Recent Advances in Life-Loss and Flood Damage Estimation for Dam and Levee Failures

Maged A. Aboelata, Ph.D., P.E., CFM
Presentation Outline

- Why estimate life loss?
- LIFESim and HEC-FIA Methodologies
- Similarities and differences
- Future Development
Why Estimate Life Loss?

- Dam Failure Consequence Analysis
- Risk reduction measures
- Cost effectiveness/justification
Background

- **Friedman (1975)**
  - Function of the number of damaged dwellings and flood type (normal or flash)

- **Petak and Atkinson (1982)**
  - Loss of life is only due to structure damage.

- **Paté-Cornell and Tagaras (1986)**
  - 90% in the path of the flood wave and 10-15% in the rest of inundation area.
  - Factors are subjectively adjustable.

- **USBR model (Brown and Graham, 1988)**
  - Insufficient warning (function of Par.)
  - Sufficient warning.
  - Second version added warning time.

- **Stanford/FEMA Model**
  - Different functions for residential and commercial districts.
  - Function of Par, flood depth, and river mile.
  - Modified by IWR(1986) to include warning time instead of river mile.

  - Function of population, warning time, and flood severity
Limitations of Statistical Methods

- Depending on limited number of factors.
- Large-scale averaging for flooding characteristics.
- Lumping of population at risk.
- Ignoring dynamics of warning and evacuation.
- Depending on regression for various events.
Factors Affecting Life-Loss

- **PAR Location**
  - Downstream distance
  - Elevation

- **Warning System**
  - Coverage
  - Effectiveness throughout the day

- **Mobilization**
  - Believability
  - Knowledge

- **Roads**
  - Capacity
  - Destinations
Modeling System Overview

- Initial Development at USU funded by US Army Corps of Engineers, ANCOLD & USBR

- Modular, Spatially-distributed, Dynamic Simulation System

Diagram:

1- HAZUS Data Module
2- Data Preparation Module
3- Loss of Shelter Module
4- Warning & Evacuation Module
5- Loss of Life Module
6- Population Tracking Diagram

User input:
- Time(s) of day
- Warning system
- Damage criteria

Summary & detailed results tables

HAZUS DBase

Warning curves

Population distribution

Evac. Routes D&V

Depth(time)

Velocity(time)

Loss of shelter Type/height/level

Population redistribution

Read flood zone categories

Loss of life/ census block

DEM

Census blocks

Roads

Shelters
Hurricane Katrina Life-Loss Modeling

- USACE Interagency Performance Evaluation Task (IPET) Force.
- Estimate loss of life associated with hurricane-related future flood events.
- Pre- and post-event analysis:
  - 27 drainage basins.
  - Incremental life-loss.
  - Uncertainty analysis.
LIFESim Modifications

- Assumed evacuation rate.
- Damage by submergence.
- Age-dependent vertical evacuation.
- Variable first floor level.
- Rescue of survived PAR.
- Model Calibration
Wolf Creek Dam

- Owned and operated by the USACE
- Operation restrictions during repair
- Impact assessment for over 60 miles downstream of the dam

Events
- Eight dam breach cases

Exposure
- At two-hour intervals
Wolf Creek Dam

- Lessons learned:
  - Time of day population and activities variation
  - Extra-long warning time
  - Multiple Emergency Planning Zones
  - Structure Survey Data
Method Overview

➢ Two Versions:

1) **LIFESim**
   - Deterministic Mode
   - Uncertainty Mode

2) **HEC-FIA**
   - Simplified processes
   - Less data requirement

➢ Development Philosophy

- Include important processes
- Readily available data
- Empirically-based fatality rates
- Reasonable implementation effort
Life Loss Cases for RA

**Event-Exposure Scenarios**

**Events:**
- Failure modes and locations
- Reservoir levels and inflow floods
- No-failure floods

**Exposure Cases:**
- Season
- Time of day
- Weekend/weekday
Data Sources

- **Census Data**
  - Census blocks
  - Roads
  - Hydrology

- **USGS**
  - DEM

- **HAZUS-MH**
  - Population activity distributions for 3 time-of-day scenarios
    - Night
    - Day
    - Commuting
  - Building information
Modeling Approach

Warning & Evacuation Module

Initial PAR

Warned

Mobilized

Evacuated

Not Cleared Area

Not Mobilized

Not Warned

Not Warned

Mobilized

Safe Shelter

Partially-damaged Shelter

CHANCE ZONE - Destroyed Shelter

Life-loss

Survived

Loss of Life Module
Loss-of-Shelter Categories/Flood Zones for Buildings

Building Type in each grid cell

Structure Damage State*
None
Negligible
Partial
Total

Building Floors
Roof
Floor n
Floor 1
Basement

Submergence**
No Inundation
Not Submerged
Submerged
Not submerged

Loss-of-Shelter Categories

None
Low
High

Flood Zones
None
Safe
Compromised
Chance

* Use building performance criteria
** Use loss of shelter by submergence criteria
*** Use human stability criteria
LIFESim Outputs

Aggregate Results

- Location: Community A
- Case name: EQ Sudden Failure
- Warning Initiation time: 1.25 Hours after failure
- Time of day: 04:00

Mobilized by cars:
- 29 (0.8%)
- 82 (2.3%)
Mobilized by SUV's:
- 86 (2.4%)
- 145 (4%)
Mobilized on foot:
- 6 (0.2%)
- 10 (0.3%)

- Cleared
  - Total: 121 (3.3%)
- Survived
  - Total: 911 (25.2%)
- Lost life
  - Total: 2581 (71.4%)

Received warning:
- 323 (8.9%)

No warning:
- 3291 (91.1%)

In buildings:
- 3270 (90.5%)

Par:
- Total: 3614 (100%)

High-Rise:
- Survived: 326 (9%)
- Lost life: 0 (0%)
Wood:
- Survived: 299 (8.3%)
- Lost life: 1925 (53.3%)
Concrete:
- Survived: 0 (0%)
- Lost life: 4 (0.1%)
Steel:
- Survived: 0 (0%)
- Lost life: 3 (0.1%)
Masonry:
- Survived: 3 (0.1%)
- Lost life: 24 (0.7%)
Manufactured:
- Survived: 79 (2.2%)
- Lost life: 606 (16.8%)
LIFESim Outputs

Spatially Distributed Results
LIFESim Outputs

Probability Distributions

Graph showing probability distributions for Life Loss with lines indicating Warned, Mobilized, Cleared, and Survived categories.
Other LIFESim Outputs

- Percent PAR warned per census block.
- Percent PAR mobilized per census block.
- Time to blockage by flood.
- Number of people trapped in vehicles and on foot per road segment.
- Fatalities in vehicles and on foot per road segment.
HEC-FIA

- **Simplified Data Requirements**
  - Peak flood profile
  - Flood wave arrival time

- **Simplified Methodology**
  - Basic evacuation model
  - Depth-only loss of shelter
### What’s Different?

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LIFESim or HEC-FIA?

- Study area characteristics
- Goals of assessment
- Time limitations
Current Status

- **Collaboration with USACE-HEC:**
  - Reprogramming to improve user friendliness
  - Rigorous model verification
  - Socio-economic analysis for mobilization

- **HEC-FIA:**
  - Requires less data
  - Produces faster estimate

- **Additional improvements**
  - Rescue simulation
  - Improve evacuation simulation
Conclusions

- Reasonable life-loss estimates are an essential input to Dam Safety Risk Assessment.

Life loss is intrinsically uncertain
- Incorporate uncertainty in:
  - life-loss estimates and
  - Risk Assessment results for decision makers.

LIFESim & HEC-FIA
- Under continuing development
- Requires reasonable effort
- Multiple levels of details
- Demonstrated and applied to several dams and levees
- A tool for evacuation planning tool for emergency managers.
Questions??

E-mail:
maged.aboeelata@urs.com