the following supplies to last approximately 2 to 4 weeks:

Gases used in laboratories

Most commonly used laboratory supplies

Most commonly used office supplies

Supplies used frequently for repairs

VII. Exercising Plan & Informing Staff

The Department of Civil and Environmental Engineering Emergency Management of Operations Plan will be shared with the faculty and staff and an exercise to test the plan and maintain awareness will be implemented annually at the first faculty and staff meeting in the fall.

Scheduled Test	Scheduled Test Dates
Staff orientation meeting	November 20, 2007
Interdepartmental exercise	January 15, 2008
Emergency communication test	December 14, 2007
Off site information access test	Spring Semester
Unscheduled work at home day	December 14, 2007

Annual Update Activities

ANNUAL UPDATE ACTIVITIES	PERSON RESPONSIBLE		Completion
	Primary	Alternate	DATE
Attend Annual Training Meeting	Dayakar Penumadu	Jane Taylor	10/18/07
Schedule Unit Review Meeting	Dayakar Penumadu	Richard Bennett	11/20/07
Update Unit Plan	Dayakar Penumadu	Jane Taylor	October 2008
Notify Facilities Services of any building leaks or breaches in building integrity in your area.	Ken Thomas	Larry Roberts	11/01/07
Establish a list of supplies & vendors for specialized recovery operations	Jane Taylor	Marion Dills	11/01/07
Distribute copies of the updated Unit Plan	Jane Taylor	Dayakar Penumadu	11/01/07
Forward an electronic copy of the updated Unit Plan to the Emergency Management Coordinator	Dayakar Penumadu	Jane Taylor	11/01/07

VII. Recovery After the Emergency

The plan for the Department of Civil and Environmental Engineering to fully resume operations as soon as possible after an emergency will be to immediately have a faculty and staff meeting of all who are available. At the meeting individuals will be identified to contact appropriate people to accommodate the department's needs. Faculty will be assigned to contact faculty who are not available to teach and make arrangements for all classes to be held and for all students in classes to be contacted through BlackBoard. Staff will make a list of the department's immediate needs and assigned staff will be responsible accordingly. If faculty and staff have emotional needs they will be encouraged to contact the Employee Assistance Program (800-308-4934) which offers UT employees six free counseling sessions.

A. Special Considerations for Department

In the event of a pandemic influenza, faculty and staff will be asked not to report to work if they are sick. Employees will be encouraged to communicate through telephone or email as much as possible to avoid transmitting the disease.

Vita

Kelli Taylor was born in Nashville, Tennessee, on August 17, 1984. She was raised in Hermitage, Tennessee and attended elementary school there at Tulip Grove Elementary. At the beginning of middle school she then moved to Pleasant View, Tennessee and attended Coopertown Middle School and Springfield High School, where she graduated in 2002. She then moved on to the University of Tennessee, Knoxville, and received a B.S. in Civil Engineering in 2006. She is currently pursuing her M.S. in Structural Engineering, also at the University of Tennessee.