# Brazoria Drainage District No. 4
# 2011 Hazard Mitigation Plan

October, 2011

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# Executive Summary

Brazoria Drainage District No.4 (BDD4) plans to develop an All Hazard Mitigation Plan because of an increasing awareness that natural disasters, especially flood hazards, have affected and may continue to affect many people and property in their jurisdiction area. BDD4 will work with key stakeholders, including the general public, to assess hazards and provide a plan to potentially mitigate against future hazards. The plan will include all hazards and will be developed in accordance with current FEMA and State planning requirements.

The Plan was prepared by a Mitigation Planning Committee (MPC) composed of staff representatives from BDD4 Operations and Management, an engineering consultant and a mitigation consultant. The MPC followed a process to collect, analyze, prioritize and prepare data and information necessary for incorporation to the Plan. Detailed discussion of the process can be found in Section 2 of this Plan. In addition to the MPC, a larger stakeholder group that included staff representatives from the City of Pearland and Brookside Village, local adjacent drainage districts, and the general public were asked to review and provide their expertise to the drafting of the Plan.

The HMP was completed in October 2011 and set the stage for long-term disaster resistance through identification of actions that will, over time, reduce the exposure of people and property to natural hazards. Sections of the Plan:

Provide overviews of the hazards that threaten Brazoria Drainage District No. 4 jurisdiction,
Characterize the people and property that are exposed to some risk due to those hazards,
Outline the planning process,
Describe how hazards are recognized in BDD4's normal processes and functions, and
Identify the status and prioritize mitigation action items.

Section 5 of this Plan provides an overview of past hazard events and associated losses in Brazoria Drainage District No. 4. The following is a list of hazards overviewed in Section 5:

- Tornadoes
- Thunderstorms/High Winds
- Hurricanes and Tropical Storms
- Extreme Heat
- Drought
- Wildland Fire
- Winter Storm
- Earthquake/Seismic
- Landslide

Flooding poses the most significant risk in to the District. Section 6 of the Plan outlines flood hazards, past flood events, and summaries of the people and property that are at risk. Most bayous and streams in the planning area have some existing buildings that are exposed to flood damage. It is estimated that over 15% of all buildings in BDD4 jurisdiction are prone to some degree of flooding. BDD4 has experienced a number of flood events, most resulting in localized damage. Section 6 also includes a detailed risk assessment of the National Flood Insurance Program (NFIP) Repetitive Loss and Severe Repetitive Loss properties within the planning area.

It is estimated that over 8,508 buildings and many more parcels of undeveloped land in the planning area are located in flood-prone areas.

| Number of Buildings insured through the NFIP within the City of Pearland, Brookside Village and Brazoria County* | |
|---|---|
| Brookside Village | 240 |
| Brazoria County | 15,500 |
| City of Pearland | 7,893 |
| Total | 23,633 |

*NFIP information is only available for the City of Pearland, Brookside Village, and unincorporated Brazoria County, but not BDD4 specifically.

This is an indication that many homeowners outside the floodplain are aware of the flooding risks throughout the area and have chosen to carry flood insurance, even though it is not required.

The final draft for the Plan was presented at a public meeting and was made available for comment on BDD4's web site, and in District facilities. The final Plan was presented at a public meeting of BDD4 Board of Directors on _______________. Copies of the Plan are available for review at the BDD4 Office's located at 4813 W Broadway Pearland, TX 77581.

As part of the planning process for the 2011 Plan, the initial draft of this Plan was presented at a public meeting on March 1, 2011. The public was provided a second opportunity to review and comment on the Plan at the point of the final draft stage when it was posted on BDD4's web site and a printed copy available for review at the BDD4 offices listed in the paragraph above on [insert date]

Section 3 discusses the Approval and Adoption of the Plan. The BDD4 Board of Commissioners was responsible for approving and adopting the Plan. The Board reviewed and adopted the Plan on [insert date]. Upon approval and adoption, the 2011 Plan will also be available for review at BDD4 offices.

Contact information for the BDD4 official submitting this Plan is as follows:

**Name:** **Mr. Mike Yost**
**Title:** **Superintendant**
**Phone:** **(281) 485-1434**
**Fax:** **(281) 485-0065**
**Email Address:** **mybdd4@swbell.net**

The structure of the HMP was guided by a Mitigation Planning Committee (MPC). The MPC determined that in addition to the small committee that would steer the planning process, a larger group of interested individuals called "Stakeholders" would be included in the planning process to review drafts and provide comments at critical points in the plan development. Membership in these groups and the specifics of their tasks are described in Section 1.5.

Section 10 of the Plan (Plan Maintenance and Implementation) describes the schedule and procedures for ensuring that the Plan stays current. The section identifies when the Plan must be updated, who is responsible for monitoring the Plan and ensuring that the update procedures are implemented. This section provides a combination of cyclical dates (oriented toward FEMA requirements) and triggering events that will initiate amendments and updates to the Plan. The Superintendant is responsible for monitoring the Plan and initiating the cyclical update process.

## 1.1 Introduction

Brazoria Drainage District No. 4 (BDD4) undertook development of a Hazard Mitigation Plan ("the Plan") because of increasing awareness that natural hazards, especially flood hazards, may affect people and property in the area. The Plan was a requirement associated with receipt of certain federal mitigation grant program funds administered by the State of Texas' Division of Emergency Management (TDEM) and the Texas Water Development Board (TWDB). In addition, the Plan was a pre-qualification of eligibility for other mitigation funds.

44 CFR Part 201, Hazard Mitigation Planning, establishes criteria for State and local hazard mitigation planning authorized by Section 322 of the Stafford Act, as amended by Section 104 of the Disaster Mitigation Act. After November 1, 2004, local governments applying for mitigation funds through the States must have an approved local mitigation plan prior to the approval of local mitigation project grants. States are also required to have an approved Standard State mitigation plan in order to receive. Therefore, the development of State and local multi-hazard mitigation plans are key to maintaining eligibility for potential mitigation funding under FEMA mitigation grant programs. In 2010, BDD4 received a grant from FEMA, through TDEM, to develop a natural hazard mitigation plan.

## 1.2 Authority

Brazoria Drainage District No. 4 was created under the provisions of Section 59 of Article XVI, Constitution of Texas, as a government agency for the purpose of reclamation and drainage of its overflowed lands and other lands needing drainage in BDD4 and all property and territory situated within the Drainage District. BDD4 is governed by a three member Board of Commissioners. The Board chooses a Superintendant who is responsible for implementing the Board policies and projects and who leads the overall management of the District.

The Hazard Mitigation Plan (HMP) was prepared pursuant to the Flood Mitigation Assistance Program (44 CFR 78.6), the Hazard Mitigation and Pre-Disaster Mitigation Programs (44 CFR Parts 201 and 206), and the process outlined in materials prepared by FEMA.

## 1.3 Geography, Climate, and Population

Brazoria Drainage District No.4 is located near the City of Pearland, just south of Houston, TX along State Highway 288. Brazoria Drainage District No.4 encompasses an 83.4 square mile area of northern Brazoria County which includes the Cities of Pearland and Brookside Village. Its boundaries from west to east are Fort Bend County to Galveston County and from Clear Creek (Harris County) to a point just north of Alvin, Texas and Manvel, Texas.

The climate of the region is humid subtropical, with hot summers and mild winters. The area is typically sunny and mild with an average annual temperature of 68.9 degrees. The climate during the summer is moderated by prevailing cool southeasterly winds from the Gulf of Mexico. Summers are long with high daytime and moderate nighttime temperatures. Normally, the winters are short and mild. The average minimum January temperature is in the low 40's. During December, January, and February, the winds are generally northerly, but during the balance of the year southerly winds predominate.

Generally, the heaviest precipitation occurs during thunderstorms in the spring, summer, and fall, and often is associated with tropical systems and hurricanes moving through the region. Rainfall averages about 48 inches per year and, although generally evenly distributed, the heaviest occurs in late spring or early fall.

**Figure 1-1**
**Average climate in Pearland, Texas**
(Source: BDD4 Homepage)

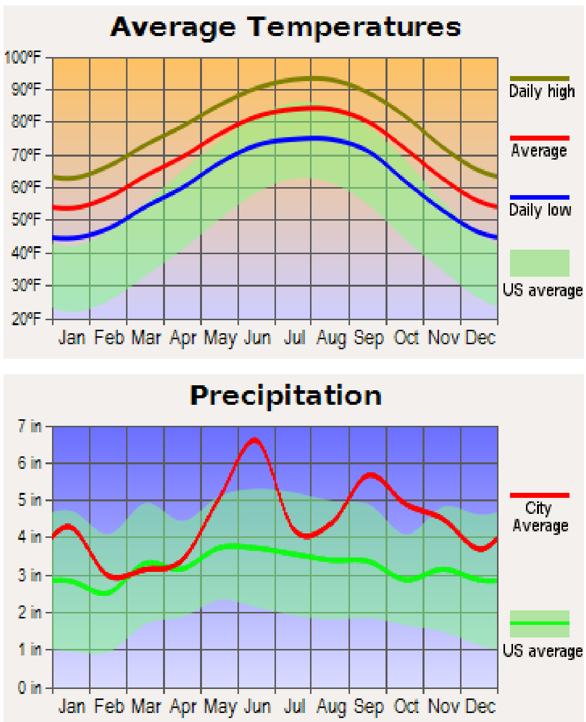

**Figure 1-2**
**Vicinity Map: State of Texas**
(Source: Mapquest)


## 1.4 Planning Area

Brazoria Drainage District No.4 is located near the City of Pearland, just south of Houston, TX along State Highway 288. Brazoria Drainage District No.4 encompasses an 83.4 square mile area of northern Brazoria County which includes the Cities of Pearland and Brookside Village. Its boundaries from west to east are Fort Bend County to Galveston County and from Clear Creek (Harris County) to a point just north of Alvin, Texas and Manvel, Texas. Major drainage arteries include: Clear Creek, Hickory Slough, Mary's Creek, Cowart Creek, Chigger Creek and portions of Mustang Bayou. Principal subdivisions located in the district include: Country Place, Silver Lake, Southwyck, Crystal Lake, West Oaks, Springfield, Sunset Meadows, Sunset Lakes, Meadow View, Pine Hollow, West Wood, Dixie Woods, and Oak Brook Estates. The Drainage District seat, Pearland, is at 29°33' north latitude and 95°17' west longitude, 285 miles southeast of Dallas.

Figure 1-3 illustrates the area that BDD4 has responsibility over.

**Figure 1-3**
**Brazoria Drainage District No. 4**
(Source: BDD4 Homepage)

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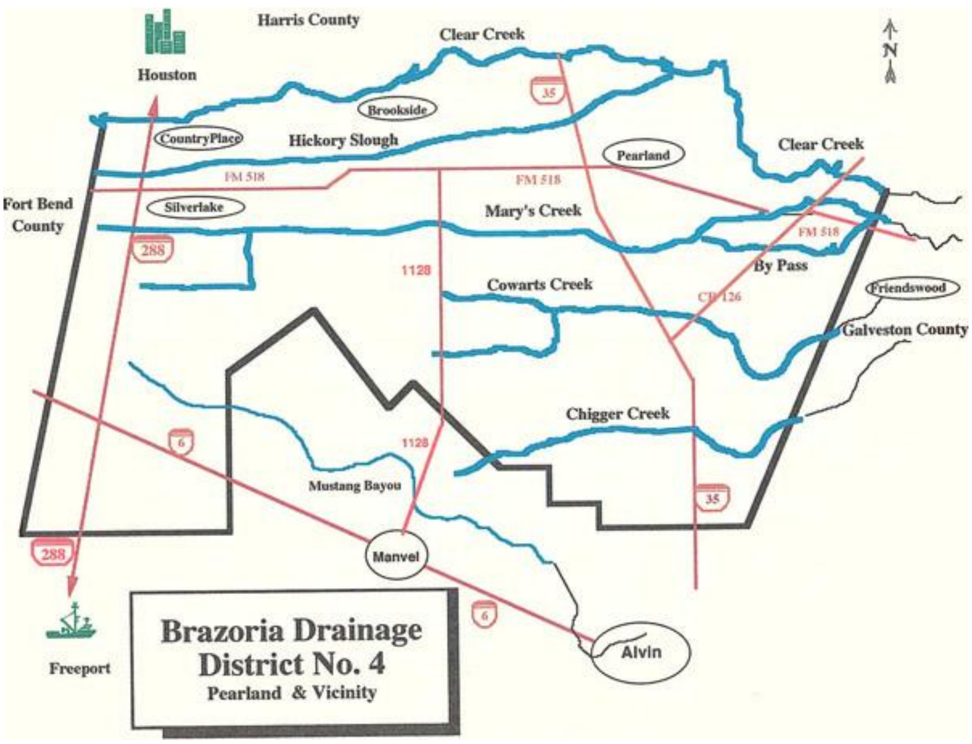



## 1.4.1 Population and Growth

According to the United States Census Bureau, Pearland as a whole (which is the majority of BDD4's area of responsibility) had an estimated total population of 68,305 in 2008.[1] This is a 44.8 percent increase from the 2000 census data, which estimated the Pearland's population at 37,640. The population density per square mile in 2000 was 174.3 (statewide average was 79.6 persons per square mile). BDD4 includes both incorporated and unincorporated areas.

## 1.4.2 Special Consideration Communities

For the purpose of this Plan, there are no jurisdictions within the BDD4's area of responsibility that are classified as "special consideration communities." The Federal government defines special

[1] United States Census Bureau - Quickfacts; 2008 Estimate.

consideration communities to be “small and impoverished communities”. According to the 1999 census data, 4.7% of the population was living below the poverty level.

## 1.5 Composition of the Brazoria Drainage District No. 4 Mitigation Planning Committee and Stakeholders

BDD4 used the following organization to develop its Hazard Mitigation Plan. The organization has three tiers:

- Mitigation Planning Committee (MPC)
- Stakeholders Group
- BDD4 Board

The process used to develop the Plan was guided by a Mitigation Planning Committee (MPC) which carried out most of the planning duties. The MPC was comprised of the following individuals listed in Table 1-1.

The MPC determined that in addition to the small committee that would steer the planning process, a larger group of interested individuals called “Stakeholders” would be included in the planning process to review drafts and provide comments at critical points in the plan development. Once the Plan was drafted, the MPC reviewed the contents with Board for their comment and approval (Table 1-3).

**Table 1-1**
**Brazoria Drainage District No. 4 Hazard Mitigation Plan**
**Mitigation Planning Committee (MPC)**

| Team Member | Job Title | Organization |
|---|---|---|
| Mike Yost | Superintendent | Brazoria Drainage District No. 4 |
| Kim Woodall | Administrative Assistant | Brazoria Drainage District No. 4 |
| Bryan Garner | Foreman | Brazoria Drainage District No. 4 |
| Bobby Lira | Code Enforcement | Brookside Village |
| Narcisco Lira | Engineer | City of Pearland |
| Mike Blissett | Road Superintendent | Brazoria Roads and Bridges |
| Al Lentz | District Engineer | Lentz Engineering |
| Jeff Ward | Mitigation Planning Consultant | JSWA |
| Jarrod D. Aden | P.E., Senior Project Manager | Lentz Engineering |
| Kristen Thatcher | Mitigation Planning Consultant | JSWA |

At the initial Plan meeting on January 19, 2011, the MPC determined that the Stakeholders group would be comprised of a group of interested groups, neighboring communities, businesses, academia and other organizations and individuals with an interest in the Plan. This Stakeholders Group was provided regular updates on the planning process and given the opportunity to review the Plan at key points in its development. Members of the Stakeholders group were also invited to attend and participate in all public meetings. The Stakeholder Group was identified by the MPC and are listed in Table 1.2.

As drafts of the Plan were prepared, the MPC used email to distribute them to Stakeholders, and requested that they provide comments. Stakeholders were requested to provide feedback through email or by telephoning the BDD4 point of contact, Mr. Mike Yost or a member of the consultant team. At various points during the process, comments from Stakeholders were periodically emailed to Mr. Mike Yost or a member of the consultation team. The consultant was responsible for archiving the comments and including them in edited versions of the Plan. The Stakeholders Group was comprised of the following individuals:

**Table 1-2**
**Brazoria DD4 Hazard Mitigation Plan**
**Stakeholders Group**

| Group Member | Title | Organization |
|---|---|---|
| Jeff Sundseth | EMS Director | Pearland Emergency Medical Services (EMS) |
| Chris Doyle | Police Chief | Pearland Police Department |
| Michelle Smith | Director | Pearland Parks and Recreation |
| Claire Bogard | Director | Pearland Finance Department |
| Danny Cameron | Public Works Director | Pearland Public Works |
| Michael Masters | GIS Coordinator | Pearland GIS |
| Lata Krishnarao | Director of Planning | Pearland Planning Department |
| Bill Eisen | Pearland City Manager | City of Pearland |
| Mike Hodge | Pearland Assistant City Manager | City of Pearland |
| Jon Branson | Pearland Assistant City Manager | City of Pearland |
| Jack Colbath | Director of Fire Services | City of Pearland |
| Dr. Kirk Lewis | Superintendent | Pasadena Independent School District |
| Curtis Lampley | Project Coordinator, Precinct 1 | Harris County Flood Control District |
| Larry Heckathron, P.E. | District Engineer | Texas DOT – Brazoria County Area Office |
| Jim Hunt, P.E. | District Engineer | Texas DOT – Fort Bend County Area Office |
| Bruce Fundling | Mayor | Brookside Village |
| Jeff Braun | Emergency Management Coordinator | Fort Bend County |
| Doc Adams | Emergency Management Coordinator | Brazoria County |
| Mark Sloan | Emergency Management Coordinator | Harris County |

**Table 1-3**
**BDD4 Board of Commissioners**

| Team Member | Title |
|---|---|
| Jeff Brennan | Chairman |

| | |
|---|---|
| Dan Keller | Secretary |
| Harrison Rogers | Member |

## 1.6 Acknowledgments

The Plan was supported by a planning grant provided by the State of Texas Division of Emergency Management, Mitigation Division. The plan was facilitated by Jeffrey S. Ward & Associates, Inc.

## 2.1 Introduction

An important step in the lengthy process of improving resistance to hazards is the development of a hazard mitigation plan. The Brazoria Drainage District No. 4 Mitigation Plan was prepared in accordance with the guidelines provided by FEMA and advice from the TDEM and the TWDB.

The Plan was prepared for several purposes. It set the stage for long-term disaster resistance through identification of actions that will, over time, reduce the exposure of people and property to hazards. Completion of the Plan, and adoption by the BDD4 Board of Commissioners, was a significant step toward identifying potential hazards that threaten the jurisdiction, assessing risk, and implementing mitigation actions that will reduce property damages, injuries, and loss from hazards. Approval of the Plan by TDEM and FEMA will allow for eligibility for certain mitigation grant funds.

Sections of the Plan provide overviews of the natural hazards that threaten BDD4, the people and property exposed to those hazards, the planning process, how hazards are recognized in BDD4's normal processes and functions, and priority mitigation action items. The hazards summary and disaster history help to characterize future hazards. When taking into account the magnitude of past events, the number of people and properties affected, and the severity of damage, flood hazards clearly are the most significant natural hazard to threaten BDD4. Therefore, this Plan concentrates primarily on flood hazards. As part of BDD4's ongoing efforts to reduce flood losses, the areas within the District participate in the NFIP program.

## 2.2 Interim Final Rule Requirements for the Planning Process

**IFR §201.6(c)(1):** [*The Plan shall document] the planning process used to develop the Plan, including how it was prepared, who was involved in the process, and how the public was involved.*

**IFR §201.6(b):** *In order to develop a more comprehensive approach to reducing the effects of natural disasters, the planning process shall include:*

*(1) An opportunity for the public to comment on the Plan during the drafting stage and prior to Plan approval;*

*(2) An opportunity for neighboring communities, local and regional agencies involved in hazard mitigation activities, and agencies that have the authority to regulate development, as well as businesses, academia and other private and non-profit interests to be involved in the planning process; and*

*(3) Review and incorporation, if appropriate, of existing Plans, studies, reports, and technical information*.

**IFR §201.6(c)(4)(ii):** [*The Plan shall include a] process by which local governments incorporate the requirements of the mitigation Plan into other planning mechanisms such as comprehensive or capital improvement Plans, when appropriate…*

## 2.3 The Mitigation Planning Process

Brazoria Drainage District No. 4 followed a well-established planning process to develop the original *Hazard Mitigation Plan* and to fulfill multiple requirements. The process is fully documented throughout the Plan but follows the following steps:

**Step 1** Organize resources and plan process
**Step 2** Assess risks
**Step 3** Develop a mitigation plan
**Step 4** Implement the plan and monitor progress

## Step 1 Organize Resources and Plan Process

The mitigation planning process for the 2011 HMP was facilitated by a mitigation planning consultant. The Plan process followed the FEMA guidance document titled *Local Multi-Hazard Mitigation Planning Guidance (July 1, 2008)*. This document interprets and explains the Local Hazard Mitigation Plan regulations from the 44 Code of Federal Regulations (CFR) Part 201, and is FEMA's official source for defining the requirements local hazard mitigation plans.

The MPC met three times during the planning process. These meetings took place at BDD4's office in Pearland, Texas. See Appendix B for all meeting minutes and list of attendees. The meeting dates are summarized below.

The first MPC meeting took place on January 19, 2011. The purpose of the meeting was to begin the planning process, to make certain decisions about contents of the plan, and to assign specific tasks to Brazoria Drainage District No. 4 staff and consultants. Most of the tasks were related to collecting information, data, studies and maps. The MPC agreed that they would meet quarterly and with the data and information collected during this quarter would begin to profile and assess the hazards and discuss the goals and objectives at the next meeting.

A second MPC meeting was held on March 1, 2011. The purpose of the meeting was to review the status of various tasks assigned and discuss the proposed schedule for completing the update. The team reviewed the status of all remaining tasks such as collecting any remaining data and integrating the information into the Plan. Subsequent interactions among the group were conducted through email and telephone calls.

The third meeting was held on ________

The Plan process took place in multiple steps:

| | |
|---|---|
| MPC and Consultant | Collect and analyze data, information, studies and maps |
| MPC | Discussion, modifications and approval of drafts |
| Consultant | Prepare drafts from information collected |
| Consultant | Outline the technical requirements |
| Consultant and MPC | Review of complete first draft |
| Consultant | Modifications based on review, stakeholder feedback |
| Consultant | Presentation to public, compile feedback |
| Consultant | Final draft |

| | |
|---|---|
| Consultant | Second public outreach, compile feedback |
| Consultant | Prepare and submit final draft |
| TDEM and FEMA | Review and letter of approvability |
| MPC and Board of Commissioners | Final approval and adoption |

## Step 2 Assess Risks

In accordance with general mitigation planning practice, as well as the process FEMA established in its Planning "How-To" series of guides, the risk assessment forms the basis for this hazard mitigation plan by quantifying and rationalizing information about how natural hazards affect the Brazoria Drainage District No. 4. The processes used to complete the hazard identification and risk assessments, and the results of these activities, are described in detail in Sections 5, 6 and 7 of this Plan. The assessment determined several aspects of the risks of natural hazard faced by the jurisdiction and its constituents:

- The natural hazards that are most likely to affect BDD4's jurisdiction
- How often hazards are expected to impact the BDD4's jurisdiction
- The expected severity of the hazards
- What areas of the District are likely to be affected by hazards
- How BDD4 assets, operations, people and infrastructure may be impacted by hazards
- How private and commercial assets, operations, infrastructure may be impacted by hazards
- The expected future losses if the risk is not mitigated

Through a rating system (explained in detail in Section 5) and based on the BDD4 mission and limited jurisdictional responsibility, the MPC reduced the initial hazard list to two. These are predominant risks to the area: floods and high winds (hurricanes and tornadoes). For each of these hazards, the planning team performed detailed risk assessments, i.e. calculations of future expected damages, expressed in dollars. These findings were presented to the MPC, discussed by the group, and approved by the Committee as the basis for later phases of the planning process. The results of the risk assessment were also made available to the public during the public presentations noted elsewhere in this Plan. As noted above, a more detailed description of this process and its results are presented in Section 5.

## Step 3 Develop the Mitigation Plan

As noted elsewhere in this section and others, the process employed to develop this Plan was based on the FEMA 386-series of guides describing hazard mitigation planning procedures, The Interim Final Rule and the FEMA crosswalk. Throughout the document there are cross references to Interim Final Rule and FEMA crosswalk criteria.

## Step 4 Implement the Plan and Monitor Progress

BDD4 is responsible for implementing the plan after it is adopted by the Board of Commissioners. The Superintendent will evaluate the plan approximately annually by assembling the Mitigation Planning Committee to review key sections of the document. The group will determine if the plan continues to correctly characterize BDD4's exposure and vulnerability to natural hazards, and if the goal and actions adequately address BDD4's priorities for addressing natural hazards. The MPC will prepare a report that will be forwarded to the Board of Commissioners for review and approval. The Superintendent will maintain a written record of these procedures, and will incorporate written records of the Board of Commissioners' review, comment and approval of progress reports.

## 2.4 Public Involvement in Mitigation Planning

Consistent with BDD4's standard objective to inform and involve citizens, and to fulfill the public involvement requirements of the mitigation planning programs, during the plan development process, BDD4 solicited input and notified and invited residents to review the document and attend two public meetings. For both public meetings, press releases were prepared informing the public about the Hazard Mitigation Planning process and urged the public to be involved in this process. The meeting outlined the planning process and information about the Plan and then went to an open discussion format, where each person attending had the opportunity to volunteer information about the community and present ideas.

During the drafting of the Plan, the public was involved by requesting attendance and participation in a public presentation/meeting on March 1, 2011. Preliminary drafts of the Plan were available for public review, and the public was invited to provide input on the document. In accordance with legal requirements, BDD4 published public notices about the presentation in the Reporter News on February 23, 2011 prior to the meeting (See Appendix C, Public Notice Documents). The notice explained the purpose of the meeting, and provided the date, time, and location of the meeting. The meeting minutes (and attendee lists) for the public meeting is included in Appendix C of the Plan.

The public had a second opportunity to review the final draft Plan when the document was posted on the Brazoria Drainage District No. 4 website and placed at BDD4 offices. Prior to placing the document online, BDD4 placed an advertisement in the Reporter News newspaper explaining that BDD4's HMP was in the final draft stages and available for review. The advertisement can be found in Appendix C. The public meeting and timeframe for the Plan were also posted online.

The MPC also identified local Civic and Acedemic Groups located in or near BDD4. These groups were notified via mail about the availability of the Plan on the BDD4's website and at BDD4 offices and encouraged to participate in the planning process and review the Plan. The Civic groups and academia included:

| Group Member | Title | Organization |
|---|---|---|
| Dr. Kirk Lewis | Superintendent | Pasadena Independent School District |
| Kenneth Carter | Compliance Coordinator | Alvin School District |
| Cary Partin | Senior Assistant Superintendent for Support Services | Pearland Independent School District |
| Larry Heckathorn, P.E. | District Engineer | Texas DOT - Brazoria County Area Office |
| Jim Hunt, P.E. | District Engineer | Texas DOT – Fort Bend County Area Office |
| Bruce Fundling | Mayor | Brookside Village |
| Carol Artz | Chamber President | Chamber of Commerce |

### 2.4.1 Public Work Session at Board Meetings

Two Board of Commissioners public work sessions were held as part of the HMP development. The first work session was held on March 1, 2011 where the consultant provided a detailed overview of the planning process and the desired outcomes. The second work session was coincidental with the second public meeting and was held on August 16, 2011.

### 2.4.2 Public Meetings

Although well advertised, there was no attendance at either public meeting. Both Board of Commissioners work sessions were open to the public and the agenda was advertised. There were members of the public at these meetings/presentations but no public comment was provided.

## 2.5 Incorporating Mitigation Plan Requirements into Other Local Planning Mechanisms

As required by the FEMA Interim Final Rule that governs mitigation planning, the project requirements from the Hazard Mitigation Plan are incorporated into other planning mechanisms, as applicable, during the routine development of local Plans. As part of the HMP development, BDD4 integrated components of the Plan into other planning mechanisms and requested when Brazoria Drainage District No. 4 prepares their HMP update, they include reference to this Plan. The MPC is currently reviewing the plans listed in Section 2.6 and looking for opportunities where components of the HMP can be integrated into these other plans and studies.

The NFIP's Community Rating System (CRS) is another method that communities can benefit from the mitigation planning requirements addressed in the Plan. These requirements and mitigation actions can work to improve a community's CRS rating. Since BDD4 is considered a District and not a community it is not eligible to participate in the CRS, a voluntary program for NFIP participating communities. However, jurisdictions within BDD4 can participate. The goals of the CRS are to reduce flood losses, to facilitate accurate insurance rating, and to promote the awareness of flood insurance. The CRS rewards communities that undertake activities beyond the requirements of the NFIP. The CRS is a point system program that reduces flood insurance premiums for the citizens of participating communities.[2] All communities start with a Class 10 rating and activities are offered to earn credit points that reduce their classification. The lower a community's Class rating, the greater the premium discounts offered by the NFIP. Any future CRS activities such as flood damage reduction or flood preparedness as a result of this should be considered by these jurisdictions if they determine to participate in the CRS program. The City of Pearland is currently a class 7 in the CRS.

## 2.6 Review and Incorporation of Plans, Studies, Reports and Other Information

Other planning documents can be used as a valuable resource for integrating information related to hazard mitigation into the BDD4's HMP. As part of the development, other plans, studies, and reports that are applicable to the hazards discussed in the Plan were reviewed and incorporated where applicable.

[2] Emergency Management Institute (EMI) web site, CRS Resource Center

The following Plans were reviewed along with a discussion on how they were incorporated into the Plan.

- **2010 State of Texas Mitigation Plan Update.** The State HMP update was reviewed and summarized in Section 2.7 of this Plan. The mitigation strategies from the State Plan are also summarized in Section 2.7 for the flood, wildfire, tornado, hurricane and tropical storm, and drought hazards. The goals from the State Plan update were also reviewed and included in Section 4.3 of BDD4's Plan.
- **Brazoria County Flood Insurance Rate Map (FIRM).** The Flood Insurance Rate Maps (FIRMs) prepared by FEMA offer the best overview of flood risks. FIRMs are used to regulate new development and to control the substantial improvement and repair of substantially damaged buildings. Brazoria County FIRMs were reviewed and included in the Plan to develop a floodplain map identifying the 100-year floodplain.
- **Brazoria County Study (FIS).** The most recent FIS's for Brazoria County is dated August 31, 2009. Information describing the flood hazard was added to Section 6.

The following are a list of plans and studies that have been completed for the planning area. These plans were reviewed and referenced during the plan development process. Actions items in this plan include recommendations from several of these studies. As work is proposed from these studies and plans, the BDD4 team refers back to this plan for consistency in prioritization and implementation and to determine if there is a potential for federal mitigation funds to support the mitigation efforts.

**BRAZORIA DRAINAGE DISTRICT 4**
**LIST OF PLANS AND DOCUMENTS**

**Flood, Mitigation and Planning Studies**

| | STUDY NAME | DATE | ENGINEER |
|---|---|---|---|
| 1 | Clear Creek Regional Flood Control Plan | December, 1992 | Dannenbaum Engineering |
| 2 | Clear Creek, Texas Flood Risk Management General Revaluation Report | July, 2008 | U.S. Army Corps of Engineers |
| 3 | Clear Creek Watershed Modeling Update | January, 2010 | Dannenbaum Engineering |
| 4 | Flood Protection Plan for Brazoria Drainage District No. 4 | November, 1997 | Rust Lichlitier/Jameson |
| 5 | Clear Creek Modeling Update - Hickory Slough, Mary's Creek & Cowart Creek | January, 2006 | Dannenbaum Engineering |
| 6 | Cowart Creek Watershed Master Plan | March, 2008 | Dannenbaum Engineering |
| 7 | Cowart Creek Watershed Modeling Update | January, 2009 | Dannenbaum Engineering |
| 8 | Preliminary Hydrologic and Hydraulic Analysis for Proposed Clear Creek Detention on Alexander Tract | June, 2010 | Lentz Engineering, L.C. |
| 9 | Cowart Creek - Proposed Pipe Diversion | October, 2010 | Dannenbaum Engineering |
| 10 | Flood Control Improvement Verification | October, 2004 | Dannenbaum Engineering |

## 2.7 The State Mitigation Plan

The State of Texas has long been aware that it is exposed to a variety of natural hazards. Of particular concern are flood hazards associated with thunderstorms, hurricanes, and tropical storms. The 2010 *State of Texas Hazard Mitigation Plan Update* is summarized below.

Originally prepared by TDEM to fulfill the requirements set forth by Congress in the Stafford Act (Section 409), the State's Hazard Mitigation Plan was completed in 2004 and was updated in 2007 and again in 2010 to satisfy new planning requirements prompted by the Disaster Mitigation Act of 2000.

The State's Plan acknowledges that people and property in Texas are at risk from a variety of hazards that have the potential to cause widespread loss of life and damage to property, infrastructure, and the environment. The Plan "establishes hazard mitigation goals, strategies, and specific measures designed to reduce the occurrence or severity of the consequences of hazards." It also documents procedures for implementation and administration of certain mitigation grant programs.

The State Hazard Mitigation Team is designated to coordinate and influence mitigation and is composed of several agencies that participate on the Emergency Management Board. Primary agencies are the Texas Division of Emergency Management; Texas Water Development Board Texas

Department of Housing and Community Affairs; Texas Parks and Wildlife Department; Texas Department of Environmental Quality (formerly the Texas Natural Resource Conservation Commission); Texas Department of Transportation, General Land Office; Railroad Commission of Texas; Texas Department of Insurance; Texas Forest Service; and Texas Engineering Extension Service;. Brief summaries of each of these primary agencies are provided in the State Plan, noting key natural hazard mitigation measures associated with each agency. For the most part, existing measures are ongoing agency functions and responsibilities.

As currently structured, the State's Hazard Mitigation Plan contains attachments outlining specific strategies for dealing with hazards related to floods, tornadoes, hurricanes and tropical storms, wildfires, and drought. Strategies particularly pertinent to local jurisdictions are described below:

Flood Mitigation

Historically, floods are and continue to be one of the most frequent, destructive, and costly natural hazards facing the State of Texas, constituting over 90% of the disaster damage in the State. Texas, on average, suffers approximately 400 floods annually, double the number of the second highest State. State Strategies include: 1. Mitigating severe repetitive loss properties (SRL) either by elevation or acquisition. According the 2010 State Hazard Mitigation Plan, there were 3,162 properties on the SRL list (Statewide); 2. Redirecting $6.1 million in taxes and license fees collected biannually and given to TWDB so they can fund floodplain management training compliance functions and other mitigation activities; and 3. Adopt a —No Adverse Impact Policy to ensure that future development activity both in and out of the floodplain be part of mitigation planning.

Tornado Mitigation

Tornadoes occur annually and most frequently in the northern two-thirds of the State caused by cool frontal systems that enter from the north and west, and in the remainder of the State primarily caused as a cascading hazard from tropical storms. State Strategies include: 1. Adopt and enforce building codes and/or design criteria for construction of storm shelters and the construction of safe rooms, 2. Promote and provide for expanded coverage options for standard peril and windstorm insurance coverage for public and private property; 3. Promote and provide enhanced statewide awareness concerning the risks and consequences of tornadoes; and 4. Promote and provide enhanced warning capabilities.

Hurricane/Tropical Storm Mitigation

Texas has experienced 23 Federal disaster declarations due to hurricane/ tropical storm events, the most recent events being Hurricane Rita (DR-1607) that was declare on September 24, 2005, Hurricane Dolly (DR-1780) that was declared on July 24, 2008, Hurricane Ike (DR-1791) that was declared on September 13, 2008, and Hurricane Alex (DR-1931) that was declared on September 16, 2010. State Strategies include: 1. Continue to fund Coastal Erosion and Response Act Projects, and 2. Continue to promote the Hurricane Local Grant Programs.

Wildfire Mitigation

With the semi-arid climate of the western, southern and panhandle counties of the State, wildland fires are most common in the spring and summer months, but can occur at anytime during the year. These wildland fires can have significant economic impact to local and regional economies. Threats to improved structures are a growing problem. State Strategies include: 1. Provide Urban Forestry Grants to improve community forestry programs, 2. Establish and implement burning standards, 3. Continue Urban Wildfire Interface, a traveling exhibit maintained by the Texas Forest Service (TFS) and 4. Continued maintenance of the TFS website that contains fire safe mitigation initiatives.

Drought Mitigation

Given the expanse of the land mass within Texas and the geographic location of 2/3rds of the counties of the State are located either in an arid or semi-arid climate, roughly those west of a North-South line formed by Interstate Highway 35, are almost always in varying stages of drought. During the past 15 years, the worst droughts in Texas occurred in 1996, 2000, 2002, 2006, and 2009. Mitigation Strategies include providing training and education programs for EMCs. The Texas Department of State Health Services maintains a web site that provides tips and actions for citizens, governments and medical facilities.

## 2.8 Federal Mitigation Planning Requirements

As mentioned elsewhere in the Plan, the Disaster Mitigation Act of 2000 requires State and local governments to develop and adopt natural hazard mitigation plans in order to be eligible for some types of federal assistance, including mitigation grants. The Act authorizes up to seven percent of Hazard Mitigation Grant Program (HMGP) funds available to a State after a disaster to be used for the development of State, tribal, and local mitigation Plans.

In addition to the Disaster Mitigation Act of 2000, mitigation planning requirements are set forth in various FEMA policies and guidance documents, including the Interim Final Rule of February 26, 2002, and the "386" series of mitigation planning how-to guides. The following series of bullets briefly describes the FEMA's six hazard mitigation programs, all of which require some form of mitigation plan in order for communities to be eligible for grants. Although the programs differ in their eligibility requirements, funding amounts, etc., requirements related to mitigation planning are substantially similar. In 2008-2009, requirements for all the mitigation grant programs except for the Hazard Mitigation Grant Program were unified under the Hazard Mitigation Assistance (HMA) program guidance.

- **Flood Mitigation Assistance Program (FMA).** To qualify to receive grant funds to implement projects such as acquisition or elevation of flood-prone homes, local jurisdictions must prepare a mitigation plan.
- **Pre-Disaster Mitigation Grant Program (PDM).** By November 2003, to qualify for pre-disaster mitigation funds, local jurisdictions must adopt a mitigation plan that is approved by FEMA.
- **Hazard Mitigation Grant Program (HMGP)**. By November 2004, to qualify for post-disaster mitigation funds, local jurisdictions must adopt a mitigation plan that is approved by FEMA.

- **NFIP Community Rating System (CRS).** The CRS offers recognition to communities that exceed minimum requirements of the National Flood Insurance Program. Recognition comes in the form of discounts on flood insurance policies purchased by citizens. The CRS offers credit for mitigation plans that are prepared according to a multi-step process.

**FEMA/NFIP Severe Repetitive Loss Program (SRL).** The SRL program was authorized by the Flood Insurance Reform Act of 2004 to provide funding to reduce or eliminate the long-term risk of flood damage to residential structures under the NFIP which have suffered repetitive losses. SRL properties have at least four NFIP claim payments over $5,000, with at least two of the claims within a 10 year period. SRL properties are also residential structures that have at least two separate claim payments made within a 10 year period with the cumulative amount of the building portion of the claims exceeding the value of the property. States are required to have SRL mitigation plans in order for local communities to be eligible for grant funds through this program.

**FEMA/NFIP Repetitive Flood Claim Program (RFC).** The SRL program was authorized by the Flood Insurance Reform Act of 2004 to assist States and communities reduce flood damages to properties that have at least one NFIP claim payment. Various hazard mitigation activities are eligible including acquisition, elevation, and dry floodproofing of residential structures.

## 3.1 IFR Requirement for Approval and Adoption

***IFR §201.6(c)(5):*** *[The local hazard mitigation plan shall include] documentation that the plan has been formally adopted by the governing body of the jurisdiction requesting approval of the plan (e.g., Board of Commissioners, County Commissioner, Tribal Board).*

## 3.2 Authority

Authority for the preparation of the Hazard Mitigation Plan (HMP) is derived from the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988, P.L. 93-288, as amended by the Disaster Mitigation Act of 2000, P.L. 106-390. The Disaster Mitigation Act of 2000 (The Act) required State and local governments to develop and formally adopt natural Hazard Mitigation Plans by November 2003 in order to be eligible to apply for Federal assistance under the HMGP. The Act was further amended to extend the planning requirement deadline to November 2004.

When the DMA 2000 was signed into law on October 30, 2000, the Robert T. Stafford Disaster Relief and Emergency Assistance Act was amended by adding a new section, 322 – Mitigation Planning. Section 322 places new emphasis on local mitigation planning. It requires local governments to develop and submit mitigation plans as a condition of receiving Hazard Mitigation Grant Program (HMGP) project grants. An Interim Final Rule (IFR) for implementing Section 322 was published in the Federal Register, 44 CFR Parts 201 and 206, on February 26, 2002. The requirements for local plans, or Local Mitigation Plan Criteria, are found in part 201.6.

In addition to the Plan requirement, the Act also requires communities to utilize a specific planning process developed for an all hazards approach to mitigation planning. This four step planning process is crucial to ensure that the effective planning by a community meets all the Plan content criteria required by the Act. The Act requires adoption by the local governing body and specifies a stringent review process, by which States and FEMA Regional Offices will review, evaluate and approve hazard mitigation plans.

## 3.3 Approval and Adoption Procedure

Throughout the 2011 HMP process, the MPC and Stakeholders Group had opportunities to provide comments and feedback. On _______ 2011, BDD4 submitted the initial draft of the Plan to TDEM for review and comment. After addressing TDEM's comments in the document, the HMP was resubmitted for final consideration and approval by TDEM and FEMA. FEMA provided a letter of approvability on [insert date], and the Plan was forwarded to the BDD4 Board for adoption, which occurred on [insert date]. The adoption resolution is provided as Appendix E in the 2011 HMP. Following adoption, the plan was resubmitted to FEMA for final approval, which occurred on [insert date]. The FEMA approval letter is included as Appendix F.

## 3.4 Adoption Resolution

BDD4 Board of Commissioners formally adopted the HMP on [insert date].

## 4.1 Introduction

State and federal guidance and regulations pertaining to mitigation planning require the development of mitigation goals to reduce or avoid long-term vulnerabilities to identified hazards. Mitigation goals have been established by the Federal Emergency Management Agency, the Texas Division of Emergency Management, and BDD4.

## 4.2 BDD4's Mitigation Goals

State and federal guidance and regulations pertaining to mitigation planning require the development of a mitigation goal statement that is consistent with other goals, mission statements and vision statements. To do so, the MPC reviewed FEMA's national mitigation goals, several examples of goal statements from other states and communities, and the State of Texas' Mitigation Goal. The committee also considered information about natural hazards that may occur in the area and their potential consequences and losses.

As part of the Plan, BDD4's mitigation goal statement was reviewed by the MPC during the initial meeting held on January 19, 2011. The mitigation goal statement remains as follows:

**BDD4's Mitigation Goal Statement**

*The mitigation goals of BDD4 are:*

To protect public health, safety, and welfare
To reduce losses due to hazards by identifying hazards, minimizing exposure of citizens and property to hazards, and increasing public awareness and involvement
To facilitate the development review and approval process to accommodate growth in a practical way that recognizes existing stormwater and floodplain problems while avoiding creating new problems or worsening existing problems
To seek solutions to existing problems

## 4.3 State of Texas Mitigation Goals

The Texas' Division of Emergency Management (TDEM) is designated by the Governor as the state's coordinating agency for disaster preparedness, emergency response, and disaster recovery assistance. TDEM also is tasked to coordinate the state's natural disaster mitigation initiatives and administer grant funding provided by FEMA. A key element in that task is the preparation of the State of Texas Hazard Mitigation Plan. The State's 2010 plan includes a series of mitigation goals, as follows:

**Texas State Mitigation Goals**

- *Reduce or eliminate hazardous conditions that cause loss of life;*
- *Reduce or eliminate hazardous conditions which inflict injuries;*
- *Reduce or eliminate hazardous conditions which cause property damage; and*
- *Reduce or eliminate hazardous conditions which degrade important natural resources.*

Texas Hazard Mitigation Plan (2010)

## 4.4 FEMA's Mitigation Goal

FEMA's mitigation strategy is set forth in a document originally prepared in the late 1990s. This strategy is the basis on which FEMA implements mitigation programs authorized and funded by the U.S. Congress. The national mitigation goal statement is as follows:

FEMA's Mitigation Goals
To engender fundamental changes in perception so that the public demands safer environments in which to live and work; and
To reduce, by at least half, the loss of life, injuries, economic costs, and destruction of natural and cultural resources that result from natural disasters.

## 5.1 Introduction

As part of its efforts to support and encourage hazard mitigation initiatives, the TDEM prepared an assessment of hazards that have caused or have the potential to cause disaster situations in communities throughout the State of Texas. Results of the study are found in the *State of Texas Hazard Assessment* (2010). Other public sources of information provide some information about natural hazards and past events. Of the 84 Presidential Disaster Declarations that Texas received between 1953 and 2010, 49 were for floods, 16 for tornadoes, 18 for hurricane/tropical storms, two for winter storms, one for extreme wildfire, and the remaining were a combination of events, or designated as "other."

The following subsections provide an overview of past hazard events and associated losses. Natural hazards other than flood hazards that are deemed pertinent to BDD4 are described, along with summary statements about exposure to risks associated with those hazards. Because flooding poses the most significant risk in BDD4, Section 5 outlines flood hazards, past flood events, and Section 6 provides summaries of the people and property that are at-risk.

Although BDD4 is subject to a range of hazards typical of the northern Gulf Coast, for the reasons outlined below, BDD4 has determined that the most appropriate and useful approach to developing its mitigation plan is to eliminate certain hazards from detailed consideration in its HMP. There are three reasons for this: (1) the hazards are not significant enough to warrant detailed vulnerability assessment and loss estimation; (2) BDD4's mission and jurisdictional authority is explicitly limited to activities related to controlling floods (although the organization does have the authority to complete actions to protect and mitigate damage to its own facilities, and; (3) non-BDD4 assets and populations that are potentially exposed to hazards are part of another mitigation plan, and hence including them in the present document would be redundant and serve no meaningful purpose. BDD4 and the incorporated areas within the District have both the authority and the responsibility to sponsor mitigation activities for their constituent populations and communities. BDD4 will continue to coordinate with the local jurisdictions to ensure that mitigation actions are developed and implemented in a rational manner, reducing or eliminating conflict and overlap between the jurisdictions.

Based on this reasoning, the MPC and Management have determined that flood and wind (hurricane wind and tornado) hazards will be described and assessed in detail in this HMP, and that the other hazards will be profiled, but not included as part of more detailed vulnerability and risk assessments. Although State and FEMA guidance permits jurisdictions to simply eliminate hazards from consideration, the District believes that it is important to profile these hazards to ensure general consistency with mitigation plans in surrounding (and overlapping) jurisdictions, but that they are addressed sufficiently in other plans and processes. It is also worth noting that as part of carrying out its flood control mission, BDD4 has assessed potential damages to its own facilities from flood and wind hazards, and has developed specific mitigation measures to address these, where appropriate.

## 5.2 IFR Requirement for Hazard Identification, Profiling, and Risk Assessments

***IFR §201.6(c)(2)(i)**: [The risk assessment shall include a] description of the … location and extent of all natural hazards that can affect the jurisdiction. The plan shall include information on previous occurrences of hazard events and on the probability of future hazard events.*

***IFR §201.6(c)(2):** The plan shall include a risk assessment that provides the factual basis for activities proposed in the strategy to reduce losses from identified hazards. Local risk assessments must provide sufficient information to enable the jurisdiction to identify and prioritize appropriate mitigation actions to reduce losses from identified hazards.*

***IFR §201.6(c)(2)(ii):** [The risk assessment shall include a] description of the jurisdiction's vulnerability to the hazards described in paragraph (c)(2)(i) of this section. This description shall include an overall summary of each hazard and its impact on the community.*

## 5.3 Overview of Risks

Damages and losses (including physical damage, indirect and economic losses, and injuries and deaths) that are associated with hazards result when an event affects areas where people and improved property are located. After hazards are identified, estimates of how exposed people and property are, "at-risk" can be prepared, especially if the hazards can be characterized by areas on a map.

When the full range of possible natural and man-made hazards are reviewed, it becomes apparent that some events occur frequently and some are extremely rare. Some hazards impact large numbers of people to a limited degree, while others may cause very localized but very significant damage. As described in Section 5.1, floods have historically caused the most property damage in BDD4.

The National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC) collects and maintains certain hazard data in summary format, indicating injuries, deaths, and estimated damages. According to the NCDC database, between 1950 and 2011, Brazoria County (data was unavailable for BDD4 specifically) has experienced 123 severe thunderstorms (seven of which had greater than 60 knot winds), 69 tornadoes, nine severe droughts, 90 hail storms (40 of which had a one inch diameter or greater hail), two hurricanes, seven tropical storms, six extreme heat waves, and 55 floods/flash floods. A number of these events caused property damage and loss of life. The NCDC database indicates that as of spring, 2011 these hazard events caused a combined total of over $5.7 billion in property damage. The database also indicates that there have been 272 injuries and 72 deaths as a result of these events.

### 5.3.1 Weather-Related Deaths

The National Weather Service maintains data on weather-related deaths. Summary statistics for the State of Texas based on those data are provided in Table 5-1. Because the reporting periods are different, percentages, not actual numbers, are provided.

**Table 5-1**
**Texas Weather-Related Deaths**
**(as percent of all weather-related deaths)**

| Hazard | Statewide (1989–2000) | Brazoria County/Pearland (1989–2002) |
|---|---|---|
| Flood/Flash Flood | 35% | 1% |
| Tornado | 10% | 0% |
| Lightning | 8% | 1% |
| Winter Storm/Ice Storm | 6% | 4% |
| Extreme Heat | 34% | 56% |
| Severe Thunder Storm | 4% | 1% |
| Hurricane/Tropical Storm | 3% | 37% |

## 5.4 Public Awareness of Hazards & Risk

The public becomes aware of local hazards in a number of ways. For example, public awareness of flood hazards is enhanced during the following activities:

Buying property in a floodplain triggers the federal requirement to obtain flood insurance when obtaining a federally insured and regulated mortgage. Federally insured and regulated mortgage lenders are required to make homebuyers purchase flood insurance if the building is located in a mapped flood hazard area. Buyers are supposed to be notified well in advance of closing.
Applying for permits leads to a determination that the property or construction site is within a mapped floodplain and therefore subject to floodplain management requirements.
When flooding occurs the news media frequently carries stories about travel hampered by flooded roads and homes damaged by floodwaters. Research has shown that many flood victims themselves tend to discount the likelihood that flooding will occur again. This tendency is attributed to a general lack of understanding of probability (see Comparing Risks, below). All too often, people interpret the phrase "100-year storm" to mean that it only occurs once every 100 years, rather than that such an event has a 1-in-100 chance of happening each year. FEMA reports that, based on insurance statistics, a building in the floodplain is five times more likely to be damaged by flood than to sustain major damage by fire.
Flood warnings reach the public as regional warnings from the National Weather Service.

## 5.5 Overview of BDD4's Natural Hazards History

Numerous federal agencies maintain a variety of records regarding losses associated with natural hazards. Unfortunately, no single source is considered to offer a definitive accounting of all losses. FEMA maintains records on federal expenditures associated with declared major disasters. The U.S.

Army Corps of Engineers (USACE) and the Natural Resources Conservation Service (NRCS) collect data on losses during the course of some of their ongoing projects and studies. As mentioned earlier in this Section, NOAA's NCDC database is another source where data statistics such as injuries, deaths, and damage estimates are maintained for a variety of natural hazards. The data is maintained throughout the District, with more recent entries listing the specific location within the district. Although not always specific to BDD4, this hazard data from the NCDC is often the best available resource for documenting historical events. For many of the hazards profiled, the query results from the NCDC database are provided in the hazard specific subsections of Section 5.6.

In the absence of definitive data on some of the natural hazards that may occur in BDD4, illustrative examples are useful. Table 5-2 provides brief descriptions of particularly significant natural hazard events occurring in BDD4's recent history. This list is not meant to capture every event that has affected the area; rather it lists one or two examples of the types of events than have affected the area in the past.

Data on Presidential Disaster Declarations characterize some natural disasters that have affected the area. In 1965, the federal government began to maintain records of events determined to be significant enough to warrant declaration of a major disaster by the President of the United States. Presidential Disaster Declarations are made at the county level and are not specific to any one city or sub-area, such as BDD4. Given that it should be noted that not all disaster declarations for Brazoria County affected the Brazoria Drainage District No. 4. However, as of 2010, 13 such disasters had been declared in Brazoria County and are identified as part of the summary in Table 5-2. Declared disasters that directly affected BDD4 are noted in Table 5-2.

**Table 5-2**
**Natural Hazard Events and Declared Major Disasters in Brazoria County**
(Sources: Public Entity Risk Institute (PERI) website, FEMA, NCDC database)

| Date & Disaster (DR) | Nature of Event |
|---|---|
| July 11, 1973<br>DR-398 | **Severe Storm and Flooding (Limited damage in the District)**. Clear Creek, Chigger Creek, Cowards Creek, and Mary's Creek flooded due to protracted rains. The storms responsible for the rains also triggered tornadoes within the area. The flooding event inundated roads within the District |
| July 28, 1979<br>DR-595 | **Storms and Flash Floods.** Tropical Storm Claudette formed in the Central Atlantic the morning of July 15, 1979. It never reached hurricane intensity as it wandered across the northern Caribbean, and the Gulf of Mexico 10 days, making landfall near Port Arthur the evening of the 24th. The storm veered left and stalled over Alvin, TX the evening/early morning hours of the 25th/26th. This was a weak tropical storm, and went through the "Core Rain" phase during that period. An observer 3.2 miles northwest of Alvin reported 8.0" in one 4-hour period. Alvin recorded the maximum 24-hour rainfall on record for the United States of 43 inches |
| September 25, 1979<br>DR-603 | **Severe Storm and Flooding.** Torrential rains caused Clear Creek to overflow its banks. Many streets and homes within the District were flooded |
| August 19, 1983<br>DR-689 | **Hurricane Alicia.** Category 3 hurricane which caused $3.0 billion damage/costs and 21 deaths statewide |
| April 12,1991<br>DR-900 | Severe Storms, Tornadoes, and Flooding – (limited damage in the District) |

| | |
|---|---|
| December 26, 1991<br>DR-930 | **Severe Thunderstorms**. (Limited damage in the District) "Christmas Flood". This was not a historic event in terms of large rainfall totals. But in terms of total rain volume that fell from the sky in one event, this certainly was one of the largest in Texas recorded history, if not the largest. Thousands of previously unsuspecting home owners were flooded as Oyster Creek became several miles wide in Brazoria County where five hundred homes suffered serious flood damage |
| February 25, 1993 | **Tornado**. The public reported a tornado near the grade school at Southdown and Highway 288. This tornado was 100 yards wide and caused about $5,000 in damages |
| April 25, 1993 | **Hail**. A SkyWarn spotter reported golf ball-size hail on the east side of Pearland. The hail was 1.75" in diameter and caused $5,000 in damages |
| October 18, 1994<br>DR-1041 | **Severe Thunderstorms and Flooding**. Disastrous flooding passed down Cypress and Spring Creeks, the W and E Fork San Jacinto Rivers, producing a record elevation in Lake Houston by nearly 3 feet. Three hundred forty thousand cfs passed over the emergency spillway down the San Jacinto River below Lake Houston. The Houston Chronicle listed 15,775 homes damaged - 3,069 destroyed - 22 flood related deaths along these streams. Some homes flooded to the roofs of two story homes. – IA Only |
| July 21, 1995 | **Heat Wave.** Heat Advisories were issued covering all of Southeast Texas for an eight day period. Overnight lows hovered around 80 degrees, while afternoon highs were near 100 each day. The afternoon heat indices ranged from 105-115 degrees. Approximately 200 people reported signs of heat stress or exhaustion. There were also two deaths reported due to the excessive heat |
| April – May 1996 | **Drought.** Continuation of drought conditions from April. May, normally one of the wettest months, had very little rainfall across Southeast Texas. Many stations actually received less than 0.10 of an inch of rain during May. The effects on agricultural products continued to worsen with many spring crops being lost due to lack of rainfall. Property damage for Southeast Texas this month were $10 million, agricultural losses $50 million |
| September 23, 1998<br>DR-1245 | **Severe Storm and Flooding - Tropical Storm Francis** Tropical Storm Frances, and a localized thunderstorm that followed later in the same month, resulted in widespread flooding. IA Only |
| May 20, 2000 | **Thunderstorm.** Severe wind damage at Clover Field. Two airplane hangars, 8 trailers, 1 helicopter, and an unknown number of small airplanes overturned or destroyed. Large awning and billboard down at FM 518 and SH 35. Large trees and power lines down in the Pearland area. There was over $1 M in property damage |
| June 9, 2001<br>DR-1379 | **Severe Storm and Flooding - Tropical Storm Allison**. Tropical Storm Allison produced flooding throughout Southeast Texas, Louisiana, and across the eastern United States. Rainfall rates in the Houston area exceeded both the 100 and 500-year rainfall rates resulting in over 50,000 homes flooded. Damages were estimated at $5 Billion and prompted a Presidential disaster declaration for 30 counties in Texas. BDD4 experienced devastating flooding from this storm |
| April 8, 2002 | **Flash Floods.** Heavy rains caused street flooding in the neighborhood of Corrigan. Many roads in this neighborhood were impassable. There was $5,000 in property damage |
| September 26, 2002<br>DR 1434 | **Tropical Storm Fay**. Limited damage in the District |

| | |
|---|---|
| September, 24, 2005<br>DR-1606 | **Hurricane Rita**. Minimal damage and no flooding reported in the District from the event. Four neighborhoods experienced isolated and intermittent power outages |
| September 13, 2008<br>DR-1791 | **Hurricane Ike.** The District experienced a direct strike from Hurricane Ike an extremely large Category 2 storm with maximum sustained winds near 90 miles per hour and gusts exceeding 100 miles per hour. Ike caused wind damage to District facilities, damaged approximately two thousand homes and businesses, and created citywide power outages |
| April 18, 2009 | **Severe thunderstorms** dumped six to seven inches of rain in four hours. The heavy rains caused localized flooding along area creeks. Several subdivisions in the District had street flooding with water threatening homes. The South side of Pearland from Fite South and along Magnolia and Bailey the ditches were overflowing and there was extensive field flooding |

## 5.6 Losses Due to Major Disasters

No definitive record exists of all losses – public and private – due to disasters for BDD4. For the United States as a whole, estimates of the total public and private costs of natural hazards range from $2 billion to over $6 billion per year. Most of those costs can only be estimated. In most declared major disasters, the federal government reimburses 75% of the costs of cleanup and recovery, with the remaining 25% covered by the state and affected local jurisdictions.

FEMA's estimate of its expenditures in the State of Texas for flood disasters alone for the period from 1991 through 2009 exceeds $8 billion. This period includes Tropical Storm Allison, and Hurricanes Rita and Ike. These costs, which do not include costs incurred by other federal agencies or by state and local agencies, include those associated with:

Public assistance for debris removal, emergency services, roads and bridges, flood control facilities, public buildings and equipment, public utilities, and parks and recreational facilities.
Assistance paid out for individual and family grants, emergency food and shelter, and other assistance to individuals.
Funds set aside to support hazard mitigation grants.

BDD4 received Public Assistance (PA) funds after several of the events described above in Table 5-2. In addition to PA funds outlined in Table 5.3, BDD4 has also received hazard mitigation funds to support numerous mitigation initiatives. A detailed description of mitigation projects and funds received can be found in Section 7.7, Ongoing and Previous Mitigation Initiatives. Section 7.7 also describes additional mitigation projects that the BDD4 has recently applied for federal funding after Hurricane Ike in 2008.

**Table 5-3**
**Public Assistance Summary Brazoria Drainage District No. 4**
(Sources: PA PWs)

| | **BDD4 Public Assistance Worksheets for DR 1791- Hurricane Ike** | |
|---|---|---|
| Event | Damage | Amount |
| DR 1791 | High winds damages and destroyed trees, limbs, and structures with a large amount of vegetative debris scattered in BDD4 maintained ditches. BDD4 removed and hauled 4,500 (est) CY of mixed debris to landfill | $550,000 |
| DR 1791 | Hurricane winds and windborne debris damaged BDD4 owned fencing. Fencing was repaired and/or replaced | $65,000 |
| DR 1791 | Hurricane winds and windborne debris damaged two BDD4 owned warehouses. Roof, walls, ridge cap, doors, window panes repaired/replaced | $121,500 |
| | Total | $736,500 |

## 5.7 Hazards Other than Flood

Natural hazards other than flood hazards that are deemed pertinent to BDD4 are described, along with summary statements about exposure to risks associated with those hazards. Because flooding poses the most significant risk in BDD4, Section 6 outlines flood hazards, past flood events, and summaries of the people and property that are at-risk. The following subsections provide an overview of past hazard events and associated losses:

- Tornadoes
- Thunderstorms/High Winds
- Hurricanes and Tropical Storms
- Extreme Heat
- Drought
- Wildland Fire
- Winter Storm
- Earthquake/Seismic
- Landslide

Table 5-4 identifies the total number and estimated value of buildings/infrastructure within BDD4. The table indicates there are 35,654 residential buildings, 3,094 mobile homes and 5,709 commercial buildings. The total population of the incorporated areas within BDD4 is estimated to be 100,544[3]. The

[3] Number of residents based on the number of residential buildings times the average number of people per household (2.82 in Brazoria County).

total population in BDD4 is slightly higher than this figure when considering the additional residents living within the unincorporated areas. The data in Table 5-4 is used periodically throughout Section 5.7 to identify the overall District-wide exposure for certain hazards that equally impact the entire planning area such as hurricanes/tropical storms and drought.

**Table 5-4**
**Buildings/Infrastructure Within Brazoria Drainage District Four**
(Sources: US Census Bureau, Central Appraisal District)

| Type | Number of Structures/Estimated Value | |
|---|---|---|
| Residential Buildings | 35,654 | $5,219,745,600* |
| Commercial Buildings | 5,709 | N/A |
| District owned Buildings | 6 | $2,312,800** |
| **Total** | **41,369** | **$5,222,058,400** |

* – Data obtained from Central Appraisal District – based on average value of buildings within the County multiplied by number of buildings

** –Value based on insured value of District owned structures

### General Assessment of Probability and Potential Impacts

For each hazard profiled in the present section, the planning team assigned a high, medium, or low probability of future occurrences. The hazard probability was assigned by dividing the period of record by the numbers of previous events, then scaling the probabilities as low, medium, and high, as shown in Table 5-5. Note that the percent ranges in the table below are not intended as exact probabilities; they are estimates made by the planning team, intended to be used as a general guide for future planning purposes. Also note that future probability is only one component of the risk calculation (the others being severity vulnerability and value). Some hazards, such as major hurricanes and earthquakes have a low probability but potentially very high impact on life and property in the planning area.

**Table 5-5**
**Annual Percent Probability Ranges**

| Probability | Annual Percent Probability Range (%) |
|---|---|
| Low | 1-9 |
| Medium | 10-24 |
| High | 25-100 |

For each hazard profiled, to determine the impact on life and property the MPC categorized the impact by minor, moderate, and major. To assess the impact on property, these categories were assigned a dollar range based on the estimated annual damages. For the impact on life, the category values were based on the number of deaths caused by the hazard. The categories and dollar ranges are shown in Table 5-6.

**Table 5-6**
**Impact on Life and Property**

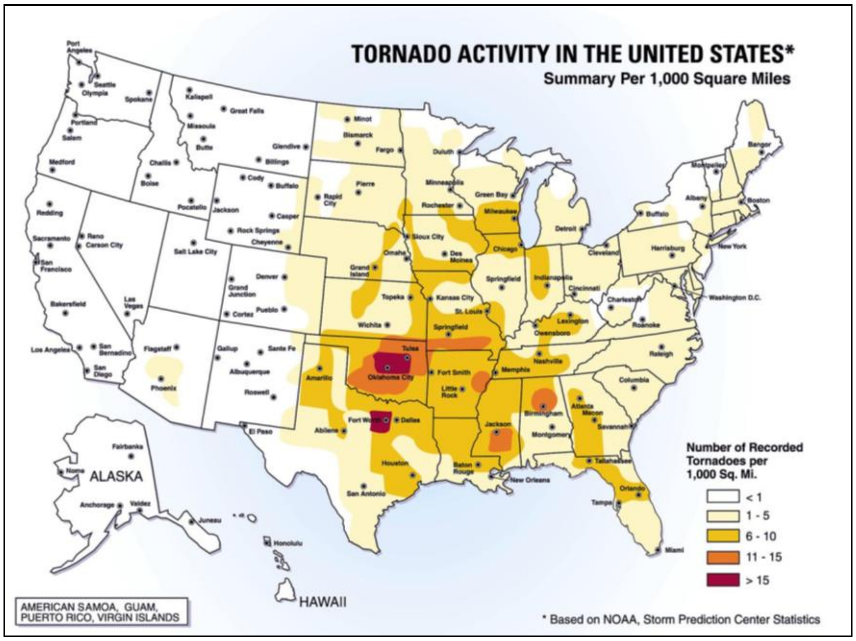
| Impact | Estimated Annual Damages ($) | Deaths | Injuries |
|---|---|---|---|
| Minor | <250,000 | 0 | 1 – 10 |
| Moderate | 250 - 1,000,000 | 1 - 3 | 11 – 25 |
| Major | >1,000,000 | > 4 | > 25 |

### 5.7.1 Tornadoes

Tornadoes pose a significant threat to life and safety in BDD4. The National Weather Service defines a tornado as a violently rotating column of air in contact with the ground and extending from the base of a thunderstorm. Tornadoes can form any time of the year; but the season of greatest activity runs from March to August. See Appendix A for a more detailed description of the tornado hazard.

Figure 5-1 illustrates the frequency of tornado strikes in the U.S. per 1,000 square miles. With an average of 153 tornadoes touching down each year, Texas is considered the U.S. "tornado capital." While Texas tornadoes can occur in any month and at all hours of the day or night, they occur with greatest frequency during the late spring and early summer months during late afternoon and early evening hours. The tornado hazard affects the entire planning area approximately equally. Generally, engineered commercial (and other non-residential) structures are less vulnerable to the effects of tornadoes than are residential structures, with exceptions.

**Figure 5-1**
**Tornado Activity in the U.S.**
(Source: NOAA – Storm Prediction Center)




In BDD4, most wind damage has been limited to downed trees, blocked roads, and disabled power lines. In the Brazoria region there have been no weather-related deaths associated with tornadoes, and only two were associated with lightning and severe thunderstorms combined. The NCDC indicates that between 1950 and 2010 there were 69 tornadoes in Brazoria County. For these events, the NCDC database reported no deaths, 45 injuries and over of $6.4 million in damages. Table 5-7 summarizes all the tornadoes within the county between 1950 and 2010

**Table 5-7**
**Brazoria County: Tornadoes since 1950, 1950 - 2010**
(Source: NOAA/NCDC)

**69 TORNADO**(s) were reported in **Brazoria County, Texas** between **01/01/1950** and **09/30/2010**.

*Click on **Location or County** to display Details.*

**Mag**: Magnitude
**Dth**: Deaths
**Inj**: Injuries
**PrD**: Property Damage
**CrD**: Crop Damage

**Texas**

| Location or County | Date | Time | Type | Mag | Dth | Inj | PrD | CrD |
|---|---|---|---|---|---|---|---|---|
| 1 BRAZORIA | 02/11/1950 | 1310 | Tornado | F2 | 0 | 0 | 25K | 0 |
| 2 BRAZORIA | 02/08/1956 | 1100 | Tornado | F0 | 0 | 0 | 0K | 0 |
| 3 BRAZORIA | 03/17/1957 | 1518 | Tornado | F1 | 0 | 0 | 250K | 0 |
| 4 BRAZORIA | 03/17/1957 | 1700 | Tornado | F | 0 | 0 | 0K | 0 |
| 5 BRAZORIA | 07/10/1958 | 1215 | Tornado | F0 | 0 | 0 | 0K | 0 |
| 6 BRAZORIA | 08/13/1959 | 1309 | Tornado | F0 | 0 | 0 | 0K | 0 |
| 7 BRAZORIA | 06/28/1963 | 0800 | Tornado | F1 | 0 | 0 | 0K | 0 |
| 8 BRAZORIA | 04/18/1966 | 0053 | Tornado | F3 | 0 | 0 | 0K | 0 |
| 9 BRAZORIA | 09/20/1967 | 0820 | Tornado | F | 0 | 0 | 3K | 0 |
| 10 BRAZORIA | 09/21/1967 | 1110 | Tornado | F | 0 | 0 | 0K | 0 |
| 11 BRAZORIA | 08/08/1968 | 1215 | Tornado | F0 | 0 | 0 | 0K | 0 |
| 12 BRAZORIA | 09/15/1968 | 0700 | Tornado | F0 | 0 | 0 | 0K | 0 |
| 13 BRAZORIA | 08/11/1970 | 1830 | Tornado | F1 | 0 | 0 | 3K | 0 |
| 14 BRAZORIA | 05/12/1972 | 0445 | Tornado | F1 | 0 | 1 | 0K | 0 |
| 15 BRAZORIA | 05/12/1972 | 0446 | Tornado | F1 | 0 | 6 | 250K | 0 |
| 16 BRAZORIA | 05/12/1972 | 1215 | Tornado | F1 | 0 | 0 | 3K | 0 |
| 17 BRAZORIA | 06/05/1973 | 1855 | Tornado | F1 | 0 | 0 | 0K | 0 |
| 18 BRAZORIA | 06/20/1973 | 1230 | Tornado | F1 | 0 | 0 | 25K | 0 |
| 19 BRAZORIA | 09/13/1974 | 1145 | Tornado | F0 | 0 | 0 | 0K | 0 |
| 20 BRAZORIA | 06/27/1975 | 0945 | Tornado | F0 | 0 | 0 | 0K | 0 |
| 21 BRAZORIA | 03/08/1976 | 1301 | Tornado | F3 | 0 | 18 | 2.5M | 0 |
| 22 BRAZORIA | 03/08/1976 | 1335 | Tornado | F1 | 0 | 0 | 250K | 0 |
| 23 BRAZORIA | 09/26/1976 | 1230 | Tornado | F1 | 0 | 0 | 0K | 0 |
| 24 BRAZORIA | 09/18/1979 | 1330 | Tornado | F1 | 0 | 0 | 25K | 0 |
| 25 BRAZORIA | 09/06/1980 | 0955 | Tornado | F0 | 0 | 0 | 0K | 0 |
| 26 BRAZORIA | 05/03/1981 | 1840 | Tornado | F2 | 0 | 10 | 250K | 0 |
| 27 BRAZORIA | 06/03/1981 | 0005 | Tornado | F0 | 0 | 0 | 3K | 0 |
| 28 BRAZORIA | 08/31/1981 | 0815 | Tornado | F1 | 0 | 0 | 250K | 0 |
| 29 BRAZORIA | 08/31/1981 | 1145 | Tornado | F1 | 0 | 0 | 25K | 0 |
| 30 BRAZORIA | 05/06/1982 | 1630 | Tornado | F1 | 0 | 0 | 25K | 0 |
| 31 BRAZORIA | 05/13/1982 | 1440 | Tornado | F1 | 0 | 0 | 250K | 0 |
| 32 BRAZORIA | 01/31/1983 | 1307 | Tornado | F1 | 0 | 0 | 250K | 0 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 33 BRAZORIA | 02/09/1983 | 1425 | Tornado | F2 | 0 | 0 | 25K | 0 |
| 34 BRAZORIA | 03/16/1983 | 0720 | Tornado | F0 | 0 | 0 | 25K | 0 |
| 35 BRAZORIA | 03/26/1983 | 0630 | Tornado | F1 | 0 | 7 | 250K | 0 |
| 36 BRAZORIA | 03/26/1983 | 0640 | Tornado | F0 | 0 | 0 | 3K | 0 |
| 37 BRAZORIA | 07/15/1983 | 1055 | Tornado | F1 | 0 | 2 | 250K | 0 |
| 38 BRAZORIA | 08/18/1983 | 0220 | Tornado | F0 | 0 | 0 | 0K | 0 |
| 39 BRAZORIA | 08/18/1983 | 1830 | Tornado | F0 | 0 | 0 | 0K | 0 |
| 40 BRAZORIA | 08/18/1983 | 1835 | Tornado | F0 | 0 | 0 | 0K | 0 |
| 41 BRAZORIA | 01/29/1989 | 1353 | Tornado | F0 | 0 | 0 | 25K | 0 |
| 42 BRAZORIA | 01/29/1989 | 1420 | Tornado | F0 | 0 | 0 | 25K | 0 |
| 43 BRAZORIA | 01/18/1991 | 1020 | Tornado | F0 | 0 | 0 | 250K | 0 |
| 44 BRAZORIA | 05/04/1991 | 2205 | Tornado | F0 | 0 | 0 | 25K | 0 |
| 45 BRAZORIA | 02/22/1992 | 0615 | Tornado | F1 | 0 | 0 | 25K | 0 |
| 46 BRAZORIA | 02/22/1992 | 0659 | Tornado | F0 | 0 | 0 | 3K | 0 |
| 47 BRAZORIA | 11/21/1992 | 1510 | Tornado | F1 | 0 | 0 | 250K | 0 |
| 48 Pearland | 02/25/1993 | 1145 | Tornado | F0 | 0 | 0 | 5K | 0 |
| 49 Brazosport | 04/14/1993 | 1400 | Tornado | F1 | 0 | 0 | 50K | 0 |
| 50 BRAZORIA | 11/16/1993 | 0710 | Tornado | F0 | 0 | 0 | 1K | 0 |
| 51 Surfside | 09/10/1994 | 1130 | Tornado | F0 | 0 | 0 | 50K | 0 |
| 52 Manvel | 04/11/1997 | 04:15 AM | Tornado | F0 | 0 | 0 | 25K | 0 |
| 53 Manvel | 07/16/1997 | 06:15 PM | Tornado | F0 | 0 | 0 | 50K | 0 |
| 54 Oyster Creek | 11/05/1997 | 06:00 AM | Tornado | F0 | 0 | 0 | 5K | 0 |
| 55 Rosharon | 02/16/1998 | 06:03 PM | Tornado | F0 | 0 | 0 | 30K | 0 |
| 56 Angleton | 10/05/1998 | 12:35 AM | Tornado | F0 | 0 | 0 | 15K | 0 |
| 57 Angleton | 03/28/1999 | 04:35 AM | Tornado | F0 | 0 | 0 | 50K | 0 |
| 58 Rosharon | 05/02/2000 | 02:30 AM | Tornado | F0 | 0 | 0 | 25K | 0 |
| 59 Manvel | 06/05/2001 | 04:30 PM | Tornado | F0 | 0 | 0 | 40K | 0 |
| 60 Alvin | 08/30/2001 | 05:25 PM | Tornado | F0 | 0 | 0 | 45K | 0 |
| 61 Brazoria | 08/30/2001 | 08:05 PM | Tornado | F0 | 0 | 0 | 5K | 0 |
| 62 Brazoria | 12/12/2001 | 02:20 AM | Tornado | F1 | 0 | 0 | 200K | 0 |
| 63 Brazoria | 12/12/2001 | 02:30 AM | Tornado | F0 | 0 | 0 | 200K | 0 |
| 64 Lake Jackson | 09/06/2002 | 11:45 PM | Tornado | F0 | 0 | 0 | 5K | 0 |
| 65 West Columbia | 09/07/2002 | 12:30 AM | Tornado | F0 | 0 | 0 | 25K | 0 |
| 66 Iowa Colony | 10/09/2003 | 04:45 PM | Tornado | F0 | 0 | 0 | 2K | 0 |
| 67 Brazoria | 11/17/2003 | 02:50 PM | Tornado | F0 | 0 | 1 | 75K | 0 |
| 68 Oyster Creek | 05/14/2006 | 03:40 PM | Tornado | F0 | 0 | 0 | 5K | 0 |
| 69 Oyster Creek | 04/25/2007 | 11:05 AM | Tornado | F0 | 0 | 0 | 0K | 0K |
| | | | | TOTALS: | 0 | 45 | 6.448M | 0 |

**Table 5-8**
**Fujita Tornado Measurement Scale**
(Source: NOAA)

| Category | Wind Speed | Examples of Possible Damage |
|---|---|---|
| F0 | Gale (40-72 mph) | Light damage. Some damage to chimneys; break branches of trees; push over shallow rooted trees; damage to sign boards. |
| F1 | Moderate (73-112 mph) | Moderate damage. Peel surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off roads. |
| F2 | Significant (113-157 mph) | Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light-object missiles generated. |
| F3 | Severe (158-206 mph) | Severe damage. Roofs and some walls torn off well constructed houses; trains overturned; most trees in forest uprooted; cars lifted off ground and thrown. |
| F4 | Devastating (207-260 mph) | Devastating damage. Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated. |
| F5 | Incredible (261-318 mph) | Incredible damage. Strong frame houses lifted off foundations and carried considerable distance to disintegrate; automobile sized missiles fly through air in excess of 100 yards; trees debarked; incredible phenomena will occur. |

In February of 2007 the F-Scale (Table 5-8) was replaced with a more accurate Enhanced Fujita Scale (Enhanced F-scale). It was the Jarrell, Texas tornado of May 27, 1997 and the Oklahoma City/Moore tornado of May 3, 1999 that brought to the forefront the problem that perhaps the wind estimates were too high in the F-Scale. The changes to the original scale were proposed by a committee of meteorologist and engineers searching for a more accurate method of assessing the magnitude of tornadoes. Changes to the original Fujita scale were designed to ensure compatibility with the existing databases of tornado hazards, including the one maintained by the NCDC.

The Enhanced F-scale has the same basic design as the original Fujita scale, six categories from zero to five representing increasing degrees of damage.[4] It was revised to reflect better examinations of tornado damage surveys, so as to align wind speeds more closely with associated storm damage. The new scale also considers damages to a wider variety of structures and better accounts for variables such as differences in construction quality. Table 5-9 displays the wind speed ranges for the original Fujita Scale, the derived wind speeds (Enhanced F-scale), and the new Enhanced F-scale, in wide use since February of 2007.

[4] NOAA; Storm Prediction Center – Summary of Enhanced F-scale

**Table 5-9**
**Wind Speed Comparison of the Fujita Scale and Enhanced Fujita Scale**
(Source: NOAA – National Weather Service)

| Fujita Scale | | | Derived EF Scale | | Operational EF Scale | |
|---|---|---|---|---|---|---|
| F Number | Fastest 1/4-mile (mph) | 3 Second Gust (mph) | EF Number | 3 Second Gust (mph) | **EF Number** | **3 Second Gust (mph)** |
| 0 | 40-72 | 45-78 | 0 | 65-85 | **0** | **65-85** |
| 1 | 73-112 | 79-117 | 1 | 86-109 | **1** | **86-110** |
| 2 | 113-157 | 118-161 | 2 | 110-137 | **2** | **111-135** |
| 3 | 158-207 | 162-209 | 3 | 138-167 | **3** | **136-165** |
| 4 | 208-260 | 210-261 | 4 | 168-199 | **4** | **166-200** |
| 5 | 261-318 | 262-317 | 5 | 200-234 | **5** | **Over 200** |

It is possible for tornadoes of any intensity (up to EF-5) to occur anywhere within the planning area. Although the NCDC indicates the strongest recorded tornadoes in Brazoria County were rated as F3s (two total) on the Fujita scale, the climate in southeastern Texas, and the potential for extreme atmospheric instability, allow for the possibility that tornadoes in the planning area could reach EF-5 severity. For example the Jarrell, Texas tornado in 1997 mentioned above was officially categorized by NOAA as an F5. This tornado occurred only several hundred miles from Brazoria County where climate conditions are relatively similar. It should be noted that a normal probabilistic distribution of events would mean that events on the lower end of the scale would predominate, while more severe events will be less common.

According to the NCDC database, Brazoria County experienced 69 tornadoes (42 F0s, 22 F1s, 3 F2s, and 2 F3s) between 1950 and 2010. Again, the majority of the tornadoes listed in the database did not indicate the specific location within the County. Therefore, the county-wide estimate of $6.4 million from the NCDC was used to estimate the potential dollar value of losses to existing buildings in BDD4. Dividing this prior loss by the span of years in which this loss was incurred (60 years), it is estimated that Brazoria County has a potential annual loss from tornadoes of $106,666. Using county and city census data the county-wide annual loss estimate can be proportioned for the BDD4. The 2009 US Census reported there were 117,993 housing units in Brazoria County and Table 5-4 indicates 35,654 residential housing units in BDD4 with a certificate of occupancy. The 35,654 housing units in the District represent approximately 30.2% of the county-wide total. Using this percentage, it is estimated that the annual loss from tornadoes in the District is $32,231.

**Table 5-10**
**Brazoria County: Tornadoes Resulting in Injuries, 1950 - 2009**
(Source: NOAA/NCDC)

**7 TORNADO**(s) were reported in **Brazoria County, Texas** between **01/01/1950** and **09/30/2010** with **at least 1 injuries**.

*Click on* ***Location or County*** *to display Details.*

**Mag**: Magnitude
**Dth**: Deaths
**Inj**: Injuries
**PrD**: Property Damage
**CrD**: Crop Damage

**Texas**

| Location or County | Date | Time | Type | Mag | Dth | Inj | PrD | CrD |
|---|---|---|---|---|---|---|---|---|
| 1 BRAZORIA | 05/12/1972 | 0445 | Tornado | F1 | 0 | 1 | 0K | 0 |
| 2 BRAZORIA | 05/12/1972 | 0446 | Tornado | F1 | 0 | 6 | 250K | 0 |
| 3 BRAZORIA | 03/08/1976 | 1301 | Tornado | F3 | 0 | 18 | 2.5M | 0 |
| 4 BRAZORIA | 05/03/1981 | 1840 | Tornado | F2 | 0 | 10 | 250K | 0 |
| 5 BRAZORIA | 03/26/1983 | 0630 | Tornado | F1 | 0 | 7 | 250K | 0 |
| 6 BRAZORIA | 07/15/1983 | 1055 | Tornado | F1 | 0 | 2 | 250K | 0 |
| 7 Brazoria | 11/17/2003 | 02:50 PM | Tornado | F0 | 0 | 1 | 75K | 0 |
| | | | | TOTALS: | 0 | 45 | 3.575M | 0 |

With a total of 69 tornado events between 1950 and 2010, Brazoria County experiences on average approximately 1.15 tornados per year. With more than one event every year, there is a statistical annual probability of greater than 100% that a tornado of some magnitude will occur in Brazoria County. Note that this percentage is based on tornado events for all of Brazoria County. It should also be noted that the majority of tornadoes here (and other places) are low-magnitude events that cause little or no damage. The probability calculation estimate would be somewhat lower than this if only the BDD4 planning area were considered. Based on the high, medium, and low ranges identified in Table 5-5, there is a high probability of future tornadoes occurring in BDD4.

Within BDD4, Tornadoes risks to people and property cannot be distinguished by area; the hazard is reasonably predicted to have uniform probability of occurrence across the entire County. All people and assets are considered to have the same degree of exposure. Historically, lightly constructed residential structures (in particular, manufactured housing, specifically mobile homes) within the planning area are most vulnerable to the tornado hazard. Data related to the number of structures by building type and past damages for specific building types was unavailable at the time of the 2011 Plan, and therefore the loss estimates for the tornado hazard are based on total property damage as reported by the NCDC.

As mentioned above, past tornados in the County have caused an estimated $6.4 million in damages. Dividing this prior loss total for tornadoes by the span of years in which this loss was incurred (60 years), and dividing the percent of housing units in the district (30.2% of units in Brazoria County are located within BDD4), it is estimated that buildings within the BDD4 planning area have a potential annual loss from tornadoes of $32,231. With these annual losses, tornadoes could have a minor impact on the planning area (see Table 5-6).

BDD4 has no plans for constructing any new facilities in the near future. As the assessment of wind risk/damage, is based solely on BDD4 owned facilities, there is no estimated risk to future development from tornadoes.

Relative to other parts of the nation, the overall tornado risk is moderate in Brazoria County. The MPC determined that there is significant enough exposure to the tornado hazard to warrant a more detailed risk assessment to characterize the potential future losses. The calculation is done using FEMA's Benefit-Cost Analysis (BCA) software (version 4.5.5.0). It should be noted that this software was designed to assess risk at a single site or building, so the methodology must be adapted to reflect an assessment of an entire community. Furthermore, the software bases the risk calculation (and by extension, benefits, when risk is reduced) on avoided injuries and casualties, not damage to structures or loss of operations. These limitations mean that the results of the analysis should be regarded as a preliminary indication of potential life safety risk, based on very basic inputs. Evaluation of specific mitigation alternatives requires technical information that was not available for this version of the plan.

The FEMA BCA analysis methodology and tornado element of the software are based entirely on avoided injuries and fatalities (Table 5-10). The calculation is based on the population or occupancy at risk rather than the square footage or value of buildings or functions. The software uses default values for various levels of injury related to tornadoes. These values are shown in Figure 5-2 and include $5.8 million for death and $1.088 million for injuries requiring hospitalization.

**Figure 5-2**
**Injury and Death Costs**
(FEMA Benefit-Cost Analysis [BCAR] Tool, Version 4.5.5.0)

Save and Go Back

Injury Death Cost

Injury Costs

| Severity of Injury | WTP Value (Rounded $) |
|---|---|
| Dead - Fatal | $5,800,000 |
| Hospitalized | $1,088,000 |
| Self Treat | $12,000 |
| Treat & Release | $90,000 |

### Tornado Risk – Public Assets

The tornado risk assessment for Brazoria County Drainage District No. 4 was completed for all six buildings owned by the District. The analysis was completed based on data provided by the District and entered into the tornado module of the FEMA BCAR software. Table 5-11 below summarizes the data inputs.

**Table 5-11**
**BDD4 Tornado Risk Assessment - Project Information**

(Source: FEMA BCA Software, Version 4.5.5.0)

| Data | Value |
|---|---|
| Loss estimation horizon (years) | 100 |
| Zip Code used (Administrative Office) | 77581 |
| Assumed structure design wind speeds (mph) of safe room | 200 |
| Assumed structure type | Small Professional Building (steel frame) |
| **Occupancy Percentage** | |
| Day | 100% |
| Evening | 25% |
| Night | 5% |

The software then uses these inputs to calculate the expected loss of life and number of injuries for tornado classes EF0 to EF5. The FEMA software used for assessing tornado risk is based exclusively on life safety, so there is a strong correlation between the occupancy of a facility and the risk. Based on the number of total occupants, the software calculates the population on site based on statistics related to the probabilities of tornadoes impacting the building, by time of day. Table 5-12 shows the summary of benefits from the tornado risk assessment. The Table includes the annual and 100-year risk for each building and indicates the Administrative Office has the highest 100-year risk. This facility has a 100-year risk of $34,605.

**Table 5-12**
**Estimated Tornado Risk to Brazoria Drainage District No. 4 Public Facilities,**
**100 year Planning Horizon**
(Source: FEMA BCA Software [BCAR]**,** Version 4.5.5.0)

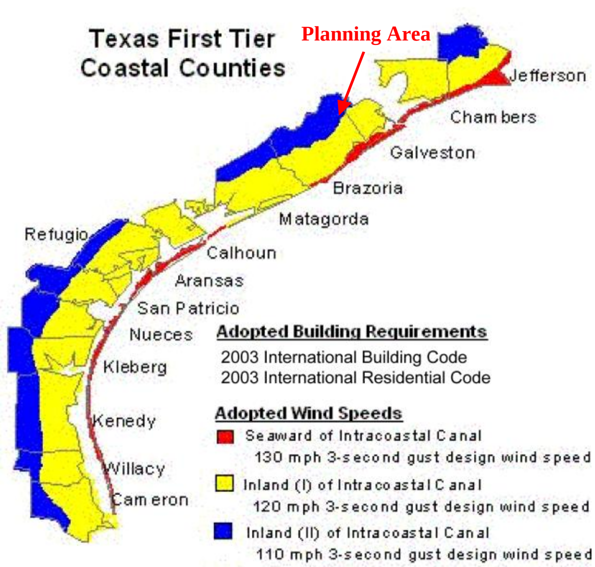
| Facility Description | Occupancy | Annual Risk | 100-year Risk |
|---|---|---|---|
| Administrative office | 14 | $2,425 | $34,605 |
| Field Service Operations - North Service Center | 9 | $1,559 | $22,246 |
| Field Service Operations - Covered Equipment / Parking | 9 | $1,559 | $22,246 |
| Storage and Workshop | 9 | $1,559 | $22,246 |
| Field Service Operations - Offices | 7 | $1,213 | $17,304 |
| Field Service Operations - Truck Wash Station | 2 | $346 | $4,942 |
| **Grand Total** | **50** | **$8,661** | **$123,589** |

### 5.7.2 Thunderstorms/High Winds

Several meteorological conditions can result in winds severe enough to cause property damage. High winds have been associated with extreme hurricanes traveling inland, tornadoes, and locally strong thunderstorms. Thunderstorms are the by-products of atmospheric instability, which promotes vigorous rising of air particles. A typical thunderstorm may cover an area three miles wide. The National Weather Service considers a thunderstorm "severe" if it produces tornadoes, hail of 0.75 inches or more in diameter, or winds of 58 miles per hour or more. Structural wind damage may imply the occurrence of a severe thunderstorm. See Appendix A for a more detailed description of the high wind hazard.

Figure 5-3 shows the "basic wind speed" map from the International Building Code. This map is used as the basis for structural design of buildings, such that they can withstand reasonably anticipated winds in order to minimize property damage [5] BDD4 falls within the area where the "design wind" speed is 110 miles per hour. The building code administered within the incorporated areas of Brazoria County require all new construction to be designed and constructed for 110 mile per hour wind loads. This design wind speed contemplates the potential effects of hurricanes, thunderstorms and tornadoes, and is based on three-second peak gusts at a height of 33 feet above the ground. Since this design wind speed is based on three kinds of events, it is not possible to state definitively that the potential high wind speed for thunderstorms is 110 mph, but it is safe to assume that the maximum potential straight line wind is perhaps in the 90 mph range.

**Figure 5-3**
**Basic Wind Speed: Texas First Tier Coastal Counties**
(Source: Texas Windstorm Insurance Association)




[5] American Society of Civil Engineers, 2002

In BDD4, most wind damage has been limited to downed trees, blocked roads, and disabled power lines. Since 1989, only 2% were associated with lightning and severe thunderstorms combined. The NCDC database indicates that between 1950 and 2010, Brazoria County experienced 118 severe thunderstorms and high wind events (seven of which had greater than 60 knot winds). All of the events listed occurred after 1965. There are most likely additional events between 1950 and 1965 that were not reported in the database. The database does not indicate why it does not include any events prior to 1965. Also note that the thunderstorm and high winds category of the NCDC database excludes hurricane wind events. High winds associated with hurricanes are captured under the Hurricanes and tropical storms category of the database. Therefore, events such as Hurricane Ike in September of 2008 are not included as part of the query results for high winds. Table 5-13 summarizes the seven high wind events with greater than 60 knot winds.

**Table 5-13**
**Brazoria County: Thunderstorm/High Wind Events Over 60 Knots, Excluding Tornado Winds, 1950 – 2009**
(Source: NOAA/NCDC)

**7 THUNDERSTORM WINDS** event(s) were reported in **Brazoria County, Texas** between **01/01/1950** and **09/30/2010**.

*Click on **Location or County** to display Details.*

**Mag**: Magnitude
**Dth**: Deaths
**Inj**: Injuries
**PrD**: Property Damage
**CrD**: Crop Damage

**Texas**

| Location or County | Date | Time | Type | Mag | Dth | Inj | PrD | CrD |
|---|---|---|---|---|---|---|---|---|
| 1 BRAZORIA | 05/30/1975 | 1406 | Tstm Wind | 73 kts. | 0 | 0 | 0 | 0 |
| 2 BRAZORIA | 05/30/1975 | 1406 | Tstm Wind | 73 kts. | 0 | 0 | 0 | 0 |
| 3 BRAZORIA | 05/02/1978 | 2245 | Tstm Wind | 63 kts. | 0 | 0 | 0 | 0 |
| 4 BRAZORIA | 01/17/1980 | 1450 | Tstm Wind | 70 kts. | 0 | 0 | 0 | 0 |
| 5 BRAZORIA | 01/14/1991 | 2010 | Tstm Wind | 75 kts. | 0 | 0 | 0 | 0 |
| 6 Freeport | 09/06/2002 | 10:25 PM | Tstm Wind | 61 kts. | 0 | 0 | 50K | 0 |
| 7 Lake Jackson | 12/30/2002 | 08:45 PM | Tstm Wind | 65 kts. | 0 | 0 | 1K | 0 |
| | | | | TOTALS: | 0 | 0 | 51K | 0 |

All people and assets in the District are considered to have the same degree of exposure to this hazard. Within the District, the risk to people and property from the high wind hazard cannot be distinguished by area; the hazard is expected to have a relatively uniform probability of occurrence across all of BDD4. Typically, assets of lighter construction (such as mobile homes) are most vulnerable to the high winds hazard. Data related to the number of structures by building type and past damages for specific building types was unavailable at the time of the 2011 Plan and therefore the loss estimates for the thunderstorm/high wind hazard are based on total property damage as reported by the NCDC.

As mentioned above, the severe thunderstorm/high wind results from the NCDC indicates that between 1950 and 2010 there have been 79 damaging thunderstorm/high wind events within Brazoria County that have caused an estimated $3.134 million in damages. Dividing this prior loss total for thunderstorms/high winds by the span of years in which this loss was incurred (60 years), and the percent of housing units, it is estimated that BDD4 as a whole has a potential annual loss from thunderstorms/high winds of $15,774. With these annual losses, thunderstorm/high winds could have a minor impact on the planning area (see Table 5-6).

With a total of 79 damaging thunderstorm/high wind events between 1950 and 2010, the County experiences a significant thunderstorm/high wind event on average approximately 1.3 times a year. With over one event per year, there is a greater than a 100% annual probability of a future thunderstorm/high wind events occurring in Brazoria County. Based on the historical thunderstorm/high wind data, the probability of future events impacting BDD4 is considered high. See Table 5-5 for the definition of high, medium and low probability.

BDD4 has no plans for constructing any new facilities in the near future. As the assessment of thunderstorm/high wind risk/damage, is based solely on BDD4 owned facilities, there is no estimated risk to future development from tornadoes.

### 5.7.3 Hurricanes and Tropical Storms

A hurricane is a tropical storm with winds that have reached a constant speed of 74 miles per hour or more. Hurricane winds blow in a large spiral around a relative calm center known as the "eye." The "eye" is generally 20 to 30 miles wide, and the storm may extend outward 400 miles. As a hurricane approaches, the skies will begin to darken and winds will grow in strength. As a hurricane nears land, it can bring torrential rains, high winds, and storm surges. A single hurricane can last for more than 2 weeks over open waters and can run a path across the entire length of the eastern seaboard. August and September are peak months during the hurricane season that lasts from June 1 through November 30. See Appendix A for a more detailed description of the hurricane and tropical storm hazard.

In Brazoria Drainage District No. 4, located within close proximity to the Gulf of Mexico, the District is exposed to risk from hurricanes. The hurricane and tropical storm hazard affects the entire planning area. The NCDC database indicates that between 1950 and 2008 there were nine hurricanes or tropical storms that impacted Brazoria County. The events occurred between 1995 and 2005. There are most likely additional events prior to 1995 that were not reported in the database. It is unclear why the database does not include any events prior to 1995. In addition, Hurricane Ike in September of 2008 was also not included as part of the query results. For the events listed, the NCDC database reported 28 deaths, 8 injuries and a total of $5.6 billion in property damages. Table 5-14 summarizes the 9 hurricanes and tropical storms that have impacted Brazoria County.

**Table 5-14**
**Hurricane and Tropical Storm Events in Brazoria County, 1950 - 2008**
(Source: NOAA/NCDC)

**9 HURRICANE & TROPICAL STORM** event(s) were reported in **Brazoria County, Texas** between **01/01/1950** and **09/30/2010**.

*Click on **Location or County** to display Details.*

**Mag**: Magnitude
**Dth**: Deaths
**Inj**: Injuries
**PrD**: Property Damage
**CrD**: Crop Damage

**Texas**

| Location or County | Date | Time | Type | Mag | Dth | Inj | PrD | CrD |
|---|---|---|---|---|---|---|---|---|
| 1 TXZ 200 - 213>214 - 235>238 | 07/30/1995 | 1400 | Tropical Storm Dean | N/A | 0 | 0 | 400K | 50K |
| 2 TXZ213>214 - 235>238 | 08/21/1998 | 12:00 AM | Tropical Storm | N/A | 0 | 0 | 25K | 0 |
| 3 TXZ163>164 - 176>179 - 195>200 - 210>214 - 226>227 - 235>238 | 09/07/1998 | 05:00 PM | Tropical Storm | N/A | 3 | 0 | 287.2M | 0 |
| 4 TXZ163>164 - 177>179 - 197>200 - 212>214 - 227 - 237>238 | 06/05/2001 | 01:00 PM | Tropical Storm | N/A | 22 | 0 | 5.2B | 0 |
| 5 TXZ226>227 - 235>238 | 09/05/2002 | 12:00 AM | Tropical Storm | N/A | 0 | 3 | 4.5M | 0 |
| 6 TXZ213>214 - 235>238 | 07/14/2003 | 06:00 PM | Hurricane/typhoon | N/A | 0 | 2 | 10.9M | 0 |
| 7 TXZ200 - 213>214 - 237>238 | 08/30/2003 | 11:00 AM | Tropical Storm | N/A | 0 | 0 | 50K | 0 |
| 8 TXZ164 - 177 - 214 - 236>238 | 09/01/2003 | 12:00 AM | Tropical Storm | N/A | 0 | 0 | 63K | 0 |
| 9 TXZ163>164 - 177>179 - 199>200 - 213>214 - 237>238 | 09/23/2005 | 09:00 PM | Hurricane/typhoon | N/A | 3 | 3 | 159.5M | 0 |
| | | | | TOTALS: | 28 | 8 | 5.613B | 50K |

***Note that the $5.2B for tropical storm Allison is statewide, not just damages in Brazoria**

In addition to the NCDC database, the National Hurricane Center's (NHC) Hurricane and Tropical Storm Tracker database was also queried to identify past hurricane events. According to the NHC, from 1900 to 2009, the eastern coast of Texas has been impacted by nine major hurricanes (Categories 3, 4, and 5). During the same time period, eastern Texas experienced 22 Category 1 or 2 hurricanes. Based on approximately 110 years of historical data from the NHC, the probability of future hurricanes impacting coastal area of eastern Texas is high, averaging one event approximately every four years.[6]

[6] National Hurricane Center (NHC), Historical Hurricane Tracks

Data from the NHC indicates there were eight additional major hurricanes between 1900 and 1998 that were not included in the NCDC database. Table 5-15 summarizes the six additional major hurricanes not captured in the NCDC database query prior to 1998.

**Table 5-15**
**Major Hurricane and Tropical Storm Events Impacting Brazoria County Within a 25 Mile Radius, 1950 - 1995**
(Source: National Hurricane Center – Hurricane and Tropical Storm Tracker)

| Event Date | Storm Name | Category | Maximum Winds (kts) |
|---|---|---|---|
| July 25, 1959 | Debra | H-1 | 75 |
| September 6, 1973 | Delia | TS | 60 |
| September 1, 1979 | Elena | TS | 35 |
| September 6, 1980 | Danielle | TS | 50 |
| August 18, 1983 | Alicia | H-3 | 100 |
| June 26, 1989 | Allison | TS | 45 |

In addition to the 4 hurricanes over the last 60 years, Brazoria County has also experienced 11 tropical storms. Perhaps the most significant tropical storm to impact the region was Tropical Storm Allison, which descended on southeast Texas in June of 2001. Tropical Storm Allison produced flooding throughout Southeast Texas, Louisiana, and across the eastern United States. Total damages were estimated at $5 billion and prompted a Presidential Disaster Declaration for 30 counties in Texas. The event claimed a total of 23 lives in Texas. The storm damaged approximately 73,000 residential homes and impacted over two million people.[7]

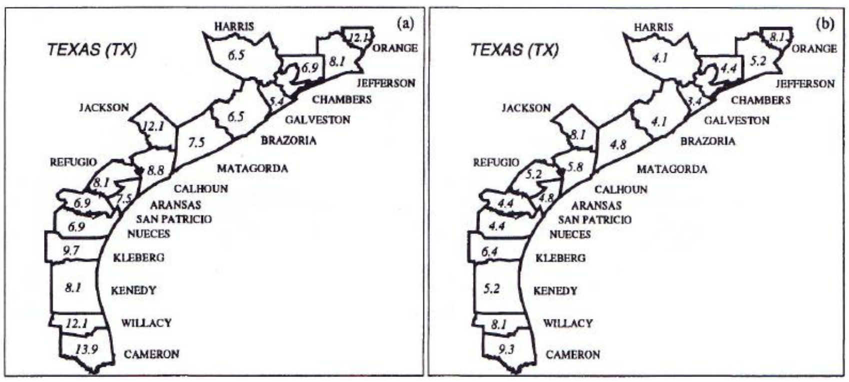
According to the National Weather Service's (NWS) Tropical Prediction Center, from 1900 to 1996, Texas experienced 12 direct hits from major hurricanes (Categories 3, 4, and 5). During the same time period, Texas experienced 13 direct hits from other hurricanes (Category 1 and 2). Based on approximately 100 years of historical data from the Tropical Prediction Center, the probability of future hurricanes impacting Texas is high, averaging approximately one event every four years.
Hurricane probability in southeastern Texas can also be assessed based on data from the 1999 study *Hurricanes of the North Atlantic, Climate and Society*. The study includes a series of maps showing the return periods and wait times for the Counties along the Texas coastline over the time period 1900 - 1996. The maps are shown in Figures 5-4 and 5-5 and include the following:

(a) hurricane return periods (Categories 1-5)
(b) wait times in coastal Counties (Categories 1-5)
(c) major hurricane return periods
(d) wait times in coastal Counties (major hurricanes)

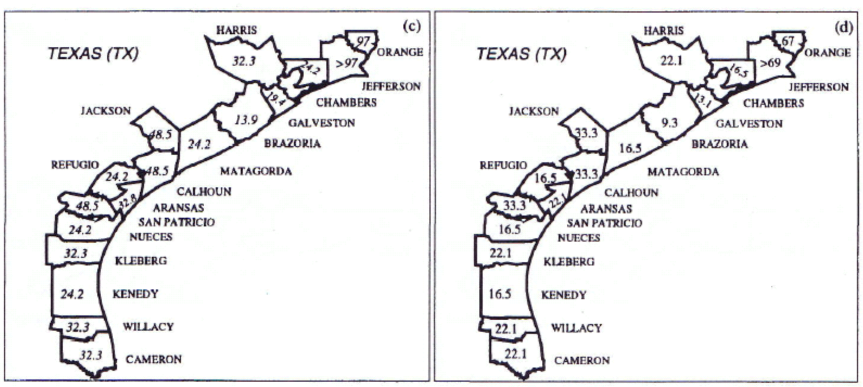
The number in each County is the return period or wait time in years. The wait time is the average time in years between hurricanes.

[7] 2007 State of Texas Mitigation Plan Update

**Figures 5-4 and 5-5**
**Southeast Texas Hurricane Return Periods and Wait Times**
(Source: *Hurricanes of the North Atlantic, Climate and Society, 1999*)
**All Hurricanes (Categories 1-5)**




**Major Hurricanes (Categories 3-5)**




The upper left hand map in the figure above (map *a*) shows the return period for all hurricanes (categories 1-5) in Brazoria County is 6.5 years, which equates to an approximate 15.5% annual probability of future occurrences. Major hurricanes have occurred less than every 13.9 years, which translates to an approximate 7.2% annual probability[8]. Based on high, medium, and low probability ranges in Table 5-4, the hurricane probability is considered medium for Category 1 and 2 magnitude storms, and low for Category 3 and higher. As mentioned earlier, future probability is only one component of the risk calculation. Although the hurricane hazard is considered to have a medium probability, a hurricane (particularly a major hurricane) has potential for catastrophic impacts on life and

[8] *Hurricanes of the North Atlantic, Climate and Society,* James Elsner and A. Birol Kara, New York, Oxford University Press, 1999

property in the planning area. Potential impacts are high for all hurricane categories. As mentioned above in the NCDC data, there have been nine hurricane/tropical storms between 1995 and 2010; causing approximately $1.42 billion in damages (the dollar value in damages was unavailable for events prior to 1995 and because the $5.2 billion for tropical storm Allison was statewide, only $1 Billion will be included for it within Brazoria). Dividing this prior loss total for hurricanes/tropical storms by the span of years in which this loss was incurred (15 years) is $97.5 million in damages for Brazoria County annually, then dividing the percent of housing units, it is estimated that BDD4 as a whole has a potential annual loss from hurricanes/tropical storms of $29.44 million (tropical storm Allison greatly skews this data, as it contributed to $1 billion of the $1.42 billion in property damage).

### 5.7.3.1 Hurricane Wind Risk in Brazoria Drainage District No. 4

Brazoria Drainage District No. 4 is located close enough to the Gulf Coast that high winds from hurricanes and tropical cyclones present significant risks to private and public assets and operations. This subsection presents the results of wind loss estimations for District assets that were completed with the FEMA benefit-cost analysis software (BCAR). Although this software is specifically intended to assess mitigation projects, it is possible to use it to estimate losses (risk), when sufficient data is available. It should be clearly understood that these results are general, and any site-specific risk assessment or mitigation project proposal should be analyzed in more detail, using additional details about structural characteristics, physical surroundings, and occupancies.

As part of the 2011 HMP, the District provided information about its facilities, including area, occupancy and structure type. Brazoria Drainage District No. 4 owns a total of six facilities. District facilities include an Administrative office, three Field Services Operations buildings, and a Storage and Workshop building. To calculate future losses, the analysis uses information about District assets in conjunction with open-source hazard data and FEMA software. The section below describes the methodologies and results. It was necessary to estimate some data parameters for the calculations that are summarized below. These inputs were used to calibrate the software model. Selected data inputs are shown in Table 5-16 below.

**Table 5-16**
**Brazoria Drainage District No. 4 Hurricane and Tropical Storm Wind Data Parameters**
(FEMA Benefit-Cost Analysis [BCAR] Tool, Version 4.5.5.0)

| Data | Value |
|---|---|
| Loss estimation (planning) horizon (years) | 100 |
| Displacement Costs ($/s.f./month) | $1.44 |
| Zip code | 77581 |
| Contents value | 50% of building replacement value |
| Exposure (urban and dense suburban or open) | Urban and dense suburban |
| Assumed wind debris source | Residential/commercial mix |
| Demolition threshold | 50% (default) |

The zip code 77581 for the BDD4 Administration Office was entered into the BC module to identify the wind speeds for each of the recurrence intervals identified in Table 5-17, which shows the wind hazard profile for BDD4.

**Table 5-17**
**Hurricane Wind Speed (3 second gusts) Recurrence Intervals at Pearland, Texas**
(FEMA Benefit-Cost Analysis [BCAR] Tool, Version 4.5.5.0)

HURRICANE WIND - WIND SPEED

Wind Gust (3 seconds) (mph)

| Recurrence Interval (yr) | Default Wind Speed (mph) |
|---|---|
| 10 | 64 |
| 20 | 82 |
| 50 | 105 |
| 100 | 117 |
| 200 | 127 |
| 500 | 138 |
| 1000 | 146 |

Table 5-18 summarizes the abbreviations for FEMA HAZUS-based structure and contents damage functions, which determine the extent of damage when structures are exposed to wind forces of various magnitudes.

**Table 5-18**
**Abbreviations for HAZUS Structure Types**
(FEMA Benefit-Cost Analysis Tool, Version 4.5.5.0)

| HAZUS Structure Type | Abbreviation |
|---|---|
| Masonry, engineered commercial building, low-rise (1-2 stories) | MECBL |
| Steel, pre-engineered metal building, Medium | SPMBM |
| Steel, pre-engineered metal building, Small | SPMBS |

Table 5-19 summarizes the hurricane and tropical storm wind risk to public assets for Brazoria Drainage District No. 4, based on the methodologies and inputs described above. The table shows that the Administrative office has the highest 100-year risk. This building has a 100-year risk of $128,967.

**Table 5-19**
**Estimated Hurricane Wind Risk to Brazoria Drainage District No. 4 Public Assets, ordered by 100-Year Risk**
(Source: FEMA BCA Software [BCAR]**,** Version 4.5.5.0)

| Facility Description | HAZUS Type | Area (s.f.) | Building Replacement Value | Annual Budget | 100-year Risk |
|---|---|---|---|---|---|
| Administrative office | MECBL | 7,000 | $1,300,000 | $840,000 | $128,967 |
| Field Service Operations - Offices | MECBL | 6,800 | $113,200 | $420,000 | $125,283 |
| Field Service Operations - North Service Center | SPMBM | 9,000 | $587,100 | $540,000 | $37,334 |
| Field Service Operations - Covered Equipment / Parking | SPMBM | 9,000 | $111,500 | $540,000 | $37,334 |
| Storage and Workshop | SPMBM | 8,800 | $200,000 | $540,000 | $36,504 |
| Field Service Operations - Truck Wash Station | SPMBS | 1,500 | $187,500 | $120,000 | $33,005 |
| **Grand Total** | **-----** | **42,100** | **$2,499,300** | **$3,000,000** | **$398,426** |

Again, it should be noted that these loss estimates are intended only as an initial assessment, for the purpose of allowing the District to determine priorities for additional study and/or mitigation actions.

### 5.7.4 Extreme Heat

Extreme heat kills by pushing the human body beyond its limits. Under normal conditions, the body's internal thermostat produces perspiration that evaporates and cools the body. However, in extreme heat and high humidity, evaporation is slowed and the body must work extra hard to maintain a normal temperature.

Temperatures that hover 10 degrees or more above the average high temperature for the region and last for several weeks are defined as extreme heat. Humid or muggy conditions, which add to the discomfort of high temperatures, occur when a "dome" of high atmospheric pressure traps hazy, damp air near the ground. Excessively dry and hot conditions can provoke dust storms. See Appendix A for a more detailed description of the extreme heat hazard.

In BDD4 and the surrounding area, numerous heat-related deaths have occurred. The climate is humid subtropical, with hot summers and frequent, prolonged heat waves. The extreme heat hazard affects the entire planning area. Many of these deaths are likely to have occurred in more rural areas of Brazoria County where there are a greater number of homes without air conditioning. Within BDD4, Extreme Heat risks to people and property cannot be distinguished by area; the hazard is reasonably predicted to have uniform probability of occurrence across the entire District. All people and assets are considered to have the same degree of exposure (See Table 5-3 for District-wide totals for population, buildings/infrastructure and estimate values).

To estimate potential dollar value of losses to existing buildings, the District evaluated the prior loss data from the NCDC database. This data indicated that between 1950 and 2008, there were six extreme heat events that affected the entire County, to include the District. These events are summarized below in Table 5-20. The NCDC database indicates that for the six extreme heat events there were a total of 38 deaths, 200 injuries and no property damage in Brazoria County.

**Table 5-20**
**Extreme Heat Events in Brazoria County, 1950 - 2009**
(Source: NOAA/NCDC)

**6 TEMPERATURE EXTREMES** event(s) were reported in **Brazoria County, Texas** between **01/01/1950** and**09/30/2010**.

*Click on **Location or County** to display Details.*

**Mag**: Magnitude
**Dth**: Deaths
**Inj**: Injuries
**PrD**: Property Damage
**CrD**: Crop Damage

| Texas | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Location or County** | **Date** | **Time** | **Type** | **Mag** | **Dth** | **Inj** | **PrD** | **CrD** |
| 1 TXZ176>179 - 226>227 - 195>200 - 235>238 - 210>214 | 07/21/1995 | 2050 | Heat Wave | N/A | 2 | 200 | 0 | 0 |
| 2 TXZ163>164 - 176>179 - 195>200 - 210>214 - 226>227 - 235>238 | 06/26/1999 | 06:00 AM | Excessive Heat | N/A | 3 | 0 | 0 | 0 |
| 3 TXZ163>164 - 176>179 - 195>200 - 210>214 - 226>227 - 235>238 | 08/01/1999 | 06:00 AM | Excessive Heat | N/A | 6 | 0 | 0 | 0 |
| 4 TXZ163>164 - 176>179 - 195>200 - 210>214 - 226>227 - 235>238 | 07/06/2000 | 06:00 AM | Excessive Heat | N/A | 19 | 0 | 0 | 0 |
| 5 TXZ163>164 - 176>179 - 195>200 - 210>214 - 226>227 - 235>238 | 08/29/2000 | 06:00 AM | Excessive Heat | N/A | 3 | 0 | 0 | 0 |
| 6 TXZ163>164 - 176>179 - 195>200 - 210>214 - 226>227 - 235>238 | 09/01/2000 | 12:00 AM | Excessive Heat | N/A | 5 | 0 | 0 | 0 |
| | | | | TOTALS: | 38 | 200 | 0 | 0 |

The extreme heat hazard affects all residential and commercial building types about equally within the planning area. None of the events identified in the NCDC database caused any prior property damage. Due to the fact that there is no record of any historical building damage as a result of extreme heat, the estimated annual dollar value damage to existing or future buildings due to extreme heat is negligible. The potential annual losses from deaths and injuries is calculated by using the values in the current FEMA BCA guidance (June 2009), which are $5.8 million for deaths and $90,000 for treat and release injuries. Thus the annual estimated value of loss of life from extreme heat in Brazoria County is $3.673 million, and for injuries it is $300,000. Similar to other hazards, using county and city census data the county-wide annual loss estimate can be proportioned for the BDD4.

BDD4 had no jurisdictional authority to mitigate against extreme heat and there is not potential impact from extreme heat on BDD4 owned facilities. It has been determined that the planning area, based on jurisdictional authority, and owned facilities will not be negatively impacted from extreme heat. For this reason, extreme heat has been eliminated from further consideration and there are no mitigation action items associated with extreme heat.

### 5.7.5 Drought

Drought is generally defined as a condition of climatic dryness severe enough to reduce soil moisture and water supplies below the requirements necessary to sustain normal plant, animal, and human life. In Texas, drought is often defined in terms of agricultural and hydrologic drought:

Agricultural drought is considered a dry period of sufficient duration and intensity that crop and animal agriculture are markedly affected.

Hydrologic drought is considered a long-term condition of abnormally dry weather that ultimately leads to the depletion of surface and ground water supplies. During hydrologic drought, a significant reduction in flow of rivers, streams, and springs is notable.

Texas is divided into ten climatic divisions that range from substantially heavy precipitation through semi-arid to arid climates. Most of Texas is prone to periodic droughts of differing degrees of severity. One reason is the state's proximity to the Great American Desert of the southwestern United States. In every decade of this century, Texas has fallen victim to one or more serious droughts. The severe-to-extreme drought that affected every region of the state in the early to mid-1950s was the most serious in recorded U.S. history. See Appendix A for a more detailed description of the drought hazard.

A drought's severity depends on numerous factors, including duration, intensity, and geographic extent as well as regional water supply demands by humans and vegetation. The severity of drought can be aggravated by other climatic factors, such as prolonged high winds and low relative humidity[9]. Due to its multi-dimensional nature, drought is difficult to define in exact terms, and also poses difficulties in terms of comprehensive risk assessments.

One method used by scientists to calculate the severity and duration of a drought is the Palmer Drought Severity Index (PDSI). The PDSI indicates the prolonged and abnormal moisture deficiency or excess and indicate general conditions, not local variations caused by isolated rain. The PDSI is an important climatological tool for evaluating the scope, severity, and frequency of prolonged periods of abnormally dry or wet weather.[10]

The equation for the PDSI was empirically derived from the monthly temperature and precipitation scenarios of 13 instances of extreme drought in western Kansas and central Iowa and by assigning an index value of -4 for these cases. Conversely, a +4 represents extremely wet conditions. From these values, seven categories of wet and dry conditions can be defined. Table 5-21 identifies the values used to define the PDSI.[11]

[9] FEMA, 1997
[10] NOAA. NWS. Climate Prediction Center. Drought Indices – Explanation.
[11] NOAA. NWS. Climate Prediction Center. Drought Indices – Explanation.

**Table 5-21**
**Palmer Drought Severity Index**
(Source: NOAA, National Weather Service - Climate Prediction Center)

| Palmer Drought Severity Index |
|---|
| -4.0 or less (Extreme Drought) |
| -3.0 or -3.9 (Severe Drought) |
| -2.0 or -2.9 (Moderate Drought) |
| -1.9 to +1.9 (Near Normal) |
| +2.0 or +2.9 (Unusual Moist Spell) |
| +3.0 or +3.9 (Very Moist Spell) |
| +4.0 or above (Extremely Moist) |

In Brazoria Drainage District No. 4**,** drought periods were experienced in 1996, 1998, and 2000. The drought hazard affects the entire planning area. The 1996 drought affected the entire state. Its impacts were greatest on major population centers, prompting water conservation and reduction measures over an extended period. The Texas Agricultural Extension Service projected a $4 billion statewide economic loss as a result of the 1996 drought. In the Southeast Texas area, damage from the extended drought reached record proportions as many crops were completely lost and large numbers of animals were sold because of lack of grass. In the Southeast Texas region, property damage was estimated at $10 million and agricultural losses were estimated at $100 million. Specific numbers for BDD4 were not available.

Within BDD4, Drought risks to people and property cannot be distinguished by area; the hazard is reasonably predicted to have uniform probability of occurrence across the entire planning area. All people and assets are considered to have the same degree of exposure (See Table 5-3 for District-wide total number of buildings/infrastructure and estimate values). The drought hazard affects all residential and commercial building types about equally within the planning area. Data related to the number of structures by building type and past damages for specific building types was unavailable at the time of the Plan and therefore the loss estimates for the drought hazard are based on total property damage as reported by the NCDC.

This data indicated that between 1950 and 2008, there were nine severe drought events that affected the County as a whole. The database provides no indication as to why there are no events prior to 1996, although presumably occurrences follow the same pattern and frequency as shown in the NCDC list. The events are summarized below in Table 5-22. The events in the table are listed by month. For example, if a drought lasts several continuous months, it is listed in the database as a separate event. If the continuous months are combined into single events, the number of events is reduced from nine to three.

**Table 5-22**
**Drought Events in Brazoria County, 1950 - 2009**
(Source: NOAA/NCDC)

**9 DROUGHT** event(s) were reported in **Brazoria County, Texas** between **01/01/1950** and **09/30/2010**.

*Click on **Location or County** to display Details.*

**Mag**: Magnitude
**Dth**: Deaths
**Inj**: Injuries
**PrD**: Property Damage
**CrD**: Crop Damage

**Texas**

| Location or County | Date | Time | Type | Mag | Dth | Inj | PrD | CrD |
|---|---|---|---|---|---|---|---|---|
| 1 TXZ163>164 - 176>179 - 195>200 - 210>214 - 226>227 - 235>238 | 04/01/1996 | 12:00 AM | Drought | N/A | 0 | 0 | 0 | 0 |
| 2 TXZ163>164 - 176>179 - 195>200 - 210>214 - 226>227 - 235>238 | 05/01/1996 | 12:00 AM | Drought | N/A | 0 | 0 | 0 | 0 |
| 3 TXZ163>164 - 176>179 - 195>200 - 210>214 - 226>227 - 235>238 | 06/01/1996 | 12:00 AM | Drought | N/A | 0 | 0 | 0 | 0 |
| 4 TXZ163>164 - 176>179 - 195>200 - 210>214 - 226>227 - 235>238 | 05/01/1998 | 12:00 AM | Drought | N/A | 0 | 0 | 0 | 0 |
| 5 TXZ163>164 - 176>179 - 195>200 - 210>214 - 226>227 - 235>238 | 06/01/1998 | 12:00 AM | Drought | N/A | 0 | 0 | 0 | 0 |
| 6 TXZ163>164 - 176>179 - 195>200 - 210>214 - 226>227 - 235>238 | 07/01/1998 | 12:00 AM | Drought | N/A | 0 | 0 | 0 | 0 |
| 7 TXZ163>164 - 176>179 - 195>200 - 210>214 - 226>227 - 235>238 | 08/01/1998 | 12:00 AM | Drought | N/A | 0 | 0 | 23.0M | 167.9M |
| 8 TXZ163>164 - 176>179 - 195>200 - 210>214 - 226>227 - 235>238 | 08/01/2000 | 12:01 AM | Drought | N/A | 0 | 0 | 0 | 0 |
| 9 TXZ163>164 - 176>179 - 195>200 - 210>214 - 226>227 - 235>238 | 09/01/2000 | 12:00 AM | Drought | N/A | 0 | 0 | 0 | 102.3M |
| | | | | TOTALS: | 0 | 0 | 23.000M | 270.200M |

The nine events caused an estimated $23,000,000 in property damage across the entire County. This number divided by the span of years (15 years) and the percent of housing units in BDD4 it is estimated that the District will incur $463,066 annually. Based on the medium probability indicated above, droughts will most likely continue in BDD4. Based on previous events that have impacted the planning area, future droughts in BDD4 will occasionally be severe, though generally impacts can be considered low to moderate based on losses. Based on the historical drought data there is a 20% chance of drought annually within the County. Therefore, the probability of future events impacting BDD4 is considered medium.

BDD4 had no jurisdictional authority to mitigate against drought and there is not potential impact from drought on BDD4 owned facilities. It has been determined that the planning area, based on jurisdictional authority and owned facilities, will not be negatively impacted from drought. For this reason, drought has been eliminated from further consideration and there are no mitigation action items associated with drought.

### 5.7.6 Wildland Fire

Wildfires are uncontrolled fires often occurring in wildland areas, and can consume houses or agricultural resources if not contained. Wildfires/urban interface is defined as the area where structures and other human development blend with undeveloped wildland. The U.S. Department of the Interior has developed the Wildland Fire Assessment System Web site to communicate information to the public via the Internet. Web visitors can view real-time maps showing potential for fire on any given day, including satellite-derived "greenness" maps. See Appendix A for a more detailed description of the wildland fire hazard.

Parts of Texas face major wildfire problems each year. The risk is increased and compounded by increasing development within the zone commonly referred to as the “urban-wildland interface.” Within this zone of natural landscape, buildings become additional fuel for fires when fires do occur. Most wildland fires are man-caused and occur in the interface of developed lands and forest and range lands. In particular, the dry conditions, high temperatures, and low humidity that characterize drought periods set the stage for wildfires. In 1998, in what is considered the worst wildfire in state history, wildfires throughout the State burned a total of 422,939 acres and threatened 4,031 structures.

In BDD4, because there is little urban-wildland interface, there is limited risk for wildfires. To estimate potential dollar value of losses to existing buildings, BDD4 evaluated the prior loss data from the NCDC database. This data indicated that between 1950 and 2008, there were no wild fire events that affected the County or the District. Due to the fact that there is no record of any historical building damage as a result of wild fire, the estimated annual dollar value damage to existing or future buildings due to wild fire is zero.

BDD4 had no jurisdictional authority to mitigate against wildland fires and there is not potential impact from wildland fires on BDD4 owned facilities. It has been determined that the planning area, based on jurisdictional authority, and owned facilities will not be negatively impacted from wildland fires. For this reason, wildland fires have been eliminated from further consideration and there are no mitigation action items associated with wildland fires.

### 5.7.7 Winter Storm

Winter storms bring various forms of precipitation that occur only at cold temperatures. These kinds of precipitation include snow, sleet, or a rainstorm where ground temperatures are cold enough to allow icy conditions. These cold weather storms can also take the form of freezing rain or a wintry mix. Winter storms in Texas, although not as numerous or severe as in the northern states, do occur often enough and with sufficient severity to be a threat to people and property. Generally, the winter storm season in Texas runs from late November to mid-March, although severe winter weather has occurred as early as October and as late as May in some areas. On average, central Texas is affected by one to two winter storms each year. See Appendix A for a more detailed description of the winter storm hazard.

In BDD4, where the climate is subtropical, winter storms of such severity that property damage results are extremely rare. The winter storm hazard affects the entire planning area. The Texas Department of

Transportation has posted a number of bridges to warn drivers that icy conditions may occur. Within BDD4, winter storm risks to people and property cannot be distinguished by area; the hazard is reasonably predicted to have uniform probability of occurrence across the entire District. All people and assets are considered to have the same degree of exposure. The winter storm hazard affects all residential and commercial building types about equally within the planning area.

The NCDC data indicated that between 1950 and 2009, there were two winter storm events that affected the County as a whole (Table 5-23). The first event was an ice storm in January, 1997 that caused no property damage, but three deaths. The second event occurred on December 4, 2009. The event caused no injuries or property damage.

**Table 5-23**
**Winter Storm Events in Brazoria County, 1950 - 2009**
(Source: NOAA/NCDC)

**2 SNOW & ICE** event(s) were reported in **Brazoria County, Texas** between **01/01/1950** and **09/30/2010**.

*Click on **Location or County** to display Details.*

**Mag**: Magnitude
**Dth**: Deaths
**Inj**: Injuries
**PrD**: Property Damage
**CrD**: Crop Damage

**Texas**

| Location or County | Date | Time | Type | Mag | Dth | Inj | PrD | CrD |
|---|---|---|---|---|---|---|---|---|
| 1 TXZ163>164 - 176>179 - 195>200 - 210>214 - 226>227 - 235>238 | 01/12/1997 | 06:00 AM | Ice Storm | N/A | 3 | 0 | 0 | 0 |
| 2 TXZ227 - 236 - 237 | 12/04/2009 | 08:00 AM | Winter Storm | N/A | 0 | 0 | 0K | 0K |
| TOTALS: | | | | | 3 | 0 | 0 | 0 |

Based on past winter storm events, it would be possible for BDD4 to experience an occasional snow or ice storm. Accumulations of several inches of snow or a coating of ice are possible.

With a total of two winter storm events between 1950 and 2010, the County experiences a significant winter storm on average approximately once every 30 years. With one event every 30 years, there is a 3.3% annual probability of a future winter storm event occurring in Brazoria County. Based on the historical winter storm data, the probability of future events impacting BDD4 is considered low.

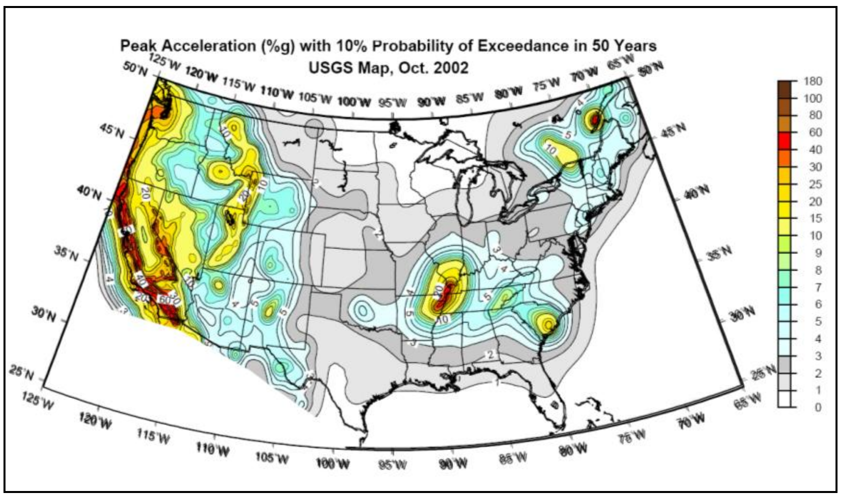
BDD4 had no jurisdictional authority to mitigate against winter storms and there is not potential impact from winter storms on BDD4 owned facilities. It has been determined that the planning area, based on jurisdictional authority, and owned facilities will not be negatively impacted from winter storms. For this reason, winter storms have been eliminated from further consideration and there are no mitigation action items associated with winter storms.

### 5.7.8 Seismic/Earthquakes

An earthquake is a sudden motion or trembling caused by an abrupt release of accumulated strain on the tectonic plates that comprise the Earth's crust. Tectonic plates become stuck, putting a strain on the ground. When the strain becomes so great that rocks give way, fault lines occur. At the earth's surface, earthquakes may manifest themselves by a shaking or displacement of the ground, which may lead to loss of life and destruction of property. The size of an earthquake is expressed quantitatively as magnitude and local strength of shaking as intensity. The inherent size of an earthquake is commonly expressed using a magnitude. See Appendix A for a more detailed description of the earthquake hazard.

Figure 5-13 displays the United States Geological Survey (USGS) earthquake hazard map produced in October of 2002. The map shows peak ground acceleration (pga) with a 10% chance of being exceeded over 50 years. In Texas, the majority of the State falls in the low seismic risk range. The *FEMA How-To guidance, Understanding Your Risks*, suggests the earthquake hazard should be profiled the pga is greater than 3%g.[12] The map shows that southeastern Texas, including Brazoria County, is located in the 1%g range, a relatively low risk area. The earthquake hazard affects the entire planning area.

**Figure 5-13**
**United States Seismic Hazard Map, Showing Peak Ground Acceleration In Percent Of g, With 10% Exceeded In 50 Years.**
(Source: USGS, October 2002)




In BDD4, seismic risks to people and property cannot be distinguished by area; the hazard is reasonably predicted to have uniform probability of occurrence (extremely rare) across the entire District. All people and assets are considered to have the same degree of exposure. The earthquake hazard affects all residential and commercial building types about equally within the planning area.

Due to the extremely low probability of an earthquake within BDD4 and the fact that there is no record of any historical building damage as a result of seismic activity in the District, the estimated dollar value damage to existing or future buildings due to earthquakes is zero.

BDD4 had no jurisdictional authority to mitigate against earthquakes and there is almost no potential impact from earthquake on BDD4 owned facilities. It has been determined that the planning area, based on jurisdictional authority, and owned facilities will not be negatively impacted from earthquakes.

[12] FEMA. *How-To guidance, Understanding Your Risks* (386-2), page 1-7

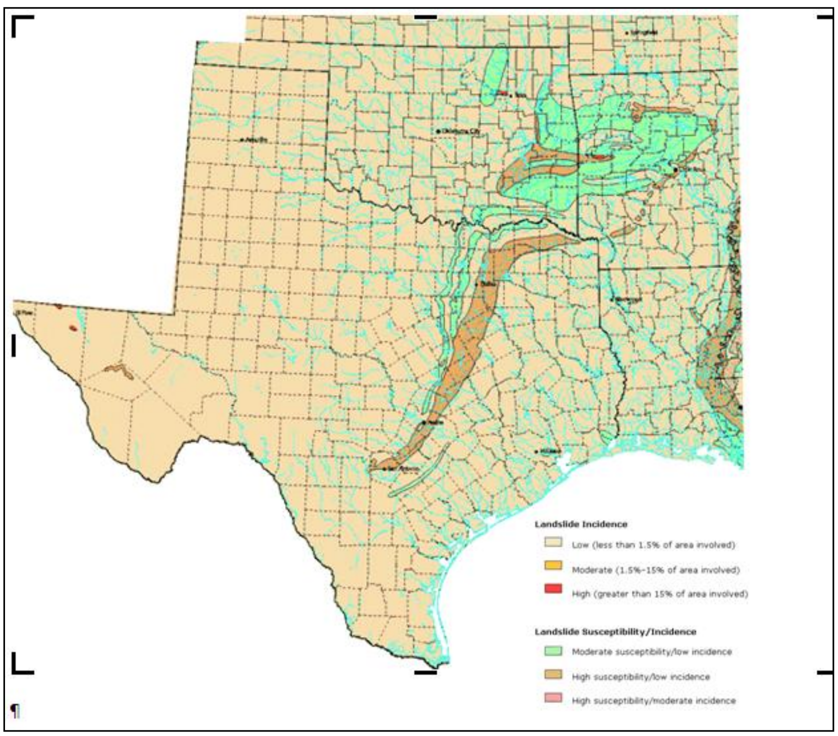
For this reason, earthquakes have been eliminated from further consideration and there are no mitigation action items associated with earthquakes.

### 5.7.9 Landslides

The term landslide is used to describe the downward and outward movement of soils and rocks moving down a slope under the force of gravity. Landslides include mudflows, mudslides, debris flows, rock falls, rock slides, debris avalanches, debris slides, and earth flows. Most landslides are associated with heavy, prolonged rains which saturate soils. The landslide hazard affects the entire planning area approximately equally. See Appendix A for a more detailed description of the landslide hazard.

In 1997, USGS published a national map to illustrate landslide risk areas. The map combines past incidents with a measure of "susceptibility", defined as the "probable degree of response of rocks and soils to natural or artificial cutting or loading of slopes, or to anomalously high precipitation." Figure 5-14 displays the USGS landslide map for the State of Texas. The map indicates the entire Texas coastal plain, including Brazoria County, is shown has having had less than 1.5% of its land area affected by movement of soils on slopes (no planning period is identified). The map also shows that the planning area is outside of any moderate or high "susceptibility/incidence" area.

**Figure 5-14**
**Landslide Overview Map for the State of Texas**
(Source: USGS, 1997)



In the planning area, landslide risks to people and property cannot be distinguished by area; the hazard is reasonably predicted to have uniform probability of occurrence across the entire District. All people and assets are considered to have the same degree of exposure.

With no prior significant landslide events occurring in BDD4, the probability of future events is considered low. See Table 5-4 for the definition of high, medium, and low probability. Due to the extremely low probability of a landslide within BDD4 and the fact that there is no record of any historical building damage as a result of landslides in the District, the estimated impacts and dollar value damage to existing or future buildings due to landslides is considered low. For these reasons, landslides have been eliminated from further evaluation and risk assessment.

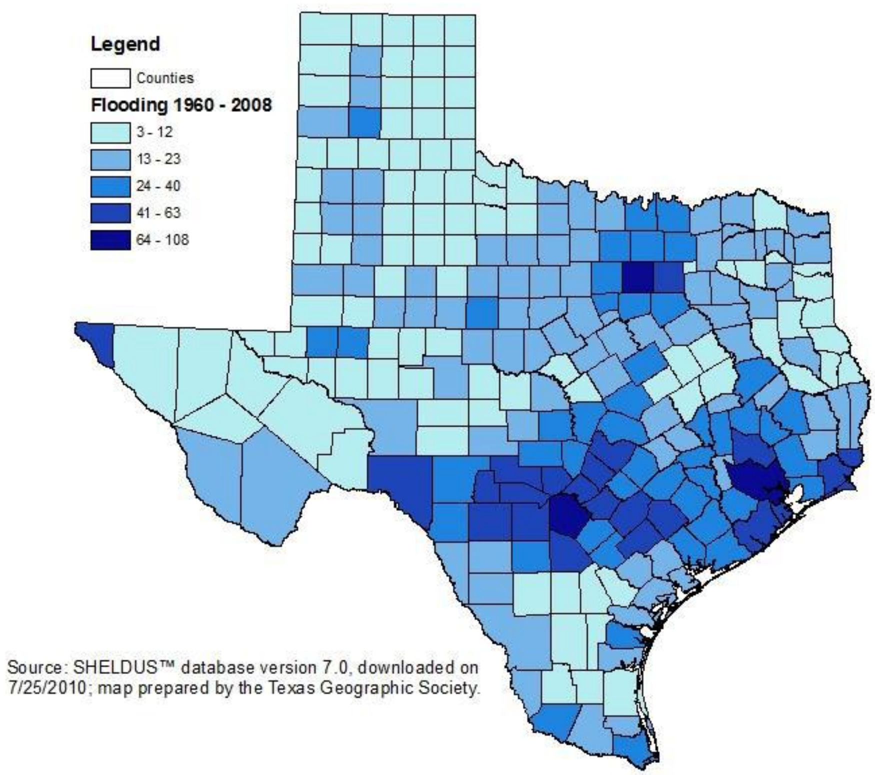
BDD4 had no jurisdictional authority to mitigate against landslides and there is not potential impact from landslides on BDD4 owned facilities. It has been determined that the planning area, based on jurisdictional authority, and owned facilities will not be negatively impacted from landslides. For this reason, landslides have been eliminated from further consideration and there are no mitigation action items associated with landslides.

## 6.1 Flood Hazards: Overview

Floods have been and continue to be the most frequent, destructive, and costly natural hazard facing the State of Texas. Ninety percent of the State's damage reported for major disasters is associated with floods. Figures maintained by the NCDC and the Centers for Disease Control indicates that Texas leads the country with more flood-related deaths than any other state (Table 5-1). Deaths due to floods, hurricanes, tropical storms and flash floods accounted for 38% of all weather-related deaths statewide and 38% in Brazoria County.

Figure 6-1 below is a map from the 2010 State of Texas Hazard Mitigation Plan that displays both previous flood occurrences and location of floods, by county, for the State of Texas between 1961 and 2008. The map is classified into four value ranges using the natural breaks (Jenks) method. The State Plan indicates that Brazoria County falls under the second highest class (41 - 63 floods).

**Figure 6-1**
**Flood Occurrences in Texas 1961-2008**
(Source: State of Texas 2010 Hazard Mitigation Plan)



The NCDC indicates that Brazoria County has experienced 55 flood events between 1950 and 2010. Of this total, 19 flood events have resulted in property damage in excess of $25,000 per event. Property damages for these events totaled close to $54 million. The 19 flood events with damages greater than $25,000 are summarized below in Table 6-1

**Table 6-1**
**Flood Events in Brazoria County Resulting in Property Damage in Excess of $25,000, 1950 - 2010**
(Source: NOAA/NCDC)

**19 FLOOD** event(s) were reported in **Brazoria County, Texas** between **01/01/1950** and **09/30/2010** with **at least $25 Thousand in Property Damage**.

*Click on **Location or County** to display Details.*

**Mag**: Magnitude
**Dth**: Deaths
**Inj**: Injuries
**PrD**: Property Damage
**CrD**: Crop Damage

**Texas**

| Location or County | Date | Time | Type | Mag | Dth | Inj | PrD | CrD |
|---|---|---|---|---|---|---|---|---|
| 1 BRAZORIA | 10/17/1994 | 1800 | Flash Flood/flood | N/A | 0 | 0 | 50.0M | 50K |
| 2 BRAZORIA | 12/17/1995 | 1115 | Flash Flood | N/A | 0 | 0 | 100K | 20K |
| 3 South Portion | 09/13/2000 | 04:00 AM | Flash Flood | N/A | 0 | 0 | 150K | 0 |
| 4 East Portion | 08/30/2001 | 07:30 PM | Flash Flood | N/A | 0 | 0 | 30K | 0 |
| 5 North Portion | 08/31/2001 | 10:00 AM | Flash Flood | N/A | 0 | 0 | 500K | 0 |
| 6 North Portion | 09/02/2001 | 01:10 PM | Flash Flood | N/A | 0 | 0 | 80K | 0 |
| 7 Angleton | 08/15/2002 | 05:45 AM | Flash Flood | N/A | 0 | 0 | 50K | 0 |
| 8 Alvin | 08/15/2002 | 11:00 AM | Flash Flood | N/A | 0 | 0 | 90K | 0 |
| 9 Freeport | 09/06/2002 | 07:55 PM | Flash Flood | N/A | 0 | 0 | 25K | 0 |
| 10 Sweeny | 09/07/2002 | 02:00 AM | Flash Flood | N/A | 0 | 0 | 250K | 0 |
| 11 Freeport | 09/09/2002 | 07:40 AM | Flash Flood | N/A | 0 | 0 | 30K | 0 |
| 12 Countywide | 09/10/2002 | 01:10 AM | Flash Flood | N/A | 0 | 0 | 30K | 0 |
| 13 Pearland | 10/24/2002 | 02:26 PM | Flash Flood | N/A | 0 | 0 | 75K | 0 |
| 14 Countywide | 11/05/2002 | 01:25 AM | Flash Flood | N/A | 0 | 0 | 35K | 0 |
| 15 Brazoria | 10/16/2006 | 00:01 AM | Flash Flood | N/A | 0 | 0 | 500K | 0K |
| 16 TXZ213 - 237 - 238 | 10/16/2006 | 02:52 AM | Coastal Flood | N/A | 0 | 0 | 75K | 0K |
| 17 Angleton | 05/28/2007 | 12:00 PM | Flash Flood | N/A | 0 | 0 | 110K | 0K |
| 18 Sweeny | 07/01/2010 | 15:00 PM | Flash Flood | N/A | 0 | 0 | 500K | 0K |
| 19 West Columbia | 07/01/2010 | 15:00 PM | Flash Flood | N/A | 0 | 0 | 1.3M | 0K |
| | | | | TOTALS: | 0 | 0 | 53.880M | 70K |

Based on past and recent history, certain parts of BDD4 clearly have a high probability of flooding repeatedly in the future. With a total of 55 floods between 1950 and 2010, BDD4 experiences approximately 1.1 floods on average every year. With flood events happening more than once a year the probability of future events is considered high.

### 6.1.1 Defining Flood Hazards

When rainfall runoff collects in rivers, creeks, bayous, and streams and exceeds the capacity of channels, floodwaters overflow onto adjacent lands. Floods result from rain events, whether short and intense, or long and gentle. In recent years, most flooding in BDD4 has been associated with storms that originate as hurricanes and tropical storms that subsequently move inland. Flood hazards are categorized as follows:

Flash floods not only occur suddenly, but also involve forceful flows that can destroy buildings and bridges, uproot trees, and scour out new channels. Most flash flooding is caused by slow-moving thunderstorms, repeated thunderstorms in a local area, or heavy rains from hurricanes and tropical storms. Although flash flooding occurs often along mountain streams, it is also common in urban areas, where much of the ground is covered by impervious surfaces and drainage ways are designed for smaller flows. Flood Insurance Rate Maps typically show the 1%-annual-chance (100-year) floodplain for waterways with at least 1 square mile of drainage area. The flood hazard areas for waterways with less than one square mile of drainage area typically are not shown.

Riverine floods are a function of precipitation levels and water runoff volumes, and occur when water rises out of the banks of the waterway. Flooding along waterways that drain larger watersheds often can be predicted in advance, especially where it takes 24 hours or more for the flood crest (maximum depth of flooding) to pass. In Brazoria County, riverine flooding is caused by large rainfall systems and thunderstorm activity associated with seasonal cold fronts. These systems can take as long as a day to pass, giving ample opportunity for large amounts of rain to fall over large areas. The Flood Insurance Rate Maps show the 1%-annual-chance floodplains.

Urban drainage flooding occurs where development has altered hydrology through changes in the ground surface and modification of natural drainage ways. Urbanization increases the magnitude and frequency of floods by increasing impervious surfaces, increasing the speed of drainage collection, reducing the carrying capacity of the land, and, occasionally, overwhelming sewer systems. Localized urban flooding is not usually shown on the Flood Insurance Rate Maps in areas with less than one square mile of contributing drainage area.

Note: Additional descriptions of the flood hazard can be found in Appendix A.

The Flood Insurance Rate Maps (FIRMs) prepared by FEMA offer the best overview of flood risks. FIRMs are used to regulate new development and to control the substantial improvement and repair of substantially damaged buildings. Flood Insurance Studies (FISs) are often developed in conjunction with FIRMs. The FIS typically contains a narrative of the flood history of a community and discusses the engineering methods used to develop the FIRMs. The study also contains flood profiles for studied flooding sources and can be used to determine Base Flood Elevations for some areas.[13]

The revised FIS for Brazoria County is dated August 31, 2009. These FIS' compile all previous flood information and include data collected on numerous waterways. Both FIS' indicate that riverine flooding results primarily from overflow of the streams and drainage ditches caused by rainfall runoff, ponding, and sheet flow. Storms occurring during the summer months are often associated with tropical storms moving inland from the Gulf of Mexico. Thunderstorms are common throughout the spring, summer, and fall months. The frequent hurricanes and tropical storms interrupt the summer with high winds, heavy rainfall, and high storm surges. FIRM maps for the City of Pearland and Brazoria County show flood zones:

AE Zones along rivers and streams for which detailed engineering methods were used to determine Base Flood Elevations (BFEs). AE Zones (or A1-30 Zones) are shaded in gray.
A Zones, which are areas inundated by the 100-year flood for which BFEs and Flood Hazard Factors (FHFs) have not been determined.

AH Zones, which are areas inundated by types of 100-year shallow flooding where depths are between one and three feet, and for which BFEs are shown, but no FHFs are determined.

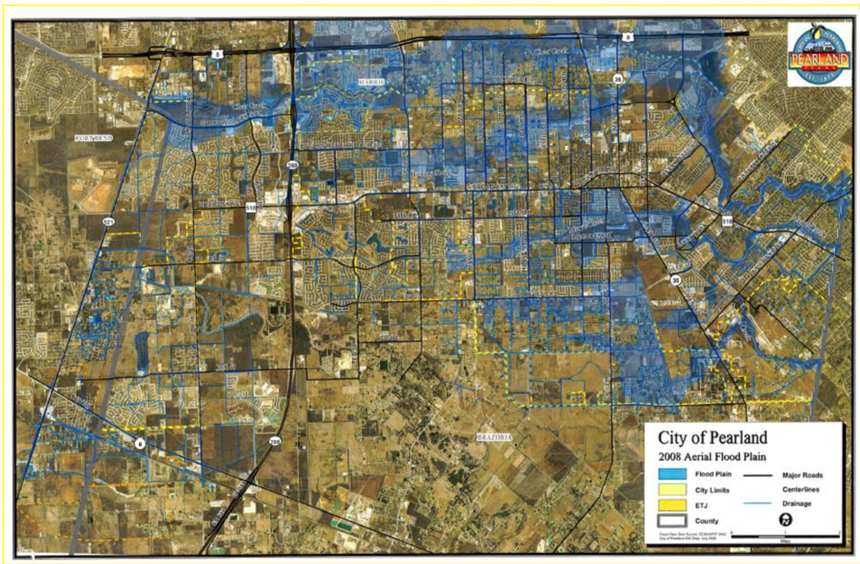
B Zones and Shaded X Zones, which are areas of "moderate" flood hazard, typically associated with the 500-year flood (or 0.2% annual chance).

C Zones and unshaded X Zones are areas of "minimal" flood hazard, typically considered to be "out of the floodplain." Although local drainage problems and ponding may still occur, these minor flood problems typically are not shown on the FIRM.

Figure 6-2 identifies the 100-year floodplain (shaded light blue) for BDD4. The map shows the 100-year floodplain is found along bayous and streams throughout the planning area.

[13] FEMA –Flood Insurance Study definition

**Figure 6-2**
**BDD4 – 100-year Floodplain Map**
(Source: FEMA – Flood Insurance Rate Map, August, 2009)




## 6.1.2 Subsidence-Related Flooding

Land subsidence is a gradual settling or sudden sinking of the Earth's surface due to subsurface movement of earth materials. The principal causes of subsidence are aquifer-system compaction, drainage of organic soils, underground mining, hydrocompaction, natural compaction, sinkholes, and thawing permafrost.

Brazoria County and incorporated communities in the region are affected by flooding related land subsidence. Land subsidence is defined in the FIS as "the lowering of the ground as a result of water, oil, gas extraction, as well as other phenomena such as soil compaction, decomposition of organic material, and tectonic movement." The City of Pearland makes up a large portion of the BDD4 planning area. Most Pearland residents get their water supply from one of nine City-owned wells. A few residents, primarily in recently annexed areas, are on private wells. The City also purchases treated surface water from the City of Houston. Removal of groundwater may have contributed to subsidence within the City.

Due to subsidence, some or all of the benchmarks used to develop the base flood elevations on the FIRM are no longer accurate. Periodically, the federal government re-levels some benchmarks to determine new elevations above datum; however, not all benchmarks are re-leveled each time. Relatively extensive re-levelings were performed in 1978, 1987, and 1995. The following passage, "Effects of Land Subsidence", is taken from the Brazoria County FIS.

> "The prevalence of land subsidence in the study area complicates the determination of the amount a given property lays above or below the base flood elevation. Complicating factors include determining which benchmark re-leveling to use to determine a property elevation and possible changes in flood hazards as a result of subsidence. Changes in flood hazards, caused by changed hydrologic and hydraulic conditions, could include increases or decreases in (1) depths of flooding, (2) the amount of land inundated, and (3) the intensity of wave action in coastal areas. The nature and extent of possible flood-hazard changes are different depending on the type of flooding (riverine, coastal, or combined riverine and coastal) present."

To account for the increased future flood hazard, the FIS text recommends that "consideration should be given to setting the lowest-floor elevation above the base flood elevation by an amount associated with potential increases in flood depths as a result of past and future subsidence."

### 6.1.3 Dams and Flooding

FEMA and the U.S. Army Corps of Engineers (USACE) maintain the National Inventory of Dams (1998), a database of high and significant hazard dams. For the most part, data are provided by State agencies responsible for regulation and inspection of dams or by the USACE. Based on that inventory, there are no high hazard dams that affect the watersheds in or draining through BDD4.

### 6.1.4 Storm Surge Flooding

Storm surges occur when the water level of a tidally-influenced body of water increases above the normal high tide. Storm surges occur with coastal storms caused by massive low-pressure systems with cyclonic flows that are typical of hurricanes. Storm surges are particularly damaging when they occur at the time of a high tide, combining the effects of the surge and the tide. This increases the difficulty of predicting the magnitude of a storm surge since it requires weather forecasts to be accurate to within a few hours. See Appendix A for a more detailed description of the storm surge hazard.

The storm surge hazard associated with hurricanes and other severe storms are responsible for coastal flooding and erosion along the Texas Gulf Coast. In addition to flooding coastal areas, storm surge can also reach further inland impacting lakes and rivers. Storm surge in BDD4 is primarily the result of hurricanes that approach land from the Gulf of Mexico moving water inland from the Gulf of Mexico. The effects of storm surge can be felt in BDD4 from hurricanes that make landfall as far away as Texas, Mississippi, or Alabama.

Storm surges inundate coastal floodplains by tidal elevation rise in inland bays and ports, and backwater flooding through coastal river mouths. Severe winds associated with low-pressure systems cause increase in tide levels and water surface elevations. Storm systems also generate large waves that run up and flood coastal areas. The combined effects create storm surges that affect the beach, marsh, and low-lying floodplains. Shallow offshore depths can cause storm driven waves and tides to pile up against the shoreline and inside bays. See Table 6-2 for factors that can influence the severity of coastal storms.

Storm surge is considered the next most dangerous part of a hurricane after severe winds, and causes nine out of ten hurricane-related deaths, according to the National Weather Service. The level of surge in a particular area is mainly determined by the slope of the continental shelf. A shallow slope off the coast, will allow a greater surge to inundate coastal communities.

**Table 6-2**
**Factors that Influence the Severity of Coastal Storms**

| Factor | Effect |
|---|---|
| Wind Velocity | The higher the wind velocity the greater the damage. |
| Storm Surge Height | The higher the storm surge the greater the damage. |
| Coastal Shape | Concave shoreline sections sustain more damage because the water is driven into a confined area by the advancing storm, thus increasing storm surge height and storm surge flooding. |
| Storm Center Velocity | Then slower the storm moves, the greater damage. The worst possible situation is a storm that stalls along a coast, through several high tides. |
| Nature of Coast | Damage is most severe on low-lying island barrier shorelines because they are easily over washed by wave action. |
| Previous Storm Damage | A coast weakened by even a minor previous storm will be subject to greater damage in a subsequent storm. |
| Human Activity | With increased development, property damage increases and more floating debris becomes available to knock down other structures. |

The NCDC database indicates there have been three storm surge events to impact Brazoria County between 1950 and 2010. No injuries or deaths death were reported from these events. Table 6-3 summarizes the major storm surge events that have impacted Brazoria County since 1950. The database provides no indication as to why there are no events prior to 2005, although presumably there are additional past occurrences that are not shown.

**Table 6-3**
**Storm Surge Events, Brazoria County 1950 – 2009**
(Source: NOAA/NCDC)

# Query Results

**3 OCEAN & LAKE SURF** event(s) were reported in **Brazoria County, Texas** between **01/01/1950** and **01/01/2011**.

*Click on **Location or County** to display Details.*

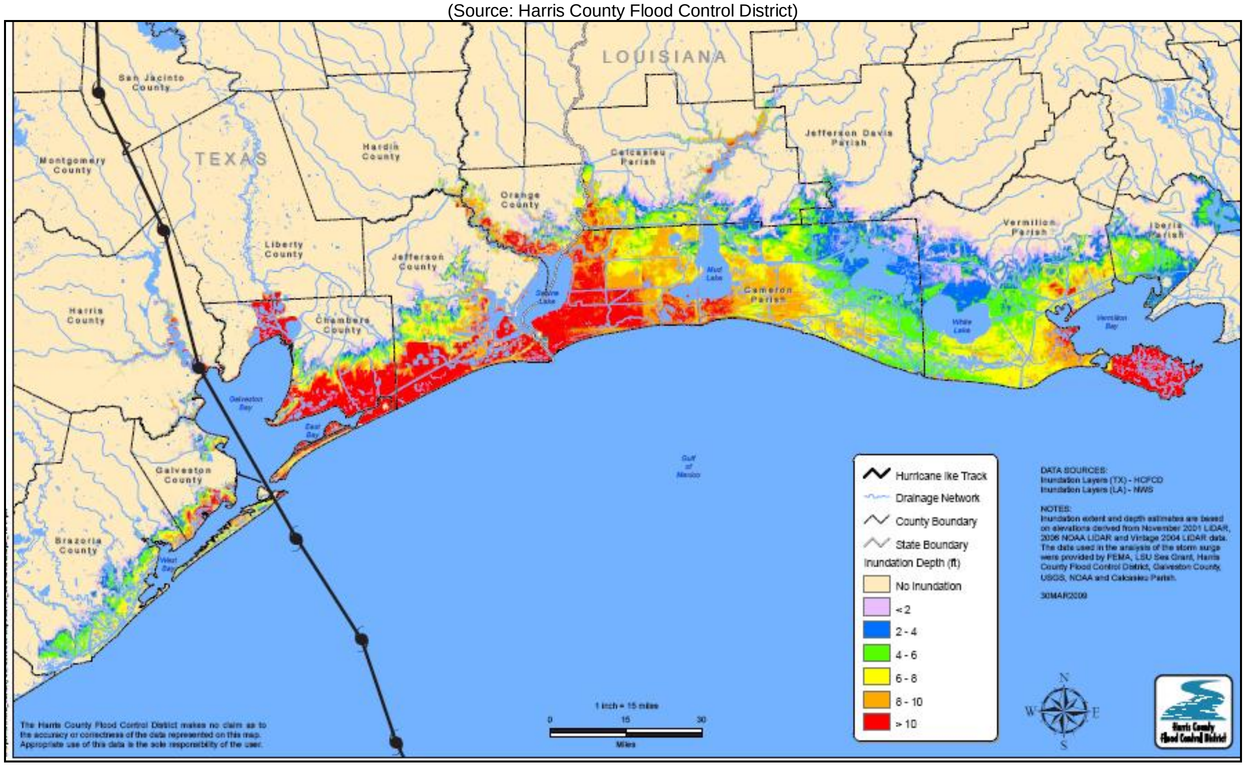
**Mag**: Magnitude
**Dth**: Deaths
**Inj**: Injuries
**PrD**: Property Damage
**CrD**: Crop Damage

**Texas**

| Location or County | Date | Time | Type | Mag | Dth | Inj | PrD | CrD |
|---|---|---|---|---|---|---|---|---|
| 1 TXZ237 | 08/29/2005 | 05:00 AM | Storm Surge | N/A | 0 | 0 | 40K | 0 |
| 2 TXZ213 - 237 - 238 | 10/16/2006 | 02:52 AM | Coastal Flood | N/A | 0 | 0 | 75K | 0K |
| 3 TXZ237 - 238 | 11/08/2009 | 16:00 PM | Coastal Flood | N/A | 0 | 0 | 0K | 0K |
| TOTALS: | | | | | 0 | 0 | 115K | 0 |

Hurricane Ike made landfall near Galveston, Texas early in the morning on September 13th as a strong category 2 Hurricane. Ike caused wind damage and significant storm surge flooding across southeast Texas. to include storm surge within Brazoria County. See Figure 6-3 below.

**Figure 6-3**
**Hurricane Ike Inundation Map for Southeastern Texas and Louisiana**
(Source: Harris County Flood Control District)



## 6.2 Flood Risk

This subsection of the HMP provides a general background regarding flood risk in BDD4, and calculations of potential future flood losses in the District, based primarily on National Flood Insurance Program (NFIP) insurance claims data.

### 6.2.1 Background

To develop more specific data about flood-prone buildings, as part of the Plan development, BDD4 worked with Lentz Engineering, Brazoria County Appraisal District (BCAD) and the City of Pearland, who have access to a Geographic Information System (GIS) database. The tool that makes this possible is the GIS computer software application that relates physical features on the ground in mapping applications and analyses.

In addition to the hazard history discussion elsewhere in this HMP, there are a few other means to generally characterize flood vulnerability in BDD4. These are discussed in turn below.

#### 6.2.1.1 Buildings and Parcels in Proximity to the Special Flood Hazard Area

The number of buildings in the floodplain can be a good general proxy for flood risk, although year-to-year weather patterns clearly have a large influence on flooding potential. Using GIS and historical knowledge, it is estimated that 4,940 residential non-mobile home buildings, 301 mobile homes and 388 non-residential buildings are located in the flood-prone areas of BDD4. Therefore, not counting buildings that are susceptible but that are outside of the mapped floodplain, approximately 12.6% of all buildings in BDD4 are prone to some degree of flooding.

**Table 6-4**
**Flood Prone Properties Located Within BDD4**

| | Residential | Mobile Homes | Non-Residential |
|---|---|---|---|
| Total number of buildings | 35,654 | 3,094 | 5,709 |
| Number of est. flood prone buildings (Note 1) (as % of total bldgs) | 4,940 (13.8%) | 301 (9.7%) | 383 (6.8%) |

Note 1: Estimate of flood prone buildings is derived from actual historical building claims plus an estimate of number of buildings experiencing prior non-insured losses

There is also considerable information available about the number of parcels in the floodplain, although this is not as good a measure of potential flood risk as the building information above (because, generally, flood risk in developed areas is related to potential impacts to structures and contents). Nevertheless, the data offers additional insight into potential exposure to floods.

According to the Brazoria Drainage District No. 4, there are 86.17 square miles of land area within BDD4's boundaries. Of this total, 36.14 square miles (or 41.94%) are located within the Special Flood Hazard Area (SFHA) or 100-year floodplain. The GIS Department also indicated the District has a total of 53,916 parcels, of which 8,508 have some exposure to the 100-year floodplain. Table 6-5 summarizes the number of parcels in the District and the number of parcels within the 100-year floodplain, broken out by residential and commercial land use categories. The table is ordered by the number of parcels in the 100-year floodplain and indicates the *Single Family Residential* category has the highest number of parcels within the floodplain. This category has 4,940 parcels in the 100-year floodplain which represents 13.87% of the 35,624 total parcels for this category.

Table 6-6 displays the same data, ordered by the percent of parcels in the 100-year floodplain. This table indicates the *Other Vacant and Improved Parcels* category has the highest percent of parcels in the floodplain. This category has 30.44% of its parcels in the floodplain. This is expected because it probably includes many vacant or undeveloped parcels of land.

**Table 6-5**
**Number of Parcels in BDD4 by Land Use Category and the Number of Parcels in the Floodplain, ordered by Number of Parcels in the Floodplain**
(Source: Brazoria Drainage District No. 4)

| Land Use Category | Description | Count | Percent of Parcels | # in Floodplain | Percent in Floodplain |
|---|---|---|---|---|---|
| Residential | Single Family Residence | 35,624 | 66.07% | 4,940 | 13.87% |
| Other | Other Vacant and improved parcels (county property, vacant lots, municipality owned, etc.) | 9,459 | 17.54% | 2,879 | 30.44% |
| Commercial | Commercial Property | 5,082 | 9.43% | 308 | 21.48% |
| Mobile Home | Mobile Homes | 3,094 | 5.74% | 301 | 18.98% |
| Commercial | Religious And Charitable Organizations | 150 | 0.28% | 40 | 26.67% |
| Commercial | Commercial Or Industrial Vacant Lots | 249 | 0.46% | 30 | 12.05% |
| Commercial | Apartments | 41 | 0.08% | 8 | 19.51% |
| Commercial | Industrial Property | 153 | 0.28% | 2 | 5.41% |
| Commercial | Unknown | 34 | 0.06% | 0 | 0.00% |
| Residential | Duplex | 30 | 0.06% | 0 | 0.00% |
| **Grand total** | | **53,916** | **100.00%** | **8,508** | **15.78%** |

**Table 6-6**
**Number of Parcels in BDD4 by Land Use Category and the Number of Parcels in the Floodplain, ordered by Number of Parcels in the Floodplain**
(Source: Brazoria Drainage District No. 4)

| Land Use Category | Description | Count | Percent of Parcels | # in Floodplain | Percent in Floodplain |
|---|---|---|---|---|---|
| Other | Other Vacant and improved parcels (county property, vacant lots, municipality owned, etc.) | 9,459 | 17.54% | 2,879 | 30.44% |
| Commercial | Religious And Charitable Organizations | 150 | 0.28% | 40 | 26.67% |
| Commercial | Commercial Property | 5,082 | 9.43% | 308 | 21.48% |
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| Land Use Category | Description | Count | Percent of Parcels | # in Floodplain | Percent in Floodplain |
|---|---|---|---|---|---|
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| Commercial | Industrial Property | 153 | 0.28% | 2 | 5.41% |
| Commercial | Unknown | 34 | 0.06% | 0 | 0.00% |
| Residential | Duplex | 30 | 0.06% | 0 | 0.00% |
| **Grand total** | | **53,916** | **100.00%** | **8,508** | **15.78%** |

#### 6.2.1.2 NFIP Policies in Force

Flood insurance policies and claims information can be used to identify buildings in mapped floodplains (where lenders require insurance) and where flooding has occurred (where owners are sufficiently concerned that they purchase flood insurance even if not required). This characterization of flood risk is described in the following text.

**NFIP Policies In-Force**. Data provided by FEMA indicate that as of March 2011, federal flood insurance policies were in-force on 15,500 buildings in Brazoria County, 240 in Brookside Village and 7,893 in the City of Pearland. These insurance policies are administered by the National Flood Insurance Program (NFIP). This represents a dollar value of property and contents coverage in excess of $6.3 Billion.

For the most part, two factors prompt people to purchase flood insurance – when mortgage lenders require it and when actual flood damage makes it clear to homeowners that a building is, indeed, located in a flood-prone area. Thus, the number and distribution of flood insurance policies is one way to characterize potential risk throughout BDD4.

**NFIP Claims Paid.** Between 1978 and March 2011, there were 9,124 flood insurance claims (building and contents combined) in Brazoria County. These totals include Brookside Village, the City of Pearland and unincorporated Brazoria County. Many of these properties are located outside the 100-year floodplain. Review of the NFIP claims data for BDD4 indicates that the large majority of these claims were for residential properties. Total claims paid for building and contents payments exceed $124.4 million. Table 6-7 summarizes the NFIP claims data for the City of Pearland, Brookside Village and Brazoria County.

**Table 6-7**
**NFIP Claims Statistics for Pearland, Brookside Village and Unincorporated Brazoria County**
(Source: FEMA NFIP query December, 2009, FEMA. NFIP - Flood Insurance Statistics)

| | # of Claims | # of Policies | Total Paid Claims ($) |
|---|---|---|---|
| City of Pearland | 2,629 | 7,893 | $46,212,938 |
| Brookside Village | 198 | 240 | $4,376,349 |
| Brazoria County (unincorporated) | 6,297 | 15,500 | $73,899,038 |
| **Total** | **9,124** | **23,633** | **$124,488,325** |

### 6.2.2 Flood Loss Estimates for NFIP Repetitive Loss Properties

This subsection provides estimates of potential future flood losses (risk), based on analysis of National Flood Insurance Program (NFIP) data on repetitive flood loss (RL) properties. The NFIP defines repetitive loss properties as those that have received least two NFIP insurance payments of more than $1,000 each in any rolling ten-year period. As of May, 2010, Brazoria County had 920 such properties, based on a query of the FEMA BureauNet NFIP interface. Of the 920 County-wide RL properties, 386 were located within the boundary of Brazoria Drainage District No. 4. Of the 386 RL properties in BDD4, 372 were characterized as residential properties and 14 were non-residential. The RL properties for BDD4 are summarized by municipality in Table 6-8. The Table indicates that the City of Pearland has the highest number of RL properties in BDD4. Pearland has not only the highest number of properties, but also has the highest building, contents, and total claims value compared to Brookside Village and the unincorporated areas of Brazoria Drainage District No. 4.

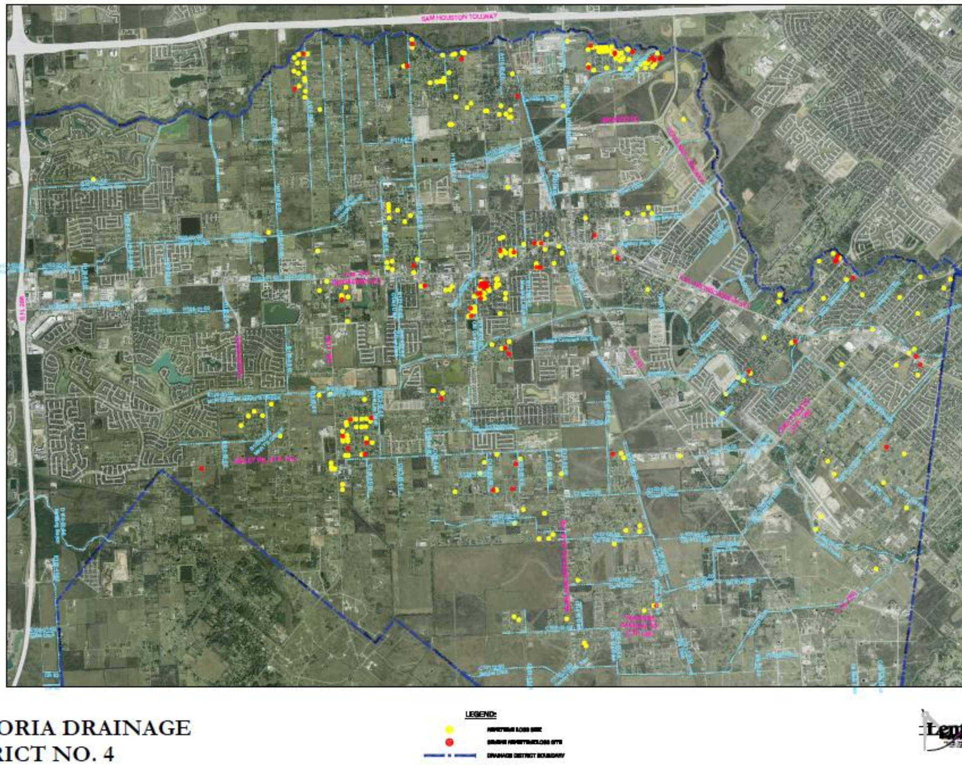
**Table 6-8**
**Summary of NFIP RL Statistics, Brazoria Drainage District No. 4, Ordered by Number of Properties in Each Municipality**
(Source: FEMA NFIP Query May, 2010)

| Municipality Name | Properties | Building | Contents | Total | # Claims | Average |
|---|---|---|---|---|---|---|
| Pearland, City of | 218 | $13,553,780 | $4,690,519 | $18,244,299 | 695 | $26,251 |
| Brazoria County (unincorporated areas) | 138 | $7,153,202 | $2,370,743 | $9,523,945 | 417 | $22,839 |
| Brookside Village of | 30 | $1,879,184 | $603,016 | $2,482,200 | 99 | $25,073 |
| **Grand Total / Average** | 386 | $22,586,166 | $7,664,278 | $30,250,444 | 1,211 | $24,980 |

Figure 6.4 is a map of the residential and non-residential RL properties located within Brazoria Drainage District No. 4. The map also identifies severe repetitive loss (SRL) properties which are discussed later in this section.

**Figure 6-4**
**Map of Repetitive Loss Properties and Severe Repetitive Loss Properties in Brazoria Drainage District No. 4**
(Sources: FEMA/NFIP, Brazoria DD4 - GIS)

FEMA REPETITIVE LOSS AND SEVERE REPETITIVE LOSS SITES
WITHIN BRAZORIA DRAINAGE DISTRICT NO. 4




BRAZORIA DRAINAGE
DISTRICT NO. 4

## Residential Repetitive Loss Properties
## Background and General Statistics

As mentioned, there are a total of 372 residential RL properties in Brazoria Drainage District No. 4. The 372 properties are located within the unincorporated areas of Brazoria County, the City of Pearland and Village of Brookside. Table 6-9 provides a summary of residential RL claims for the unincorporated areas of Brazoria County and the two municipalities that have RL properties. The table includes the number of RL properties in each municipality, building and contents damages, the total number of claims, and the average claim amounts. The figures are from an NFIP query performed in May, 2010. The table shows that for the 372 residential RL properties in BDD4 (to include incorporated areas) there have been 1,162 RL claims totaling just over $29 million.

**Table 6-9**
**Summary of Residential NFIP RL Statistics, Brazoria Drainage District No. 4, Ordered by Number of Properties in Each Municipality**
(Source: FEMA NFIP Query May, 2010)

| Municipality Name | Properties | Building | Contents | Total | # Claims | Average |
|---|---|---|---|---|---|---|
| Pearland, City of | 209 | $12,691,866 | $4,505,992 | $17,197,858 | 660 | $26,057 |
| Unincorporated areas of Brazoria Drainage District No 4 | 134 | $7,070,656 | $2,329,260 | $9,399,916 | 405 | $23,210 |
| Brookside Village of | 29 | $1,862,859 | $599,440 | $2,462,299 | 97 | $25,385 |
| **Grand Total / Average** | **372** | **$21,625,380** | **$7,434,693** | **$29,060,073** | **1,162** | **$25,009** |

The table indicates that the City of Pearland is the municipality with the highest number of residential RL properties in BDD4. Pearland has not only the highest number of properties, but also has the highest building, contents, and total claims value compared to Brookside Village and the unincorporated areas of Brazoria County. The average claim amount is similar for Pearland, Brookside and the unincorporated areas of Brazoria County.

The RL claims for Brazoria Drainage District No. 4 can be further broken down by focusing on individual street level data. Table 6-10 provides a summary of residential RL claims for the 74 individual streets within BDD4 that include two or more RL properties. The building, contents, and total claims data has been combined for streets that include RL properties. Address data about individual sites is omitted for reasons of confidentiality. The data shows that Green Tee Drive in the City of Pearland has the most RL properties in BDD4. Green Tee Drive has 17 RL properties and 47 prior NFIP claims totaling $1,442,594. Of the 75 streets, Rip Van Winkle Drive has the highest average claim value. Rip Van Winkle Drive has an average claim value of $98,119.

**Table 6-10**
**Summary of Residential NFIP Repetitive Loss Statistics, Brazoria Drainage District No. 4, ordered by number of Properties on each Street**
(Source: FEMA NFIP query May, 2010)

| Street Name | Properties | Building | Contents | Total Paid Claims Value ($) | Claims | Average |
|---|---|---|---|---|---|---|
| Green Tee Drive | 17 | $988,128 | $454,467 | $1,442,594 | 47 | $30,693 |
| Robinson Drive | 15 | $1,070,110 | $472,596 | $1,542,706 | 40 | $38,568 |
| Carmona Lane | 11 | $981,530 | $472,239 | $1,453,768 | 48 | $30,287 |
| Skylark Way | 10 | $787,267 | $235,901 | $1,023,169 | 32 | $31,974 |
| Sunbrook Drive | 8 | $491,781 | $127,153 | $618,934 | 26 | $23,805 |
| East Broadway Street | 7 | $353,015 | $29,101 | $382,116 | 19 | $20,111 |
| Glastonbury Drive | 7 | $462,188 | $231,217 | $693,404 | 26 | $26,669 |
| Max Road | 7 | $457,248 | $227,665 | $684,912 | 22 | $31,132 |
| Meadowlark Way | 7 | $349,207 | $91,703 | $440,911 | 22 | $20,041 |
| Bishopton Drive | 6 | $353,644 | $149,769 | $503,413 | 23 | $21,888 |
| Cunningham Drive | 6 | $211,342 | $52,183 | $263,525 | 23 | $11,458 |
| Piper Road | 6 | $512,304 | $118,643 | $630,948 | 20 | $31,547 |
| Route 2 | 6 | $110,244 | $43,939 | $154,184 | 14 | $11,013 |
| Apple Springs Drive | 5 | $208,003 | $94,592 | $302,594 | 13 | $23,276 |
| Francis Drive | 5 | $317,369 | $73,409 | $390,778 | 17 | $22,987 |
| Kelly Drive | 5 | $321,233 | $70,607 | $391,839 | 13 | $30,141 |
| South Austin Ave | 5 | $321,522 | $112,143 | $433,665 | 17 | $25,510 |
| Sleepy Hollow Drive | 5 | $364,118 | $128,944 | $493,062 | 18 | $27,392 |
| Union Valley Drive | 5 | $466,166 | $150,429 | $616,595 | 16 | $38,537 |
| Amie Lane | 4 | $324,613 | $130,938 | $455,551 | 14 | $32,539 |
| Bluebird Way | 4 | $265,031 | $61,552 | $326,583 | 12 | $27,215 |
| Comal Street | 4 | $148,695 | $42,426 | $191,121 | 9 | $21,236 |
| Leggett Lane | 4 | $233,835 | $85,185 | $319,021 | 12 | $26,585 |
| Livingston Drive | 4 | $145,786 | $58,738 | $204,524 | 9 | $22,725 |
| Over St | 4 | $176,708 | $88,792 | $265,500 | 12 | $22,125 |
| Rockland Drive | 4 | $243,701 | $61,534 | $305,236 | 15 | $20,349 |
| Route 1 | 4 | $70,424 | $31,923 | $102,347 | 11 | $9,304 |
| Route 4 | 4 | $101,454 | $33,472 | $134,925 | 10 | $13,493 |
| Brookside Road | 3 | $99,271 | $16,124 | $115,396 | 7 | $16,485 |
| Camden Lane | 3 | $119,104 | $34,453 | $153,558 | 8 | $19,195 |
| Cantu Road | 3 | $108,519 | $13,264 | $121,784 | 8 | $15,223 |
| Colmesneil Street | 3 | $124,058 | $68,129 | $192,187 | 9 | $21,354 |
| Creek Drive | 3 | $223,309 | $84,435 | $307,743 | 10 | $30,774 |
| Dana Lynn Lane | 3 | $118,325 | $35,550 | $153,875 | 7 | $21,982 |
| Dixie Farm Road | 3 | $61,853 | $13,036 | $74,890 | 7 | $10,699 |
| Eiker Road | 3 | $243,104 | $37,476 | $280,580 | 8 | $35,073 |
| Glenda Street | 3 | $354,098 | $128,899 | $482,997 | 16 | $30,187 |

| Street Name | Properties | Building | Contents | Total Paid Claims Value ($) | Claims | Average |
|---|---|---|---|---|---|---|
| Heron Lane | 3 | $186,533 | $36,380 | $222,913 | 8 | $27,864 |
| Mclean Road | 3 | $384,126 | $162,183 | $546,309 | 18 | $30,351 |
| Meadowville Drive | 3 | $130,146 | $74,806 | $204,952 | 7 | $29,279 |
| Oakline Drive | 3 | $313,122 | $168,119 | $481,241 | 18 | $26,736 |
| Ryan Acres Drive | 3 | $316,786 | $123,346 | $440,132 | 12 | $36,678 |
| Scott Road | 3 | $161,251 | $40,659 | $201,910 | 11 | $18,355 |
| Trelawney Drive | 3 | $134,077 | $68,195 | $202,272 | 10 | $20,227 |
| Woodville Lane | 3 | $254,576 | $84,566 | $339,141 | 10 | $33,914 |
| Bailey Road | 2 | $83,537 | $64,769 | $148,306 | 7 | $21,187 |
| Bobby Street | 2 | $140,572 | $49,595 | $190,167 | 8 | $23,771 |
| County Road 125 | 2 | $97,858 | $44,499 | $142,358 | 5 | $28,472 |
| County Road 127 | 2 | $75,757 | $12,521 | $88,278 | 4 | $22,070 |
| David Street | 2 | $110,570 | $31,059 | $141,629 | 7 | $20,233 |
| Fairway Circle | 2 | $67,189 | $3,823 | $71,011 | 4 | $17,753 |
| Fm 1128 Road | 2 | $176,463 | $59,613 | $236,076 | 5 | $47,215 |
| Garden Road | 2 | $101,588 | $61,653 | $163,241 | 4 | $40,810 |
| Hollingsworth Drive | 2 | $106,892 | $29,953 | $136,845 | 9 | $15,205 |
| Kreis Road | 2 | $279,016 | $103,627 | $382,642 | 16 | $23,915 |
| Lazy Bend Street | 2 | $87,981 | $7,560 | $95,541 | 4 | $23,885 |
| Longherridge Drive | 2 | $162,109 | $62,196 | $224,305 | 10 | $22,430 |
| Longwood Drive | 2 | $7,063 | $1,780 | $8,842 | 4 | $2,211 |
| Marys Creek Lane West | 2 | $225,927 | $104,010 | $329,937 | 11 | $29,994 |
| Mckeever Road | 2 | $87,579 | $38,532 | $126,111 | 7 | $18,016 |
| Moore Road | 2 | $60,968 | $25,087 | $86,055 | 6 | $14,343 |
| Neches River Drive | 2 | $127,900 | $31,787 | $159,687 | 8 | $19,961 |
| Pearland Sites Road | 2 | $74,332 | $17,245 | $91,577 | 6 | $15,263 |
| Regal Oaks Drive | 2 | $186,367 | $85,947 | $272,314 | 4 | $68,078 |
| Rip Van Winkle Drive | 2 | $382,360 | $206,354 | $588,714 | 6 | $98,119 |
| Robert Street | 2 | $24,383 | $2,351 | $26,734 | 4 | $6,683 |
| Route 5 | 2 | $25,755 | $17,468 | $43,223 | 6 | $7,204 |
| Route 6 | 2 | $40,267 | $14,082 | $54,349 | 5 | $10,870 |
| Thelma Street | 2 | $179,622 | $46,643 | $226,264 | 7 | $32,323 |
| Wellborne Drive | 2 | $121,443 | $17,053 | $138,496 | 8 | $17,312 |
| West Lea | 2 | $222,817 | $70,408 | $293,226 | 5 | $58,645 |
| Westcreek Drive | 2 | $102,903 | $22,986 | $125,889 | 4 | $31,472 |
| Wingtail Way | 2 | $85,703 | $38,359 | $124,062 | 4 | $31,016 |
| Yupon Circle | 2 | $40,237 | $1,477 | $41,714 | 5 | $8,343 |
| **Grand Total/Average** | 288 | $17,654,079 | $6,393,319 | $24,047,398 | 917 | $26,224 |

Note: (1) The NFIP claims data in this table is limited to streets that include two or more RL properties, and therefore includes 288 of the 372 residential RL properties.

The residential RL claims data for Brazoria County also includes the cumulative paid claims and the building replacement value (BRV). These figures can be compared to provide a perspective about the dollar amount that has been paid from past claims, in comparison to the BRV. The table shows that for 15 of the 25 RL properties, the present claims value exceeds 100% of the BRV. The property on Anna Lane has the highest ratio of past claims compared to the BRV. This property has a total present value claims of $428,086 and a BRV of $62,000, a ratio of 397%.

## Residential Repetitive Loss Properties
## Loss Estimation

Residential flood risk is calculated by a simple methodology that uses the FEMA default present-value coefficients from the benefit-cost analysis software modules. To perform this calculation, the repetitive loss data was reviewed to determine an approximate period over which the claims occurred. This method should not be used for risk assessments for individual properties because of the generalizations that are used, i.e. that an unknown number of properties in the County have been flooded, but did not have flood insurance, and therefore do not appear in the data. Flood claims in the most recent query occurred between 1979 and the present, a period of 31 years.

As shown in Table 6-11, there have been 1,162 claims in the 31-year period, for an average number of claims per year of 37.5, though it is typical for losses to be clustered around significant flood events. Based on a 100-year horizon and a present value coefficient of 14.27 (the coefficient for 100 years using the mandatory OMB discount rate of 7.0 percent), the projected flood risk to these properties is shown at the bottom of the table. It must be understood that individuals can obtain and cancel flood insurance policies, and the flood hazard depends on many variables, including the weather, so this projection is simply an estimate of potential damages. Nevertheless, it offers a useful metric that can be used in assessing the potential cost effectiveness of mitigation actions.

**Table 6-11**
**Projected 100-year Flood Risk in Brazoria Drainage District No. 4**
**for Residential Repetitive Loss Properties**
(Source: FEMA NFIP query May, 2010)

| Data | Value |
|---|---|
| Number of properties | 372 |
| Period in years | 31 |
| Number of claims | 1,162 |
| Average claims per year | 37.48 |
| Total value of claims | $29,060,073 |
| Average value of claims per year | $937,422 |
| **Projected risk, 100-year horizon** | **$13,377,077** |

The next table (6-12) shows 100-year risk projections for the three streets that appear to have the most risk in the county, based on NFIP RL records. The streets with the most risk include Route 1, Route 2, and Green Tree Drive. These projections are done in the same manner as the calculation described above. The Table shows that Green Tree Drive and Robinson Drive are somewhat similar in terms of the average amount of claims, while Route 1 has a lower average claim amount. Although Route 1 has the highest number of claims (93 total), Robinson Drive has the highest total paid claims, average, and 100-year risk. The 100-year risk figure is a good basis for determining the total amount that can be spent (either overall, or per typical property) on mitigation actions, although the ultimate cost effectiveness is also a function of the effectiveness and useful life of the project itself.

**Table 6-12**
**Projected 100-year Flood Risk, Select Streets in Brazoria Drainage District No 4 with Highest Number of RL Claims in the NFIP Database**
(Source: FEMA NFIP, Query May, 2010)

| **Green Tee Drive** | |
|---|---|
| Total number of paid claims | 47 |
| Average number of paid claims per year | 1.51 |
| Total value of claims | $1,442,594 |
| Average value of paid claims per year | $46,535 |
| Projected risk, 100-year horizon | $664,058 |
| Number of claimants | 17 |
| Projected risk per policy, 100-year horizon | $39,062 |
| **Robinson Drive** | |
| Total number of paid claims | 40 |
| Average number of paid claims per year | 1.29 |
| Total value of paid claims | $1,542,706 |
| Average value of paid claims per year | $49,765 |
| Projected risk, 100-year horizon | $710,142 |
| Number of claimants | 15 |
| Projected risk per policy, 100-year horizon | $47,343 |
| **Carmona Lane** | |
| Total number of paid claims | 48 |
| Average number of paid claims per year | 1.54 |
| Total value of paid claims | $1,453,768 |
| Average value of paid claims per year | $46,895 |
| Projected risk, 100-year horizon | $669,202 |
| Number of claimants | 11 |
| Projected risk per policy, 100-year horizon | $60,837 |

## Non-Residential Repetitive Loss Properties

As noted earlier, as of May 2010, Brazoria Drainage District No. 4 had 14 non-residential RL properties in the NFIP database. Table 6-13 provides a summary of non-residential RL claims for the unincorporated areas of Brazoria Drainage District No. 4 and the two municipalities that include non-residential RL properties. The table identifies the number of RL properties in each municipality, building and contents damages, the total number of claims, and the average claim amounts. Of the 14 total non-residential properties, nine are located within the City of Pearland.

**Table 6-13**
**Summary of Non-Residential Repetitive Flood Loss Claims in Brazoria Drainage District No. 4, Ordered by Number of Properties in Each Municipality**
(Source: FEMA NFIP Query May, 2010)

| Municipality Name | Properties | Building | Contents | Total Paid | # Claims | Average |
|---|---|---|---|---|---|---|
| Pearland, City of | 9 | $861,914 | $184,527 | $1,046,441 | 35 | $29,898 |
| Unincorporated areas of Brazoria Drainage District No 4 | 4 | $82,546 | $41,483 | $124,030 | 12 | $10,336 |
| Brookside Village, City of | 1 | $16,325 | $3,575 | $19,900 | 2 | $9,950 |
| **Grand Total/Average** | **14** | **$960,786** | **$229,585** | **$1,190,371** | **49** | **$24,293** |

The data indicates that the City of Pearland has the highest number of non-residential repetitive loss properties and total number of claims. Pearland also has by far the highest building damages, contents, and total claims value for non-residential properties in the District.

## Non-Residential Repetitive Loss Properties Loss Estimation

As with the residential flood loss history, the past claims information can be used to project future flood losses. The methodology is the same as what is described in the residential section. As shown in Table 6-14, there have been 49 non-residential RL claims in the 31-year period, for an average number of claims per year of slightly more than 1.5. Similar to the residential RL data, the 1.5 claims per year is the average over a 31 year period and it is typical for losses to be clustered around significant flood events. Based on a 100-year horizon and a present value coefficient of 14.27 (the coefficient for 100 years using the mandatory OMB discount rate of 7.0 percent), the projected flood risk to these properties is $547,954.

**Table 6-14**
**Projected 100-year Flood Risk in Brazoria Drainage District No. 4 for Non-residential Repetitive Loss Properties**
(Source: FEMA NFIP query May, 2010)

| Data | Value |
|---|---|
| Number of properties | 14 |
| Period in years | 31 |
| Number of claims | 49 |
| Average claims per year | 1.58 |
| Total value of claims | $1,190,371 |
| Average value of claims per year | $38,399 |
| **Projected risk, 100-year horizon** | **$547,954** |

The flood risk to non-residential RL properties can be further broken down by focusing on individual properties. Table 6-15 below shows the 100-year risk for the seven non-residential RL properties with three or more RL claims. As with the residential RL properties, address data about individual sites is omitted for reasons of confidentiality. The table results show that the projected 100-year risk is highest for the RL property along East Broadway Street. The property on East Broadway has a total claims value of $428,795 and 100-year risk of $197,384.

**Table 6-15**
**Projected 100-year Flood Risk, Select Non-Residential**
**RL Properties in Brazoria Drainage District No. 4, ordered by 100-year risk**
(Source: FEMA NFIP, Query March, 2008)

| Municipality Name | Street Name | Flood Zone | # of Claims | Total Claims | Average Annual Value | 100-year risk |
|---|---|---|---|---|---|---|
| Pearland, City of | East Broadway Street | A05 | 8 | $428,795 | $13,832 | $197,384 |
| Pearland, City of | North Galveston | X | 11 | $233,602 | $7,536 | $107,532 |
| Brazoria County * | Piper Road | X | 4 | $85,320 | $2,752 | $39,275 |
| Pearland, City of | Cherry Street | X | 3 | $47,946 | $1,547 | $22,071 |
| Pearland, City of | Cherry Street | X | 3 | $23,643 | $763 | $10,883 |
| Brazoria County (unincorporated areas) | County Road 129 | A | 4 | $14,361 | $463 | $6,611 |
| Pearland, City of | Cherry Street | X | 3 | $23,643 | $763 | $10,883 |

The table above includes the flood zone for each property. The flood zones included in the table are defined by FEMA as follows

- **Zones AE and A1-30.** Areas subject to inundation by the 1-percent-annual-chance flood event determined by detailed methods. Base Flood Elevations (BFEs) are shown. Mandatory flood insurance purchase requirements and floodplain management standards apply.
- **Zone B.** Moderate flood hazard areas, labeled Zone B or Zone X (shaded) are also shown on the Flood Insurance Rate Map (FIRM), and are the areas between the limits of the base flood and the 0.2-percent-annual-chance (or 500-year) flood.
- **Zone C or X.** The areas of minimal flood hazard, which are the areas outside the SFHA and higher than the elevation of the 0.2-percent-annual-chance flood, are labeled Zone C or Zone X (unshaded).

### 6.2.3 Flood Loss Estimates for NFIP Severe Repetitive Loss Properties

**Residential Severe Repetitive Loss Properties**
**Background and General Statistics**

This subsection provides estimates of potential future flood losses (risk), based on analysis of National Flood Insurance Program (NFIP) data on repetitive flood loss (RL) properties. In 2004 FEMA began to develop the Severe Repetitive Loss (SRL) Grant Program in an effort to reduce or eliminate flood damages to residential properties that met certain minimum requirements. The Agency initiated the program early in 2008. An SRL property is defined as a residential property that is covered under an NFIP flood insurance policy and (1) has at least four NFIP claim payments (including building and contents) over $5,000 each, and the cumulative amount of such claims payments exceeds $20,000; or for which at least two separate claims payments (building payments only) have been made with the cumulative amount of the building portion of such claims exceeding the market value of the building.

As of May 2010, a query of the FEMA BureauNet NFIP interface indicates that Brazoria County had 136 properties on the SRL list. Of this total, 66 were located within Brazoria Drainage District No. 4. The SRL properties are located in the unincorporated areas of Brazoria County, the City of Pearland, and the City of Brookside.

Table 6-16 provides a summary of SRL claims for the unincorporated areas of BDD4 and the two municipalities that have SRL properties. The table includes the number of SRL properties in each municipality, building and contents damages, the total number of claims, and the average claim amounts. The figures are from an NFIP query performed in May, 2010. The table shows that for the SRL properties in BDD4 (to include incorporated areas) there have been 363 SRL claims totaling $11,061,452.

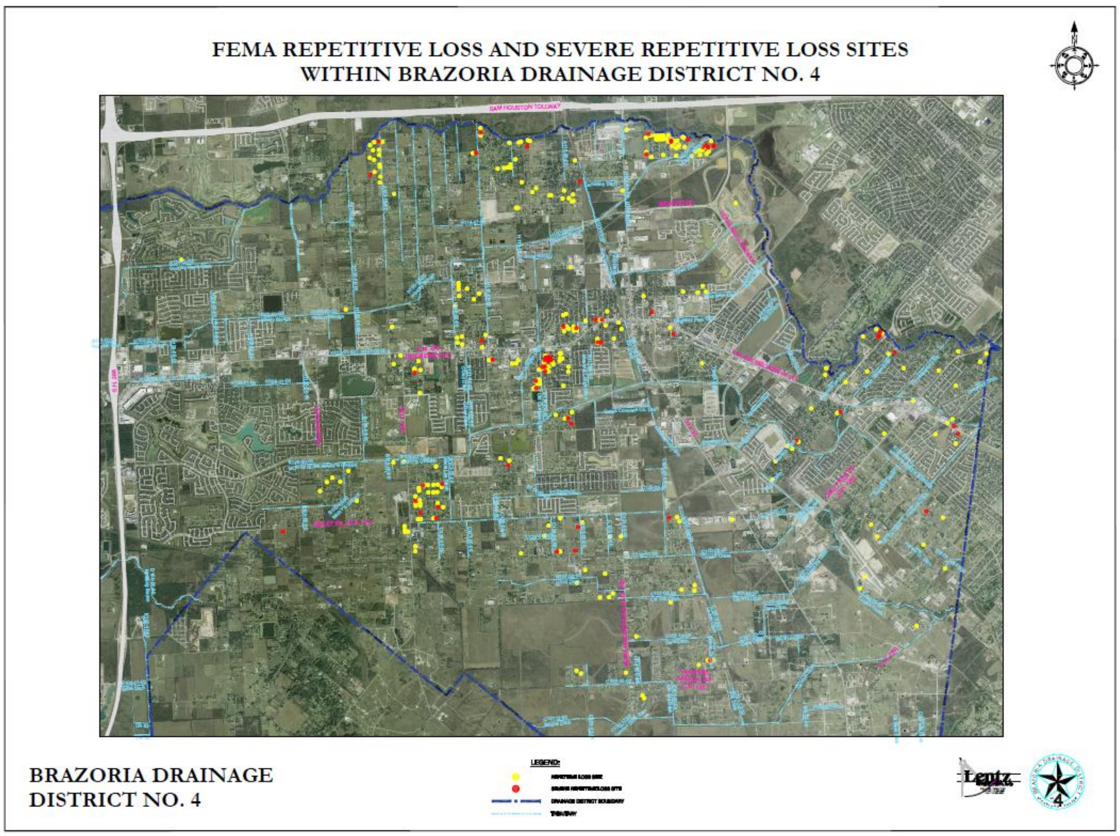
**Table 6-16**
**Summary of NFIP SRL Statistics, Brazoria Drainage District No. 4, Ordered by Number of Properties in Each Municipality**
(Source: FEMA NFIP Query May, 2010)

| Municipality Name | Properties | Total Building | Total Contents | Total Paid | # of SRL Claims | Average Claim |
|---|---|---|---|---|---|---|
| Pearland, City of | 46 | $5,829,643 | $1,879,923 | $7,709,566 | 240 | $32,123 |
| Unincorporated areas of Brazoria Drainage District No 4 | 15 | $1,837,862 | $646,979 | $2,484,841 | 87 | $28,561 |
| Brookside, Village of | 5 | $650,019 | $217,026 | $867,045 | 36 | $24,085 |
| **Grand Total/Average** | **66** | **$8,317,524** | **$2,743,928** | **$11,061,452** | **363** | **$30,472** |

The table shows that 46 of the 66 SRL properties are located in the City of Pearland. The City of Pearland has not only the highest number of properties, but also has the highest building, contents, and total claims value. The average claim amount is also slightly higher than the unincorporated areas of Brazoria Drainage District No. 4.

The following map (Figure 6.7) identifies the NFIP SRL properties in Brazoria Drainage District No. 4. The map includes major County thoroughfares, but detailed street names have been omitted for confidentiality purposes to prevent the identification of exact address locations of SRL properties. Note that the appendices for individual jurisdictions include maps of any repetitive loss or severe repetitive loss properties in their boundaries.

**Figure 6-7**
**Map of Severe Repetitive Loss Properties in Brazoria Drainage District No. 4**
(Sources: FEMA/NFIP, Brazoria DD4 - GIS)



## Severe Repetitive Loss Properties
## Loss Estimation (combined residential and non-residential)

Similar to the RL data, the SRL flood risk was calculated using the FEMA default present-value coefficients from the benefit-cost analysis software modules. See the residential RL subsection "*Flood Risk to Residential Properties*" for a detailed explanation of the methodology. Flood claims in the SRL query also occurred between 1979 and the present, a period of 31 years.

Table 6-17 provides the projected risk for all 66 SRL properties over a 100-year planning horizon. With a total of 363 claims over the 31 year period there has been an average of 11.7 SRL claims per year. The average value of claims over this same time period was $616,672. Based on a 100-year horizon and a present value coefficient of 14.27 (the coefficient for 100 years using the mandatory OMB discount rate of 7.0 percent), the projected flood risk to all SRL properties is $5,091,836. The 100-year risk for the SRL properties ($5,091,836) represents 36.5 percent of the combined risk calculated for all residential and non-residential RL properties, which is $13,925,031. As mentioned previously, this projection is simply an estimate of potential damages, but can provide a useful metric that can be used in assessing the potential cost effectiveness of mitigation actions.

**Table 6-17**
**Projected 100-year Flood Risk in Brazoria Drainage District No. 4**
**for Severe Repetitive Loss Properties**
(Source: FEMA NFIP query May, 2010)

| Data | Value |
|---|---|
| Number of properties | 66 |
| Period in years | 31 |
| Number of SRL claims | 363 |
| Average SRL claims per year | 11.70 |
| Total value of claims | $11,061,452 |
| Average value of claims per year | $356,821 |
| **Projected risk, 100-year horizon** | **$5,091,836** |

The flood risk for the SRL properties can be further broken down by focusing on individual properties. Table 6-18 provides loss estimates for 17 of the 66 SRL properties. The columns labeled "annual risk" and "100-year Risk" show the expected future losses over those respective planning horizons for the 17 properties with cumulative paid claims greater than $200,000. It should be noted that this methodology does not express a complete range of potential risk (and benefits if the data is used in a Benefit-Cost Analysis (BCA) for a mitigation project), so individual properties should not be dropped from consideration for mitigation based solely on this calculation. More extensive risk assessment and benefit-cost analysis would include additional loss calculations that would likely increase the apparent risk along with the concomitant benefits of reducing or eliminating it.

**Table 6-18**
**Flood Risk for 17 of the 66 SRL Properties in Brazoria Drainage District No. 4, ordered by 100-year Risk**
(Source: FEMA/NFIP, Query May 2010)

| Municipality Name | Street Name | Occupancy | Flood Zone | Losses | Total Paid Claims | Annual Risk | 100-year Risk |
|---|---|---|---|---|---|---|---|
| Pearland, City of | Route1 | Condominium | AE | 6 | $697,806 | $22,510 | $321,216 |
| Pearland, City of | East Broadway Street | Non Residential | A05 | 8 | $428,795 | $13,832 | $197,384 |
| Brazoria County * | Mclean Road | Single Family | X | 10 | $384,355 | $12,399 | $176,927 |
| Pearland, City of | Rip Van Winkle Drive | Single Family | AE | 3 | $296,204 | $9,555 | $136,349 |
| Pearland, City of | Rip Van Winkle Drive | Single Family | A04 | 3 | $292,510 | $9,436 | $134,649 |
| Brazoria County * | Kreis Road | Single Family | A | 14 | $285,424 | $9,207 | $131,387 |
| Pearland, City of | Carmona Lane | Single Family | AE | 5 | $277,692 | $8,958 | $127,828 |
| Pearland, City of | Glenda Street | Single Family | AE | 4 | $267,592 | $8,632 | $123,179 |
| Brookside, Village of | Oakline Drive | Single Family | AE | 9 | $249,065 | $8,034 | $114,650 |
| Brazoria County * | Anna Lane | Single Family | X | 8 | $246,124 | $7,939 | $113,296 |
| Pearland, City of | Glastonbury Drive | Single Family | AE | 7 | $240,709 | $7,765 | $110,804 |
| Pearland, City of | North Galveston | Non Residential | X | 11 | $233,602 | $7,536 | $107,532 |
| Brazoria County * | Amie Lane | Single Family | X | 5 | $230,527 | $7,436 | $106,117 |
| Pearland, City of | Glastonbury Drive | Single Family | AE | 6 | $215,974 | $6,967 | $99,418 |
| Pearland, City of | Carmona Lane | Single Family | AOB | 5 | $215,298 | $6,945 | $99,106 |
| Pearland, City of | Longherridge Drive | Single Family | B | 6 | $214,304 | $6,913 | $98,649 |
| Pearland, City of | Marys Creek Lane West | Single Family | A03 | 3 | $209,967 | $6,773 | $96,653 |

The information in this section should be used for planning purposes only, i.e. as the basis for additional steps in risk assessment, and eventually (where warranted) targeted mitigation actions to reduce the risk. For example, a property that has received a number of claim payments not much higher than $1,000 would be considered an unlikely candidate for mitigation using public funds. It may, however, be an excellent candidate for damage-reduction actions taken by the owner.

## 6.3 Flood Risks – Public Buildings

BDD4 owns three complexes of buildings on West Broadway and one on South Main Street. These buildings are not located in the Special Flood Hazard Area and have never experienced flooding.

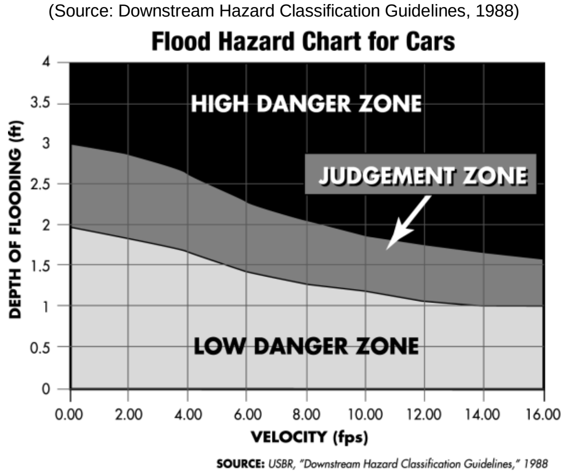
**Public Schools.** The Pearland Independent School District (PISD) owns all of the areas 27 public schools. Based on a review of the FIRM, of the 27 schools, 25 are in Zone X. The only addresses that fall within the 100-year floodplain are Pearland Junior High South located at 4719 Bailey Road and Alexander Middle School located at 3001 Old Alvin Road. The school buildings were permitted as being in the 100-year floodplain and are elevated at least one foot above the base flood elevation.

## 6.4 Flood Risks – Roads

Nationwide, flooded roads pose the greatest threat to people during floods. Most of the more than 200 people who die in floods each year are lost when they try to drive across flooded roads. Driving into water is the number one weather-related cause of death in Central Texas. Statewide, between 1960 and 1996, 76% of flood-related deaths were vehicle-related.[14]

As illustrated in Figure 6-8, flood hazards for cars vary with both velocity and depth of floodwaters. Many cars will float in less than 24 inches of water. Fast-moving water can quickly wash cars off the road or wash out a low section of road.

**Figure 6-8**
**Flood Hazard Chart for Cars**
(Source: Downstream Hazard Classification Guidelines, 1988)




[14] Texas Environmental Center

Although most roads in the area are unlikely to have deep or fast-moving water during flood conditions up to the level of the 100-year flood, many are still known to flood regularly.

The Texas Department of Transportation (TXDOT) maintains the freeways that run through the District and County. These major roadways include the following:

State highway 288
State highway 35
State highway 6
FM 518
CR 126
FM 1128

When building new State roads or upgrading existing roads, the TXDOT considers the NFIP's floodplain and floodway requirements to evaluate the impact of new and replacement structures. The City of Pearland and Brazoria County consider floodplain and floodway impacts in its planning and design for area roads. Within the City of Pearland, developers must satisfy the City's drainage criteria and other aspects of road designs in order for the City to accept ownership.

Replacing roads and bridges damaged or washed out by floods costs millions of dollars each year. If the damage is caused by a Presidentially-declared disaster, FEMA may pay up to 75% of the repair or replacement costs, with the remaining 25% covered by the State and local governments. The full costs of a damaging event that is not declared a major disaster must be borne by the State and local communities.

TXDOT inspects State bridges for structural integrity and to determine if erosion is a risk. Where erosion has been identified, stabilization measures have been put into place.

Roads and drainage structures in the area have sustained limited erosion damage due to flooding. There was some erosion to the wooden bridge into Centennial Park as a result of Tropical Storm Allison; the erosion and the bridge were repaired by Brazoria Drainage District No. 4.

Debris collects at bridges during major storms; TXDOT cleans bridges on state roads, Brazoria Drainage District No. 4 and/or City are responsible for debris clearance at other bridges.

Most roads in the area are designed to carry water and, therefore, flood even in small events. The worst street flooding tends to be on feeder roads.

## 6.5 Flood Risks – Local Drainage

Many areas and streets experience accumulations of rainfall that are slow to drain away, which may cause disruption of normal traffic, soil erosion, and water quality problems. Local drainage problems contribute to the frequency of flooding, increase ditch maintenance costs, and are perceived to adversely affect the quality of life in some neighborhoods.

Many areas prone to shallow, local drainage flooding are not shown on the District or County's Flood Insurance Rate Maps. One measure of the magnitude of this problem is the number of flood insurance policies in-force on buildings that are outside of the mapped floodplain. Local drainage flooding throughout some subdivisions in BDD4 is a problem, even during frequent rainstorms. It is a concern because access for emergency services (fire, emergency medical) can be limited. While the depth of water generally is relatively shallow, a number of homes have been flooded repetitively and are identified by FEMA as repetitive loss properties.

## 6.6 Summary: Exposure to Flood Risks

As described in Section 6.3, digital maps of the floodplain are used for flood hazard identification and assessments of risk. The data, combined with the footprint information for buildings, allow determination of residents and assets of the built environment that are at risk only by identifying whether such assets are in or out of the flood hazard area. No other characterization of flood risk can be made, i.e., depth of flooding or whether houses are in the floodway or the flood fringe.

Table 6-19, based on a form provided in the State's Mitigation Handbook (DEM 21) is a summary of flood risks. For the purpose of this table, number of people per home is based on the U.S. Census value of 2.82 occupants per household for Brazoria County. Special facilities include fire stations and schools.

**Table 6-19**
**State Mitiation Handbook - DEM 21:**
**Vulnerability and Risk Assessment Worksheet for the Flood Hazard**

| People/Property at Risk in the Floodplain | Total |
|---|---|
| People (estimate) | 100,544 |
| Housing Units | 35,654($5.2B) |
| Commercial Facilities | 5,709 |
| District-Owned Buildings | 6($2.1M) |
| Critical Facilities | 154 |
| Special Facilities (schools; fire stations) | 32 |

### 6.6.1 Estimate of Annualized Damage from Floods

The Plan uses the following approach to estimate the potential total estimated annualized damages. From actual historical paid losses combined with historical knowledge of the total of uninsured losses, it is estimated that buildings within BDD4 have experienced over $100 million in flood losses. These losses occurred from April 1979 to 2010 and included 19 primary events (and several smaller, less costly events).

## 7.1 Organization of Brazoria Drainage District No. 4

Brazoria Drainage District No. 4 (BDD4) is a conservation and reclamation district and a political subdivision of the State of Texas. BDD4 was created by Brazoria County Commissioners Court on June 28, 1910 and on May 22, 1929, was made a Conservation and Reclamation District by Special Bill No. 25 of the Texas State Legislature.

In addition to the Board of Commissioners, BDD4 is organized into the following departments:

Administration – personnel, finance, and general management of BDD4
Operations – maintain, reclaim and modify the drainage arteries within its jurisdiction
*Engineering* – flood studies of problem areas, identification and engineering of mitigation alternatives, and coordination with maintenance and new construction

There are a variety of flood mitigation activities within the District that are a joint responsibility of BDD4 and the County.

## 7.2 Emergency Response

Emergency response is the responsibility of the Cities and County. The Cities owns and maintains several roadside ditches, however BDD4 owns the majority of ditches within the planning area and are responsible for routine maintenance. After an event, it is a cooperative effort between the Cities, County Precincts, and BDD4 to identify ditches that need cleaning (as well as crossings). There are known problem areas that are regularly checked during and after an event.

The Cities and the County have early warning capability. Citizens in the area rely mostly on local weather, which is reported to be very capable.

## 7.3 Communicating about Hazards

BBD4 works closely with the Cities and the County to ensure communication with residents about flood hazards in the area. The Cities actively communicate with residents using a variety of media, each of which have been used to convey information, including content about hazards. Specifically in the City of Pearland: - The quarterly newsletter Pearland in Motion, is mailed to every address in town. This large format, full color newsletter regularly reports on the City's activities, progress on various initiatives, and conveys information important to the residents. Flood issues have periodically been addressed in quarterly newsletter.

- The Cities' and County web sites post information about activities and upcoming events. Regulations are posted and public access to GIS maps are provided.

-Group Builder: Citizens can subscribe to City email alerts to obtain a variety of hazard related information including emergency management news and ongoing public works projects.

-The local government public access channel is accessible to residents who subscribe to Time Warner Cable. Council meetings and other public meetings are shown on this channel. The channel is used to disseminate information during hazardous events. In addition, after major flooding, jurisdictions post information slides to include information on post-disaster permit requirements.

## 7.4 How BDD4 Addresses Hazards

As part of the planning process, members of the Mitigation Planning Committee (MPC) were interviewed to gain an understanding of awareness of hazards and how they are addressed, and to gather information about damage associated with past hazard events. Minutes of committee meetings can be found in Appendix A. City and County ordinances and documents were also reviewed to identify specific provisions pertinent to BDD4's hazards.

### 7.4.1 Local Regulation of Development

BDD4 has no direct responsibility for oversight of development in the floodplain. When development is proposed within the Cities or County, within the floodplain, BDD4 is asked to review and comment on the subdivision plans. The Cities have strong development and permitting requirements for development in and out of the floodplain.

**Table 7-1**
**BDD4: Buildings Permits and**
**Development Permits (2006 - 2010)**
(Source: City permit information provided by the City MPC member, County permit info from County MPC member)

| Jurisdiction | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|
| Brookside Village | 11 residential and 3 commercial building permits over this 5 year period | | | | |
| City of Pearland – Residential | 2,358 | 1,633 | 1,242 | 829 | 727 |
| City of Pearland – Commercial | 66 | 77 | 52 | 78 | 40 |
| Brazoria County Unincorporated - Residential | 644 | 585 | 437 | 453 | 564 |

Table 7-2 identifies the number of building permits per year within BDD4 issued within Flood Zone A (areas inundated by the 100-year floodplain) between 2006 and 2010. Based on the data in the Table, on average about xx building permits are issued within Flood Zone A every year.

**Inspections.** Brazoria Drainage District No. 4 has no inspectors, as there is no budget within the District to support an inspection department. For development in the floodplain, the District relies on the certified information provided by an engineer on the elevation certificate. Elevation Certificates are collected before the certificate of occupancy is issued for buildings in the SFHA.

### 7.4.2 Flood Hazards

Brookside Village, Pearland and Brazoria County administer a suite of regulations and ordinances that combine to comprehensively regulate flood hazard areas to minimize exposure of people and property. Within the Cities, administration of these provisions is the joint responsibility of the City's Floodplain Manager and the Building Code Official. Within Brazoria County, these ordinances are administered within the engineering department. As indicated previously, development permits are provided to BDD4 engineering department for review and comment.

**Processing Floodplain Development Proposals.** Most homes built in the floodplain are slab-on-grade, elevated by the placement of a minimum quantity of fill. Elevation Certificates are required for all construction in the floodplain. City regulations require that the lowest floor, including basement, be at least one foot above the Base Flood Elevation. Within unincorporated Brazoria County, regulations require the lowest floor, including basement, be at the Base Flood Elevation.

**Reviewing and Approving Subdivisions.** The Cities and Brazoria County, submit all subdivisions proposals within the floodplain to BDD4 for review and comment. BDD4 evaluates both current floodplain/BFE requirements and known historical flooding when providing their recommendations.

## 7.5 Future Development Trends in BDD4

To identify future development trends in Brazoria Drainage District No. 4, the *2004 Comprehensive Plan Update* was reviewed as well as detailed discussions with Brazoria County unincorporated Engineering department. Since Pearland is the largest City in the District this area was primarily used to identify potential future development trends. In the 1990s, the City of Pearland experienced tremendous growth and the 2004 Comprehensive Plan indicated that the rate of growth has been accelerating. The Plan projected that the population of the City is expected to at least double over the next two decades. Most of the future development is anticipated to occur on the western portion of the City. BDD4 works very closely with the Cities and County to understand where future development is predicted to occur and encourages the Cities and County to take into account drainage impacts associated with future development and to properly plan for these potential impacts.

As mentioned elsewhere in this plan, BBD4's jurisdictional authority applies only to flood. BDD4, the City of Pearland, the City of Brookside Village, and Brazoria County closely coordinate permitting and development in the floodplain. The Cities and County require elevations of new construction above FEMA minimum requirement of first floor elevations at BFE. For this reason, vulnerability to future buildings, infrastructure, and critical facilities (relative to BDD4's jurisdictional authority limited to flood mitigation), is low. BDD4 has no plans to construct infrastructure or facilities in the floodplain, in floodprone areas, or in any other area that would be unduly, negatively impacted by any other natural hazard

## 7.6 Continued Compliance with the NFIP

Participation in the National Flood Insurance Program (NFIP) is important to BDD4 and its residents. This is evidenced by the Cities, and the County's commitment to regulating development and redevelopment, by adoption of provisions that exceed the minimum requirements, and by its active pursuit of mitigation opportunities. The Cities and Brazoria County, with support from BDD4, are firmly committed to continued compliance with the NFIP.

BDD4 is a conservation and reclamation district and a political subdivision of the State of Texas. Considering BDD4 is a separate entity and does not directly participate in the NFIP, specific actions will be determined by representatives and officials with the incorporated areas and Brazoria County within the District. With this in mind, BDD4 did not identify and prioritize NFIP actions as part of the planning process. BDD4 will continue to work closely with the City of Pearland, Brookside Village and Brazoria County to identify and recommend actions that will ensure continued compliance with the NFIP.

Pearland satisfied requirements for initial participation in the NFIP and joined the Emergency Program in 1978. Upon issuance and final approval of the Flood Insurance Rate Map in July 1984, the City joined the Regular Program. The effective Flood Insurance Rate Map for Pearland has been revised a number of times to reflect more detailed information and changes to the floodplain, and is now used as the minimum flood hazard area within which development must conform to floodplain management regulations.

Brazoria County satisfied requirements for initial participation in the NFIP and joined the Emergency Program. Upon issuance and final approval of the Flood Insurance Rate Map in June of 1983, the County joined the Regular Program. The effective Flood Insurance Rate Map for the County has been revised a number of times to reflect more detailed information and changes to the floodplain, and is now used as the minimum flood hazard area within which development must conform to floodplain management regulations.

### 7.6.1 Future Actions Related to NFIP Compliance

As mentioned at the beginning of this Section, BDD4 is a conservation and reclamation district and a political subdivision of the State of Texas. Considering BDD4 is a separate entity and does not directly participate in the NFIP, specific actions will be determined by representatives and officials with the incorporated areas and Brazoria County within the District. With this in mind, BDD4 did not identify and prioritize NFIP actions as part of the planning process. BDD4 will continue to work closely with the City of Pearland, Brookside Village and Brazoria County to identify and recommend actions that will ensure continued compliance with the NFIP.

## 7.7 Ongoing and Previous Mitigation Initiatives

Dealing with flood hazards, the most significant natural hazard in the Brazoria County area is not a new proposition. Indeed, BDD4 has spent considerable funds for projects and studies to reduce and/or eliminate the severity of flooding in the area. The specific studies and projects are described in the following subsections.

### 7.7.1 Clear Creek Regional Flood Control Plan

The regional Flood Control Plan for the Clear Creek watershed is summarized in a report comprised of two separate volumes. The first volume is the Text Report which describes the project scope, background, design consideration, and cost estimates. The Text Report provides the reader with an understanding of the magnitude of the flood control problem in the Clear Creek watershed and discusses potential recommendation to mitigate flooding to its solution.

The second volume is the Exhibit Report, is a graphical presentation of the plan concept and its system components. Its purpose is to provide graphic description of how drainage will be accommodated as the Clear Creek watershed develops.

The Report is divided into two sections. The first section, entitled "Mainstem Improvements and Watershed Plan Components", summarizes the plan requirements for regional detention, channelization, and open space along the mainstem of Clear Creek. The second section, entitled "Tributary Watershed Improvements".

### 7.7.2 Clear Creek Texas Flood Risk Management General Revaluation Report

This write-up documents hydrologic modeling studies conducted for the Clear Creek General Reevaluation Report (GRR). The overall modeling process is reviewed, and the simulations for a large array of flood damage reduction measures are described. The GRR study authority addresses flood damages from stream flooding, so the hydrologic analysis is limited to that flood source. Flood damages were analyzed along the main stem of Clear Creek and also on six major tributaries including Hickory Slough, Mary's Creek, Cowart Creek, Chigger Creek, Mud Gully, and Turkey Creek. The total length of damage reaches over 93 miles.

### 7.7.3 Clear Creek Watershed Modeling Update

The Clear Creek Watershed Steering Committee (CCWSC) updated the hydrologic and hydraulic models of the tributaries within the Clear Creek Watershed. These updates included the addition of ponds on Hickory Slough, Cowart Creek, Chigger Creek and Mary's Creek. The proposed scope of work included updating the hydrology for the Clear Creek Watershed to include any major improvements that have been completed in this time, as well as updating hydraulic models for the mainstem of Clear Creek, Hickory Slough, Mary's Creek, Cowart Creek and Chigger Creek. The study was limited to features that are either complete, or under construction by June of 2009. These models can be utilized to determine the effectiveness of proposed storm water features. The features include those proposed by the USACE GRR, scaled down versions of these features, or other components as the local partners see fit.

### 7.7.4 Flood Protection Plan for Brazoria Drainage District No. 4

Rust Lichliter/Jameson prepared a drainage study of the BDD4 planning area to develop a Flood Protection Plan for the area. Five watersheds were included in the study: Clear Creek, Hickory Slough, Mary's Creek, Cowart Creek and Chigger Creek. Engineering recommendations were developed to identify the causes of flooding and recommend appropriate solutions to the flooding problems.

### 7.7.5 Clear Creek Modeling Update – Hickory Slough, Mary's Creek and Cowart Creek

As part of FEMA's Map Modernization program, the development of DFIRM data for Brazoria and Galveston Counties was initiated in the fall of 2005. The FEMA DFIRM updates will not include new hydrologic or hydraulic modeling, but will simply convert the effective FIRM panel data for Brazoria and

Galveston Counties into a digital (DFIRM) format. Several entities, including the Clear Creek Watershed Steering Committee (CCWSC) and the City of Pearland, recognized the Map Modernization program as an opportunity to update the flood hazard areas for some of the major tributaries to Clear Creek. The hydraulic model update will be completed by supplementing the effective hydraulic models with overbank topography from LiDAR data.

### 7.7.6 Cowart Creek Watershed Master Plan

The residents in the region of the study have experienced major flooding in the past. Through evaluation of the National Flood Insurance Paid Claims database for the City of Friendswood, the City of Pearland, Brazoria County, and Galveston County, it was determined there have been ten major floods and several small events that have caused damage within the study area within the past 34 years. This purpose of this study was to develop an implementable and cost effective comprehensive watershed master plan that will result in the elimination or significant reduction of flood damages within the watershed. Reduction in the watersheds flood damages will be achieved without negatively impacting downstream communities. The drainage improvements proposed in the Cowart Creek Watershed Master Plan significantly reduce the amount of overbank floodings during the 10% exceedence event. As a result, the number of structures below 10% exceedence event flood stages is reduce from 234 to 25, which is an 89% reduction in the number of flooded structures.

### 7.7.7 Cowart Creek Watershed Modeling Update

As part of FEMA's Map Modernization program, the development of the DFIRM data for Brazoria and Galveston Counties was initiated in the Fall of 2005. The FEMA DFIRM updates with not include new hydrologic or hydraulic modeling, but will simply convert the effective FIRM panel data for Brazoria and Galveston Counties into a digital (DFIRM) format. Several entities, including the Clear Creek Watershed Steering Committee (CCWSC) and the City of Pearland recognized the map Modernization program as an opportunity to update the flood hazard areas for some of the major tributaries to Clear Creek. Even though funding for the flood hazard updates would not be provided by FEMA, the local entities decided to take advantage of the opportunity to incorporate the latest modeling results in the Brazoria County and Galveston County DFIRM update.

### 7.7.8 Preliminary Hydrologic and Hydraulic Analysis For Proposed Clear Creek Detention on Alexander Tract

The purpose of this report was provide the hydrologic and hydraulic analysis performed for a proposed detention facility on the Alexander tract, which would service Clear Creek. The reports provide a brief summary of the approach used to model this proposed facility along with a discussion about the findings and results enclosed in this report. As expected, a reduction in peak flows was realized as a direct result of the proposed detention pond being added to the model. For the 10% event, the peak flow was reduced by approximately 22%. Similarly, the peak flow was reduced by 17% for the 1% event. Furthermore, the water surface elevation for the 10% storm was reduced by as much as 1.01 feet. Likewise, the water surface elevation decreased by 1.06 feet for the 1% event. The results show a water surface reduction a distance of 2 miles upstream (~ SH-35) and a distance of 11.6 miles downstream (~ FM 2351).

### 7.7.9 Cowart Creek – Proposed Pipe Diversion

This report evaluated a proposed flow diversion in the Cowart Creek watershed. The project was initially identified due to flooding issues in the subdivision located north of Cowart Creek and east of the Pearland Regional Airport and currently outfalling to CW101-00-00. A plan was devised to prevent sheet flow from inundating the neighborhood. The proposed improvements are described below.

Dannenbaum Engineering was contracted by the Clear Creek Steering Committee to evaluate a diversion box in the Cowart Creek Watershed. The diversion box would prevent sheet flow through the subdivision and therefore alleviate the existing flooding issue.

This plan involved the installation of series of RCBs to intercept flow within the Cowart Creek watershed and outfall the flow upstream of the original outfall location on the main channel. The interceptor box prevents sheet flow from entering the subdivision.

### 7.7.10 Flood Control Improvement Verification

Dannenbaum Engineering Corporation was given the task of verifying the performance of the Brazoria Drainage District No. 4 drainage improvements described in "Flood Control Improvement Projects for BDD4 July 2003. The improvements outlined in the report were adapted from "Flood Protection Plan for Brazoria Drainage District No. 4 (Rust Lichliter/Jameson-November 1997)". Due to changes in the watershed, the report proposed modifying the improvements outlined in the November 1997 report; however, the benefits of the modifications proposed were never modeled.

This report outlined the proposed improvements suggested by BDD4 and presented recommended modifications, as necessary, to the BDD4 drainage improvements that will be necessary to avoid impacting downstream areas. Construction cost estimates for the proposed improvements were presented in the report.

The following streams were analyzed as part of this study:

- Hickory Slough (HI100-00-00)
- Mary's Creek (MA100-00-00)
- Cowart Creek (CW100-00-00)
- Cowart Creek Tributary (CW104-00-00)
- Cowart Creek Tributary (CW102-00-00)

## 7.8 Natural Resources

The City of Pearland, Brookside Village and Brazoria County require applicants that propose to impact wetlands to obtain approvals from the U.S. Army Corps of Engineers. In addition, BDD4 obtains USACE permits for construction activities that impact wetlands.

### 8.1 IFR Requirements for Mitigation Strategy

***IFR §201.6(c)(3):*** *The plan shall include a mitigation strategy that provides the jurisdiction's blueprint for reducing the potential losses identified in the risk assessment, based on existing authorities, policies, programs and resources, and its ability to expand on and improve these existing tools.*

***IFR §201.6(c)(3)(i):*** *[The hazard mitigation strategy shall include a] description of mitigation goals to reduce or avoid long-term vulnerabilities to the identified hazards.*

***IFR §201.6(c)(3)(ii):*** *[The mitigation strategy shall include a] section that identifies and analyzes a comprehensive range of specific mitigation actions and projects being considered to reduce the effects of each hazard, with particular emphasis on new and existing buildings and infrastructure.*

***IFR §201.6(c)(3) (iii):*** *[The mitigation strategy section shall include] an action plan describing how the actions identified in section (c)(3)(ii) will be prioritized, implemented, and administered by the local jurisdiction. Prioritization shall include a special emphasis on the extent to which benefits are maximized according to a cost benefit review of the proposed projects and their associated costs.*

## 8.2 Identifying Priority Actions

Throughout the planning process, the Mitigation Planning Committee (MPC) discussed hazard and the number of people and types of property that are exposed to these hazards.

As part of the planning process, factors that influenced prioritizing included the Committee's review of available information on flood hazards, other hazards, past hazard events, the number of people and types of property exposed to those hazards, and the elements of the development approval process. High priority was placed on those actions that are considered consistent with current District policies, those that are technically feasible and have high political and social acceptance, and those that can be achieved using existing authorities, budget levels, and staff.

As part of the planning process, the mitigation actions items were established to achieve the goals discussed in Section 4.2, BDD4's Mitigation Goals. Each action item identifies an appropriate lead person for each action, cost effectiveness, a schedule for completion and suggested funding sources. The MPC chose the (STAPLEE) methodology to prioritize mitigation actions. STAPLEE assesses actions based on six general criteria: **S**ocial, **T**echnical, **A**dministrative, **P**olitical, **L**egal, **E**conomic, and **E**nvironmental. Table 8-1 describes the criteria used in the STAPLEE methodology.

**Table 8-1**
**STAPLEE Methodology Criteria**

| STAPLEE | Criteria Explanation |
|---|---|
| S – Social | Mitigation actions are acceptable to the community if they do not adversely affect a particular segment of the population, do not cause relocation of lower income people, and if they are compatible with the community's social and cultural values. |
| T – Technical | Mitigation actions are technically most effective if they provide long- term reduction of losses and have minimal secondary adverse impacts. |
| A – Administrative | Mitigation actions are easier to implement if the jurisdiction has the necessary staffing and funding. |
| P – Political | Mitigation actions can truly be successful if all stakeholders have been offered an opportunity to participate in the planning process and if there is public support for the action. |
| L – Legal | It is critical that the jurisdiction or implementing agency have the legal authority to implement and enforce a mitigation action. |
| E – Economic | Budget constraints can significantly deter the implementation of mitigation actions. Hence, it is important to evaluate whether an action is cost-effective, as determined by a cost benefit review, and possible to fund. |
| E - Environmental | Sustainable mitigation actions that do not have an adverse effect on the environment, that comply with Federal, State, and local environmental regulations, and that are consistent with the community's environmental goals, have mitigation benefits while being environmentally sound. |

The MPC members developed and prioritized the actions using the STAPLEE criteria. The high priority action items in Table 8-2 were prioritized by the MPC based on the STAPLEE criteria and their potential to reduce risk to BDD4, including its operations, and physical assets. The highest priority actions are generally those that are most effective in reducing risks to multiple assets simultaneously.

The Planning Committee defined High, Medium, and Low priorities in the Action Plan as follows:

- High: Meets five of the seven STAPLEE criteria
- Medium: Meets four of the seven STAPLEE criteria
- Low: Meets three of the seven STAPLEE criteria

These priorities were applied to update the action items. The items were sorted by high and medium/ low priority. A key criterion in BDD4's prioritization of actions was the cost-effectiveness of actions and projects. Cost effectiveness will continue to be central to BDD4's decision-making processes in identifying and funding mitigation actions.

## 8.3 Mitigation Actions

Table 8-2 identifies each High-priority mitigation actions (meets five of the seven STAPLEE criteria) and identifies the proposed lead office and support assignments, cost, and schedule for completion. The proposed timeframes are consistent with the five-year review cycle required for Plan updates. For each High-priority action, the MPC characterized anticipated support by the BDD4 Board of Commissioners, BDD4 Management, and the community at-large, discussed funding limitations and status, and developed a qualitative statement regarding cost effectiveness. In this context, the cost of accomplishing the action was compared to the perceived benefits, including community-wide safety. In some cases, several of the high-priority actions and projects were subjected to preliminary feasibility assessments and benefit-cost analyses to determine if they were good candidates for mitigation actions.

**Table 8-2**
**BDD4: High and Medium Priority Mitigation Actions**

| No. | Action Item Description / Benefits | Lead Manager | Funding/Support | Schedule | Hazard | Cost-Effectiveness |
|---|---|---|---|---|---|---|
| 1 | Mary's Creek Bypass Channel Reclamation<br>The goal of this project is conservation and reclamation of the channel. The channel and berms along the bypass are experiencing erosion which is impacting the integrity of the channel. This project will reduce the erosion and allow the channel to function as built. Because of the erosion pipeline relocation will be a necessary part of the plan. The detention for this project is included in the BDD4's East Mary Creek Detention Facility located at the headwaters of the Mary's Creek Bypass. Therefore the impact on the channel will be zero. | Mike Yost | District Operating Budget, State funds, FEMA grant funds if project determined programmatically eligible, and if project is cost-effective<br><br>Support: Strong | 1 to 5 years | Flood | Believed to be Cost Effective – FEMA grant funds would required full BCA |
| 2 | Cowarts Creek Diversion Project<br>The goal of this project will alleviate flooding in the neighborhoods north of Cowarts Creek. The project will consist of installing a series of Reinforced Concrete Boxes to intercept flow within the Cowarts Creek Watershed and outfall the flow upstream of the original outfall location on the main channel. This diversion would prevent sheet flow from entering the subdivision. The detention for this project is proposed at a site upstream on Cowarts Creek near the Pearland Regional Airport. The impact on Cowarts Creek would be zero. | Mike Yost | District Operating Budget, State funds, FEMA grant funds if project determined programmatically eligible, and if project is cost-effective<br><br>Support: Strong | 1 to 5 years | Flood | Believed to be Cost Effective – FEMA grant funds would required full BCA |
| 3 | Cowarts Creek Flood Control Project<br>The goal of this project will be to alleviate flooding in the upstream areas of Cowarts Creek. The project will consist of Channel Reclamation, Bridge Replacement, And Detention. A proposed 80 acre Detention site on Cowarts Creek is located upstream of State Highway 35 near the Santa Fe Railway. Several Bridges including a RailRoad Trestle will be replaced. This project will greatly reduce the flooding of homes and other structures in the watershed The impact to the Cowarts Creek Watershed will be zero. | Mike Yost | District Operating Budget, State funds, FEMA grant funds if project determined programmatically eligible, and if project is cost-effective<br><br>Support: Strong | 1 to 5 years | Flood | Believed to be Cost Effective – FEMA grant funds would required full BCA |

| No. | Action Item Description / Benefits | Lead Manager | Funding/Support | Schedule | Hazard | Cost-Effectiveness |
|---|---|---|---|---|---|---|
| 4 | Culvert replacement and installation<br>The goal of this project will be to alleviate potential flooding in areas such Roy and Max Roads. This area experiences flooding due to inadequate culvert sizes in the outfall ditches The project will consist of replacing the inadequate sized culverts with culverts sized by BDD4's engineer. These outfall ditches are in residential areas that experience flooding. The impact on the channel will be zero | Mike Yost | District Operating Budget, State funds, FEMA grant funds if project determined programmatically eligible, and if project is cost-effective<br><br>Support: Strong | 1 to 5 years | Flood | Believed to be Cost Effective – FEMA grant funds would required full BCA |
| 5 | Mykawa Road Culvert installation<br>The goal of this project will be to alleviate flooding in the Willow Crest subdivision and street flooding along Mykawa Road. This project will consist of installing Reinforced Box Culverts in the Mykawa Road Drainage Ditch from Orange St to Cherry St. and reworking the Willow Crest Subdivision storm sewer outfalls The Detention for this project will be in the David L Smith Detention Facility. The impact to the area will be zero. | Mike Yost | District Operating Budget, State funds, FEMA grant funds if project determined programmatically eligible, and if project is cost-effective<br><br>Support: Strong | 1 to 5 years | Flood | Believed to be Cost Effective – FEMA grant funds would required full BCA |
| 6 | Develop and adopt a master drainage plan in order for BDD4 to exercise the authority granted to drainage districts under Chapter 49.211 of the Texas Water Code. Chapter 49.211 requires districts to adopt master drainage plans before adopting rules relating to the review and approval of proposed development drainage plans | BDD4 Engineering | Potential 50/50 grant from TWDB.<br><br>Support: Strong | 1 to 5 years | Flood | Cost effective |
| | Medium Priority Mitigation Actions | | | | | |
| 7 | Formalize procedures on BDD4s roles and responsibilities before, during, and after a hazard event | BDD4 Administration | Limited funds required. Can be funded out of operating budget<br><br>Support: Strong | 2015 | Flood, hurricanes and tropical storms, Thunderstorms /High Winds and Tornado | likely |
| 8 | Periodically perform engineering and structural surveys of BDD4 facilities to ensure that they are sufficiently protected from effects of hazards, especially wind | BDD4 Engineering | BDD4 operating budget. Support: moderate | Ongoing | Hurricanes and tropical storms, Thunderstorms /High Winds and Tornado | Cost Effective |
| 9 | Based on the results of number 7 above harden BDD4r owned facilities to make a safe harbor for any person that so chooses to stay in these buildings during an event. | BDD4 Administration | District Operating Budget, State funds, FEMA grant funds if project determined programmatically eligible, and if project is cost-effective<br>.<br>Support: Strong | 3 to 5 years | Hurricanes and tropical storms, Thunderstorms /High Winds and Tornado | Very Cost effective |

| No. | Action Item Description / Benefits | Lead Manager | Funding/Support | Schedule | Hazard | Cost-Effectiveness |
|---|---|---|---|---|---|---|
| 10 | Create severe weather action plan, conduct drills, identify and promulgate evacuation and sheltering options. | BDD4 Engineering | District Operating Budget, State funds, FEMA grant funds if project determined programmatically eligible, and if project is cost-effective<br><br>Support: Strong | 2015 | Flood, hurricanes and tropical storms, Thunderstorms /High Winds and Tornado | Cost effective |

It should be noted that BDD4 was created primarily to provide drainage of overflow lands within the district. As such, BDD4 has no authority to address hazards other than flood. Brazoria County and incorporated jurisdictions within BDD4 are currently developing their own All-hazards mitigation plans. These plans include action items relating to all hazards, including floods. BDD4 cooperates with these jurisdictions on the identification and implementation of mitigation projects, as allowed by law. This coordination is focused on mitigation projects designed to prevent future flood damage and wind damage to BDD4 owned facilities.

## 8.4 Links to Mitigation Goal Statement

**BDD4's Mitigation Goal Statement**

*The mitigation goals of BDD4 are:*

To protect public health, safety, and welfare
To reduce losses due to hazards by identifying hazards, minimizing exposure of citizens and property to hazards, and increasing public awareness and involvement
To facilitate the development review and approval process to accommodate growth in a practical way that recognizes existing stormwater and floodplain problems while avoiding creating new problems or worsening existing problems
To seek solutions to existing problems

Table 8-5 shows how the proposed actions listed in Section 8.3 directly support BDD4's Mitigation Goal Statement. A number of actions individually support more than one element of the goal.

**Table 8-3**
**Linking Mitigation Goals & Actions**

| Element of Goal Statement | Actions Relating to Goal |
|---|---|
| Protect public health, safety, and welfare; | 7 - 10 |
| Reduce losses due to hazards by identifying hazards, minimizing exposure of citizens and property to hazards, and increasing public awareness and involvement; | 1 - 10 |
| Facilitate the development review and approval process to accommodate growth in a practical way that recognizes existing stormwater and floodplain problems while avoiding creating new problems or worsening existing problems | 6 |
| Seek solutions to existing problems | 1 - 5 |

## 9.1 Overview

Mitigation of flood hazards traces its roots to Congressional deliberations about how to address continued and repetitive flood disasters throughout the first half of the 20th Century. The National Flood Insurance Program, authorized in 1968, prompted State and local government actions primarily intended to recognize and account for flood hazards in decisions on local development. It was not until 1988 that the concept of mitigation planning was articulated in a statute, known as "Section 409" planning. In 2000, the statute was revised under the Disaster Mitigation Act of 2000.

At the federal level, the Federal Emergency Management Agency administers mitigation programs that foster planning and project implementation to address existing risks. At the State and regional levels, several agencies and organizations sponsor programs that bear on hazard mitigation. The following sections provide an overview of existing Texas agencies, organizations, and programs addressing hazard mitigation.

## 9.2 Texas Division of Emergency Management

The Texas' Division of Emergency Management (TDEM) (www.txdps.state.tx.us/dem) is designated by the Governor as the State's coordinating agency for disaster preparedness, emergency response, and disaster recovery assistance. TDEM is also tasked with coordinating the State's natural disaster mitigation initiatives, chairing the State Hazard Mitigation Team, and maintaining the State of Texas Emergency Management Plan. TDEM fosters local mitigation planning and administers Hazard Mitigation Grant Program funds provided through the Federal Emergency Management Agency.

## 9.3 Texas Water Development Board

The Texas Water Development Board (TWDB; www.twdb.state.tx.us) administers a variety of programs related to water. The TWDB is the agency charged with statewide water planning and administration of financial assistance programs for the planning, design, and construction of water supply, wastewater treatment, flood control, and agricultural water conservation projects. TWDB administers funding from FEMA under the Flood Mitigation Assistance Program (see Section 2.8).

## 9.4 Texas Commission on Environmental Quality

The Texas Commission on Environmental Quality (TCEQ; www.tceq.state.tx.us) is a diversified agency dealing with permitting, licensing, compliance, enforcement, pollution prevention, and educational programs related to preservation and protection of air and water quality and the safe disposal of waste. Related to mitigation of natural hazards are TCEQ programs that deal with drought, dam safety, and flood control and floodplain management.

TCEQ is designated by the Governor as the State Coordinating Agency for the National Flood Insurance Program. In this capacity, the agency assists communities with floodplain mapping matters and interpretation and enforcement of local floodplain management regulations.

## 9.5 FEMA National Flood Insurance Program

In 1968, Congress authorized FEMA's National Flood Insurance Program (NFIP) for two primary purposes: (1) to have flood-prone property owners contribute to their own recovery from flood damage through an insurance program; and (2) to guide development such that it is less prone to flood damage. To facilitate implementation, the NFIP created Flood Insurance Rate Maps (FIRMs) that, based on best available information and engineering methodologies, show areas subject to flooding by the 1-percent-annual chance flood (also called the "100-year flood"). Communities use the maps to guide and regulate development. Citizens and insurance professionals use the maps to determine insurance needs.

It is notable that, whereas flood insurance claims are paid when damage is sustained from any qualifying flood event, federal disaster assistance is available only after a flood is determined to be a "major disaster." A major disaster exceeds State and local capabilities. In addition, disaster grants to individuals and families are limited to approximately $14,000 (average payment is $6,000). Therefore, owners of insured buildings that are in areas known to flood, especially as shown on FIRMs, are protected financially as long as they carry sufficient flood insurance coverage. Additional information on flood insurance coverage for property owners and consumers is available online at www.fema.gov/nfip.

Basic federal flood insurance helps pay for property damage and loss of contents. Under certain circumstances – for example, if flood damage causes "substantial damage" – an additional mitigation claim payment is available to help owners bring buildings into compliance with NFIP flood protection standards (as of May, 2003, this additional payment is capped at $30,000). In addition, compliance is required when a building is substantially improved (includes repair of substantial damage). Substantial improvement is defined as improvements valued at 50% or more of the building's market value before improvement.

**Flood Insurance in Texas (as of 3/31/2011)**

With 673,073 NFIP policies in force (over 12% of all policies nationwide), Texas ranks second among all States in number of flood-insured properties (Florida is #1).
Property owners in Texas have received over 237,000 claim payments totaling $5.47 Billion; only Louisiana has had more claims paid.

Source: NFIP Statistics online at www.fema.gov/nfip

## 10.1 IFR Requirements for Plan Monitoring and Maintenance

***IFR §201.6(c)(4)(i):*** *[The plan maintenance process shall include a] section describing the method and schedule of monitoring, evaluating, and updating the mitigation plan within a five-year cycle*

***IFR §201.6(c)(4)(ii):*** *[The plan shall include a] process by which local governments incorporate the requirements of the mitigation plan into other planning mechanisms such as comprehensive or capital improvement plans, when appropriate.*

***IFR§201.6(c)(4)(iii):*** *[The plan maintenance process shall include a] discussion on how the community will continue public participation in the plan maintenance process.*

## 10.2 Distribution

The 2011 Brazoria Drainage District No. 4 (BDD4) Hazard Mitigation Plan will be posted on the District's Web site and notices of its availability will be distributed to the following:

The federal and State agencies that were notified and invited to participate in Plan development (see Sec. 1.3);

Brazoria County, City of Pearland, Brookside Village and Galveston County Consolidated Drainage District

Citizens who attended public meetings and provided contact information; and

The stakeholders which, included civic organizations, agencies, and elected officials who received notices of public meetings.

## 10.3 Implementation

Through the mitigation planning process, BDD4 departments that are involved in managing hazards and implementing measures to minimize future risk considered a range of mitigation actions. High priority actions were identified and prioritized, and are shown in Table 8-2.

For each mitigation action, Table 8-2 identifies the lead agency, support agencies, priority level, and time period for implementation. Each lead agency is responsible for factoring the action into its work plan and schedule over the indicated time period. Annual meetings will be held to discuss the status of implementation and identify and obstacles that may impede progress toward achieving the mitigation goals and actions.

## 10.4 Monitoring & Progress Reports

For the Plan, the planning committee determined that progress would be better monitored by annual meetings of the MPC. Upon adoption, the MPC will meet on an annual basis to discuss the status of the Plan and determine if any significant changes are warranted. As part of the meeting, the BDD4 Superintendent will note progress made on the mitigation action items listed in Table 8-2 to this end, the General Manager may convene a meeting of the appropriate District, City of Pearland, Brookside

Village and Brazoria County Departments to discuss and determine progress, and to identify obstacles to progress, if any.

In addition to annual meetings, the Superintendent will convene meetings after damage-causing natural hazard events to review the effects of such events. Based on those effects, adjustments to the mitigation priorities listed in Table 8-2 may be made or additional event-specific actions identified. Such revisions shall be documented as outlined in the following sub-section (Section 10.5).

## 10.5 Circumstances that will Initiate Plan Review and Updates

This section identifies the circumstances or conditions under which BDD4 will initiate Plan reviews and updates.

1. On the recommendation of the Superintendent or on its own initiative, BDD4 Board of Commissioners may initiate a Plan review at any time.
2. At approximately the one-year anniversary of the Plan's re-adoption, and every year thereafter.
3. After natural hazard events that appear to significantly change the apparent risk to District assets, operations and/or citizens.
4. When activities of BDD4, County, or the State significantly alter the potential effects of natural hazards on District assets, operations and/or citizen. Examples include completed mitigation projects that reduce risk, or actions or circumstances that increase risk.
5. When new mitigation opportunities or sources of funding are identified.

In addition to the circumstances listed above, revisions that warrant changing the text of this Plan or incorporating new information may be prompted by a number of circumstances, including identification of specific new mitigation projects, completion of several mitigation actions, or requirements for qualifying for specific funding. Minor revisions may be handled by addenda.

Major comprehensive review of, and revisions to this Hazard Mitigation Plan will be considered on a five-year cycle. To be adopted in 2011, the Plan will enter its next review cycle sometime in 2015, with adoption of revisions anticipated in 2016. The Mitigation Planning Committee will be convened to conduct the comprehensive evaluation and revision.

## 10.6 Continued Public Involvement

Upon adoption of the 2011 Plan, the public will be notified of any substantial changes to the document between 2011 and the next scheduled Plan update in 2016. Any changes proposed by the MPC considered significant will be distributed to the list of stakeholders identified in Table 1-4. The Stakeholders will be encouraged to review the changes and provide comments on any proposed plan revisions.

BDD4 will involve the public in the plan maintenance process and during the Plan Update in 2016, using the same methods as the original plan development. The public will be notified when the revision process is started and provided the opportunity to review and comment on changes to the plan and priority action items. It is expected that a combination of informational public meetings, draft documents posted on the web site, and public Board of Commissioner's meetings will be undertaken.

# Appendix A

The following is a general description for each of the hazards listed below. The profile for each hazard can be found in Section 5 and Section 6 of the 2011 Hazard Mitigation Plan (HMP).

General descriptions completed for the following natural hazards;

1. Tornadoes
2. Thunderstorms/High Winds
2. Hurricanes and Tropical Storms
3. Extreme Heat
4. Drought
5. Wildand Fire
6. Winter Storm
7. Seismic/ Earthquake
8. Landslides
9. Flood
10. Storm Surge

# 1. Tornadoes

### Definition of the Tornado Hazard

A tornado is a rapidly rotating funnel (or vortex) of air that extends toward the ground from a cumulonimbus cloud. Most tornadoes do not touch the ground, but when the lower tip of a tornado touches the earth, it can cause extensive damage. Tornadoes often form in convective cells such as thunderstorms or at the front of hurricanes. Tornadoes may also result from earthquake induced fires, wildfires, or atomic bombs (FEMA, 1997). The formation of tornadoes from thunderstorms is explained in Figure A-1.

### Characteristics of Tornadoes

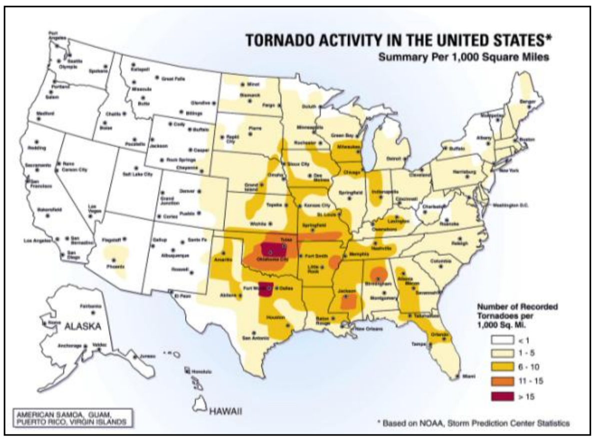
Tornadoes in the dissipating stage can appear like narrow tubes, or ropes, twisting into all manner of curls, twists, and s-shapes. These tornadoes, such as the one pictured above, are *roping out*, or becoming a *rope tornado*. Multiple-vortex tornadoes can appear as a family of swirls circling a common center, or may be completely obscured by condensation, dust, and debris, appearing to be a single funnel. In addition to these appearances, tornadoes may be obscured completely by rain or dust. These tornadoes are especially dangerous, as even experienced meteorologists might not spot them. As shown in the following table, tornadoes are measured by the Fujita Scale, an empirical system that determines the severity by observed damages (last column).

**Table A-1**
**The Fujita Tornado Scale**
(Source: FEMA 1997)

| Category | Wind Speed | Description of Damage |
|---|---|---|
| F0 | 40-72 mph | Light damage. Some damage to chimneys; break branches off trees; push over shallow-rooted trees; damage to sign boards. |
| F1 | 73-112 mph | Moderate damage. The lower limit is the beginning of hurricane speed. Roof surfaces peeled off; mobile homes pushed off foundations or overturned; moving autos pushed off roads. |
| F2 | 113-157 mph | Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light-object missiles generated. |
| F3 | 158-206 mph | Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; cars lifted off ground and thrown. |
| F4 | 207-260 mph | Devastating damage. Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated. |
| F5 | 261-318 mph | Incredible damage. Strong frame houses lifted off foundations and carried considerable distance to disintegrate; automobile-sized missiles fly through the air in excess of 100-yards; trees debarked. |

Figure A-1 illustrates the frequency of tornado strikes in the U.S. per 1,000 square miles. While tornadoes can occur in any month and at all hours of the day or night, they occur with greatest frequency during the late spring and early summer months during late afternoon and early evening hours.

**Figure A-1**
**Historic Tornado Activity in the United States,**
**Summary per 1,000 Square Miles**



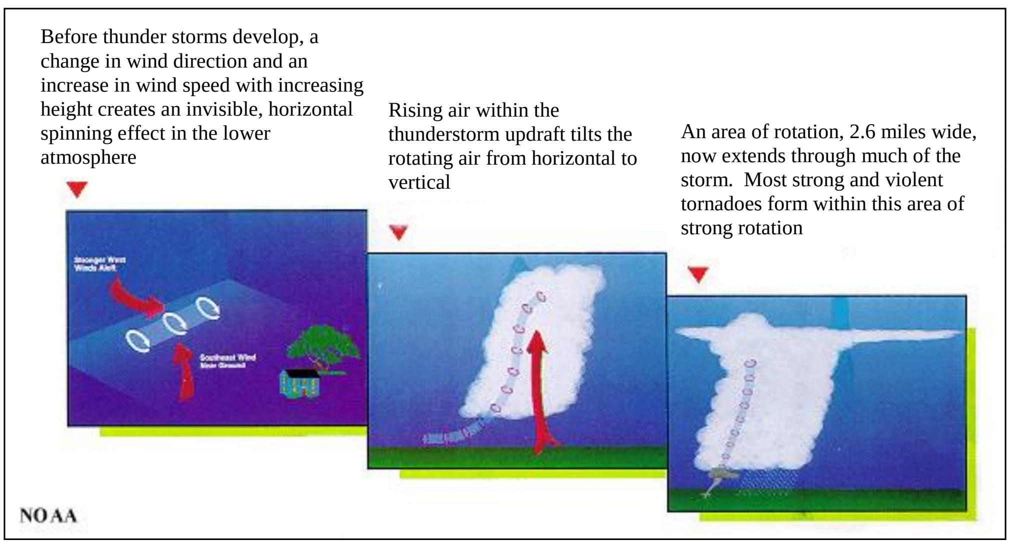

The severity and duration of tornadoes is a function of several factors, including weather conditions, topography and the F class of the event. As noted earlier, tornado severity is measured with the Fujita scale, an empirical system that classifies events after they occur. In some cases there are anomalous patterns for various reasons (including the reliability and completeness of reporting), but generally speaking smaller events are more probable, larger (more severe) ones are less likely.

Tornado duration is usually relatively short, varying from a matter of seconds to several minutes on the ground, although in rare cases they can last significantly longer. The path width of a single tornado generally is less than 0.6 miles. The path length of a single tornado can range from a few hundred yards to miles. A tornado typically moves at speeds between 30 and 125 mph and can generate internal winds exceeding 300 mph.

**Figure A-2**
**Strong Wind Effects**
(Source: FEMA)

Most tornadoes take on the traditional appearance of a narrow funnel, a few hundred yards across, with a small cloud of debris near the ground. Tornadoes can appear, however, in all manner of shapes and sizes.

**Figure A-3**
**Formation of Tornadoes**
(Source: NOAA)




Small, relatively weak landspouts might only be visible as a small swirl of dust on the ground. While the condensation funnel may not extend all the way to the ground, if associated surface winds are greater than 40 mph (64 km/h), it is considered a tornado. Large single-vortex twisters, often violent, can look like a large wedge stuck into the ground, and are known as *wedge tornadoes* or *wedges*. Wedges can be so wide that they appear to be a block of dark clouds. Even experienced storm observers may not be able to tell the difference between a low-hanging cloud and a wedge tornado from a distance.

# 2. Thunderstorms/High Winds

## Definition of the Thunderstorm/High Winds Hazard

Wind is the uneven horizontal movement of air resulting from the irregular heating of the earth's surface. It can range from local breezes produced by heat from land surfaces and lasting tens of minutes to powerful global winds resulting from solar heating of the earth. Severe winds typically result from hurricanes, nor'easters, tropical storms, tornadoes, thunderstorms, or winter storms.

By definition, the National Weather Service *(NWS)* classifies a thunderstorm as severe if it contains hail of three-quarter inches or larger and/or winds gusts of 58 mph or higher. Severe thunderstorm watches, meaning conditions are suitable for severe storm development during the next several hours, are issued for areas several hundred miles on a side by the NWS Storm Prediction Center in Norman, Oklahoma. A severe thunderstorm warning is issued by the local National Weather Service Office, usually for several counties or parts thereof for the next hour or so based upon spotter reports of conditions exceeding severe levels and/or by radar indications of the same.[15]

## Characteristics of Thunderstorm/High Winds

High winds are capable of imposing large lateral (horizontal) and uplift (vertical) forces on buildings. Residential buildings can suffer extensive wind damage when they are improperly designed and constructed and when wind speeds exceed design levels. The effects of high winds on a building will depend on several factors:

- Wind speed (sustained and gusts) and duration of high winds
- Height of building above the ground
- Exposure or shielding of the building (by topography, vegetation, or other buildings) relative to wind direction
- Strength of the structural frame, connections, and envelope (walls and roof)
- Shape of building and building components
- Number, size, location, and strength of openings (windows, doors, vents)
- Presence and strength of shutters or opening protection
- Type, quantity, velocity of windborne debris

Proper design and construction of residential structures, particularly those close to water or near the coast, demand that every factor mentioned above be addressed. Failure to do so may result in building damage or destruction by wind.

Thunderstorms arise when clouds develop sufficient upward motion and are cold enough to provide the ingredients (ice and supercoooled water) to generate and separate electrical charges within the cloud. Warm, moist air rising in sufficiently large volume with a high enough velocity results in a thunderstorm. The fuel for these storms is warm, moist air present near the surface of the earth. If the atmosphere around the cloud is unstable, that is the temperature of the air falls faster than that of the rising parcel air within the

[15] National Weather Service – Facts about thunderstorms

storm, then the updraft becomes ever warmer than the air outside, and therefore more buoyant. The release of latent heat when water vapor turns to liquid and then the liquid to ice further warms the rising parcel, stoking the “fires” of the updraft. A trigger is often necessary to get the warm bubble of air rising in the first place. Sometimes it can be a warm air thermal rising from a large, heated field or a sunlit mountain top, or the upward motion produced by fronts pushing air together so it has no place to go but up. [16]

[16] National Weather Service – Facts about thunderstorms

# 3. Hurricanes and Tropical Storms

### Definition of Hurricanes and Tropical Storms

Hurricanes, tropical storms, and typhoons, collectively known as tropical cyclones, are among the most devastating naturally occurring hazards in the United States. They present flooding, storm surge, and high wind hazards to the communities that they impact.

A hurricane is defined as a low-pressure area of closed circulation winds that originates over tropical waters. A hurricane begins as a tropical depression with wind speeds below 39 mph. As it intensifies, it may develop into a tropical storm, with further development producing a hurricane. Table A-2 below identifies the criteria for each stage of development.

**Table A-2**
**Classification of Hurricanes**

| Stage of Development | Criteria |
|---|---|
| Tropical Depression (development) | Maximum sustained surface wind speed is < 39 mph |
| Tropical Storm | Maximum sustained wind speed ranges 39 - <74 mph |
| Hurricane | Maximum sustained surface wind speed 74 mph+ |
| Tropical Depression (dissipation) | Decaying stages of a cyclone in which maximum sustained surface wind speed has dropped below 39 mph |

Hurricane winds blow in a large spiral around a relative calm center known as the "eye." The "eye", the storms core, is an area of low barometric pressure and is generally 20 to 30 miles wide. The storm may extend outward 100 - 400 miles in diameter. As a hurricane approaches, the skies will begin to darken and winds will grow in strength. As a hurricane nears land, it can bring torrential rains, high winds, storm surges, and severe flooding.

As shown in Table A-3, the Saffir / Simpson Hurricane Scale is used to classify storms by numbered categories. Hurricanes are classified as Categories 1 through 5 based on central pressure, wind speed, storm surge height, and damage potential.

**Table A-3**
**Saffir/Simpson Hurricane Scale**

| Storm Category | Central Pressure | Sustained Winds | Storm Surge | Potential Damage |
|---|---|---|---|---|
| 1 | > 980 mbar | 74 - 95 mph | 4 – 5 ft | Minimal |
| 2 | 965 – 979 mbar | 96 - 110 mph | 6 – 8 ft | Moderate |
| 3 | 945 – 964 mbar | 111 – 130 mph | 9 – 12 ft | Extensive |
| 4 | 920 – 944 mbar | 131 – 155 mph | 13 – 18 ft | Extreme |
| 5 | < 920 mbar | > 155 mph | > 18 ft | Catastrophic |

A single hurricane can last for more than two weeks over open waters and can run a path across the entire length of the eastern seaboard. August and September are peak months during the hurricane season that lasts from June 1 through November 30.

### Characteristics of Hurricanes and Tropical Storms

Hurricanes and Tropical Storms are categorized based on their wind speed. Both bring strong winds and are characterized by torrential rain that often results in widespread damage. Hurricanes can produce both extreme high winds and heavy rains. Tropical storms are most often associated with heavy rains that have the potential to produce severe flooding.

High winds from Hurricanes and Tropical Storms are capable of imposing large lateral (horizontal) and uplift (vertical) forces on buildings. Residential buildings can suffer extensive wind damage when they are improperly designed and constructed and when wind speeds exceed design levels. The effects of high winds on a building will depend on several factors:

- Wind speed (sustained and gusts) and duration of high winds
- Height of building above the ground
- Exposure or shielding of the building (by topography, vegetation, or other buildings) relative to wind direction
- Strength of the structural frame, connections, and envelope (walls and roof)
- Shape of building and building components
- Number, size, location, and strength of openings (windows, doors, vents)
- Presence and strength of shutters or opening protection
- Type, quantity, velocity of windborne debris

Proper design and construction of residential structures, particularly those close to water or near the coast, demand that every factor mentioned above be addressed. Failure to do so may result in building damage or destruction by wind. See Appendix M for recommended Stability System Design Tables for wind loads.

# Extreme Temperature (Heat)

## Definition of Extreme Temperature (Heat)

Extreme summer heat is the combination of very high temperatures and exceptionally humid conditions. If such conditions persist for an extended period of time, it is called a heat wave (FEMA, 1997). Heat stress can be indexed by combining the effects of temperature and humidity, as shown in Table A-4. The index estimates the relationship between dry bulb temperatures (at different humidity) and the skin's resistance to heat and moisture transfer. The higher the temperature or humidity, the higher the apparent temperature.

**Table A-4**
**Heat Index and Disorders**
(Sources: FEMA, 1997; NWS, 1997)

| Danger Category | | Heat Disorders | Apparent Temperatures (°F) |
|---|---|---|---|
| IV | Extreme Danger | Heatstroke or sunstroke imminent. | >130 |
| III | Danger | Sunstroke, heat cramps, or heat exhaustion likely; heat stroke possible with prolonged exposure and physical activity. | 105-130 |
| II | Extreme Caution | Sunstroke, heat cramps, and heat exhaustion possible with prolonged exposure and physical activity. | 90-105 |
| I | Caution | Fatigue possible with prolonged exposure and physical activity. | 89-90 |

In the northeastern U.S. periods of warmer than normal temperatures typically occur several times a summer. Extreme heat waves may occur about once every five years or so where maximum daily temperatures exceed 100 degrees Fahrenheit for an extended period of time. The passing of a cold front usually moderates temperatures after a few days to a week.

## Characteristics of Extreme Temperature (Heat)

The main impact of extreme heat is its affect on the human body. In a very hot environment, the most serious concern is heat stroke. In absence of immediate medical attention, heat stroke could be fatal. Heat stroke fatalities do occur every summer. Heat exhaustion and fainting (syncope) are less serious types of illnesses which are not fatal but interfere with a person's ability to work.

The major human risks associated with extreme heat can be summarized as follows.

- **Heatstroke:** Considered a medical emergency, heatstroke is often fatal. It occurs when the body's responses to heat stress are insufficient to prevent a substantial rise in the body's core temperature. While no standard diagnosis exists, a medical heatstroke condition is usually diagnosed when the body's temperature exceeds 105°F due to environmental temperatures. Rapid cooling is necessary to prevent death, with an average fatality rate of 15 percent even with treatment.

- **Heat Exhaustion:** While much less serious than heatstroke, heat exhaustion victims may complain of dizziness, weakness, or fatigue. Body temperatures may be normal or slightly to moderately elevated. The prognosis is usually good with fluid treatment.

- **Heat Syncope:** This refers to sudden loss of consciousness and is typically associated with people exercising who are not acclimated to warm temperatures. Causes little or no harm to the individual.

- **Heat Cramps:** May occur in people unaccustomed to exercising in the heat and generally ceases to be a problem after acclimatization.

# 5. Drought

## Definition of Drought Hazard

A drought is an extended dry climate condition when there is not enough water to support urban, agricultural, human, or environmental water needs. It usually refers to a period of below-normal rainfall, but can also be caused by drying bores or lakes, or anything that reduces the amount of liquid water available. Drought is a recurring feature of nearly all the world's climatic regions.

Drought is the result of a decline in the expected precipitation over an extended period of time, typically one or more seasons in length. Meteorological drought is defined solely on the degree of dryness, expressed as a departure of actual precipitation from an expected average or normal amount based on monthly, seasonal, or annual time scales. Hydrological drought is related to the effects of precipitation shortfalls on streamflows and reservoir, lake, and groundwater levels. Agricultural drought is defined principally in terms of soil moisture deficiencies relative to water demands of plant life, usually crops. Socioeconomic drought associates the supply and demand of economic goods or services with elements of meteorological, hydrologic, and agricultural drought. Socioeconomic drought occurs when the demand for water exceeds the supply as a result of weather-related supply shortfall. This may also be called a water management drought.

**Figure A-4**
**Lake Travis in Austin Texas, July, 2009**
(Source: Texas Water Development Board)

## Characteristics of Drought

Drought produces a complex web of impacts that spans many sectors of the economy and reaches well beyond the area experiencing physical drought. This complexity exists because water is integral to our ability to produce goods and provide services. Impacts are commonly referred to as direct or indirect. Reduced crop, rangeland, and forest productivity; increased fire hazard; reduced water levels; increased livestock and wildlife mortality rates; and damage to wildlife and fish habitat are a few examples of direct impacts. The consequences of these impacts illustrate indirect impacts. For example, a reduction in crop, rangeland, and forest productivity may result in reduced income for farmers and agribusiness, increased prices for food and timber, unemployment, reduced tax revenues because of reduced expenditures, increased crime, foreclosures on bank loans to farmers and businesses, migration, and disaster relief programs.

Drought is a normal part of virtually every climate on the planet, including areas of both high and low normal rainfall. The severity of drought can be aggravated by other climatic factors, such as prolonged high winds and low relative humidity (FEMA, 1997). A drought's severity depends on numerous factors, including duration, intensity, and geographic extent as well as regional water supply demands by humans and vegetation. Due to its multi-dimensional nature, drought is difficult to define in exact terms and also poses difficulties in terms of comprehensive risk assessments.

Drought differs from other natural hazards in three ways. First, the onset and end of a drought are difficult to determine due to the slow accumulation and lingering effects of an event. Second, the lack of an exact and universally accepted definition adds to the confusion of its existence and severity. Third, in contrast with other natural hazards, the impact of drought is less obvious and may be spread over a larger geographic area. These characteristics have hindered the preparation of drought contingency or mitigation plans by many governments.

Droughts may cause a shortage of water for human and industrial consumption and cause a decrease in hydroelectric power. Water quality may also decline while the number and severity of wildfires may increase. Severe droughts may result in the loss of agricultural crops and forest products, undernourished wildlife and livestock, lower land values, and higher unemployment.

# 6. Wildland Fires

## Definition of Wildland Fire Hazard

A wildfire, also known as a forest fire, vegetation fire, grass fire, brush fire, or hill fire, is an uncontrolled fire often occurring in wildland areas, which can also consume houses or agricultural resources. Common causes include lightning, human carelessness, and arson.

Wildfires are fueled by naturally occurring or non-native species of trees, brush, and grasses. Topography, fuel, and weather are the three principal factors that impact wildfire hazards and behavior.

**Figure A-5**
**Brush Fire**
(Source: FEMA)

## Characteristics of Wildfires Interface

Wildfires often begin unnoticed, spread quickly, and are usually signaled by dense smoke that may fill the area for miles around. As mentioned, wildfires can be human-caused through acts such as arson or campfires, or can be caused by natural events such as lightning. Wildfires can be categorized into three types:

1. Wildland fires occur in very rural areas and are fueled primarily by natural vegetation.

2. Interface fires occur in areas where homes or other structures are endangered by the wildfires. The fires are fueled by both natural vegetation and man-made structures. These are often referred to as Wildland Urban Interface fires.

3. Firestorms occur during extreme weather (e.g., high temperatures, low humidity, and high winds) with such intensity that fire suppression is virtually impossible. These events typically burn until the conditions change or the fuel is exhausted.

The following three factors contribute significantly to wildfire behavior:

Fuel: The type of fuel and the fuel loading (measured in tons of vegetative matter per acre) have a direct impact on fire behavior. Fuel types vary from light fuels (grass) to moderate fuels (Southern Rough) to heavy fuels (slash). The type of fuel and the fuel load determines the potential intensity of the wildfire and how much effort must be expended to contain and control it.

Weather: The most variable factor affecting wildfire behavior is weather. Important weather variables are precipitation, humidity, and wind. Weather events ranging in scale from localized thunderstorms to large cold fronts can have major effects on wildfire occurrence and behavior. Extreme weather, such as extended drought and low humidity can lead to extreme wildfire activity.

Topography; Topography can have a powerful influence on wildfire behavior. The movement of air over the terrain tends to direct a fire's course.

# 7. Winter Storms

## Definition of Winter Storm Hazards

A winter storm is a type of precipitation in which the dominant varieties of precipitation are forms that only occur at cold temperatures, such as snow or sleet, or a rainstorm where ground temperatures are cold enough to allow ice to form (i.e. freezing rain). In temperate continental climates, these storms are not restricted to the winter season, and may occur in the late autumn and early spring. Also, there are very rare occasions when they form in summer, although it would have to be an abnormally cold summer, such as the summer of 1816 in the Northeast U.S. In many locations in the Northern Hemisphere, the most powerful winter storms usually occur in March and, in regions where temperatures are cold enough, April.

**Figure A-6**
**Split Tree Caused by Ice Storm**
Source: FEMA

## Characteristics of Winter Storms

Winter storms typically form along a front generally following the meandering path of the jet stream. These storms, called mid-latitude cyclones or extra-tropical cyclones, differ from hurricanes, in that they move from west to east as opposed to east to west. These weather patterns carry cold air from Canada and the Rockies into the southern U.S. The origins of the weather patterns that cause winter storms in Texas are affected by differences in temperature and pressure, moisture availability, and wind direction as well as weather systems in the Atlantic Ocean and Gulf of Mexico.

Winter storms vary in size and strength and include heavy snowstorms, blizzards, freezing rain, sleet, ice storms and blowing and drifting snow conditions. Extremely cold temperatures accompanied by strong winds can result in wind chills that cause bodily injury such as frostbite and death. Severe winter and ice storms can cause unusually heavy rain or snowfall, high winds, extreme cold, and ice storms throughout the continental United States.

NOAA describes the jet streams that carry storm systems across the United States as narrow bands of strong wind in the upper atmosphere that follow the boundaries between hot and cold air masses. These boundaries are most pronounced during the winter months, when the jet streams travel to their southernmost position over the United States and surrounding water.

In the last 11 winters, no region in the United States has escaped flooding during the winter months. The Southeastern and Gulf Coast States (regularly hit by autumn hurricanes) experience damaging floods in the winter months, too. No region is immune. Global warming threatens to disrupt weather patterns around the world and may increase the frequency of winter flooding.

Another weather phenomenon, El Niño, can have a significant effect on precipitation in the United States. Named by Peruvian fishermen who noticed the periodic appearance of warming surface temperatures in the Pacific Ocean around Christmas, El Niño is now understood to be the warm phase of a temperature oscillation in the Pacific Basin’s water and atmosphere. The cool phase of the oscillation is nicknamed La Niña. During the warm phase, heat and moisture are released into the upper atmosphere, creating precipitation. El Niño alters the course of the jet stream - pushing it farther south than usual.

According to NOAA, El Niño winters tend to be wetter than normal in the Southeastern United States, as well, and contribute to flooding along the Gulf Coast. Storms that spin up in the Gulf of Mexico typically track northeast on the southern jet stream, bringing rain as well as ice and even snow to the Gulf States.

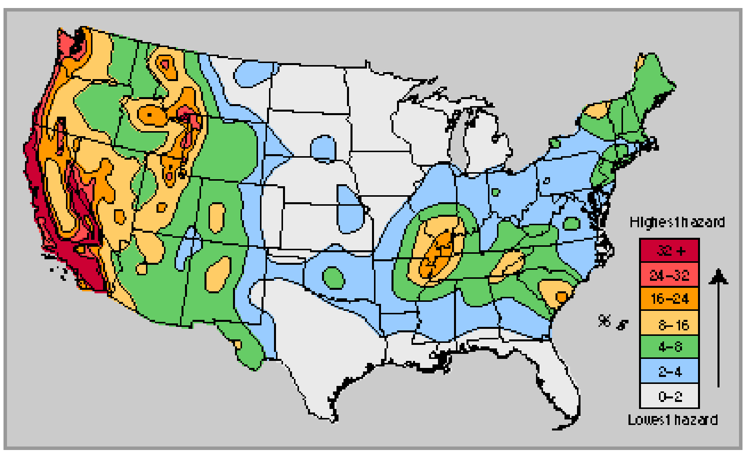
Winter storm occurrences tend to be very disruptive to transportation and commerce. Trees, cars, roads, and other surfaces develop a coating or glaze of ice, making even small accumulations of ice extremely hazardous to motorists and pedestrians. The most prevalent impacts of heavy accumulations of ice are slippery roads and walkways that lead to vehicle and pedestrian accidents; collapsed roofs from fallen trees and limbs and heavy ice and snow loads; and felled trees, telephone poles and lines, electrical wires, and communication towers. As a result of severe ice storms, telecommunications and power can be disrupted for days. Such storms can also cause exceptionally high rainfall that persists for days, resulting in heavy flooding.

# 8. Earthquakes

### Definition of Earthquake Hazard

An earthquake is "…a sudden motion or trembling caused by an abrupt release of accumulated strain in the tectonic plates that comprise the earth's crust." These rigid plates, known as tectonic plates, are some 50 to 60 miles in thickness and move slowly and continuously over the earth's interior. The plates meet along their edges, where they move away from or pass under each other at rates varying from less than a fraction of an inch up to five inches per year. While this sounds small, at a rate of two inches per year, a distance of 30 miles would be covered in approximately one million years (FEMA, 1997). Figure A-7 shows a USGS seismic probability map for the continental U.S.

**Figure A-7**
**United States Earthquake Zones**




### Characteristics of Earthquakes

The vibration or shaking of the ground during an earthquake is described by ground motion. Severity of ground motion generally increases with the amount of energy released and decreases with distance from the fault or epicenter of the earthquake. Ground motion causes waves in the earth's interior, also known as seismic waves, and along the earth's surface, known as surface waves. The following are the two kinds of seismic waves:

P (primary) waves are longitudinal or compressional waves similar in character to sound waves that cause back-and-forth oscillation along the direction of travel (vertical motion), with particle motion in the same direction as wave travel. They move through the earth at approximately 15,000 mph.

S (secondary) waves, also known as shear waves, are slower than P waves and cause structures to vibrate from side-to-side (horizontal motion) due to particle motion at right-angles to the direction of wave travel. Unreinforced buildings are more easily damaged by S waves.
Earthquakes are often relatively short duration, but there may be aftershocks and other effects (such as liquefaction) that prolong and exacerbate their effects. The potential for either of these effects depends on local conditions and other technical factors that are not discussed in this Plan.

There is some potential for seismic activity virtually anywhere on the earth. Locations that are close to tectonic faults, however, are much more likely to be impacted by earthquakes than other places. The United States Geologic Survey and other organizations develop maps to indicate the relatively probability of earthquakes in particular areas.

**Figure A-8**
**Earthquake Damage**
**Source: FEMA**

# 9. Landslide (non-seismic)

## Definition of Landslide Hazard

A landslide is a natural geologic process involving the movement of earth materials down a slope, including rock, earth, debris, or a combination of these, under the influence of gravity. However, there are a variety of triggers for landslides such as: a heavy rainfall event, earthquakes, or human activity. The rate of landslide movement ranges from rapid to very slow. A landslide can involve large or small volumes of material. Material can move in nearly intact blocks or be greatly deformed and rearranged. The slope may be nearly vertical or fairly gentle (Delano and Wilshusen, 2001).

## Characteristics of landslides

Landslides are usually associated with mountainous areas but can also occur in areas of generally low relief. In low-relief areas, landslides occur due to steepening of slopes: as cut and fill failures (roadway and building excavations), river bluff failures, collapse of mine waste piles, and a wide variety of slope failures associated with quarries and open-pit mines (USGS, Landslide Types and Process, 2004).

**Figure A-9**

**Small landslide in a residential area**

# 10. Floods

## Definition of Flood Hazard

Flooding is the accumulation of water within a water body (e.g., stream, river, lake, or reservoir) and the overflow of excess water onto adjacent floodplains. As illustrated in Figure A-1, floodplains are usually lowlands adjacent to water bodies that are subject to recurring floods. Floods are natural events that are considered hazards only when people and property are affected. Nationwide, hundreds of floods occur each year, making them one of the most common hazards in the U.S. (FEMA, 1997). There are a number of categories of floods in the U.S., including the following:

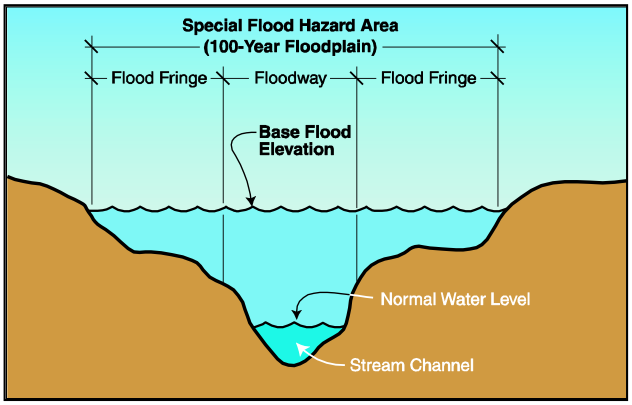
- Riverine flooding, (river channel, flash floods, alluvial fan floods, ice-jam floods, dam breaks)
- Local drainage or high groundwater levels
- Fluctuating lake levels
- Coastal flooding, including storm surges
- Debris flows
- Subsidence

## Characteristics of Floods

While there is no sharp distinction between riverine floods, flash floods, alluvial fan floods, ice jam floods, and dam-break floods, these types of floods are widely recognized and may be helpful in considering the range of flood risk and appropriate responses.

The most common kind of flooding event is riverine flooding, also known as overbank flooding. Riverine floodplains range from narrow, confined channels in the steep valleys of mountainous and hilly regions, to wide, flat areas in plains and coastal regions. The amount of water in the floodplain is a function of the size and topography of the contributing watershed, the regional and local climate, and land use characteristics. In steep valleys, flooding is usually rapid and deep, but of short duration, while flooding in flat areas is typically slow, relatively shallow, and may last for long periods of time.

**Figure A-10**
**Floodplain Definition**
(Source: FEMA, August 2001)




Flash floods involve a rapid rise in water level, high velocity, and large amounts of debris, which can lead to significant damage that includes the tearing out of trees, undermining of buildings and bridges, and scouring new channels. The intensity of flash flooding is a function of the intensity and duration of rainfall, steepness of the watershed, stream gradients, watershed vegetation, natural and artificial flood storage areas, and configuration of the streambed and floodplain. Dam failure and ice jams may also lead to flash flooding.

Alluvial fan floods occur in the deposits of rock and soil that have eroded from mountainsides and accumulated on valley floors in the pattern of a fan. Alluvial fan floods often cause greater damage than overbank flooding due to the high velocity of the flow, amount of debris, and broad area affected. Human activities may exacerbate flooding and erosion on alluvial fans via increased velocity along roadways acting as temporary drainage channels or changes to natural drainage channels from fill, grading, and structures.

Ice jam flood occur when an upstream part of a river thaws first (possibly because it flows away from the equator), and the ice gets carried downstream into the still-frozen part. Masses of ice can become lodged under bridges and other wiers, causing an ice dam, flooding areas upstream of the jam. After the ice dam breaks apart, the sudden surge of water that breaks through the dam can then flood areas downstream of the jam. While this usually occurs in spring, it can happen as winter sets in when the downstream part becomes frozen first. Dam-break floods may occur due to structural failures (e.g., progressive erosion), overtopping or breach from flooding, or earthquakes.

Local drainage floods may occur outside of recognized drainage channels or delineated floodplains for a variety of reasons, including concentrated local precipitation, a lack of infiltration, inadequate facilities for drainage and stormwater conveyance, and/or increased surface runoff. Such events often occur in flat areas, particularly during winter and spring where the ground is frozen. Drainage floods are found also in urbanized areas with large impermeable surfaces. High groundwater flooding is a seasonal occurrence in some areas, but may occur in other areas after prolonged periods of above-average precipitation.

## 11. Storm Surge

## Definition of Storm Surge Hazard

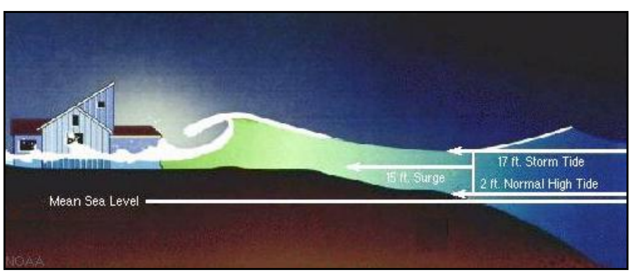
Storm surges occur when the water level of a tidally influenced body of water increases above the normal high tide. Storm surges occur with coastal storms caused by massive low-pressure systems with cyclonic flows that are typical of hurricanes.

Changes in the earth's surface also contribute to the effects of surges. Rising seas and erosion have led to the deterioration of the State's barrier islands and marsh, important shields against storm surge. Furthermore, erosion has caused the entire delta to sink, meaning homes, businesses and highways are becoming more susceptible to surges. New Orleans actually has pumps to keep rising seawaters from inundating the entire city, but they would hold little power in the face of a powerful hurricane.

## Characteristics of Storm Surge

Storm surges are characterized by several factors that allow the displacement of water from oceans, bays or rivers to travel so far inland. Much of the coastlines along the Atlantic and Gulf Coast lie less than 10 feet above mean sea level. These coastal areas are also densely populated making the danger from storm tides a major concern to life and property. As shown in Figure A-11, the level of surge in a particular area is also determined by the slope of the continental shelf. A shallow slope off the coast will allow a greater surge to inundate coastal communities. Communities with a steeper continental shelf will not see as much surge inundation, although large breaking waves can still present major problems. Storm tides, waves, and currents in confined harbors have the potential to severely damage ships, marinas, and pleasure boats (Source: NOAA).

**Figure A-11**
**Storm Surge**
(Source: NOAA)



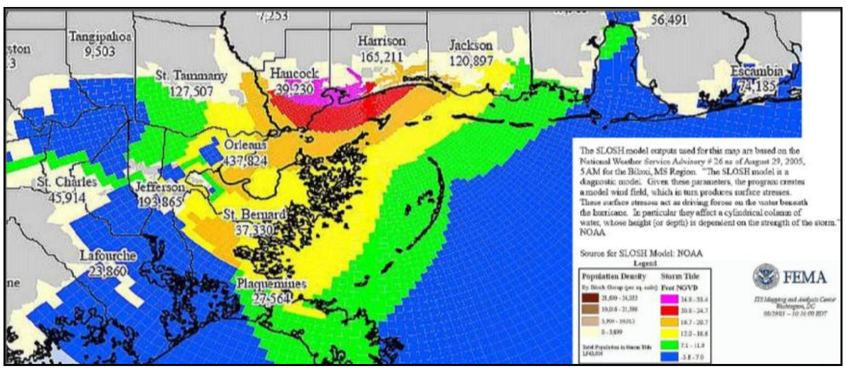

One tool used to evaluate the threat from storm surge is the Sea, Lake and Overland Surges from Hurricanes (SLOSH) Model. SLOSH is a computerized model run by the National Hurricane Center (NHC) to estimate storm surge heights and winds resulting from historical, hypothetical, or predicted hurricanes by taking the following into account:

- Pressure
- Size

- Forward speed
- Track
- Winds

Graphical output from the model displays color coded storm surge heights for a particular area in feet above the model's reference level, the National Geodetic Vertical Datum (NGVD), which is the elevation reference for most maps. Emergency managers often use the data produced from the SLOSH model to assist with determining which areas must be evacuated in advance of an approaching hurricane.

**Figure A-12**
**Hurricane Katrina SLOSH Model**
(Source: NOAA – National Hurricane Center)



# Appendix B

## Mitigation Planning Committee Meeting Minutes

**Meeting #1**
**January 19, 2011**

These minutes document the proceedings of the first meeting of the Brazoria Drainage District Four (BDD4) Mitigation Planning Committee (MPC). The MPC held its first meeting on Wednesday, January 19, 2011 beginning at 9:30 a.m., at the BDD4 main offices on W. Broadway, Pearland TX. These minutes were prepared by Jeff Ward.

**Participants**

| | |
|---|---|
| Jeff Ward | Jeffrey S. Ward & Associates (consultant) (JW) |
| BDD4, County and City Reps | See attached sign-in sheet |

There was good representation at this first meeting from the District, Brazoria County, and the City of Brookside Village. The City of Pearland representative was unable to attend this first meeting. JW will follow up with the City of Pearland to inform them of the items discussed in this meeting and encourage their participation. The Cities and the County are not participants in this plan but the District is interested in their input for this plan to ensure mitigation actions take into consideration, City and County issues and concerns.

**Agenda**
The agenda for this meeting is attached for reference

**General**

Mike Yost, BDD4 General Manager opened the meeting with a discussion of the importance of mitigation, mitigation planning, and the plan requirement.

**1. Introductions (Sign-in)**

A sign-in sheet was distributed to all meeting members (see attached). Each meeting attendee introduced themselves. Mike Yost introduced the Consultant that has been hired to assist with the planning process.

**2. Presentation**

JW presented an overview of the mitigation planning process. This presentation included:

- Overview of the State of Texas major disaster declarations (principal causes, and specific declarations/federal funding available)
- Specific Repetitive Loss (RL) and Severe Repetitive Loss (SRL) data for the District and jurisdictions within
- Types of viable mitigation projects

- Examples of ineligible mitigation projects
- Progress made to date on the plan
  - Grant awarded
  - Contract in place
  - Initial structure of the revised plan draft complete
- Detailed Request for Information (RFI) developed
- High level overview of the type of data to be requested from each participating jurisdiction
- Documenting the planning process – JW explained how the process will be documented in accordance with FEMA planning requirements.
- Hazard identification and profiling – the team had a detailed discussion of the types of hazards that will be in the plan and those that will likely be eliminated from further risk assessment due to a low probability of occurrence and low impact on property or lives. It is anticipated the list of hazards for which a more detailed risk assessment will be completed will be wind and flood.
- Vulnerability assessment and loss estimation (facilities) – the team had a detailed discussion about the data needed to complete this section. A request for information was reviewed and assignments of responsibility were made. See revised RFI attached to these minutes. This RFI includes a template to be used to provide information on District-owned facilities.
- Mitigation actions – Discussion centered on the importance of identifying actions for the plan that address the hazards that impact the District. JW highlighted the importance of having geographically-specific actions in the plan and the desire to have actions that could result in potential, fundable Mitigation grant applications.
- Plan monitoring and maintenance – JW discussed the importance of reconvening the MPC after any future disaster and/or at least annually to review current actions included in the plan and to discuss whether or not any actions needed to be added to the approved plan.
- Plan adoption – the team discussed the process that will be followed to get the plan adopted once FEMA has reviewed and tentatively approved the draft for adoption.

**General Discussion**

The MPC reviewed a couple of Mitigation Goal Statements and concurred on the following:

- To protect public health, safety, and welfare;
- To reduce losses due to hazards by identifying hazards, minimizing exposure of citizens and property to hazards, and increasing public awareness and involvement;
- To facilitate the development review and approval process to accommodate growth in a practical way that recognizes existing stormwater and floodplain problems while avoiding creating new problems or worsening existing problems; and
- To seek solutions to existing problems.

The team decided on the membership of the MPC and Stakeholders

MPC

Mike Yost – BDD4
Kim Woodall – BDD4
Bryan Garner – BDD4
Bobby Lira – Code Enforcement, Brookside Village

Narcisco Lira – City of Pearland, Engineering
Mike Blissett – Brazoria Roads and Bridges
Al Lentz – BDD4 Consultant Engineer

Stakeholders
City of Pearland
City of Manville
Iowa Colony
Brazoria County
Galveston County Consolidated Drainage District
Pearland Independent School District

**Actions from this meeting**

- JW to provide updated RFI with assignments
- JW to provide a draft of the public notice for public meeting on draft plan
- JW to confirm next meeting date for public meeting, Board Meeting, and second MPC meeting – (now confirmed as 3/1/11)
- JW to provide a template to be used for collecting data on BDD4 facilities
- JW to provide examples of typical mitigation actions and a blank mitigation action table for completion by each jurisdiction
- JW to prepare MPC meeting minutes

The meeting adjourned at 11:30 a.m.

## Agenda
## First Meeting of the Mitigation Planning Committee

1. Introductions
2. Background and purpose of mitigation planning
3. Establishing the process
4. Communications
5. Schedule
6. The Request for Information (RFI) document
7. Mitigation Planning Committee (MPC) and Stakeholders
8. Structure of the plan/update
9. Discussion of municipalities
10. Documenting the planning process
11. Hazard identification and profiling
12. Vulnerability assessment and loss estimation (facilities)
13. Mitigation actions

14. Plan monitoring and maintenance
15. Plan adoption
16. Other discussion
17. Adjourn

| Item | Data | Assigned | Date Received | Status |
|---|---|---|---|---|
| **Baseline Information and Background** | | | | |
| 1 | Point of contact for the Plan – name, title, address, email, telephone | | | Complete – Mike Yost |
| 2 | List of all jurisdictions within BDD4 | | | Complete |
| 3 | Link to or paper copy of materials related to BDD4 mission and/or charter | Kim Woodall (KW) | | |
| 4 | List and contact information for proposed membership of the Mitigation Planning Committee (MPC) | | | Complete |
| 5 | List and contact information for proposed Stakeholders | | | Complete |
| 6 | Location map | | | Complete |
| 7 | County/District map showing any municipalities | Al Lentz (AL) | | |
| 8 | List of buildings/facilities/infrastructure owned and/or operated by BDD4, including type, location, use, age | KW | | |
| 9 | Map showing the location of all stream gauges in BDD4 | KW | | |
| 10 | Electronic copy of the official seal for BDD4 | KW | | |
| 11 | County Emergency Management Plan | Stephanie Bradford | | |
| 12 | County Comprehensive Land Use Plan | Stephanie Bradford | | |
| 13 | BDD4 Operations Plan | KW | | |
| 14 | Any other plans or documents with relation to planning, operations, mitigation, projects or other subjects as applicable | KW | | |
| 15 | Number of building permits between 2003 and 2009 for both residential and non-residential structures in BDD4 | JW | | |
| 16 | Map showing location of residential and non-residential building permits (2006-2009) in BDD4 (and any municipalities) | JW/AL | | |
| 17 | Square footage of residential/commercial properties in BDD4 (and if known, in the municipalities) | JW | | |
| 18 | NFIP status (date community joined) | JW | | |
| 19 | CRS rating (date community joined, rating changes over time) | JW | | |
| 20 | Results of any recent Community Assistance Visits | JW | | |
| 21 | List of critical facilities in both County and municipalities. Any additional data related to the critical facilities, including address, use, occupancy, structural type, replacement cost of structure and/or contents, budget/s of operations taking place in the facilities | KW/JW | | |

| Item | Data | Assigned | Date Received | Status |
|---|---|---|---|---|
| 22 | Updated inventory of levees in BDD4 | | | N/A |
| **Hazard and Risk Information** | | | | |
| 23 | Establish initial list of natural hazards to be included in plan | | | Complete |
| 24 | Most recent version of any applicable Flood Insurance Studies and Flood Insurance Rate Maps | Kelly Harvey | | |
| 25 | Inventory of dams (high, significant, and low) in BDD4 (and any municipalities) | | | N/A |
| 26 | Number of square miles and % land in BDD4 within the 100-year floodplain | AL | | |
| 27 | Number of acres protected by levees in BDD4 | | | N/A |
| 28 | FEMA project worksheets for all recently declared disasters (last 10 years or so). Including disaster date, disaster number, PA Category, applicant name, facility name, damage description, and obligated amount | KW | | |
| 29 | Records of damages to BDD4,county or municipality buildings due to natural hazards | KW | | |
| 30 | Description of any flood damages to District owned roads and low water crossings | | | None |
| 31 | Insurance claims (BDD4 and all municipalities) for any damages related to natural hazards extending back no more than 20 years. If possible details to include date, hazard, nature of damage, dollar amount of damage. | KW | | |
| 32 | Total number of residential buildings, commercial buildings, and mobile homes in BDD4 (and any municipalities) | AL | | |
| 33 | Number of buildings in the floodplain (if possible by type) | AL | | |
| 34 | List of critical facilities in the 100-year floodplain for BDD4 (and any municipalities) | AL | | |
| 35 | Map/s of critical facilities in the 100-year floodplain for BDD4 (and any municipalities) | AL | | |
| 36 | NFIP claims data for BDD4 and all municipalities | JW | | |
| 37 | List of NFIP Repetitive Loss (RL) Properties for BDD4 (and any municipalities) | JW | | |
| 38 | List of NFIP Severe Repetitive Loss (SRL) properties for BDD4 (and any municipalities) | JW | | |
| 39 | Residential and non-residential Repetitive Loss Maps depicting floodplain with RL/claims (number and value), BDD4 and any municipalities | JW | | |
| **Goals, Strategies and Actions** | | | | |
| 40 | List of any past or pending FEMA grants (PDM, HMGP, FMA, etc.) or mitigation projects initiated or completed? Include both BDD4 and municipalities | KW | | |
| 41 | List of any completed, current, planned and/or pending mitigation projects in BDD4 and any municipalities, whether funded by FEMA or other sources | Mike Yost/JW/KW | | |

| Item | Data | Assigned | Date Received | Status |
|---|---|---|---|---|
| 42 | List of any new mitigation or mitigation-related actions in progress, in development or being considered, for both BDD4 and municipalities | AL/MPC | | |
| 43 | List of mitigated RL and SRL properties for BDD4 and all municipalities. | | | N/A |

**Meeting #2**
**March 1, 2011**

These minutes document the proceedings of the second meeting of the Brazoria Drainage District Four (BDD4) Mitigation Planning Committee (MPC). The MPC held its second meeting on Tuesday March 1, 2011, at the BDD4 main offices on W. Broadway, Pearland TX. These minutes were prepared by Jeff Ward.

**Participants**

| | |
|---|---|
| Jeff Ward | Jeffrey S. Ward & Associates (consultant) (JW) |
| Mike Yost | BDD4 (MY) |
| Bryan Garner | BDD4 |
| Joseph Anderson | GCCDD |
| Bobby Lira | Brookside Village |
| Kimberly Woods | BDD4 |
| Al Lentz | Lentz Engineering/BDD4 |
| Jarrod Aden | Lentz Engineering/BDD4 |

**Agenda**

The agenda for this meeting is attached for reference

**3. Introductions (Sign-in)**

A sign-in sheet was distributed to all meeting members (see attached).

**4. Discussion and approval of minutes from last MPC meeting**

The MPC approved the minutes from the first committee meeting

**5. General status of plan**

JW provided an overview of the progress on the plan so far. The plan has been put in to a format and most general data has been inputted.

**6. Review of RFI**

The majority of the meeting was used to review the status of the RFI. Many of the items in the RFI were provided during the meeting or will be provided in the next couple of weeks. BDD4 has scheduled a meeting to discuss, in detail, actions for the plan. The results of this meeting will be reviewed and incorporated into the plan.

**7. Discussion of meeting with State and FEMA on DD plans**

JW informed the MPC of the results of a meeting with the State and FEMA regarding the approach to be used for a Drainage District plan. A Drainage District plan is unique in relationship to the hazards addressed the plan due to the fact that they only have authority to address flood hazards in general and other hazards that have a direct impact on DD facilities.

**8. Discussion of Actions**

BDD4 has scheduled a meeting to discuss, in detail, actions for the plan. The results of this meeting will be reviewed and incorporated into the plan.

**9. Public outreach/presentation**

JW discussed the presentation that was given earlier in the day to the BDD4 Board and provided an overview of the presentation that was to presented in the evening during the public meeting.

**10. Next steps – stakeholder/civic outreach, State and FEMA review – timing**

The BDD4 Board meeting was open to the public and was advertised as a public meeting. A public meeting was held the evening of March 1, 2011 – also advertised as a public meeting. Outreach, via an email, to stakeholders, will be sent in the next month informing the stakeholders the draft is available for review and comment. Stakeholders are as follows:

City of Pearland
City of Manville
Iowa Colony
Brazoria County
Galveston County Consolidated Drainage District
Pearland Independent School District

**Actions from this meeting**

- JW to provide RL and SRL list to Jerrod from Lentz Engineering – provided via email the week of 7 March.
- BDD4 to hold a meeting to develop actions for the plan

# Appendix C

## Public Notice Documents and Meeting Minutes

**March 1, 2011**

A public meeting to review the planning process, current status of the draft plan, and next steps were scheduled and publicized for March 1, 2011 at 5:00 pm at the Brazoria Drainage District No. 4 offices in Pearland. The Mitigation Planning Committee members were all in attendance, however no members of the public attended the meeting.

**Participants**

- Mr. Mike Yost, Brazoria Drainage District No. 4
- Mrs. Kim Woodall, Brazoria Drainage District No. 4
- Mr. Bryan Garner, Brazoria Drainage District No. 4
- Mr. Bobby Lira, Brookside Village
- Mr. Narcisco Lira, City of Pearland Engineer
- Mr. Jeff Ward, Jeffrey S. Ward & Associates (consultant) (JW)
- Mr. Mike Blissett, Brazoria Roads and Bridges
- Mr. Al Lentz, Brazoria Drainage District No. 4 Engineer

**Presentation Overview**

1. Introductions
2. Brief review of purpose of Plan
3. Federal requirement to complete update
4. Summary of Plan Sections
5. Hazards profiled in Plan
6. Summary of Risk Assessment
7. Overview of a Mitigation project types
8. Status of current plan
9. Path forward
10. Other questions, comments

**Figure C-1**
**BDD4 Hazard Mitigation Plan Meeting**
**Public Notice advertised in *The Reporter News* for meeting March 1, 2011**

THE REPORTER NEWS

CLASSIFIEDS 281-485-7501

LEGALS LEGALS LEGALS LEGALS LEGALS

**Notice of Public Meeting**
Brazoria Drainage District No. 4 (BDD4)
Hazard Mitigation Plan

A public meeting will be held on March 1, 2011, at 5:00 PM until 6:00 PM., in BDD4's main office, located at 4813 W. Broadway, Pearland, Texas 77581 to review the draft Hazard Mitigation Plan recently prepared by and for BDD4. Copies are also available for review at the following location:

Brazoria Drainage District No. 4, 4813 W. Broadway, Pearland, Texas 77581

The plan provides an overview of natural hazards in the District, summarizes past hazard events, describes how the District recognizes and addresses hazards in the development process and other District functions. The actions identified in this plan are intended to reduce the long-term impacts of flooding on the District and its citizens. Members of the public are encouraged to attend, especially those with property located in flood-prone areas.

Citizens have the opportunity to comment on the plan. Comments should be faxed to *Jeff Ward, (BDD4's Mitigation Consultant at 888-208-6695*, or mailed to Jeffrey S. Ward & Associates, 14401 Bookcliff Ct., Purcellville, VA 20132.

After consideration of comments and review by the Texas Division of Emergency Management, the final hazard mitigation plan will be presented to the BBD4 Board of Directors for adoption later this year.

Questions about the plan should be directed to Mitigation Plan Consultant, Jeff Ward at 888-208-6695.

Michael D. Yost, Superintendent

Posted this 23rd day of February, 2011 at 8:00 O'Clock AM

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To be added to final version of plan.

To be added to final version of plan.

# Appendix F

## Sources

### F.1 Sources for Section 1 - Introduction

- Brazoria Drainage District No. 4 Homepage. Available on the web at, http://www.pearland-drainage.dst.tx.us/index.htm
- United States (US) Census Bureau. State and County Quickfacts. Brazoria County, Texas. Available on the web at; http://quickfacts.census.gov/qfd/states/48/48039.html
- U.S. Department of Health and Human Services. Federal Register. Volume 74, Number 14. Available on the web at; http://aspe.hhs.gov/POVERTY/09fedreg.shtml

### F.2 Sources for Introduction to Mitigation Planning (Section 2)

- Federal Emergency Management Agency (FEMA). *Local Multi-Hazard Mitigation Planning Guidance*. July 1, 2008. Available on the web at: http://www.fema.gov/library/viewRecord.do?id=3336
- Texas Department of Public Safety, Division of Emergency Management. *State of Texas 2010 Plan Update*. Austin, TX. Available online at http://www.txdps.state.tx.us/dem.

### F.3 Sources for Section 5 - Hazards in BDD4

- American Society of Civil Engineers. 2002. Minimum Design Loads for Buildings and Other Structures (SEI/ASCE 7-02). Reston, VA.
- FEMA. Disaster Declarations database. Available on the web at: http://www.fema.gov/news/disasters.fema
- FEMA. *Understanding Your Risks – Identifying Hazards and Estimating Losses*. State and Local Mitigation Planning How-To Guide. September, 2002. FEMA 386-2. Available on the web at; http://www.fema.gov/library/viewRecord.do?id=1867
- National Oceanic and Atmospheric Administration (NOAA). Enhanced Fujita Scale. February, 2007.
- NOAA. National Hurricane Center (NHC). Historical Hurricane Tracks. Available on the web at; http://csc-s-maps-q.csc.noaa.gov/hurricanes/

- NOAA. National Climatic Data Center (NCDC) database. History and description of major hazard events. Available from the web at: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms
- NOAA, NCDC (U.S. Local Storm Reports). Online at http://lwf.ncdc.noaa.gov/oa/climate/severeweather/extremes.html.http://ncdc/ Accessed 2011.
- NOAA. Storm Prediction Center. Tornado Activity in the United States. Available on the web at: http://www.fema.gov/plan/prevent/saferoom/tsfs02_torn_activity.shtm
- Public Entity Risk Institute. Presidential Disaster Declarations, Available on the web at: http://www.peripresdecusa.org/mainframe.htm
- Texas Department of Public Safety, Division of Emergency Management. *State of Texas Hazard Assessment*. Austin, TX.
- Texas Department of Public Safety, Division of Emergency Management. *State of Texas 2010lan Update*. Austin, TX. Description of Tropical Storm Allison. Available online at http://www.txdps.state.tx.us/dem.
- Texas Environment Center. Online at http://www.floodsafety.com.
- United States Geological Survey (USGS). Earthquake Hazards Program. Texas Earthquake History. Available on the web at; http://earthquake.usgs.gov/earthquakes/states/texas/history.php
- United States Geological Survey (USGS). *Major and Catastrophic Storms and Floods in Texas* (U.S. Geological Survey, Open File Report 03-193). Slade, R.M., and Patton, J. Online at http://www.floodsafety.com/USGSdemo/patton.htm#1.
- USGS. United States Seismic Hazard Map, Showing Peak Ground Acceleration In Percent Of g, With 10% Exceeded In 50 Years. October, 2002. Available on the web at; http://earthquake.usgs.gov/learn/faq/?categoryID=27


## F.4 Sources for Section 6 – Flood Hazards in BDD4


- Texas Department of Public Safety, Division of Emergency Management. *State of Texas 2010 Plan Update*. Austin, TX. Flood Occurrences in Texas Map. Available online at http://www.txdps.state.tx.us/dem.
- Federal Emergency Management Agency. Various Panel Dates. Flood Insurance Study and Flood Insurance Rate Maps. Washington, DC. [Available for public review at the BDD4 Engineering Department]
- FEMA. 1997. Multi-Hazard Mitigation and Risk Assessment. Washington, DC. Available on the web at: http://www.fema.gov/mit/tsd/ft_mhira.htm.
- FEMA. National Flood Insurance Program (NFIP). Bureaunet query performed in December, 2010.
- FEMA. NFIP. Flood Insurance Policies in Force (by State). Available on the web at http://www.fema.gov/business/nfip/statistics/fy2007st.shtm
- Texas Environment Center. Statewide flood deaths (% vehicle related) between 1960 and 1996 Online at http://www.floodsafety.com.

- Texas Department of Public Safety, Division of Emergency Management. State of Texas Mitigation Handbook (DEM 21), Austin, TX. Available online at http://www.txdps.state.tx.us/dem.

# Appendix G

## Acronyms

The following acronyms are used within the 2011 HMP:

**BCA-** Benefit Cost Analysis
**BCAD-** Brazoria Central Appraisal District
**BDD4-** Brazoria Drainage District Number 4
**BFE-** Base Flood Elevation
**CFR-** Code of Federal Regulation
**CRS-** Community Rating System
**DMA-** Disaster Mitigation Act
**EMCs-** Emergency Management Coordinators
**FEMA-** Federal Emergency Management Agency
**FHFs-** Flood Hazard Factors
**FIS-** Flood Insurance Study
**FIRM-** Flood Insurance Rate Map
**FMA-** Flood Mitigation Assistance
**GIS-** Geographic Information System
**GRR-** General Reevaluation Report
**HMA-** Hazard Mitigation Assistance
**HMGP-** Hazard Mitigation Grant Program
**HMP-** Hazard Mitigation Plan
**IFR-** Interim Final Rule
**MPC-** Mitigation Planning Committee
**NCDC-** National Climatic Data Center
**NFIP-** National Flood Insurance Program
**NHC-** National Hurricane Center
**NOAA-** National Oceanic and Atmospheric Administration
**NWS-** National Weather Service
**PA-** Public Assistance
**PDM-C-** Pre-Disaster Mitigation Grant Program
**PDSI-** Palmer Drought Severity Index
**Pga-** Peak Ground Acceleration
**PWs-** Project Worksheets

**RFC-** Repetitive Flood Claim

**RFI-** Request for Information

**RL-** Repetitive Loss

**SFHA-** Special Flood Hazard Area

**SRL-** Severe Repetitive Loss

**STAPLEE- S**ocial, **T**echnical, **A**dministrative, **P**olitical, **L**egal, **E**conomic, and **E**nvironmental

**TCEQ-** Texas Commission on Environmental Quality

**TDEM-** Texas Division of Emergency Management

**TWDB-** Texas Water Development Board

**TXDOT-** Texas Department of Transportation

**USACE-** United States Army Corps of Engineers

**USGS-** United States Geological Survey

# Appendix H

## Key Terms

For the most part, terms used in the Plan have the meanings that are commonly associated with them:

**Disaster.** The occurrence of widespread or severe damage, injury, loss of life or property, or such severe economic or social disruption that supplemental disaster relief assistance is necessary for the affected political jurisdiction(s) to recover and to alleviate the damage, loss, hardship, or suffering caused thereby (DEM).

**Federal Emergency Management Agency (FEMA).** Coordinates the federal government's efforts to plan for, respond to, recover from, and mitigate the effects of natural and man-made hazards.

**Flood Insurance Rate Map (FIRM).** Prepared by the Federal Emergency Management Agency to show Special Flood Hazard Areas; this map is the basis for regulating development according to the Regulations for Flood Plain Management.

**Floodplain:** See "Special Flood Hazard Area (SFHA)" below.

**Hazard.** Defined as the natural or technological phenomenon, event, or physical condition that has the potential to cause property damage, infrastructure damage, other physical losses, and injuries and fatalities.

**Mitigation.** Defined as actions taken to reduce or eliminate the long-term risk to life and property from hazards. Mitigation actions are intended to reduce the need for emergency response – as opposed to improving the ability to respond.

**National Flood Insurance Program (NFIP).** Located within FEMA, is charged with preparing FIRMs, developing regulations to guide development, and providing insurance for flood damage.

**Risk.** Defined as the potential losses associated with a hazard. Ideally, risk is defined in terms of expected probability and frequency of the hazard occurring, people and property exposed, and potential consequences.

**Special Flood Hazard Area (SFHA) or Floodplain.** The area adjoining a river, stream, shoreline, or other body of water that is subject to partial or complete inundation. The SFHA is the area predicted to flood during the 1% annual chance flood, commonly called the "100-year" flood.