Comparative analysis between different flood assessment technologies in HAZUS-MH

Jennifer Carol Meyer
Louisiana State University and Agricultural and Mechanical College

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COMPARATIVE ANALYSIS BETWEEN
DIFFERENT FLOOD ASSESSMENT TECHNOLOGIES
IN HAZUS-MH

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
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by

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ABSTRACT

Natural disasters devastate the United States through both economic loss and loss of life. The worldwide economic damage that results from natural disasters has more than tripled in the last thirty years. Of these natural disasters, floods are the most chronic and costly disasters, comprising an average $5 billion dollars of damage each year.

FEMA has released a new software program called HAZUS-MH, which attempts to capture economic losses caused by flooding before losses occur and predict losses from real-time events. This estimate is accomplished through the coupling of flood hazard modeling with local data. FEMA’s goal is that the information constructed within the program will help planners to mitigate and capture flood related losses.

This study provides a methodology for assessing the accuracy of HAZUS level one flood loss estimates by examining the extent to which HAZUS default building stock inventory data represents the built local environment. The study area is concentrated in the northwest corner of Livingston Parish, Louisiana. The area is comprised of 200 census blocks that were chosen due to their proximity to the Amite River. Thus it is an area prone to floods. Livingston Parish is located in the Mississippi River and Lake Maurepas Basin, which collectively cover approximately 236,000 acres. 70% of the Parish’s land is located within FEMA’s 100-year flood plain.

Building count for structures was obtained using remote sensing technology, processed and used to populate HAZUS ® MH default databases. Flood loss estimations were run for all of the data sets and results were compared for a significant difference.
Differences in flood loss between the two analyses were found in isolated areas. This demonstrated the need to incorporate growth and development information into flood loss estimation methodologies.
CHAPTER 1 INTRODUCTION

The overall objective of this thesis is to provide a methodology for assessing new flood planning technology, as well as to contribute, to the academic community, a discourse on the inclusion of new technology in the policy making and public decision-making arena. Climbing flood-related costs in the United States demonstrate the need for new flood modeling technologies. Existing flood loss estimation methodologies are problematic because they are often too complex and time consuming to be used effectively by local planners. The Federal Emergency Management Agency (FEMA) answered the need for a less complex model by developing a new multi-hazards modeling software program package called HAZUS-MH (Hazards U.S.) which attempts to capture economic losses caused by flooding before losses occur and estimate losses from real-time events. (DHS 2003)

HAZUS’s flood loss estimations are accomplished by the coupling of flood hazard modeling data with information about the local built environment. The program functions at different levels with each subsequent level requiring more user-supplied input. Basic analyses use HAZUS’s default building stock inventory, while advanced analyses require that the user populate the building stock inventory with user-collected data on the built environment. FEMA’s goal is that the information constructed within the program will help planners mitigate flood related losses.

Preliminary studies conducted using HAZUS-MH to estimate Louisiana’s flood loss demonstrated the need to evaluate the accuracy of HAZUS default database of local built infrastructure. Currently there have been no studies on the difference between a basic analysis and advanced flood loss estimation analysis.
This study compares default data to the control, user-defined data to find a statistically significant difference. Building count was chosen for this analysis, as it is the primary parameter for conducting flood loss estimations. Other parameters, not used in this analysis, include elevation of structure and square footage, which are dependent upon the primary parameter, building count. Existing research conducted on the evaluation of HAZUS default building stock has dealt only with earthquake and wind hazards and their findings are contradictory: clearly demonstrating the need for new research. The study has been divided into four tasks:

1. Gain a greater understanding of HAZUS-MH and the nature of flooding. This is accomplished by literature driven research and preliminary analysis using HAZUS-MH.

2. Identify and collect necessary local data on building counts per census block for a defined study area. This is accomplished using remote sensing data.

3. Process local data into a HAZUS-MH compatible database for statistical analysis and further processing in HAZUS-MH. is accomplished by utilizing Microsoft Excel and SPSS (Statistical Package for the Social Sciences).

4. Perform and duplicate a HAZUS-MH flood hazard analyses for the set study area for a 100-year Riverine flooding event. This was accomplished by running HAZUS-MH basic hydrologic and flood hazard analyses.

5. Conduct two flood loss estimation analyses using HAZUS-MH where one analysis uses data provided by HAZUS-MH and the other uses the data collected during Step 2. This was accomplished by first editing the default building stock count data in the duplicated region.
If a comparison between default building stock dataset and surveyed dataset for the sample area show that there is a significant difference between the two databases, then this thesis will conclude that basic analysis is not sufficient. However, if there so significant difference, this thesis will conclude that a basic analysis is sufficient.
CHAPTER 2 FLOODING OVERVIEW

This portion of the thesis is intended to impart general information about flooding that is necessary for more in-depth understanding of current literature concerning flood hazard processes, technology and policy. It is meant to be a review of information more than a review of literature. It communicates a brief overview of the mechanics of flood disasters, an overview of different types of floods and their unique characteristics, existing methodologies and techniques used to capture and quantify flood hazards and their associated risks, and a brief overview of what HAZUS-MH is and how it works.

SURFACE PROCESSES AND RIVERINE FLOODING

It is necessary to first understand the mechanics of riverine flooding in order to grasp current policy related flood problems. Riverine Flooding is the product of the amount of run off, or total water flowing in a stream. (Fetter 1998) The amount of run off is often a factor of many other variables which include drainage area, topography of an area, natural drainage patterns, existing land use practices and type of soil. (Singh, 1992) Many of these variables are difficult to model or capture since they are often affected by day to day and long-term human activities.

Water makes up roughly 80% of the world’s surface. It is the basis of life, providing an essential resource for the development of civilization, environment, and climatic variability. The amount of earth’s total water volume available for human use is determined largely by the global water cycle or hydrologic cycle. The hydrologic cycle is the term used to describe water’s cyclical movements and transformations within the biosphere. The must basic spatial unit of analysis for hydrologic analysis is the
watershed. (Sing, 1992) Descriptions of the hydrologic cycle most commonly begin with evaporation of ocean surface water into water vapor. (Fetter 1994)

The amount of surface water evaporated into the atmosphere depends on the amount of energy present and is thus dependent on geographic locations. It is greatest in areas of intense solar radiation, which lie along the equator. (Fetter 1998) The water vapor is held in the atmosphere until conditions allow for precipitation such as snow or rain. Precipitants that are not revaporized into the atmosphere before reaching land end up on land, in lakes, ponds, and streams and ocean, or it can be. Once the precipitant reaches land, it flows from land to surface water, to the ocean. Regardless of where the precipitation ends up or how long it is stored there, it eventually reenters the atmosphere through evaporation or transpiration, only to be, once again, precipitated back to earth. Precipitation occurs over land at a higher rate than can be evaporated at a given time, and excess precipitation constitutes a run off flowing from surface and ground water on continents to the ocean. This characteristic is commonly expressed in the equation:

Surface runoff = Precipitation- Infiltration loss- Evaporation- Transpiration

Run off is pulled downhill by gravity to form a stream will be one part of many streams which are collectively called a stream network. Two important characteristics associated with each stream are their drainage basins and discharge. The velocity of flow and cross-sectional area determines discharge. Flooding occurs when streams overflow their channels. (Jones) The size of a flood is measured by the maximum discharge or elevation of water surface. Thus the magnitude and intensity of flooding is largely a function of the hydrologic cycle and is affected by variations within each component of the run off equation.
FLOOD CHARACTERIZATION

A commonly accepted definition of a flood is “the accumulation of water within a water body and the overflow of excess water on to adjacent flood plains.” This definition is more general than that provided by the National Flood Insurance Program (NFIP). According to the NFIP, a flood is

A general and temporary condition of partial or complete inundation of two or more acres of normally dry land area or of two or more properties (at least one of which is your property) from: Overflow of inland or tidal waters, unusual and rapid accumulation or runoff of surface waters from any source, or a mudflow.

The Federal Interagency Floodplain Management Task Force differentiates between floods resulting from:

- Riverine flooding
- Local drainage or high groundwater levels
- Fluctuating lake levels
- Storm surges
- Debris flows
- Subsidence

(FEMA 1997)

Riverine floods are the most prevalent type of flood in the United States and were, consequently, the type of flood hazard modeled during the HAZUS hazard analysis portion of this thesis. Riverine floods may further be categorized as overflow from river channels, flash floods, alluvial fan floods and ice jam floods.

The most dangerous of these floods, in terms of loss of life, are flash floods. A flash flood can be any flood that is characterized by rapid development of water height and velocity. They are dangerous because the speed of onslaught leaves little time for warning and preparatory actions. A multitude of factors, both natural and manmade,
can instigate a flash flood, but the most common of these include: structural mitigation failures such as a failure in a dam or levee and the melting of frozen rivers. (FEMA 1997)

Regional flooding is an additional term used to differentiate among types of riverine flooding. Regional floods are generally caused by slow-moving, low-pressure or frontal storm systems, including decaying hurricanes, causing persistent wet meteorological patterns. Flooding of this type can occur several days following the incipient conditions. (Perry 2000)

HAZUS-MH also has the capability for estimating losses from coastal floods. This will be especially important for Louisiana since the entire gulf coast is vulnerable to high storm surges. Coastal flood hazards depend on: the elevation and topography of the site; the erodibility of the site; the nature and intensity of coastal flood events affecting the site. Differences among these factors produce regional variations that can be quite substantial. Thus, shoreline design practices appropriate to one area of the coastline may not be suitable for another. The Gulf of Mexico coast can be divided into three regions: the eastern Gulf coast from southwest Florida to Mississippi; the Mississippi Delta region; the Chenier Plain; and the western Gulf of Mexico coast. Louisiana is in the Mississippi Delta Region and the Chenier Plain.

**QUANTIFYING FLOOD HAZARD RISK**

When quantifying a natural hazard, it is important to have a clear understanding of risk. This is accomplished through a process called risk assessment. The Tennessee Valley Authority (TVA) and U.S. Army Corps of Engineers (USACE) were early leaders in the initiative to standardize risk assessments for flood related hazards. (Platt 1998) In the most general terms, a risk assessment is the collection of quantitative and qualitative
information to identify possible risks as well as the probability and consequences of a disaster event’s occurrence.

Risk assessment involves evaluating the probability and frequency, exposure and consequences of natural hazard events, where:

- Probability and frequency is a measure of how often a natural hazard event is likely to occur at a particular location
- Exposure defines the number of people and the number, types, qualities and monetary values of property subject to the natural hazard event at a location; and
- Consequences are the quantifiable impacts to people and property that may result from an event

The most common methodology for conducting risk to hazards is that outlined by FEMA. According to FEMA (2001), productive risk assessments demand communication between various private, public and government agencies. The incorporation of communication into the risk assessment process allows the process to be an open-system, receptive and adaptable to an ever-changing environment. Communication is vital to risk management as it encourages subjective and objective input of the outside stakeholders. This results in an increase in the amount of information upon which risk managers can base their decisions. FEMA’s Guide to Understanding Your Risks imparts a four step processes that includes: 1) Establishing what kind of natural hazards can affect your state or community identifying hazards 2) profiling hazard events to determine each hazard’s potential impact 3) taking inventory of assets to determine what will be affected by each hazard and 4) estimating losses to establish how the hazard might affect the community.

Establishing probability and frequency is an important aspect of profiling hazard events. For Riverine flood hazards, a chance flood occurrence of 1 in 100 years is the
current national standard from which to evaluate the probability and frequency of the event. These types of floods are called 100-year floods. A 100-year flood does not mean that such a flood occurs once every 100 years; instead it means that there is a one in a hundred (or 1%) chance of such flooding occurring in a given year. So, it is possible that the 100-year flood could occur more than once in a relatively short period of time. A 100-year flood is calculated to be the maximum level of flood water to be expected in an average one-hundred-year period. This standard was developed by the U.S. Department of Housing and Urban Development (HUD) and represents the “magnitude and frequency that has a statistical probability of being equaled or exceeded in any given year.” (FEMA 2002) Thus the size of a hundred year flood or base flood differs on a regional basis. The Federal Emergency Management Agency, which is currently responsible for the department that administers flood insurance, regards an area characterized by a 1% annual chance of a hundred year flood at moderate risk to flooding. The National Flood Frequency Program uses hydraulic models to determine the water depths or Base Flood Elevations (BFE) and areas inundated by 100-year floods. These areas are mapped in flood hazard maps called Flood Insurance Rate Maps (FIRMs) as depicted in figure 1, which illustrate:

- Areas inundated by the 1% annual chance flood where water surface elevations or water depths are computed by hydraulic models (Zone AE)
- Areas inundated by the 1% annual chance flood for which flood elevations are not determined by hydraulic models (Zone A)
- Floodway areas (cross hatched areas)
- Elevations of the 1 % annual chance flood, also known as base flood elevations
- Areas outside the 500-year flood or 0.2 % annual chance flood
- Locations of cross sections used to develop the hydraulic model

(AEGIS 2003)
Relying solely on FIRM maps to determine frequency and probability may be problematic. Bartlomiej Wyzga (1995) conducted a study that evaluated the practice of estimating the frequency and magnitude of floods from a peak flow standard, such as the one hundred year flood, and found the practice inadequate. According to Wyzga, using FIRM maps alone to characterize probability, results in overlooking areas characterized by short return period flooding that can be just as economically damaging over time as high magnitude floods.

Like Riverine flood hazards, magnitude and probability are determined for coastal flood hazards from a base 1% annual chance of a hundred year flood. However, the methodology used to produce the base flood elevation is very different.

The determination of the 100-year stillwater elevation is usually accomplished through the statistical analysis of historical tide and water level data, or by the use of a numerical storm surge model and is presented within an areas Flood Insurance Study.
Several factors contribute to the 100-year still water elevation in a coastal area:

- Offshore bathymetry (water depth relative to sea level)
- Astronomical tide
- Wind setup (rise in water surface as strong winds blow water toward the shore)
- Pressure setup (rise in water surface from low atmospheric pressure)
- Wave setup (rise in water surface inside the surf zone from the presence of breaking waves)
- Seiches (under water waves) and long-term changes

Wave heights and elevations are computed from stillwater and topographic data with established procedures and models that account for wave dissipation by obstructions (e.g., sand dunes, buildings, vegetation) and wave regeneration across overland fetches. 100-year stillwater depth (d100) is the difference between the 100-year Stillwater elevation (E100) and the ground elevation (GS). This is used to establish the maximum wave crest elevation. Maximum wave crest elevation establishes the BFR and is determined by the maximum wave height as depicted in figure 2.

**Figure 2: Illustration of base flood elevations**
Exposure to risk is an additional factor that must be calculated when conducting a risk assessment and is the main objective of identifying assets. Local resources, U.S. Census data, and HAZUS provide excellent sources to determine population and building exposure. For the United States, flooding is a national phenomenon and exposure to flooding is very high. From FIRM maps, FEMA determined that Louisiana, Florida, Texas and Arkansas contained the most flood-prone lands in the United States. (Livingston Parish Hazard Document) A 1987 study estimated that over 146,000 square miles were at risk to a one hundred year flooding event. It is likely that the total area and population exposed to flooding has since increased due to land development and population rise.

Consequence estimates, step four of FEMA’s Risk Assessment Outline, evaluate and quantify how communities will be affected by proposed hazards. It includes estimates of losses to structures, losses to contents, losses to structure use and function and loss to life. Traditional consequence estimates of structures are produced by crude estimates where:

\[ \text{Loss to Structure} = (\text{Structure Replacement Value}) \times (\text{Percent Damage}) \]

FEMA’s Benefit-Cost Analysis Module provides a Flood Building Loss Estimation Table for determining Percent structural Damage. The table, which is based on observed historical damages, includes variables such as flood depth, structure height and structure type. (FEMA 2001) Determining flood loss, however, is not an exact science and often produces erroneous figures. Calculating flood loss can be problematic for many reasons: self-insured State and municipal losses are covered by multiple budgets making it difficult to determine true losses; individuals businesses and
Homeowners may be underinsured, thus skewing the true losses; and finally, some major losses, such as reduced agricultural yield due to shorter growing season, are difficult to define and are often overlooked. (NWS 2000)

**HAZUS**

HAZUS-MH is a comprehensive GIS output based multi-hazard loss estimation software program released by FEMA in the summer of 2003. It was developed by FEMA, the National Institute of Building Sciences (NIBS) and many technical contractors as a methodology to identify and assess community risk to a multitude of hazards including earthquake, flood, wind and even technological hazards. Because it incorporates the most recent hazard science into a user-friendly comprehensive software package, it is assumed, by FEMA, to be a valuable tool for decision makers from a wide range of disciplines and backgrounds.

This portion of the thesis conveys information about HAZUS flood hazard analysis; HAZUS flood loss estimations; and existing evaluative research on the HAZUS program. Its inclusion is critical to this thesis because the software program is new.

**Flood Hazard Analysis**

This study deals with riverine flooding and will therefore only elaborate on this aspect of HAZUS-MH. The HAZUS riverine flood model performs two inter-related analyses: flood hazard analysis and flood loss estimation. The flood hazard analysis characterizes the flood and must therefore be completed before the flood loss estimation. The first step of the flood hazard analysis is to define the study area. This can be completed at a state, county, census tract, or census block region. HAZUS automatically
imports default data pertaining to the local built environment into an inventory database for the defined region.

Once the study region has been defined, HAZUS identifies default watersheds that cover the study area and imports them into a database. The user must supply information regarding the topography of the environment by importing clipped Digital Elevation Models (DEMs) into the program. This is simple, since HAZUS supplies the coordinates for individually defined study regions based on those watersheds that cover the chosen region. Additionally, the user is now able to map various aspects of the local environment listed within the inventory database. This can be useful if the user is conducting a comprehensive risk assessment. With the correct DEMs in place, the user may now develop the stream network based on the assigned watersheds. Except for assigning the stream drainage area, the analysis is automatic. Stream reaches are networks of fluid flow. These stream reaches are defined using the value flow of touching grids. Stream segments are identified as sources, junctions, and outlets. Junctions are the joining points; sources are the upper most points, and outlets are the lowest most point. A drainage area denotes the size of the drainage basin above a given point. Watershed is the drainage area at a node less the drainage area at the next upstream node and is associated with either reaches or source nodes. To compute the flood hazard for riverines, threshold drainage areas must be set for the network of possible study areas.

Reaches are identified accordingly as those that: meet the threshold drainage area that flow to the selected reaches; those that meet the threshold drainage area to which the selected reaches flow; and default reaches that are on main streams. These categories are used to compute discharge values for selected reaches. Default gage data is then
extrapolated for the selected reaches. The important thing to understand here is that at a
level one analysis only gage data is being used. The use of the USGS’s gauge network
may increase the errors computed in HAZUS.

Critics of the system argue that the system fails in breadth, because gauge
numbers are limited. For example, Wyzga claims that flood interests generally focus on
large, rare floods, because these are the ones that dictate the need for dams, bridges and
land use planning. This is bad, she says, in the face of growing urbanization. Floods
of short recurrence intervals can respond rapidly to human activity in a catchment, such
as land use change, urbanization, channelization or dam construction. While the USGS
agrees that information does need to be made available from all areas, it is simply not
economically feasible to do so. They argue that the existing gages provide a source from
which they can empirically uncover the stream flow information in other areas. The
outputs in all possible reaches affecting the watershed are depicted, and corresponding
default from and to nodes assigned.

After the stream network has been developed, the user is now ready to perform
the hydrologic analysis. Streams are part of a hydrologic cycle as they carry water
“precipitated on the surface back to the oceans as surface runoff.” When precipitation
fails to evaporate into the atmosphere or absorb into the ground the leftover water makes
up a runoff that generally joins streams.

Because the amount of water runoff is dependent on the amount of precipitation
as well as the portion of that precipitation that is either absorbed into the ground or
evaporated into the atmosphere, the amount of water in any given stream varies greatly
from region to region. Flood hazards deal with both frequency and magnitude of an
event during a given period where magnitude is equivalent to the depth of water. Thus flood Hazards are measured by a depth-frequency curve. The purpose of HAZUS’s hydrologic analysis is to assign discharge and frequency values for nodes on each of the user-selected reaches. HAZUS performs this analysis by using one of four region-specific regression equations. This is an interpolation technique as it interpolates discharge values for main stream reaches from the gage default values denoted in the flood frequency table. The results of the hydrologic analysis are:

- The record number of the reach
- A value denoting the upstream or downstream node for reach
- The drainage area for the node
- The mean basin elevation
- The mean basin slope
- The basin length
- The Channel Length
- The elevation at a point located 10 percent of its length from the outlet
- The elevation at a point located 85 percent of its length from the outlet

(DHS 2003)

With discharge values and frequency assigned for each of the selected reaches, the user is ready to begin the hydraulic analysis. Water runoff flows down hill into streams that form a drainage network in which larger streams feed off of smaller streams. This principle, along with the discharge values as defined in the hydrologic analysis, is used to estimate peak flood flows at significant locations within a watershed. The combination of peak flood flows and discharge values is used to define the depth-frequency curve at any point in the flood plain. Flatter flood frequency curves denote higher annual precipitation that is less seasonal while steeper curves denote less annual precipitation but at seasonal times. (Pitlick 1997)
This relationship can be determined automatically during a level one analysis where depth is a function of discharge and frequency. However, a more in-depth review is given here. The size of a stream channel as well as the velocity and volume of water increases with decreasing gradients. Flood depths may be determined by “defining a surface area using the flood elevation and then subtracting the ground elevation as depicted in the DEM elevation. Because of this, DEMs with high resolutions should be used to decrease error, which can arise from misrepresented elevation values. If the DEM resolution is poor, a methodology called Triangular Approximation is used (TIN). This methodology defines cross section geometry by assuming it is triangular with a depth of zero at the flood plain boundaries and the maximum depth at the stream centerline.

The velocity of flow is dependent upon the amount of friction between the water and the stream channel. Optimally, digitized FIRM maps (DFIRM) developed by the National Flood Insurance Program are used. HAZUS users may couple cross section alignment depicted in the DFIRM and flood elevation information as defined by the flood insurance study with Digital Elevation Models to estimate friction slope and roughness coefficients.

However, DFIRMS are not always developed in which case old flood maps can be digitized to produce Q3 Maps containing the location of the 100-year flood plain boundaries must be used. The velocity and cross-sectional area of a channel per a unit of time is discharge. Floods occur when a stream overflows its channel.

Once the friction slope and roughness coefficients have been found, they are then used to solve for Manning’s equation. Once Manning’s velocity is found, it is then used to perform estimates of peak flood flows for certain points as well as the drainage
patterns of the basin and delineation of streams and basin boundaries. After frequency, discharge, depth, velocity and duration have been established, HAZUS’s hydraulic analysis is complete. The result of HAZUS’s Hydraulic analysis is assigned flood elevations, floodway encroachments, and velocities.

**Flood Loss Estimations**

The key components utilized by HAZUS’s to conduct flood damage estimations are hazard information, inventory, and damage curves. (HAZUS Flood Manual) The flood loss model can serve decision makers at various levels, each level requiring progressively more user input. The first level is the most basic level and requires little or no input. Instead, the analysis is based on HAZUS’s default inventory databases, hydraulic analysis and broad regional damage curves. More advanced analyses, however, requires user input. The user has the option of enhancing the flood hazard, supplying more region specific damage curves and enhancing the accuracy of inventory data. The major components of the HAZUS-MH default database include buildings, infrastructure, population and use.

Building stock information was collected from the US Census of population and housing, Dun & Bradstreet, and the Department of Energy. Building count is grouped by occupancy classification (residential, commercial, industrial, agricultural, religious/non-profit, education and government) and by construction type (wood, concrete, masonry, steel and manufactured housing). The general building stock inventory also includes information about the square footage of buildings by specific occupancy, dollar exposure by occupancy classification and construction type, median
### Table 1: HAZUS Default Inventory Data

<table>
<thead>
<tr>
<th>Type of Infrastructure</th>
<th>Input Data</th>
</tr>
</thead>
</table>
| General Building Stock          | • Square footage by specific occupancy class  
                                  | • Number of buildings by specific occupancy class  
                                  | • Replacement cost per square foot by specific occupancy class  
                                  | • Dollar Exposure  
                                  | • Depreciation Parameters  
                                  | • Foundation types & first floor heights by specific occupancy class |
| Essential Facilities            | • Medical care facilities  
                                  | • Emergency operations centers  
                                  | • Police stations  
                                  | • Fire Stations  
                                  | • Schools |
| High Potential Loss Facilities  | • Dams & Leves  
                                  | • Nuclear facilities  
                                  | • Military facilities |
| Transportation Systems          | • Highways infrastructure  
                                  | • Railway infrastructure  
                                  | • Airports  
                                  | • Bus, port, light rail & ferry infrastructure |
| Utility Systems                 | • Portable water systems  
                                  | • Wastewater infrastructure  
                                  | • Oil & gas infrastructure  
                                  | • Electric power infrastructure  
                                  | • Communications infrastructure |
| Hazardous Materials             | • Specific locations & characteristics |
| Demographics                    | • Population by age, race & income levels  
                                  | • Day & night population  
                                  | • Number of property owners & renters  
                                  | • Rental & vacancy rates |
| Agricultural Products           | • Type & value |
| Vehicles                        | • Vehicles by type & value |
| User defined facilities         | • Any facility which the user wishes to analyze on an individual basis |
year built and depreciation exposure by occupancy classifications where value and square footage are a function of the median income for the area.

The loss estimations are based on this depth grid and can be viewed under the results menu of HAZUS following the flood loss estimation analysis. The loss information provided by HAZUS is an aggregate dollar value for census blocks.

FEMA’s intention is that HAZUS flood loss estimations be used for a myriad of things including:

- Flood mitigation / regulatory policy-making, regional, state, federal levels
- Pre-feasibility studies
- Real-time emergency response with no warning
- Preliminary planning, zoning development
- Planning, zoning, development
- Selecting mitigation alternatives
- Pre-feasibility engineering studies
- Emergency planning and real-time response
- Environmental impact analysis
- Education
- Analysis for essential, cultural, high loss potential facilities
- Emergency planning and real-time response
- Mitigation and engineering research
- Scientific research

(DHS 2003)
CHAPTER 3 REVIEW OF LITERATURE

Research on flood hazards draws from a broad range of disciplines from sociology to engineering. The literature review portion of this thesis has been organized into three dominant broad ideologies: contributing factors, technology, and policy.

CONTRIBUTING FACTORS TO FLOODING

Recent escalations in the frequency and magnitude of disaster events led researchers to reevaluate the causal factors of flooding with a new emphasis placed on human interaction. It is thus difficult to discuss current technology or policy without first addressing existent research on the contributing factors to flooding.

Yiming Wei (2003) presents an excellent conceptualization of flood hazards. She asserts that for a flood disaster to occur, three constituents must be present: 1) Hazard-formative factors 2) Hazard-formative environment 3) Hazard-affected bodies. Hazard-formative factors are those that induce floods such as heavy rainfall. A hazard-formative environment is an environment predisposed or well conditioned to flooding due to geographic or topographic characteristics. Finally, hazard-affected bodies include the people, property, and agricultural product in the affected area. Without these three factors, the flood event would merely be a natural flood and not a flood disaster.

For many years, the inception of hazard-formative factors was thought to be independent of human action. It was never conceived that humans might play a role in altering natural weather phenomenon. Research shows, however, that anthropogenic actions may contribute to the formation and intensification of hazard-formative factors through global warming. The Intergovernmental Panel on Climate Change (IPCC), which is responsible for researching human-induced climate change and assessing
possible responses, uses “complex physically based climate models” to project future climate change due to global warming and model possible affects of changes. According to a recent report, the IPCC predicts that, due to human interaction with the environment, precipitation and extreme weather will increase during the 21st century. There is also evidence that anthropogenic actions will have an effect on natural El Nino-Southern Oscillation (ENSO) patterns. This, however, cannot be proven since current models do not yet adequately simulate ENSO patterns. (Population Council)

Due to this uncertainty, researchers argue over the extent to which human action exacerbates flood loss from ENSO. ENSO is characterized by climate variations resulting from natural interaction between atmosphere and ocean in the tropical Pacific. (IPCC). In 1993, the United States Climate Change Science Program (2002) cited natural variations in climate cycle as the driving force behind the 1993 Mississippi River floods, which caused losses in excess of 20 billion dollars. Following the floods, researchers debated whether the floods were due to natural hazard-formative factors or a human induced hazard-formative environment.

Research conducted by John Pitlick (1997) evidences natural climate variations as a flood hazard-formative factor and a leading cause of the 1993 floods. Pitlick opposes the idea that wetland reduction was responsible for the 1993 Mississippi floods on the ground that the statistical probability of receiving the amount of rainfall that fell during the flood was 1 in 1,000 and more than accounted for the amount of runoff and saturation given wetlands’ potential for storing runoff during extreme flood disaster events.
Pitlick does acknowledge, however, that poor land use practices might exacerbate flood disasters of lesser magnitude. Many other researchers have studied the role human interaction with the environment plays in the production of hazard-formative environments. Maria Sala (2003) conducted a study on the effects of urbanization on high-magnitude-flood-event impacts in the Catalan Coastal Ranges. The study was accomplished by assessing the impact of natural flood events prior to and after tourism development. Sala’s findings refuted Pitlicks assertion that human activities play no part in worsening the impact of high magnitude flood events. Instead, she found evidence that urbanization increases run off volume while decreasing response time by increasing impervious surfaces and obstructing the natural fluvial flow.

It goes without saying that the extent of existing hazard-affected bodies is also due to human interaction with environment. Charles W. Finkl (2000) estimates that, within the past 25 years, coastally located cities have grown at nearly twice the rate of those located inland. Residents who choose to live in flood prone areas often unknowingly place themselves at risk. Anthony Oliver Smith (1997, 303) best characterizes disaster victims in his observation that “disasters signal the failure of a society to adapt successfully to certain features of its natural and socially constructed environment.” The practice of individuals and societies placing themselves in hazard formative environments, such as coastal zones and other flood zones is largely a product of perceived risk. Don Macdonald et. al (2004) attempted to capture perceived risk economically by developing a model of consumers’ willingness to pay for reduction of flooding hazards in residential location. The conclusions of the study demonstrate that
consumers are willing to pay the same price for similar houses located within and outside high-risk flood hazard areas.

**TECHNOLOGY**

In 1927, the Mississippi River flood inundated approximately 20,000 square miles, killing 200 people and displacing 700,000. (Barry 1997) The severe impact of the flood on the people demonstrated that there was a need for change and for further understanding. Unfortunately, it this fact was apparent to the government, but how to get there was not; they did not yet possess the technology necessary for forecasting, warning or preparing for such flood occurrences.

Currently the United States has at its disposal, an assortment of efficient technologies to choose from. Recent advances in flood disaster technology have played an integral part in the adoption of a new perspective on flood disasters. This replaces the old view that flood disasters are extreme unpredictable events with one that perceives disasters as integral components of environmental and human systems. (Anthony Oliver-Smith 1996) This new broader perspective, called systems theory, states that the interaction of independent interrelated parts will determine the outcome. (Pine 1999) This subsection outlines advances in flood disaster technology from its origins to current.

**Origins of Technology**

Early civilizations’ understanding of natural disasters stemmed from basic observations of rain, wind, snow, and hail. Historical records indicate that early civilizations of man (pre-Neolithic) were generally nomadic hunters and gatherers whose migration was based on seasonal climatic patterns. This practice protected early populations from many natural hazards. Populations did, however, have an idea of
vulnerability derived from oral histories and various forms of written communication provided by those who had encountered major disasters. The existence of the major prehistoric floods mentioned in literature is important to researchers today because they tell us about the possible magnitude of destruction that floods can cause. To date, many scientists have supported the existence of the major prehistoric floods recorded in early literature through geologic evidence and the extinctions and survival of isolated species in specific geographic areas. (Kerr)

Following the domestication of plants and animals, populations became more sedentary; permanent shelters were more abundant and populations larger, leaving many at greater risks to natural hazards. The same rain that allowed crops to flourish one day could wash away shelter, sustenance and life the next day. Eventually these occurrences led to predictions. Little, however, was known of what truly caused disasters since many civilizations perceived in disasters acts of gods.

They did not yet have the technology necessary to understand the complex causal mechanisms of disasters. Thus, little could be done to prepare for or mitigate impacts. With technological advances, our understanding of the nature of many disasters grew. We learned that certain types of clouds brought with them destructive winds, while others brought much needed rain, and that these clouds often came in a seasonal pattern. These advancements allowed for forecasting and later, long-term planning. Hence the struggle to find the best tools to predict, warn and prepare for natural disasters was born.

**Current Technology**

This thesis differentiates current flood hazard technology used to collect data and that developed to model flood hazards. Although other important flood hazard
technologies, such as networking and communications, exist they are not acutely related to the thesis research question. Two important types of data collection technologies are direct sensing and remote sensing. Data collected by means of direct sensing is collected directly from the environment. In regard to flooding, measurements taken by the USGS stream-gaging program by means of direct sensing are a significant contribution to flood hazard technologies. Understanding regional risks to flooding is a critical component of flood disaster management. Most of our current knowledge of past floods comes from information gathered from stream-gaging stations, as depicted in figure 3, by the U.S. Geological Survey (USGS) following flood events. The most common types of data collected from gages are the stage height and discharge.

Figure 3: USGS Water gage station
[Source: U.S. Geological Survey]

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Collecting discharge, however, is less common as it requires that personnel make onsite visits to collect discharge information from a hand held device called a current meter which measures the cross-sectional area and velocity of water (Wahl). The first USGS operated station was established in 1889 and by the year 2000 over 7,000 stations existed (Wahl). Stations are defined by their intended purpose, which includes:

- Hydrologic systems: comprises 4,200 of the stations; used to account for and monitor the flow through a river basin or to define the general hydrologic condition in the basin.
- Regional Hydrology: comprises 2,900 stations; supply data from unaffected areas; used to estimate stream flow characteristics in ungaged areas
- Project operation: comprises 2,900 stations; used by water managers in making daily operational decisions
- Hydrologic forecasting: comprises 3,000 stations; provides information for flood and water-supply forecasting; Used by NWS flood-forecasting system
- Water quality monitoring: comprises 2,700 stations; allows evaluation of water quality in rivers, lakes, reservoirs and estuaries.

(USGS, Database online)

Figure 4: Location of water gage stations
[Source: http://water.usgs.gov/nsip/nsipmaps/currentgages.html]
4,200 of the stations are “telemetered” by an earth-satellite-based communications system that enables the data to be available real-time. Since 1996, stream flow data for roughly 2,600 sites has been available to the public on the World Wide Web. (NSIP) Still, problems existed with the system, including the provisions of funding for the maintenance of gages necessary for use in nation wide data sets and climate variability studies. The National Streamflow Information Program (NSIP) was introduced after a 1998 congressional report expressed concern with these problems. NSIP funding, which has increased by 2 million in 2000 and 3.1 million in 2001, is provided by 800 agencies at the Federal State and local levels (Hirsch 2001). NSIP has identified the following five federal goals as high priority for saving the USGS Streamgaging Network:

1. Interstate and International Waters- Interstate compacts, court decrees and international treaties mandate long-term accurate and un biased streamgaging by the USGS at State-line crossing, compact points and international boundaries
2. Flood Forecasts- Real time stage and stream flow data to support flood forecasting by the National Weather Service across the country
3. River Basin Outflows- Gages to account for the contribution of water from each of the Nation’s 350 major river basins to the next downstream basin, estuary, ocean or the Great lakes
4. Sentinel Watersheds- Long term stream flow information, unaffected by regulation or diversion, from each of the 800 unique ecological/hydrological areas of the Nation to describe ever-changin status of regional streamflow as it varies in response to changes in climate and land use.
5. Water Quality- Stream flow information needed to support the three national USGS water-quality networks that cover the Nation’s largest rivers, intermediate rivers and small pristine watersheds

(Hirsch 2001)

can be used to “create, manipulate, analyze, and display all types of geographically or spatially referenced data.”

Charles W. Finkl (2000) employed remote sensing techniques and GIS to define flood hazard impacts in Broward County Florida. Finkl felt that current flood hazard estimation methodologies inadequately accounted for population growth. Finkl identified a new methodology that quickly identifies possible flood zones by comparing the topology depicted on two remotely sensed satellite views for wet and dry years. The topographic elements in the wet image were analyzed to determine whether they depicted vegetation normally associated with flood prone conditions.

In regard to flooding, Digital Elevation Models (DEM$s$) are one of the most important remote sensing products. (Kiefer 1994) DEM$s$ are produced from topographic orthophotomaps and display elevation variations at a uniform resolution. (S Boyle 1998) In his research paper, S.J. Boyle (1998) presents a methodology for conducting flood loss estimates based on DEM$s$. USGS predicted water elevations are subtracted from a DEM land elevation for a given point to determine flood extent.

**POLICY**

**Current**

Flood Policy has gone through drastic changes due to significant impacts of flooding events. The need for flood policy was first demonstrated as early as 1803 to assist plantation owners located along the river. This need was not answered until 1861 when a proposal was made to provide flood control through the adoption of a system of levees along the Mississippi River. (Platt 1998) The proposal was enacted and marked
the beginning of a “levees only policy” for the United States that was upheld until the
great lower Mississippi flood of 1927.

The flood was catastrophic: killing 200 people, displacing 700 and damaging over
135,000 building structures. As a direct result, Congress passed the Mississippi Flood
Control Act in 1928, which authorized Army Corps of Engineers to carry out structural
mitigation projects throughout the Mississippi Valley. The Act instigated the movement
of flood control responsibility from local jurisdictions to federal. After flooding in Ohio
and New England, a new act was born that further extended federal participation. The
Flood Control Act of 1936 expanded flood hazard focus from the Mississippi Valley to
the entire Nation and handed funding responsibility over to Congress. The Flood
Control Act eventually led the government to identify the need for a greater
understanding of floods and their associated risks. In 1966, House Document 465 was
published. This document outlined the goals to:

- Improve basic knowledge about flood hazards
- Coordinate and plan new developments in the flood plain
- Provide technical services
- Move toward a practical national program of flood insurance
- Adjust Federal flood control policy to sound criteria and changing needs.

It was from these last two goals that the National Flood Insurance Act was born. The Act
developed the National Flood Insurance Program (NFIP) in 1968 with these goals in
mind:

- Better indemnify individuals for flood losses through insurance
- Reduce future flood damages through State and community floodplain
  management regulations
- Reduce Federal expenditures for disaster assistance control

The program encourages community adherence to flood plain management
regulations as conveyed in §1361 (c) by stipulating that insurance will not be provided
unless the set criteria are met. Insurance proved to be an insufficient incentive and so in 1973, the Flood Disaster Protection Act was passed. This act mandated that “financial assistance for acquisition or constructions of buildings and certain disaster assistance in floodplains” were not to be provided unless the community participated in the National Flood Insurance Program by July 1, 1975 or within a year of “being identified as flood prone.” Participation numbers rose from a few thousand in 1972 to 1.2 million in 1977. The major components of the Program include “Identifying and mapping flood-prone communities, adoption and enforcement of floodplain management regulations, the provision of flood insurance, Mandatory Purchase Requirement, the Community Rating System and the Flood Mitigation Assistance Program.”

Flood Insurance Rate Maps (FIRM) were developed and published, facilitating easy identification of flood prone areas. Currently, 150,000 square miles of floodplain areas have been mapped out by the Federal Emergency Management Agency (FEMA) through the program and are illustrated in FEMA’s FIRMS. These maps are used at the Federal, State, and local level to calculate flood insurance premiums and to assess need for flood insurance and emergency management.

**Wetland Regulations**

Although Wetland Preservation laws and regulations are not directed to flood hazard mitigation, the preservation of wetlands maintains critical watersheds, thus alleviating the magnitude of floods in surrounding areas. In accordance with the Code of Federal Regulations (C.F.R.) Title 44, it is FEMA’s policy to:

- Avoid long- and short-term adverse impacts associated with the occupancy and modification of floodplains and the destruction and modification of wetlands;
• Avoid direct and indirect support of floodplain development and new construction in wetlands wherever there is a practicable alternative;
• Reduce the risk of flood loss;
• Promote the use of nonstructural flood protection methods to reduce the risk of flood loss;
• Minimize the impact of floods on human health, safety and welfare;
• Minimize the destruction, loss or degradation of wetlands;
• Restore and preserve the natural and beneficial values served by floodplains;
• Preserve and enhance the natural values of wetlands;
• Involve the public throughout the floodplain management and wetlands protection decision-making process;
• Adhere to the objectives of the Unified National Program for Floodplain management;

Section 404 of the Clean Water Act requires that permits be obtained from the Corps of Engineers (Corps) for dredge and fill discharges into U.S. Waters. (Wascom 1997) The definition of “U.S waters” extends to wetlands. Wetlands, as defined by the Corps and EPA, include areas that meet two of the following criteria: saturated or inundated by water, supports existent hydrophytic vegetation, and is characterized by hydric soil. A site’s land is classified as a wetland due to the prevalence of hydrophytic vegetation and water inundation. The conversion of this wetland into solid ground would require dredge and fill practices and associated discharges.

All proposed developments in wetland areas must obtain necessary dredge and fill permits from the Corps of Engineers. EPA guidelines mandate that if a permit for dredge or fill is to be issued it must be proven that: no practicable, more ecologically sound alternatives exist; proposed activities would not contribute to significant degradation of the nation’s water; steps have been taken to minimize potential adverse impacts on the aquatic ecosystem; and that other statutes are not violated.

Additionally the Corps takes into consideration public interest. Factors considered when deciding whether an action affects public interest include: conservation,
economics, aesthetics, wetlands, cultural values, navigation, fish and wildlife values, water supply, water quality. This was the situation with the case of Cook vs. Sullivan. In 1996 Diane Sulliven unknowingly built a house in a New Hampshire wetland area without obtaining the necessary permits. Following the new development, neighbor Francis Cook observed that on her property, the presence of standing water inundation increased to the extent that portions of her property were no longer usable. She eventually sued, claiming common law nuisance and violation of state wetland laws. The court ruled that Sulliven had to move her house. (Lawlor 2004)

**Policy Failure**

To understand how HAZUS may be incorporated into policy as a tool for decision makers, it is beneficial to examine other instances of scientific knowledge incorporated into a policy tool. As communicated in the previous section, the United States has come a long way in flood policy. We have moved beyond the levees only period in history to include non-structural approaches to flood control. Unfortunately, these changes are not sufficient.

There are many proposed reasons as to why current policy fails to adequately address natural hazards. Of these allegations, failure to adjust policy to new technology is a common criticism. Kris Wernsedt and Robert Hersh (2002) conducted a study on problems encountered when trying to incorporate new scientific knowledge into flood plain policy. According to them, there are two major barriers:

- Lack of concern and support for flood planning and policy, except when disaster strikes and
- The “shared governance” of flood planning and management among multiple levels of government.
They conclude that real-time threats often take precedence over long-term flood planning; that with limited resources, decision makers must prioritize problems by both the magnitude of the hazard and the public’s concern, thus placing flood policy as the lowest priority. Wernstedt feels that local governments often perceive that the political and economic costs of proactive flood management planning are disproportionate to its benefits. He also substantiates that there is a structural problem with flood plain management, with planning occurring at the federal levels, and implementation occurring at the local levels.

Raymond Burby’s (1998) findings support those of Wernstedt and Hersh. Burby criticizes current policy, claiming that current policy fails to successfully address flood hazards due to poor allocation of responsibility through poor mandates from federal government, problems with compliance, and failure in intergovernmental coordination.

He states that without strong mandates from higher government, local governments are left to protect themselves from flood hazards, but unfortunately, due to unrealistic perceptions of risk, many local governments fail to take substantial action. He feels that the consequence of their perception is that local officials are too reactive in their policy and fail to take action until a disaster occurs. This laissez faire attitude extends into compliance. Burby uses Hurricane Andrew as an example of failure of compliance. He notes that 25% of the insured losses were traced back to poor construction practices and that houses built after 1980 were more than 68% likely to be inhabitable than houses built before the year. Furthermore, Burby concludes that local governments may fail to make use of new technology that is necessary for productive
flood management, such as flood hazard mapping, because they lack the knowledge and expertise to do so. (DHS 2003)

**HAZUS RESEARCH REVIEW**

HAZUS is relatively new software. Consequently, there have been few evaluative studies conducted on the accuracy of HAZUS’s default databases. The studies presented here illustrate two contradictory findings in regard to the accuracy of HAZUS default data.

The New York City Area Consortium for Earthquake Loss Mitigation (NYCEM) is involved with a FEMA funded project to carry out flood loss estimations for the New York City area. One of the project’s objectives was to evaluate HAZUS default information on the urban environment. To accomplish this objective, a research team led by George Mylonakis (2000) collected information on the number and building occupancy type of structures for two census blocks within the New York Area. The survey data was processed in an ACCESS database and two HAZUS earthquake loss estimations were performed using both survey data and default data. After comparing the results of the two analyses, it was concluded that their findings suggest a significant difference between HAZUS default building types and actual building type. Actual damages from earthquakes were determined to be significantly smaller than HAZUS estimations at 3.7 million in lieu of 25 million.

Anthony S. Lowe’s (2004) testimony before the U.S. House of Representatives Committee on Science Subcommittee on Research and Subcommittee on Environment, Technology and Standards communicated evidence that HAZUS default databases do provide accurate representations of the built environment. His team compared loss
estimations using HAZUS Wind prior to the landfall of Hurricane Isabel to estimations provided by the property casualty insurance industry. Their findings showed that the two lost estimations correlated well, thus suggesting that HAZUS default inventory data provides accurate representations of the built environment.
CHAPTER 4 PROBLEM STATEMENT AND DISCUSSION

This thesis assesses HAZUS-MH as an effective planning tool for flood hazards. It provides a methodology for assessing new flood loss estimation technologies by incorporating GIS concepts for a comparative analysis between HAZUS-MH default building counts and collected accurate representations of the built environment. The analysis conducted within this study will determine the capability of HAZUS-MH to lesson the policy failures presented in the previous literature review.

Thus far evaluative research on HAZUS-MH has been restricted to wind and earthquake hazards and is contradictory. Additionally, past research conducted by NYCEM was limited in study area. This thesis study differs from existing studies by type of hazard, extent of study area, and means of data collection. Previous research did, however help, build a foundation for the methodology presented in the following chapter. The methodology used by Charles Finkl’s study is similar to this study as it too used remote sensing to assess unseen flood hazards. However his study focused on the hazard-formative environment and did not analyze differences in actual possible losses.

Research communicated within the previous literature review demonstrates that current perceptions of flood disasters, technology and policy have changed drastically over the years: perception of natural disasters has shifted from one that considers the environment and the human population as separate entities to one that takes a systems theory approach, viewing the disaster-human relationship as a machine of interrelated working parts; technology has developed allowing for easier mapping and data collection and policy has taken a more proactive stance. It has also demonstrated that policy
measures fail flood hazard management due to misconceptions about risk, poor funding, and lack of expertise.

In view of the critical importance of the issue of flood disasters, it is worthwhile to explore newer flood loss assessment methodologies. One of the major tools for reducing vulnerability to hazards is a risk assessment and to conduct a productive risk assessment, it is necessary to have an adequate assessment of hazard-affected bodies. This involves identifying hazard formative environment and the population estimates of people, building structures and agricultural products of an area. Until recently this was a massive task that involved time, money and expertise. But with the introduction of computer technology, scientists are developing new programs, such as HAZUS, that everyone can use.
CHAPTER 5 METHODOLOGY

In this thesis study, a comparative analysis between two levels of flood estimations is HAZUS-MH involved the following tasks:

Task 1: Identify, characterize and develop a study area

- Identify overall area of study
- Gather information by communicating with local officials and residents to identify high-flood problem areas
- Identify the Census Tracts for the high risk area
- Develop a study region within HAZUS-MH utilizing identified Census tracts

Task 2: Identify topographic and hydrologic information for study area

- Use HAZUS-MH to identify watersheds for study area
- Import Digital Elevation Model for selected watersheds into a geographic information system within HAZUS-MH
- Identify networks of streams and reaches affecting watershed within HAZUS-MH
- Identify USGS River Gages for collected stream network
- Select reaches from network for analysis

Task 3: Perform Hazards Analysis within HAZUS-MH

- Determine affected area by selecting threshold value
- Delinate between those watersheds and gages that affect the chosen reaches and those that due not
- Use HAZUS-MH to determine areas that meet threshold value and those that due not
- Develop flood frequency curve for study area and census blocks
- Map out depth curve

Task 4: Develop two identical study regions based on preceding analysis

Task 5: Collect data on building count for census blocks affected within the hazard analysis

- Identify Data Source
- Import High Resolution Images into a Geographic Information System
- Obtain data counts from Image
Task 6: Conduct preliminary Analysis

- Process data in Microsoft Excel database
- Export data into SPSS software package for further analysis
- Conduct Descriptive Analysis within SPSS dataframe
- Conduct Statistical Analysis within SPSS dataframe

Task 7: Perform Flood Loss Estimation for two Study Regions

- Export data into one HAZUS-MH study region for Flood loss Estimation Analysis
- Use default depth damage curve to estimate damage
- Map out the results

STUDY AREA

The first step in this thesis study was to define a study area for which local data was collected and HAZUS flood loss analysis conducted. Livingston Parish, Louisiana was initially chosen as the study region due to its known flooding problems and high growth and development. Livingston Parish is located in southeast Louisiana, approximately 26 miles from Baton Rouge. Because of its proximity to Baton Rouge, the area has seen large growth in population due to out-migration. The area, comprised of 642 sq. miles, is currently the home to roughly 91,814 residents. This is a 30% increase from the 1990 population of 70,526 and the parish growth shows little signs of slowing down. (AEGIS 2003 The increase in residential and commercial developments raises the concern whether these developments are increasing flood related risks. The National Weather Service contends that between 1916 and 1989 there has been a definite increase in flood damage in Livingston Parish. The adjusted average annual damage was 902 million for the 1916 to 1950 period and $2.15 billion for the 1951 to 1985 period. (AEGIS 2003)
Table 2: Livingston Parish Land Use

<table>
<thead>
<tr>
<th>Use Area (Acres)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential, Mixed Urban or Built-up Land</td>
<td>28,447</td>
</tr>
<tr>
<td>Industrial, Transport. Communications &amp; Services</td>
<td>2,239</td>
</tr>
<tr>
<td>Agricultural Land, Cropland and Pasture</td>
<td>43,474</td>
</tr>
<tr>
<td>Forest Land</td>
<td>269,818</td>
</tr>
<tr>
<td>Water</td>
<td>25,081</td>
</tr>
<tr>
<td>Wetlands</td>
<td>70,038</td>
</tr>
<tr>
<td>Transitional Areas</td>
<td>3,135</td>
</tr>
</tbody>
</table>

The Geography of Livingston Parish makes the area prone to floods. All of Livingston Parish is located in the Mississippi River-Lake Maurepas Basin. The Amite River flows through the Parish, emptying into Lake Maurepas. Its basin covers approximately 236,000 acres of the Parish and is responsible for much of the Parish’s flood damage. The area contains three watersheds: the Amite, Tickfaw, and Lake Maurepas watersheds. 70% of the total land area of Livingston Parish is located within FEMA’s 100-year floodplain, most of which can be found along the Amite River. Local land use is predominately forest land but this use is diminished each year as the forests are cut down to make room for subdivisions, decreasing the total watershed of the area and increasing the risk to flooding. Livingston’s current land use patterns are depicted in Table 2. From Livingston Parish, the study area was narrowed down to a concentrated in the northwest corner of Livingston Parish, Louisiana. The area, chosen for its proximity to the Amite River, consists of 5 census tracts as shown in figure 5.
The United States Census Bureau collects demographic information at the Census Block, the smallest unit of aggregation, but information is also aggregated at the census block group and census tract, the largest level of aggregation. HAZUS allows users to identify study areas at the county, census tract, and census block levels. Most existing Riverine Flood Hazard studies conducted utilizing HAZUS-MH are done so by developing study areas at the Census Tract level. This study does the same but, has
expanded the study area to 5 Census Tracts. A study conducted by the New York Consortium of Engineers on the accuracy of HAZUS-MH default data within earthquake hazard losses, was based on only two census tracts. Thus, this study area utilizes a much larger than that used by the New York Consortium of Engineers. This is important because it differentiates this study from existing studies by expanding the breadth of the region.

These five census tracts were identified and recorded by their associated cataloging number during the initial creation of the study region. They were used collectively within HAZUS to determine the study region boundary at the aggregate level. From this large study region boundary, associated watersheds, stream networks and their gages were identified and used for additional Riverine Flood Hazard and Flood Loss Estimation analyses.

Although the region boundary consists of 5 census tracts, not all-surface area within the tracts will be affected by flooding the Amite River. Consequently, not all of the blocks within the 5 census tracts were needed to conduct the flood loss estimation resulting from a 100 year flooding event along the Amite River. To account for this problem HAZUS-MH identifies affected census block following the hazard analysis. The program allows users the option of displaying census blocks for the entire study area as well as only those affected by the chosen hazard. 105 Census Blocks were used by HAZUS in the flood loss estimate and are depicted in figure 6.
Figure 6: Study case census blocks.
DATA COLLECTION

Accuracy is a measurement of proximity to a true, known value or state. Thus, to assess the accuracy of HAZUS’s representation of the built environment, true representations of the built environment had to be obtained and quantified. The two available alternatives considered for collecting this data were onsite observations, and observations made from high-resolution digital images. It was determined, due to time and cost constraints, that the most efficient alternative was using high-resolution digital images. USGS High-Resolution 1500-meter Orthoimages were obtained from the Department of Defense and imported into HAZUS.

An orthoimage is a remotely sensed image data in which displacement of features in the image caused by terrain relief and sensor orientation have been mathematically removed. Orthoimagery combines the image characteristics of a photograph with the geometric qualities of a map. For this dataset, the natural color orthoimages were produced at 0.3-meter pixel resolution (approximately 1-foot). The design accuracy is estimated not to exceed 3-meter diagonal RMSE (2.12m RMSE in X or Y). Each orthoimage provides imagery for a 1500- by 1500-meter block on the ground. The projected coordinate system is UTM with a NAD83 datum. There is no image overlap between adjacent files. The naming convention is based on the U.S. National Grid (USNG), taking the coordinates of the SW corner of the orthoimage.

Five 1500 by 1500 meter blocks were needed to cover the study area. Once the images were imported into HAZUS, the census blocks shape files needed for the flood loss estimate were overlaid upon the image as depicted in Figure 7.
Figure 7: Five Block OrthoImage and Census Block Overlay
Building counts were determined by calculating the number of structures within each block. Additionally, occupancy classifications could, in most cases, be determined from the image as seen if figure 8. However, in some cases it was necessary to make on-site observations to determine the structures’ occupancy classifications.

Figure 8: OrthoImage Depicting Residential Housing
The use of this methodology, however, has incorporated a few minor errors into the study. The US Census bureau assigned blocks in the year 2000 in accordance with surrounding geographic features such as roads, lakes and rivers. These blocks were then digitized using uncentered road files. Thus the digitized blocks do not always accurately reflect the true assigned block boundaries. Because the high-resolution images are accurate representations, the building structures were not always contained within their appropriately assigned block. To ameliorate the problem, questionable structures were identified to be either predominately contained, partially contained, or not contained within the boundaries of the digitized blocks. Those structures predominately and partially contained within the boundaries of the digitized blocks were assumed to be contained. For those structures completely outside the boundaries, judgment calls were made based on the surrounding geographic structures as viewed in the images.

Structures located beneath tree coverage posed additional problems when identifying occupancy classifications. Again, judgment calls were made. Structures were determined to be residential if the visible surrounding structures were identified as such. In instances of mixed land use, field observations were made. The two datasets are summed up in the following table.
Table 3: Building Counts By Occupation

<table>
<thead>
<tr>
<th>GENERAL BUILDING OCCUPATION</th>
<th>HAZUS DEFAULT</th>
<th>EDITED</th>
<th>PERCENT CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>4674</td>
<td>4759</td>
<td>1.8</td>
</tr>
<tr>
<td>Commercial</td>
<td>20</td>
<td>56</td>
<td>180</td>
</tr>
<tr>
<td>Industrial</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Agriculture</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Religious</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Government</td>
<td>0</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Education</td>
<td>0</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Grand Total</td>
<td>4695</td>
<td>4840</td>
<td>3.1</td>
</tr>
</tbody>
</table>

**Descriptive Statistics**

Descriptive statistics are necessary to characterize the dataset prior to further analysis. This is helpful as it allows a better understanding of the results.

The data set consisted of 112 entries, half of the entries HAZUS Default values ($n=106$) and half were edited values ($n=106$). Table 3 illustrates the range values, mean and standard deviations of building counts by data source. The means and standard deviations were relatively similar for HAZUS default and edited data. However, on average, the edited entries consisted of more buildings. In addition to general occupancy, housing was delineated between single family and manufactured housing. For the default
dataset approximately 25% (1159) of the residential buildings were manufactured houses. For edited dataset, manufactured homes consisted of approximately 22% (1159) of the residential building stock.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Table 4: Descriptive Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Default</td>
<td>Total number of building structures per census block as stipulated by HAZUS</td>
</tr>
<tr>
<td>Total Edited</td>
<td>Total number of building structures per census block as calculated.</td>
</tr>
</tbody>
</table>

**DATA ANALYSIS**

The data analysis component of this thesis was completed in two separate steps. The first step was to compare the two data sets for a statistically significant difference in the number of structures and the second step was to conduct a flood loss estimate for the two areas. For both procedures datasets were assigned to both the control and experimental groups.

The statistical portion of the analysis was accomplished by utilizing SPSS statistical software to find a statistical difference and direction of difference between the two data sets. After great consideration to different types of statistical tests, a paired sample t-test was determined to be the best option. Paired-Samples $t$ Test evaluate whether mean difference between two variables, in this case Total Default and Total edited, significantly different from zero. If more than 95% of the differences are less than zero, the two datasets are determined to be significantly different.
Table 5: Variable Definitions

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Default</td>
<td>106</td>
<td>0</td>
<td>360</td>
<td>44.29</td>
<td>74.505</td>
</tr>
<tr>
<td>Total Edited</td>
<td>106</td>
<td>0</td>
<td>361</td>
<td>45.66</td>
<td>76.51</td>
</tr>
</tbody>
</table>

The test is often used for repeated-measure designs for which participants are assessed under two conditions on one measure. In this case the participants are the actual census blocks, the measure is building count, and the two conditions are whether the data is HAZUS-MH default data or data collected from the high resolution OrthoImages. Variable definitions are given in Table 4.

The second step was to actually complete a loss estimation using HAZUS default data as well as a loss estimation using edited data. The study region was defined in HAZUS according to the five census tracts and a seamless 30-meter resolution DEM was imported into the program from the USGS Seamless Data Distribution System. From this DEM (illustrated in figure 9), HAZUS-MH was used to develop the stream network for the entire area. A threshold drainage value of 10 miles was assigned to the reaches. This threshold value affects the extent of flooding. For example, if the value had been set higher, the results would show a greater extent of flooding. The initial network consisted of 145 reaches. HAZUS-MH can only calculate depth for a few reaches at a time. Because of this, and since the Amite River is the main source for the area’s flooding, only those reaches along the Amite River were chosen. Thus the chosen reaches consisted of 33 reaches that were used for analysis.
Figure 9: HAZUS map illustrating the study region DEM and Stream Network
Once the reaches for the study area were chosen, a hydrologic and hydraulic analysis for a 100-year event was completed for the hazard analysis portion of the flood loss estimation. Figure 11 shows the depth grid built following the hazard analysis.

Figure 10: Depth Grid for Control and Experimental Groups
The darker value denotes proposed areas of highest depth in the event of a one hundred year flood. The depth value is highest, at roughly 28.5 feet, in areas near the Amite River. This depth grid differs from the flood hazard areas denoted in FIRM maps in the extent of flood hazard areas because the threshold drainage area was set at 10 miles.

To ensure that all variables except building count were held constant, the files were backed up following the flood hazard analysis prior to conducting the flood loss estimations. Thus the flood depths and study region census blocks will be the same for both the default and edited flood loss estimation. The region using default building inventory data for the flood loss estimation was assigned the control group and the study using collected building inventory data was assigned the experimental group. The next step was to produce flood loss estimations for each group. This flood loss estimation took into consideration, default HAZUS-MH general Building Stock Depth-Damage Functions and the HAZUS-MH general inventory. For the experimental group, all denoted values were default but building count.

**RESULTS**

**Statistical Analysis**

A paired-samples *t* test was conducted to evaluate whether default HAZUS’s estimations of building counting differ significantly from actual building counts. This test will determine whether differences between the two datasets could be due to chance. The results indicated that the mean HAZUS estimates of building count (M=44.70, SD = 74.378) were significantly less than the actual building counts (M=45.66, SD= 76.515),
Thus, the two datasets are so different that differences between the data cannot be attributed to sampling error. 

**Flood Loss Estimation**

In this study, a flood loss estimation was run for both the experimental and control group to calculated the possible impact of a 100-year riverine flood on the defined study area. Total differences in economic loss (in U.S. Dollars) resulting from building structure loss for the two study groups are illustrated in table 6.

<table>
<thead>
<tr>
<th>Total Economic Building Loss For</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Control group</td>
<td>96723</td>
</tr>
<tr>
<td>Experimental Group</td>
<td>102047</td>
</tr>
</tbody>
</table>

Economic loss due to building damage for the experimental group was approximately 6% higher at 102,047 dollars than that experienced by the control group at 96,723 dollars. These values do not denote the full replacement value of structures. Rather they denote depreciated values.

Differences in economic loss were then mapped to show where losses varied at the census block level. Results can be viewed in figure 10. Note that differences were significant for only 4 of the census blocks.

Although this thesis study has determined that the two datasets are statistically significantly different, it has not yet determined whether differences in the results for the flood loss estimations are significantly different. This question is a bit more complex since the answer is largely qualitative and is dependent upon the context in which the question is asked. Only 3% of the total experimental census blocks have suffered
Figure 11: Results
significant damage. These results demonstrate that, at the current time, default building structure is sufficient for flood loss estimations for this study area. However, although the differences in the flood loss estimation were minimal for most of the study area, there were areas that suffered increased economic losses. Since building counts were the only factor differentiating the two study groups, the increase in losses can be attributed to an increase in the number of structures for that area.
CHAPTER 6 CONCLUSIONS AND FURTHER RECOMMENDATIONS

It was mentioned, within Chapter 4, that failures in current policy lead to unnecessary flood-related loss. These failures were attributed to: failure to capture all contributing factors to flooding; shared governance; poor risk perceptions; and inadequate funding. HAZUS-MH was identified as a tool that lessens the magnitude of these factors by making flood losses apparent to planners; allowing for the identification of new hazard-prone areas and by achieving a flood hazard analysis that is cost affective and user-friendly. However these assumptions depend on whether HAZUS default data is accurate or not.

CONCLUSIONS

A methodology to assess the accuracy of HAZUS-MH default databases and to impart environmental planners with a methodology for assessing default data and a clearer understanding of the accuracy of default data was developed within this study and presented in Chapter 5. This methodology relied heavily on new data collection technologies and the local community participation. A HAZUS-MH hazards analysis was run for a selected study area. The purpose of this analysis was to capture the extent of flooding within the chosen 5 tract Livingston Parish region. The analysis was based on HAZUS-MH default information regarding the area’s hydrologic and topographic characteristics. This provided a good control environment to evaluate default building stock values.

The results demonstrated the differences between HAZUS default data and user-supplied data. The problem, as stated in Chapter 5, of whether current policy failures can
be lessened by implementing HAZUS-MH has been addressed. In order to impede policy failures, HAZUS-MH must be cost-effective; it must allow for the inclusion of human-related hazard formative factors; and it must increase the accuracy of risk perceptions. Out of the above-mentioned criteria, the cost effectiveness factor of HAZUS-MH is of highest concern. This question was addressed by determining whether environmental planners and managers should utilize HAZUS-MH default capabilities. If this is possible, then decision makers will have available, a cost-affective tool that reduces many of the causal factors for policy failures. This study has shown that, for many areas, a basic analysis is sufficient.

However, it would be beneficial for future users to obtain a greater understanding of the area that they are studying. Caution should be exercised while deciding between basic or advanced analyses. There was only a one-year time span between the time the orthoimages were taken and the census information collected. As the time span increases between time of analysis and time of default data acquisition, there will most likely be a larger difference between flood loss estimates. Thus, when determining whether to run a basic or advanced analysis, it would be beneficial to acquire information about the development and land use trends for that area prior to initial analysis. In many instances this information may be acquired from local tax assessors and permit office.

Of second-most importance is whether HAZUS-MH allows users to capture human-related hazard formative factors. This study demonstrated, by examining one of hazard formative factor, increased development, that the program can capture human-related hazard formative factors. An easy, cost effective methodology for incorporating changes in land use patterns and structures has been developed and presented. This
methodology can serve a multitude of functions including land surveys prior to future development and identification of unseen flood hazards.

The third criterion, whether HAZUS-MH can be used to enhance risk perceptions, is based upon the previously discusses criteria. Because HAZUS-MH is cost effective and accurate, it is the perfect tool for relaying factual information concerning risk to decision makers who can use that information in their future policy decisions.

**Summary of Contributions**

Through a thorough review of literature, this thesis identified population growth and urban development as the major contributing factors to an increased risk to flooding. It also identified the need for an easy methodology for incorporating urban growth into flood loss estimation. Additionally, the methodology used in this thesis illustrates the important role that newer technologies can play in land characterization. It demonstrates how various GIS concepts and techniques can be applied for analyzing flood hazards and how they can be employed as an effective tool for environmental managers and planners. HAZUS-MH was determined to be the most suited software for such an analysis. Two levels of HAZUS-MH flood loss estimations, one that takes into account, new development and one that does not, were conducted to determine whether the new data made a significant difference in flood loss estimations. The results show that although there is a significant difference in isolated areas of the study region, overall differences are not significant.

**FURTHER RECOMMENDATIONS**

The results derived during this thesis study illustrate the important role HAZUS-MH will play in future environmental planning and policy making. HAZUS was
developed as an easy-to-use tool that can effectively serve a large arrange of people with various needs and expertise. Since economic losses were different for only small areas, this study demonstrates that in some cases, a basic analysis is sufficient. Consequently, the study shows that planners have at their disposal, an easy tool for assessing flood related risks and damages.

It is also important to mention that this study assessed only one aspect of the HAZUS-MH database. However, further evaluative research on HAZUS default databases is needed. Alterations to different components of the default databases are likely to carry varying weight depending on the hazard that is being assessed. For example, building type is most likely more critical for a HAZUS-MH Earthquake loss estimation than for flood loss estimation. However, structure elevation is most likely more critical for flood loss estimations. Consequently further research is needed on the degree of effect various database inventories have on flood loss estimations.

In addition to outlining a methodology for assessing flood loss estimation technology, a possible new application for HAZUS-MH was discovered. By comparing default building stock data from 2000 to current data on the existent built environment, areas of significant growth were uncovered. This, in itself, could be very helpful in identifying previously unseen hazard areas.
REFERENCES


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VITA

Jennifer Meyer was born in Norman, Oklahoma, on June 7, 1980. She graduated from Louisiana State University in December of 2002 with a Bachelor of Arts degree in English. She received a Graduate Assistantship at LSU graduate school in the Department of Environmental Studies working for Dr. John Pine. Ms. Meyer is currently a candidate for a Master of Science in environmental sciences to be awarded on December 17, 2004.