Chapter 12.
Direct Social Losses – Casualties

12.1 Introduction

During the Flood Model methodology development, casualty data was collected and analyzed to assess the feasibility of incorporating a flood casualty model. The data collection and review are discussed in Section 12.2. Available casualty data for flood events was essentially limited to fatalities. That is, data on flood-related injuries was not widely available. Further, review of the fatality data indicated that drowning dominated the data for cause of death. Accordingly, a fatality model for drowning deaths in floods was proposed, but its implementation was deferred by the Flood Model Oversight Committee. The model development work done to date and documented here will be used as a basis for future methodology development for eventual inclusion in the HAZUS Flood Model.

The Oversight Committee deferred the implementation of a flood casualty model because the committee felt that the methodology, while valid, was based on only a few storm events and was therefore not validated with the same level of scientific vigor as the rest of the Flood Model. Furthermore, the Oversight Committee believed that casualties related to flooding do not create the same significant impact on the medical infrastructure as those associated with earthquakes. Additional data collection following future flood events would facilitate development of more rigorous models, and is strongly recommended. In anticipation of future casualty model implementation, Section 12.3 provides suggestions for the potential form of casualty models for the Flood Model. Finally, the Flood Model Oversight Committee recommended that the Flood Model software include a PDF reference file that contains a discussion of flood-related casualties (provided here as Section 12.3) for the Flood Model users.

12.2 Summary of Collected Casualty Data

Available casualty data from U.S. floods, including the well-documented casualties in Houston, Texas associated with Tropical Storm Allison (June 2001), were reviewed to assess the types and causes of casualties in flooding. Primary data sources include the Morbidity and Mortality Weekly Report (MMWR), published by the Center for Disease Control (CDC), and various publications of the Texas Department of Health, Bureau of Epidemiology.

Data reviewed include both pure flood events (e.g., 1993 Mississippi floods) and hurricane events, which may be accompanied by heavy rainfall and significant inland flooding. For hurricane events, wind-related casualties are distinguished from flood-related casualties by cause. For example, deaths caused by fallen trees are considered wind-related, while drowning is generally flood-related. The eighteen events for which casualty data were reviewed are listed in Table 12.1. For each of these events, the total number of fatalities is provided in Table 12.2, and Table 12.3 provides a breakdown of all deaths by their cause. As shown, heavy death tolls occurred both in hurricane events (Floyd, Hugo, and Andrew) and flood events (Midwestern floods, Central Texas storms and Tropical Storm Alberto). Drowning was the cause of more than half of the deaths in all events (54%).

Table 12.1 Potential Flood Casualty Events

Event Name/Type	Date	Area Impacted	Notes
Tropical Storm Allison	June, 2001	Harris County, TX	Rapid rise flooding
Hurricane Floyd	September 16, 1999	North Carolina	Hurricane with significant inland flooding
Storm-related flooding	October 17, 1998	Central Texas	Rapid rise flooding
Hurricane Georges	September 21, 1998	Puerto Rico	
Hurricane Marilyn	September 15, 1996	US Virgin Islands & Puerto Rico	
Hurricane Opal	October 4, 1996	Florida, Alabama, Georgia, North Carolina	
Storm	May 5, 1995	Dallas Co., TX	Rapid rise flooding
Flood	October, 1994	Texas	Rapid rise flooding
Tropical Storm Alberto	July 4, 1994	Georgia	Tropical storm with significant inland flooding
Midwestern Floods	Summer/Fall, 1993	Missouri	
Midwestern Floods	Spring/ Summer 1993	Iowa	
Hurricane Andrew	August 24-26, 1992	Florida, Louisiana	
Nor'easter	December, 1992	CT, DE, MD, MA, NJ, RI, NY (Suffolk, Westchester and Nassau Counties, and 5 cos. In NY City), and Philadelphia Co PA.	
Hurricane Hugo	September 21, 1989	South Carolina	
Hurricane Hugo	September 18, 1989	Puerto Rico	
Hurricane Gloria	September 27, 1986	Rhode Island, Connecticut	
Hurricane Elena	September 2,1986	Mississippi	

Table 12.2 Fatalities, By Event

Event Type	Total Number of Deaths
Hurricane Floyd	52
Midwestern Flood - Missouri	43
Hurricane Hugo – South Carolina	35
Hurricane Andrew- Florida	33
Storm – Central Texas, 1998	31
Tropical Storm Alberto	30
Hurricane Opal	27
Tropical Storm Allison	24
Storm – Dallas, Texas	20
Flood – Texas, 1994	19
Hurricane – Louisiana	17
Hurricane Marilyn	10
Hurricane Hugo – Puerto Rico	9
Hurricane Georges	8
Hurricane Gloria	5
Nor'easter	4
Hurricane Elena	3
Midwestern Flood - Iowa	1
Total Number of Deaths	371

Table 12.3 Deaths, By Cause – All Events

Cause category	Total Number of Deaths
Drowning (in MV)	119
Drowning (other)	38
Drowning (on boat)	20
Drowning (as pedestrian)	15
Drowning (in home)	9
Sub-total: All drownings	***201 (54%)***
Trauma (inc. crush)	55
Cardiac	26
Electrocution	25
MVA	15
Fire/Burns/Smoke Inhalation	20
Asphyxiation	9
Carbon Monoxide poisoning	4
Other	12
Unknown	4
Sub-total: Non-Drowning	***170 (46%)***
TOTAL: All Causes	***371***

Of the eighteen events, only six events were "flooding" events for which both exposed population estimates and fatality data were available. These events, which may all be categorized as "rapid rise" or "very rapid rise" flooding, account for 173 of the fatalities within the overall database (47%). Only these events were included in subsequent analysis:

- Tropical Storm Allison (24 deaths)
- Hurricane Floyd (52 deaths)
- Storm-related flooding in Central Texas in 1998 (31 deaths)
- Storm-related flooding in Dallas County, Texas in 1995 (20 deaths)
- Flooding in Texas in 1994 (19 deaths)
- Midwestern Floods (27 deaths)

Table 12.4 provides a breakdown of deaths by their cause for the final six flooding events included in the analysis. As shown, drowning was the cause of more than 77% of deaths in these events. Because drowning is the primary cause of death in floods, it was proposed that the HAZUS Flood casualty model focus on drowning deaths in "rapid rise" or "very rapid rise" flooding.

Table 12.4 Deaths, By Cause – Flood Events Only

Cause Category	Total Number of Deaths
Drowning (in MV)	86
Drowning	21
Drowning (as pedestrian)	15
Drowning (on boat)*	7
Drowning (in home)	5
Sub-total: All drownings	***134 (77.5%)***
MVA	9
Cardiac	9
Trauma	7
Electrocution	7
Hypothermia	2
Fire	2
Fall	1
Carbon Monoxide poisoning	1
Asphyxiation	1
Sub-total: Non-Drowning	***39 (22.5%)***
TOTAL: All Causes	***173***

** These drownings occurred during Hurricane Floyd and are wind/rain-related drownings, rather than flood-related drownings*

It should be noted that data on non-fatal injuries was available for just six events total, and included data for just one flood event. Accordingly, the available data are insufficient to develop a non-fatal injury model for flood.

12.3 Proposed Form of Casualty Models for Eventual Inclusion into HAZUS Flood

It is suggested that the NIBS Flood Module consider three types of flood casualties, as follows:

- Casualties that occur in the floodwaters -- these casualties would be evaluated in aggregate at the community level. That is, injury and death rates per 100,000 population would be applied to the "exposed community." These casualty rates would depend on the rate of inundation (tentatively characterized into 3 classes: rapid/very rapid rise, moderate speed rise, slow rise), as well as selected demographic characteristics (Male/female, age, etc). The rates would include a reduction factor if the community has a swift-water rescue capability.

- Casualties that occur within buildings -- these casualties would be evaluated for two time frames: during the flooding, and during flood clean up. Building casualties during flooding depend on the amount of warning, flood depth or damage, and occupancy type. Building casualties during clean up depend on flood depth or damage, occupancy type, and electric power service interruption.

- Rain-related motor vehicle casualties -- in addition to the casualties that occur in the floodwaters, rain-related motor vehicle accident injuries and deaths are quantifiable. Previous research conducted by the UCLA School of Public Health, Center for Public Health and Disasters focused on the El Nino phenomenon provided source data for the development of casualty rates (per 100,000 population) based on low, medium and high rainfall rates. These casualty estimates would be optional, and the user would be expected to select the appropriate rainfall category.

12.4 Documentation Displayed in the HAZUS®*MH* Flood Model

Flooding of all types (riverine, flash flooding, coastal, fluctuating lake levels and other sources) is a major hazard in the U.S., accounting for the single largest total property losses, and major life loss, of any one hazard. Flooding has a long history in the U.S., including the infamous Johnstown flood of 1889[1], and the Mississippi floods of 1927. Recent floods have included the Mississippi Flood of 1993, the Northwest floods of 1996, and the North Dakota Red River flood of 1997. Figure 12.1 and Figure 12.2 show U.S. fatalities due to flooding, with an increasing trend that, if normalized for population growth, appears to be relatively steady (FEMA, 1997).

An effort has been made to develop methodology to estimate casualties due to flooding. Because there is limited data related to casualties beyond fatalities (i.e., injuries requiring hospitalization, minor injuries), the Flood Model Oversight Committee and FEMA decided to defer the estimation of casualties while further data collection and methodology development could continue. Below are two charts that can help the user asses the likelihood of incurring casualties during a given flood event. It should be noted that the United States averages approximately 100 deaths per year due to flooding, although this has been increasing over the last few years.

1 Johnstown PA, the victim of a disastrous flood in 1889, is one of the greatest natural disasters in U.S. history. At 3:10 PM on May 31, the South Fork Dam, a poorly maintained earthfill dam holding a major upstream reservoir, collapsed after heavy rains, sending a great wall of water rushing down the Conemaugh Valley at speeds of 20 to 40 miles per hour (32 to 64 km/h). At 4:07 PM, the 30-foot high wall of water smashed into Johnstown, which lay on the floodplain of the Conemaugh River. The flood swept away most of the northern half of the city, killing 2,209 people and destroying 1,600 homes. After another disastrous flood in 1936, a flood-control program was completed (1943), but this did not prevent heavy flooding in July 1977 in which 68 people were killed.

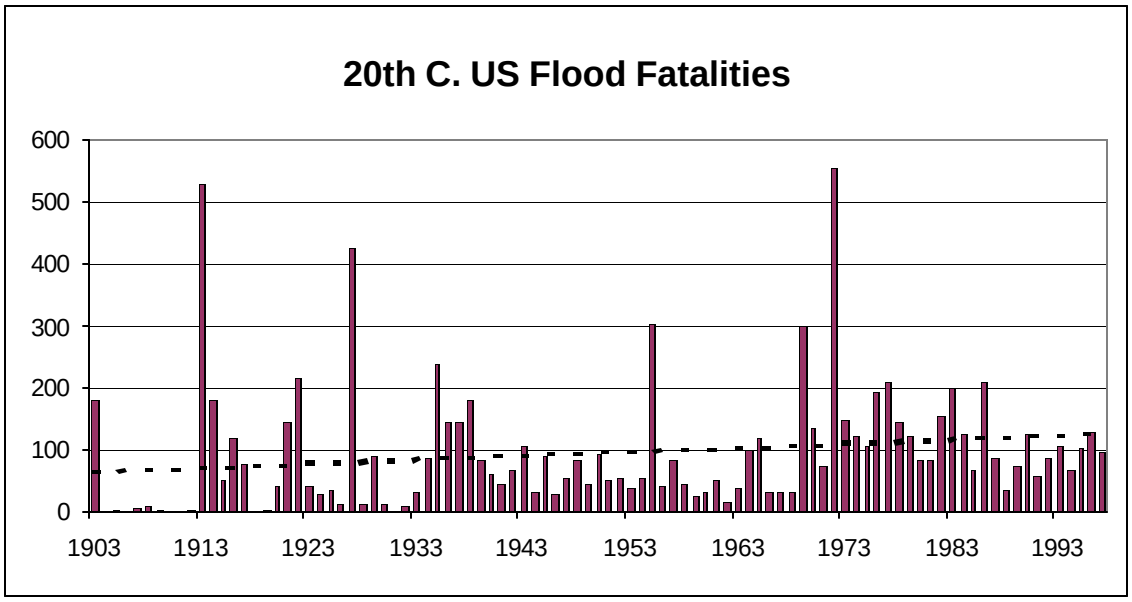

Figure 12.1 20th Century U.S. Flood Fatalities

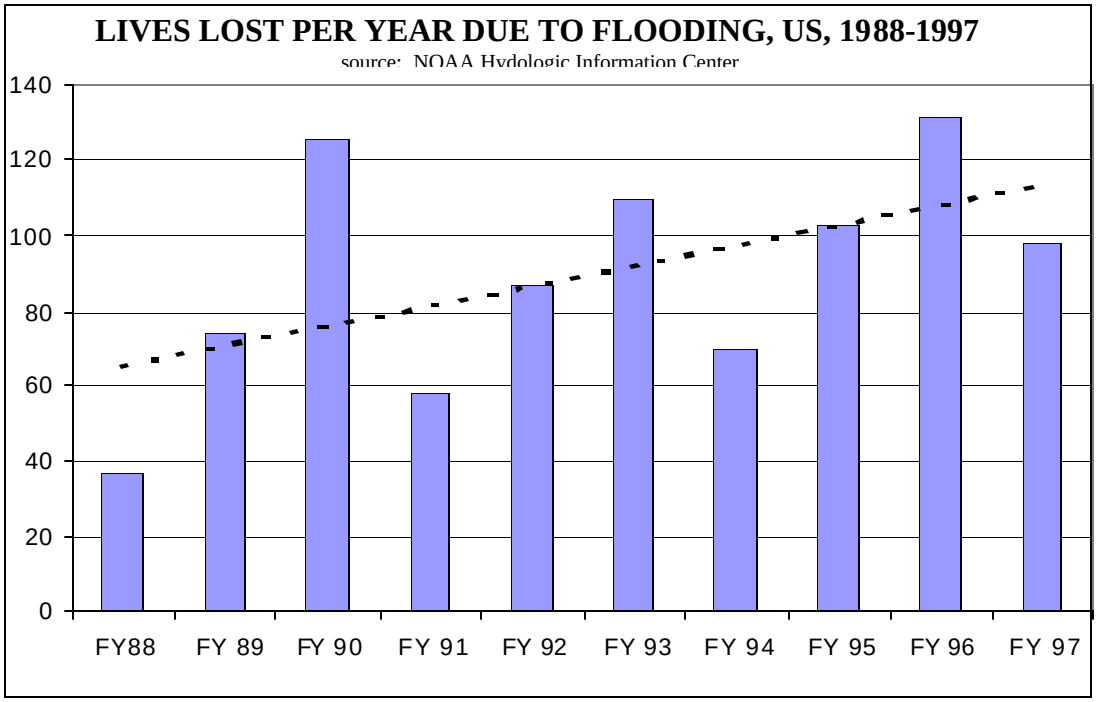

Figure 12.2 U.S. Flood Fatalities, 1988-1997

12.5 References

1. CDC (1986), "Epidemiologic Notes and Reports Hurricanes and Hospital Emergency-Room Visits -Mississippi, Rhode Island, Connecticut", MMWR 1986; 34(51-52); 765-770.

2. CDC (1989a), "Deaths Associated with Hurricane Hugo - Puerto Rico", MMWR 1989; 38(39); 680-682.

3. CDC (1989b), "Update: Work-Related Electrocutions Associated with Hurricane Hugo - Puerto Rico", MMWR 1989; 38(42); 718-725.

4. CDC (1989c), "Medical Examiner/Coroner Reports of Deaths Associated with Hurricane Hugo - South Carolina", MMWR 1989; 38(44); 754,759-762.

5. CDC (1992), "Preliminary Report: Medical Examiner Reports of Deaths Associated with Hurricane Andrew - Florida, August, 1992", MMWR 1992; 41(35); 641-644.

6. CDC (1993a), "Surveillance of Deaths Attributed to a Nor'easter - December, 1992", MMWR 1993; 42(01);4-5

7. CDC (1993b), "Public Health Consequences of a Flood Disaster - Iowa, 1993", MMWR 1993; 42(34); 653-656.

8. CDC (1993c), "Flood-Related Mortality - Missouri, 1993", MMWR 1993; 42(48); 941-943

9. CDC (1993d), "Injuries and Illnesses Related to Hurricane Andrew - Louisiana, 1992", MMWR 1993; 43(13); 242-243, 250-251

10. CDC (1993e), "Morbidity Surveillance Following the Midwest Flood - Missouri, 1993", MMWR 1993; 43(41); 797-798.

11. CDC (1994), "Flood-Related Mortality - Georgia, July 4 - 14, 1994", MMWR 1994; 43(29); 526-530.

12. CDC (1996a), "Deaths Associated with Hurricanes Marilyn and Opal - United States, September-October 1995", MMWR 1996; 45(2); 32-38.

13. CDC (1996b), "Surveillance for Injuries and Illnesses and Rapid Health-Needs Assessment Following Hurricanes Marilyn and Opal, September-October 1995", MMWR 1996; 45(4); 81-85.

14. CDC (1998), "Deaths Associated with Hurricane Georges - Puerto Rico, September, 1998", MMWR 1998; 47(42); 897-898

15. CDC (2000a), "Storm-Related Mortality - Central Texas, October 17-31, 1998", MMWR 2000; 49(07); 133-135

16. CDC (2000b), "Morbidity and Mortality Associated With Hurricane Floyd - North Carolina, September-October 1999", MMWR 2000; 49(17); 369-372.

17. FEMA (1997), Multihazard Identification and Risk Assessment, Federal Emergency Management Agency, Washington DC: U.S. Government Printing Office.

18. NOAA (2001), "Service Assessment - Tropical Storm Allison Heavy Rains and Floods, Texas and Louisiana, June, 2001", U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, Silver Spring, Maryland.

19. Texas Department of Health (1999), "Storm-Related Mortality in Central Texas, October 17-31, 1998: An Epidemiologic Investigation by the Injury Epidemiology And Surveillance Program".

20. Texas Department of Health (1995), "Storm-Related Mortality, Dallas County, Texas, May 5-12, 1995".

21. Texas Department of Health (1994), "Flood-Related Mortality, - Southeast Texas October 16-25, 1994".