Development of an Integrated Simulation Model for Flood Risk Evaluation and Damage Assessment

presented by

Professor Emeritus Charng Ning CHEN
School of Civil & Environmental Engineering (CEE), and Principal Investigator (ICRM)

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ICRM
Institute of Catastrophe Risk Management

• Launched in January 2010
• Undertake multi-disciplinary R&D works - science, eng., finance, technology, economic and social-political aspects, related to catastrophe risk arising from natural and non-traditional hazards.
• Develop innovative & comprehensive methodologies and tools for catastrophe risk management by government & industry.
• Render expert services to those at risk worldwide, and Asia in particular.
ICRM – Why the Focus on Asia

• Asia has the largest growth of real assets and urban centers on Earth. This has exacerbated the problems of Catastrophe Risks.
• Historically, Asia has suffered the most due to catastrophic events, but has the least amount of safety net or risk transfer mechanisms.
• Climate Change and urban expansion issues will potentially impact Asia more than any other continent.
• Catastrophe insurance penetration is extremely low in developing countries in Asia. Examples: under 0.5% in India, Philippines and China.
• Asia is home to the largest number of ‘poor’ people of the world. Catastrophe micro-insurance products need to be developed.
**Top 15 Urban Conglomerates (2009)**

<table>
<thead>
<tr>
<th>Rank</th>
<th>City</th>
<th>Country</th>
<th>Region</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Tokyo</td>
<td>Japan</td>
<td>Asia</td>
<td>33,800,000</td>
</tr>
<tr>
<td>2.</td>
<td>Seoul</td>
<td>South Korea</td>
<td>Asia</td>
<td>23,900,000</td>
</tr>
<tr>
<td>3.</td>
<td>Mexico City</td>
<td>Mexico</td>
<td>North America</td>
<td>22,900,000</td>
</tr>
<tr>
<td>4.</td>
<td>Delhi</td>
<td>India</td>
<td>Asia</td>
<td>22,400,000</td>
</tr>
<tr>
<td>5.</td>
<td>Mumbai</td>
<td>India</td>
<td>Asia</td>
<td>22,300,000</td>
</tr>
<tr>
<td>6.</td>
<td>New York</td>
<td>USA</td>
<td>North America</td>
<td>21,900,000</td>
</tr>
<tr>
<td>7.</td>
<td>Sao Paulo</td>
<td>Brazil</td>
<td>South America</td>
<td>21,000,000</td>
</tr>
<tr>
<td>8.</td>
<td>Manila</td>
<td>Philippines</td>
<td>Asia</td>
<td>19,200,000</td>
</tr>
<tr>
<td>9.</td>
<td>Los Angeles</td>
<td>USA</td>
<td>North America</td>
<td>18,000,000</td>
</tr>
<tr>
<td>10.</td>
<td>Shanghai</td>
<td>China</td>
<td>Asia</td>
<td>17,900,000</td>
</tr>
<tr>
<td>11.</td>
<td>Osaka</td>
<td>Japan</td>
<td>Asia</td>
<td>16,700,000</td>
</tr>
<tr>
<td>12.</td>
<td>Kolkata</td>
<td>India</td>
<td>Asia</td>
<td>16,000,000</td>
</tr>
<tr>
<td>13.</td>
<td>Karachi</td>
<td>Pakistan</td>
<td>Asia</td>
<td>15,700,000</td>
</tr>
<tr>
<td>14.</td>
<td>Guangzhou</td>
<td>China</td>
<td>Asia</td>
<td>15,300,000</td>
</tr>
<tr>
<td>15.</td>
<td>Jakarta</td>
<td>Indonesia</td>
<td>Asia</td>
<td>15,100,000</td>
</tr>
</tbody>
</table>
Asia (1960-2009)

Number of killed

- Storm: 850,000
- Drought: 1,500,000
- Flood: 201,000
- Epidemic: 70,000

Total = 3,550,000

Number of affected

- Storm: 718,000,000
- Drought: 1,580,000,000
- Flood: 2,900,000,000
- Earthquake: 126,000,000
- Epidemic: 7,800,000

Total = 5,330,000,000

Estimated Damage (USD Million)

- Storm: 155,000
- Drought: 28,000
- Flood: 242,000
- Earthquake: 315,000
- Epidemic: 0

Total = 740,000

Trend of Natural Catastrophes in Asia (1975-2002)

Source: ‘Flood Disaster Trends in Asia in the Last 30 Years’, D. Dutta, ICUS/ INCEDE Newsletter, Univ. of Tokyo, Apr-June, 2003
Flood (1960 – 2009)

Number of killed

- Asia, 200,000
- Rest of the World, 80,000

Total = 280,000

Number of affected

- Asia, 2,911,000,000
- Rest of the World, 134,000,000

Total = 3,045,000,000

Estimated Damage (USD Million)

- Asia, 242,000
- Rest of the World, 185,000

Total = 427,000

Exposures to Natural Hazards

Inter-relationship of hazard magnitude, socio-economic development & disaster resistance

Adapted from ‘Natural Disaster’ by Chen Y. & Shi P.J., 2007
Common Types & Causes of Floods

Types: Riverine, Coastal & Estuarine Floods

Causes:

• **Monsoon** Rains
  - Northeast monsoon (Nov-Jan)
  - Southwest monsoon (May-Aug)

• **Cyclones / Typhoons** (June-Nov) north of 15° N
  - Intense rainfall
  - Storm surge
  - High waves
  - Gusty winds (> 120 km/hr)

• **Distinct Storms, Depressions**, or Atmospheric Disturbances
Seasonal Rainfall Pattern in Asia
Flood Scenes in SE & South Asia
Key Factors affecting Flood Risks (a)

- Urban development: increase in % of paved and % of storm sewered land areas, resulting in manifold increases in peak flood discharge
Key Factors affecting Flood Risks (b)

- Rapid pace of areal expansion of urban, suburban, industrial and commercial lands
- Typical urban expansion pattern in Jakarta
Key Factors affecting Flood Risks (c)

• Encroachment of flood plains by buildings, structures, and other forms of developments
• Obstructions of drainage capacity by debris, etc.
• Lack of maintenance of dikes, pumps, etc.
Key Factors affecting Flood Risks (d)

- Excessive withdrawal of groundwater resulting in land subsidence
- Typical land subsidence case in Jakarta DKI
  - 50% of city area is sinking @ 2-12 cm/yr
  - Subsidence rate is about 10 times that of sea level rise (0.2-0.5 cm/yr)
  - 40% of area is under high tide (needs dike & pump for protection)
  - Sea levels were not significantly high during 1996, 2002, and 2007 floods
- Similar problem in Bangkok
Other Factors affecting Flood Risks (e)

- Climate change on potential sea level rise, typhoon & storm characteristics


Cumulative tracks of all tropical cyclones during the period 1985–2005. The Pacific Ocean west of the International Date Line sees more tropical cyclones than any other basin, while there is almost no activity in the Atlantic Ocean south of the Equator.
Startup Research Program @ ICRM

Flood Risk & Hazard Simulation Model for Watersheds in Jakarta, Indonesia - for subsequent application/adaptation to other cities with added features, such as typhoon & surges and monsoon floods

DEM of Jakarta watershed

Main sub-basins

Jakarta IDF curves

Hydrologic model

Jakarta flood scenes (Jan 2007)
Research Linkages
Integrating Earth and Environmental Sciences with Flood, and Financial Engineering

ICRM, EOS (Earth Observatory of Singapore, NTU), NEWRI of NTU

Hazard Assessment
Vulnerability Assessment & Loss Estimate
Risk Management & Financial Engineering

ICRM, Industry & Other Research Institutions

ICRM, MAS & Industry Finance / Reinsurance

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Simulation Model for Watersheds in Jakarta

DEM of Jabodetabek
(Source: SRTM, Dec 2009)
Land-use and River Network of Jabodetabek
DEM and Rivers Draining DKI Jakarta
Hydrologic Model
ArcGIS Sub-Basin Delineation
Hydrologic Model

HEC-HMS Hydrographs: Typical 2 and 100-Year Hydrographs
Hydraulic Model
Stream Digitization

Jabodetabek Land Use and River Network

DKI Jakarta Catchment Area
Source; Government of DKI Jakarta, 2009

Channel View from Google Earth

Schematic Rivers Draining DKI Jakarta
Source; Government of DKI Jakarta, 2009
Hydraulic Model
Typical HEC-RAS Outputs
Inundation Mapping (GeoRAS/ArcGIS)  
Calibration against historic floods & development of flood hazard maps
Flood Damage Assessment
Grid-Based & Site Specific Approach with data input

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Source Jakarta Data; http://jakarta.bps.go.id/
Jakarta In Figure 2009; http://jakarta.bps.go.id/JDA/JDA2009.pdf
Flood Loss/Damage Assessment

Flow of Conceptual Steps for a Flood Damage Assessment Methodology

Flow of Flood Damage Assessment based on GIS and RS
Assessment of Exposures to Flood Catastrophes

Source of natural flood disasters

Changes in land-use, bldg/structural sites & design; floodplains & drainage, GW use; climate change, etc

Watershed responses

Storms/Surges

Government & private sector initiatives in policies, regulations & incentives

Floods

Inundation/Currents

Risk Assessment & Loss Estimates

Hazards * Vulnerability
Thank You

Q&A