



Identification and Analysis of Factors Affecting Emergency Evacuations

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Background & Purpose

- **NRC-sponsored study to investigate large-scale evacuations occurring on U.S. mainland since 1990**
- **Purpose is to provide insight into factors affecting the efficacy of emergency evacuations**
- **First project of its kind since 1989**

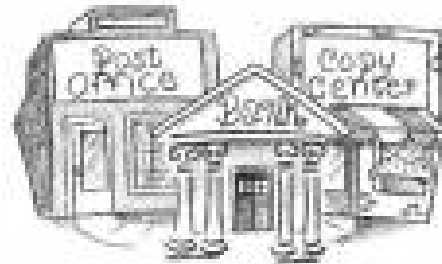


Approach

- **Perform extensive background search on evacuations in general, as well as on specific evacuation experiences**
- **Identify “universe” of evacuation incidents meeting specified criteria**
- **Conduct 50 representative case studies**
- **Develop and apply method of evaluating evacuation success**

Specific Evacuation Criteria

- **U.S. mainland public evacuation**
- **Occurred after January 1, 1990**
- **Evacuation >1,000 people**
- **Evacuation from more than a single building or industrial facility**





Research


- **Books, journals, conference proceedings**
- **News archives (AP, UPI, etc.)**
- **Government websites (NTSB, NRC, FEMA, DOT, DOD, NOAA, ARC, EPA)**
- **Professional organizations (API, NFPA)**
- **University websites (Dartmouth, U. of Delaware, U. of Colorado, FSU, etc.)**





Review of Numerous Databases

- **EPA Accidental Release Information Program (ARIP)**
- **DOD Hazardous Materials Information Resource System (HMIRS)**
- **Chemical Incidents Reports Center (CIRC) Database**
- **ATSDR Hazardous Substances Emergency Events Surveillance (HSEES)**
- **FRA Railroad Accident/Incident Reporting System (RAIRS)**



Extensive Research Yielded the Following Results

- **230 evacuation incidents identified that meet criteria in 12.5-year period (1/1/90 – 6/30/03)**
- **Considering post-1997 events, an evacuation meeting the criteria occurs every 2 weeks**
- **Data and information prior to 1997 was not as readily available**

EVACUATIONS IN THE U.S.



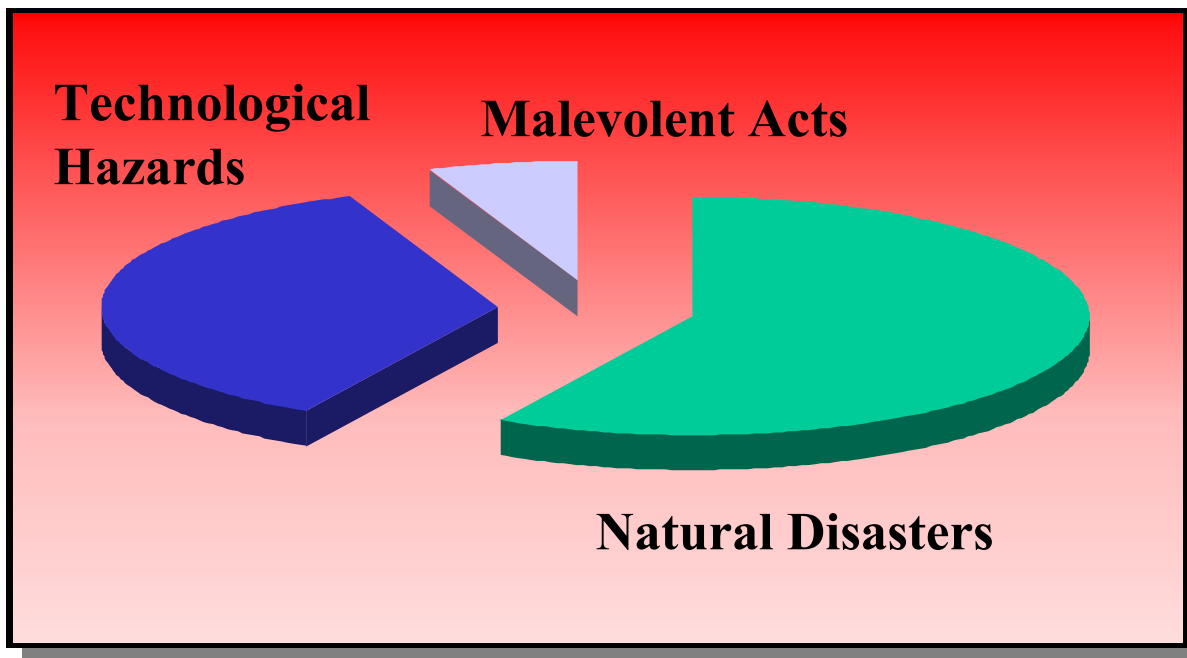


Each Incident Profiled By...

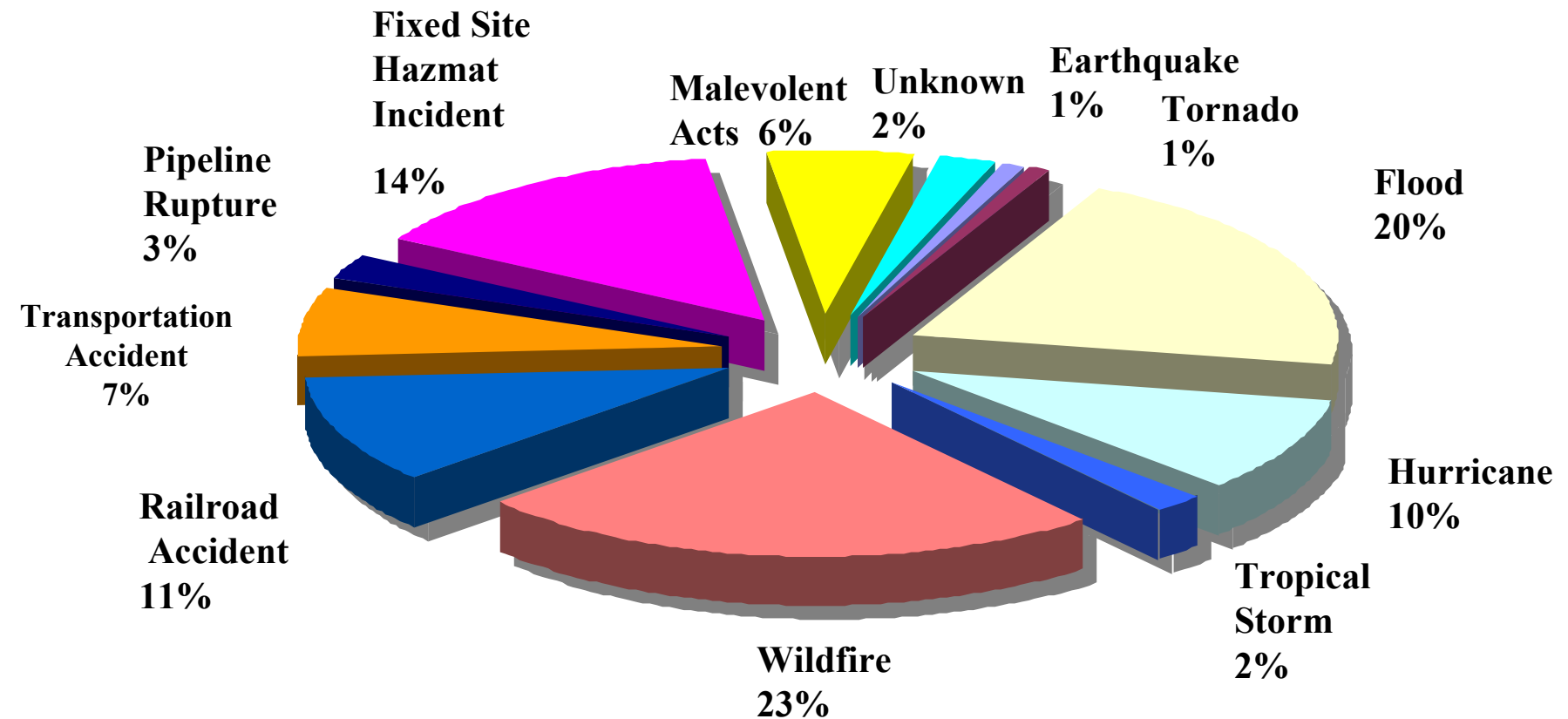
- **Size of evacuation**
- **Type of incident**
(natural, technological,
or malevolent acts)
- **Category of hazard**
(hurricane, railroad
accident, etc.)
- **Year of occurrence**
- **Special issues**
- **Community size**
- **Region in U.S.**

Evacuation Universe Cross-Section

- 133 (58%) due to natural disasters
- 84 (36%) due to technological hazards
- 13 (6%) due to malevolent acts

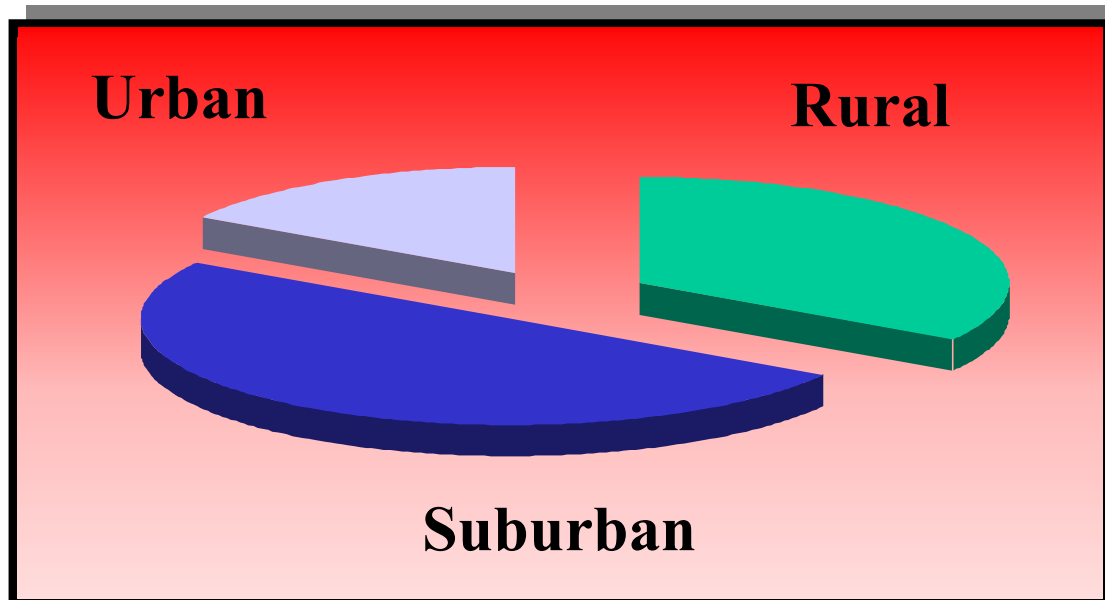


Principal Causes of Large-Scale Evacuations in the U.S.

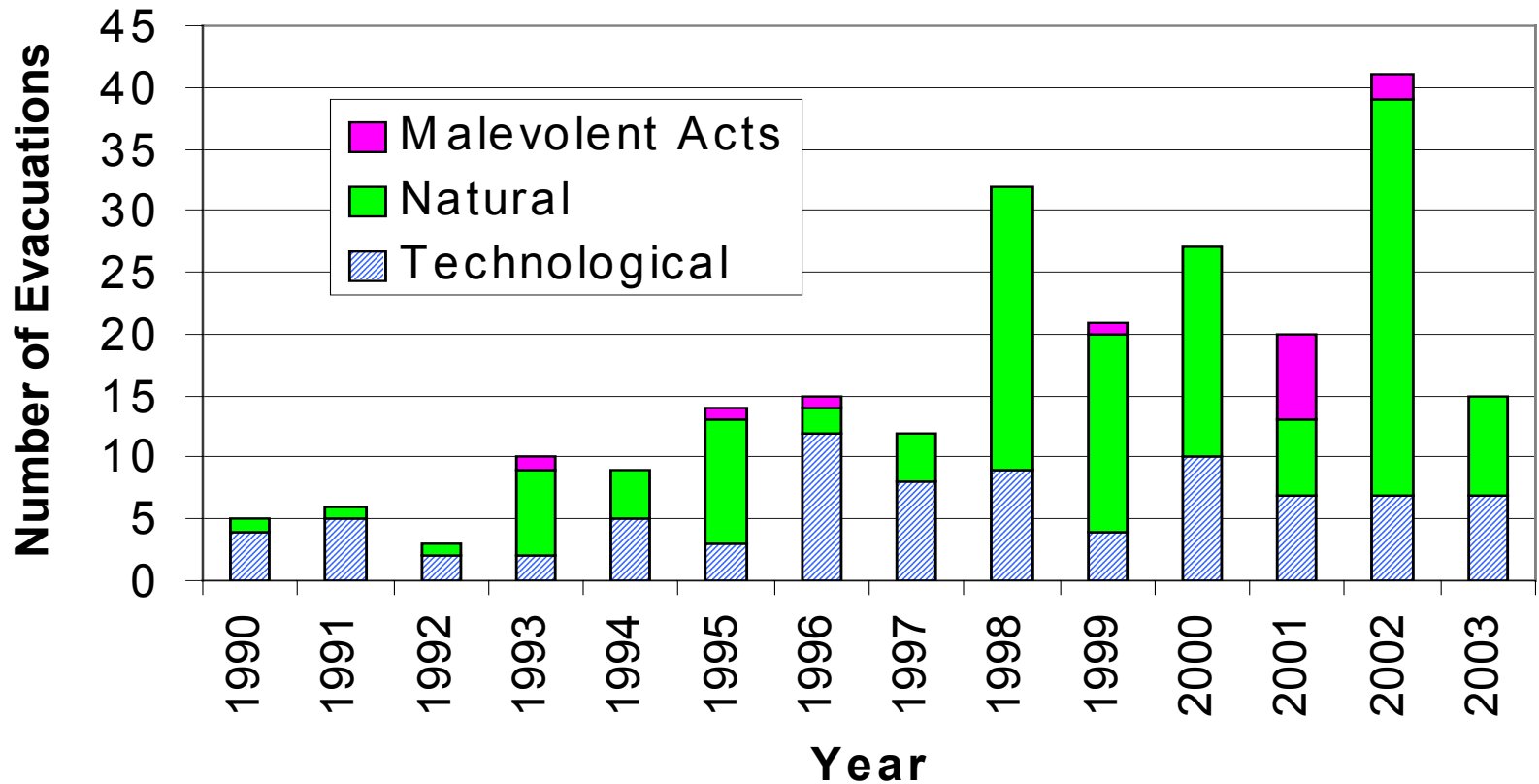


Evacuation Universe: Community Context

- 77 (34%) Rural
- 116 (50%) Suburban
- 37 (16%) Urban

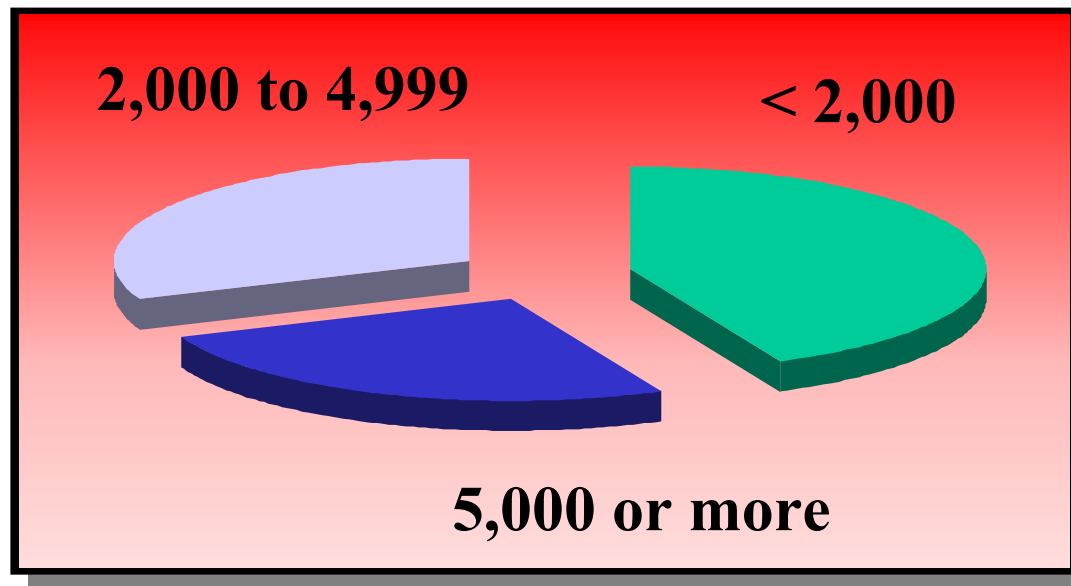


Evacuations by Year of Occurrence



Evacuation Universe: Evacuation Size

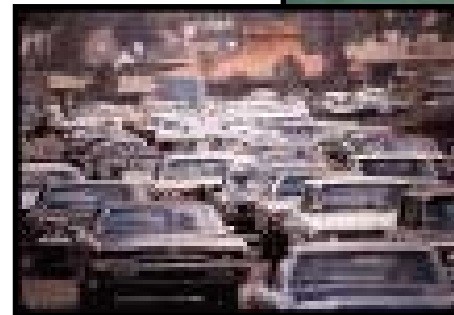
- 100 (43%) involved <2,000 people
- 60 (26%) involved 2,000 to 4,999 people
- 70 (31%) involved 5,000 or more people



Evacuation Universe: Special Issues

24% involved a special issue including:

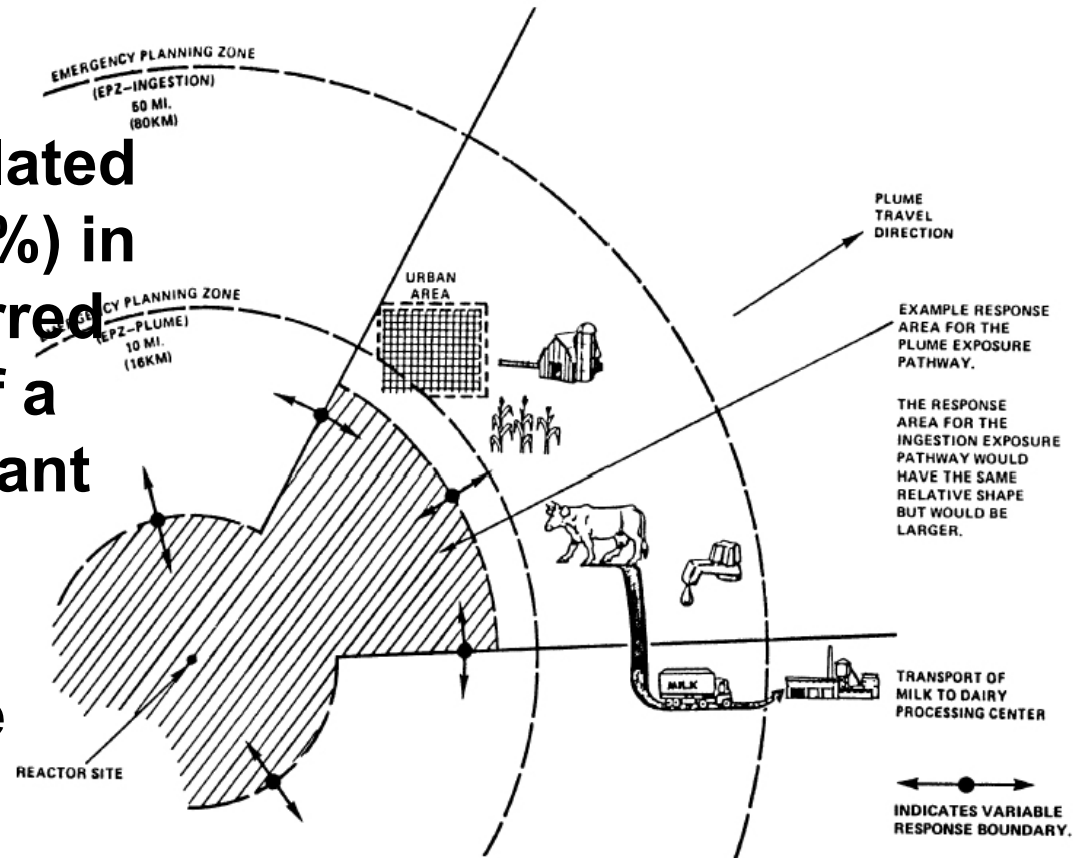
- **Evacuation of special facilities**
 - nursing homes, hospitals, prisons, or schools
- **Other evacuation methods**
 - air or boat
- **Unusual circumstances**
 - shadow evacuations, traffic issues, or law enforcement issues



Evacuation Universe: Emergency Planning Zone

6 non-nuclear-related
evacuations (2.6%) in
“universe” occurred
within the EPZ of a
nuclear power plant

4 of the 6 were
analyzed as case
studies





Case Study: Emergency Planning Zone (EPZ)

Four cases analyzed were in an EPZ:

- Warehouse chemical spill in Charlotte, NC**
- Hurricane Andrew in Miami-Dade Co., FL**
- 2 Hurricane Floyd evacuations in SE FL**



Total Ranking & Case Study Selection

- **“Total Ranking” was sum of products of weights & ratings for each factor**
- **Total rankings were then normalized to a 100-point scale (“Normalized Ranking”)**
- **50 representative cases selected from top 100 ranked incidents; selection based on ranking & professional judgment**



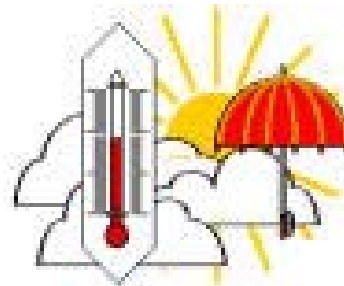
Ranking the “Universe”

FACTOR	WEIGHT	RATING
Number of Evacuees	5	3 = >5000; 2 = 2,000-5,000; 1 = <2000 evacuees
Preparedness Level	5	3 = Within an EPZ; 2 = Within a hurricane prone region ; 1 = None of above
Hazard Type	3	3 = Technological Hazard or Malevolent Act; 1 = Natural Disaster
Year	3	3 =2000-2003; 2 = 1997-1999; 1 = 1990-1996
Special Issues	3	3 = Special issues encountered; 1 = Few or no special issues
Community	1	3 = Urban; 2 = Suburban; 1 = Rural
Region of U.S.	1	3 = North, South, or Midwest; 1 = West, Southwest, or Northwest

Case Study Questionnaire

Questionnaire contained >80 questions in four major areas:

- **Community Context** (general community info, history of emergencies, emergency preparedness)
- 2. Threat Conditions** (type of hazard, time of day, road conditions, unusual circumstances)



Case Study Questionnaire (Concluded)

- **Consequences**
(number evacuated, injured, killed, cost information)
- 4. Emergency Response**
(decision-making, communications, notification and warning, traffic movement and control, sheltering, law enforcement, re-entry)



Evacuation Case Studies



Eunice, LA Train Derailment (2000)
Technological Hazard – Chemical Spill
>2,000 Evacuated

Hanford, WA Wildfire (2000)



Natural Disaster
>2,500 Evacuated

Hurricane Floyd (1999)



Natural Disaster
>1.7M evacuated

Evacuation Case Studies (Continued)

World Trade Center “9-11” (2001)



300,000 Evacuated
Some evacuated by boat

60,000 Evacuated



**Centennial Olympic Park
Bombing, Atlanta (1996)**

Evacuation Case Studies (Concluded)

Baltimore, MD Tunnel Fire (2001)



**Baseball stadium evacuated
Downtown closed for days**

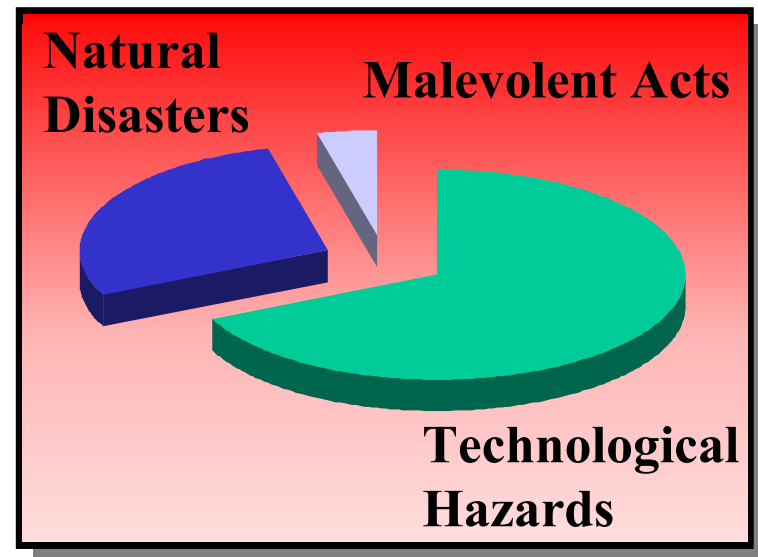
Cerro Grande Fire Evacuation, Los Alamos, NM (2000)



**Fire started from controlled burn
Entire town evacuated**

Case Study Cross-Section

- 50 case studies
- 33 (66%) due to technological hazards
- 14 (28%) due to natural disasters
- 3 (6%) due to malevolent acts





Case Study: Community Context

- **72% involved suburban communities**
- **42% had manufacturing and industry as their main economic base**
- **82% involved residential areas**



Case Study: Issues Considered

- **Emergency communications**
- **Traffic movement & control**
- **Shadow evacuations**
- **Citizen action**
- **Evacuation decision-making**
- **Re-entry**
- **Law enforcement**
- **Notification of response/officials**



Method of Evaluating Case Studies

- **Factors Considered:**
 - Direction and control (evacuation decision-making process)
 - Emergency communications
 - Notification of response personnel and local officials
 - Citizen warning
 - Traffic movement and control
 - Law enforcement
 - Re-entry



Regression Analysis Description

- **Statistical technique to find relationships between a dependent variable (success score) & one or more independent variables (from questionnaire)**
- **Each variable in questionnaire was compared to evacuation score using an ordinal logit model which is a generalized linear model**



Regression Analysis Description (Concluded)

- **Chi-squared (probability or “p”) value indicates variable’s association to success score:**
 - **If $p < 0.01$, highly statistically associated to success score**
 - **If $p 0.01 - 0.05$, statistically associated to success score**
 - **If $p 0.05 - 0.10$, marginally statistically associated to success score**



Correlation Analysis

- **Correlation coefficient (r) is a statistical measure of the interdependence of two or more random variables**
- **Variables with $|r| > 0.30$ are considered statistically significantly correlated; higher $|r|$ value, more significant the correlation**



Hazard Type

- **Hazard type statistically associated to evacuation success score**
- **Increased probability of evacuation issues for natural disasters**
- **Natural disasters generally involve larger land areas & more time between start of hazard & decision to evacuate than technological hazards or terrorism events**
- **After adjusting for hazard type, these two variables (i.e., elapsed time and land area) no longer associate to evacuation success score**



Multiple Ordinal Logistic Regression Analysis

- **Since hazard type is often associated with other variables, results were adjusted for hazard type by performing a multiple ordinal logistic regression analysis**
 - **In logistic regression, dependent variable is qualitative (rather than continuously variable) & likelihood functions are used to find best relationship**
 - **In multiple regression, dependent variable depends on more than a single independent variable**



Case Studies

Sept-99	Miami-Dade, FL	Hurricane Floyd	270,403 evacuated
Sept-99	S-Broward, FL	Hurricane Floyd	374,144 evacuated
July-01	Riverview, MI	ATOFINA Fixed Site Hazmat	6,000 evacuated
Aug-92	Miami-Dade, FL	Hurricane Andrew	650,000 evacuated
Sept-99	Central Florida, FL	Hurricane Floyd	665,969 evacuated
July-98	Mims, FL	Mims Wildfire	16,000 evacuated
Sept-02	Charlotte, NC	Charlotte Fixed Site Hazmat	1,000 evacuated
July-01	Baltimore, MD	CSX Train Fixed Site Hazmat	10,000 evacuated
Sept-01	Lower Manhattan, NY	World Trade Center Terrorism	300,000 evacuated
July-96	Atlanta, GA	Centennial Olympic Park Bombing	60,000 evacuated
Oct-95	Bogalusa, LA	Gaylord Tank Car Railroad Accident	3,000 evacuated
May-00	Eunice, LA	Union Pacific Railroad Accident	2,000-3,000 evacuated
May-03	Brandon, FL	Pipeline Rupture	2,000 evacuated
Feb-03	Slocomb, AL	Mathis Farm Supply Fixed Site Hazmat	3,500 evacuated
Mar-01	Forest, MS	Choctaw Maid Plant Fixed Site Hazmat	2,000 evacuated



Case Studies (Continued)

Aug-00	Hugo, OK	Truck Accident	2,000-2,500 evacuated
July-99	Iowa City, IA	Procter & Gamble Fixed Site Hazmat	5,000 evacuated
Jan-98	Maysville, KY	Cargill Chemical Plant Fixed Site Hazmat	2,500 evacuated
May-00	Los Alamos, NM	Cerro Grande Wildfire	12,000 evacuated
June-02	Deadwood, SD	Deadwood Wildfire	15,000 evacuated
May-00	White Rock, NM	Cerro Grande Wildfire	7,000 evacuated
June-02	Douglas County, CO	Hayman Wildfire	5,500 evacuated
July-97	Flora, MS	Railroad Accident	6,000 evacuated
July-98	Flagler County, FL	Wildfire	45,000 evacuated
Oct-01	Alexandria, LA	LSU Anthrax Hoax	2,000 evacuated
Mar-00	Sterling Heights, MI	Fixed Site Hazmat	2,400 evacuated
May-02	Pottersville, MI	Grand Trunk Railroad Accident	2,200 evacuated
Dec-00	Oshkosh, WI	Railroad Accident	2,300 evacuated
Sept-02	Farragut, TN	Norfolk Southern Railroad Accident	3,000 evacuated
Dec-95	North Attleboro, MA	Pipeline Rupture	40,000 evacuated



Case Studies (Continued)

May-02	Arlington, WA	Twin City's Plant Fixed Site Hazmat	1,500 evacuated
Mar-94	Prichard, AL	Railroad Accident	2,000 evacuated
June-92	Superior, WI	Burlington Northern Railroad Accident	40,000 evacuated
June-00	Benton City, WA	Hanford Wildfire	2,200 evacuated
Nov-00	Scottsbluff, NE	Burlington Northern Railroad Accident	5,000 evacuated
Oct-01	Morro Bay, CA	Ammonia Leak Fixed Site Hazmat	3,500 evacuated
Nov-98	Louisville, KY	Louisville Cargo Fixed Site Hazmat	2,400 evacuated
April-94	Balch Springs, TX	Pesticide Tanker Explosion	5,000 evacuated
Oct-91	Oakland, CA	East Bay Hills Wildfire	20,000-30,000 evacuated
Nov-97	Appleton, WI	Railroad Accident	5,000 evacuated
Dec-97	Bath, PA	Keystone Cement Fixed Site Hazmat	>1,600 evacuated
Oct-98	Pascagoula, MS	Pascagoula Propane Fixed Site Hazmat	>1,500 evacuated
Sept-98	Bossier City, LA	Transportation	~2,000 evacuated
Aug-97	Chicago, IL	Paint Plant Fixed Site Hazmat	2,500 evacuated
May-98	Mason City, IA	Mason City Chemical Fixed Site Hazmat	3,600 evacuated



Case Studies (Concluded)

Aug-92	Odessa, TX	Champion Inc. Fixed Site Hazmat	27,000 evacuated
May-91	Henderson, NV	Chlorine Leak Fixed Site Hazmat	~7,000 evacuated
Nov-91	Shepherdsville, KY	Railroad Accident	1,000 evacuated
June-02	Show Low, AZ	Rodeo-Chedeski Wildfire	20,000 evacuated
July-02	Cave Junction, OR	Biscuit Wildfire	1,000 evacuated



Project Status

- **Quantitative, qualitative & statistical analyses are being conducted**
- **Related NUREG, with results, summaries & recommendations is being drafted & will be delivered to the NRC at the end of this calendar year**