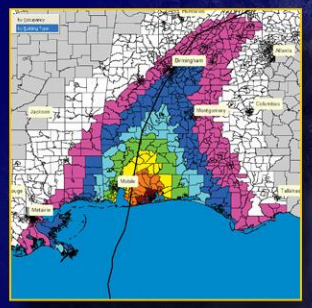

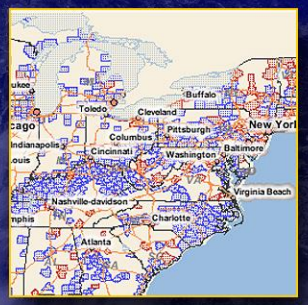

Adapting the Federal Emergency Agency's Hazus Flood Model for Curitiba, Parana - Brazil

FEMA

Jesse Rozelle, FEMA/University of Colorado
Edilberto Nunes de Moura, PUCPR

Outline

- Hazus
  - Background
  - International Methodology
- Curitiba, Brazil Hazus International Methodology
  - Citywide building inventory
  - Hydrologic and Hydraulic model
  - Essential Facilities
- Future Enhancements

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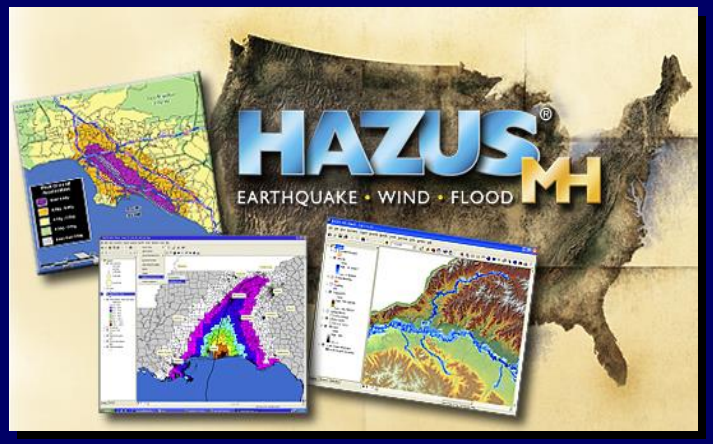
Hazus Risk Assessment Tool

- Earthquake, flood and hurricane wind modules
- Tsunami model coming 2017
- Developed in conjunction with the National Institute of Building Sciences
- Runs on ESRI ArcGIS 10.4
- Largest extension of ArcGIS
- Over 200 data layers – all open source



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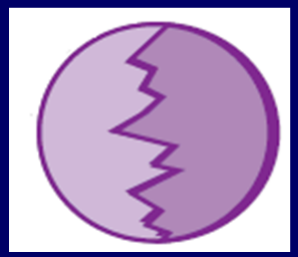
Supported Hazards

Hurricane Wind

Riverine and Coastal Floods



Earthquakes

Tsunami's (2017)

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Hazus\GIS

- Results identify specific and general vulnerabilities
- Visually displays impacts to key decision makers and the public
- Calculates scientifically-defensible damages, economic losses, and mitigation benefits
- Facilitates a risk-based approach to prioritize mitigation strategies that maximizes the return on investment

HAZUS-MH Models

	Earthquake Ground Motion Ground Failure	Flood Frequency Depth Discharge Velocity	Hurricane Winds Pressure I Missile I Rain
Direct Damage			
General Building Stock	■	■	■
Essential Facilities	■	■	■
High Potential Loss Facilities	■		
Transportation Facilities	■	■	
Lifelines	■	■	
Induced Damage			
Fire Following	■		
Hazardous Materials Sites	■		
Debris Generation	■	■	■
Direct Losses			
Cost of Repairs/Replacement	■	■	■
Income Loss	■	■	■
Crop Damage		■	
Casualties	■	Generic Output	
Shelter and Recovery Needs	■	■	■
Indirect Losses			
Supply Shortages	■	■	
Sales Decline	■	■	
Opportunity Costs	■	■	
Economic Loss	■	■	

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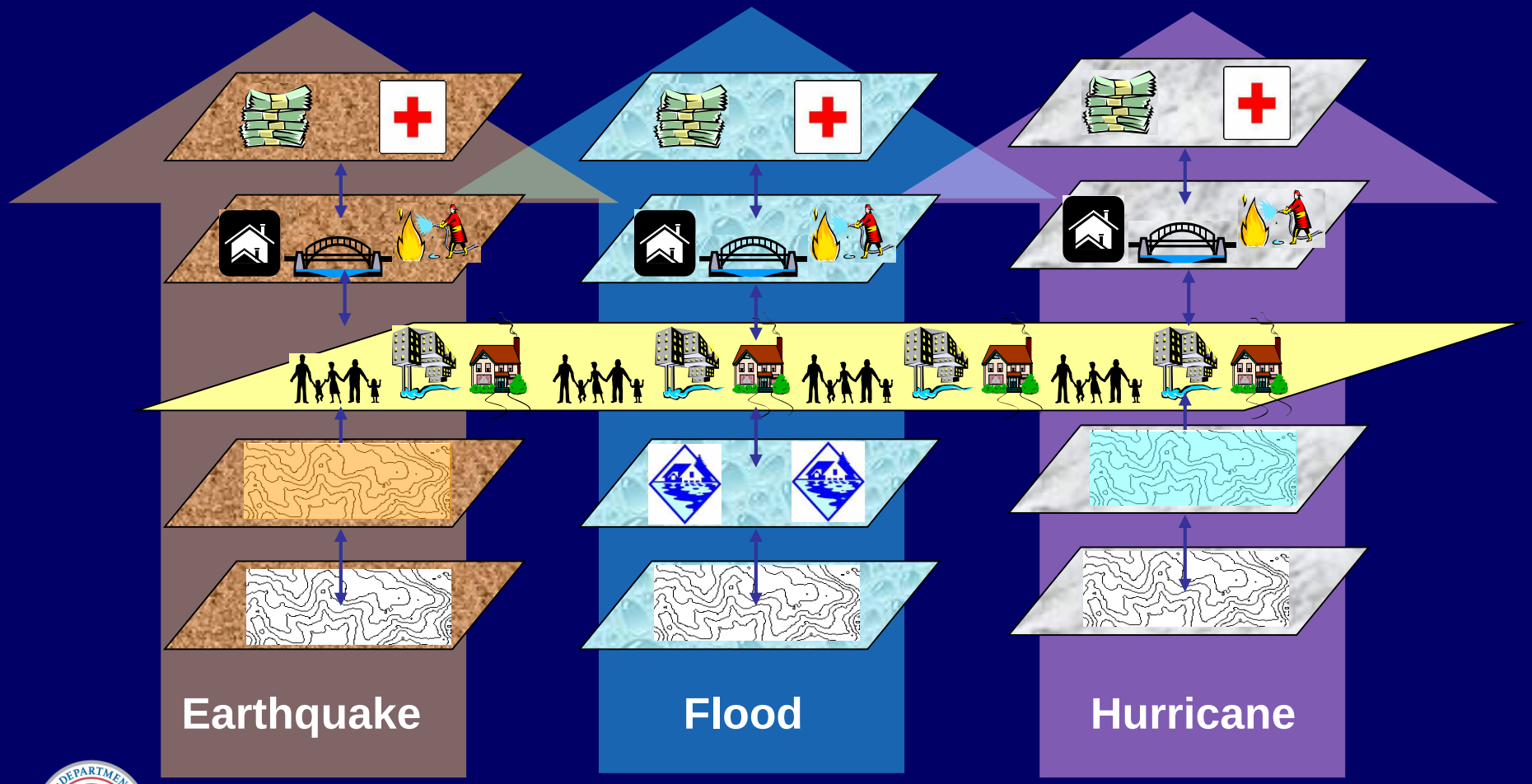
Hazus MH – Features



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Hazus is Multidisciplinary

- Subject Matter Experts/User Groups
  - GIS experience
  - Engineering expertise
  - Hazard information (seismologist, geologist, meteorologists)
  - Social scientist (housing)
  - Emergency management community
  - Decision/policy makers

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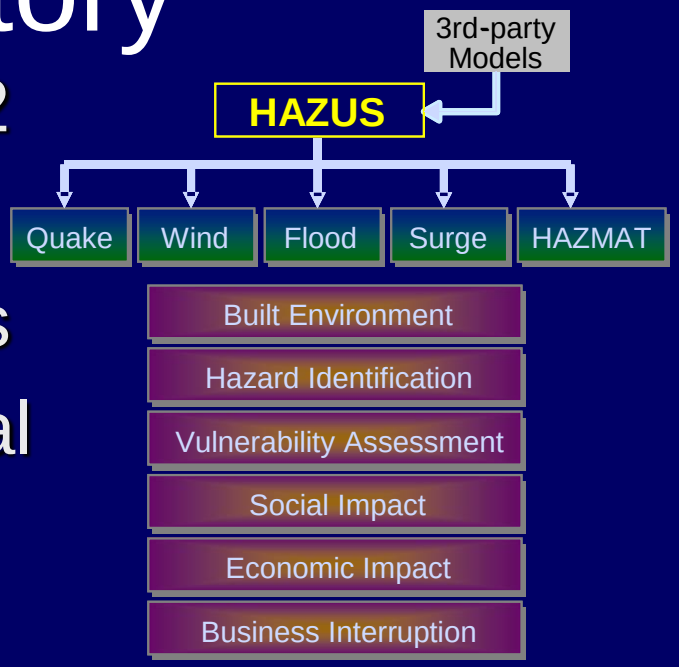
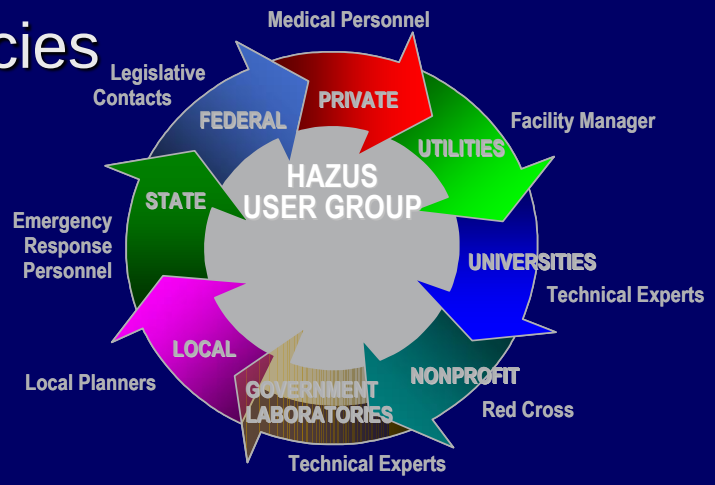
Brief History

- Project started back in 1992
- Replace “black box”
- Provide national capabilities
- Earthquake model functional since 1997
- 1,000’s of HAZUS users
  - Local, State, & Federal Agencies
  - Private Sector
  - Universities





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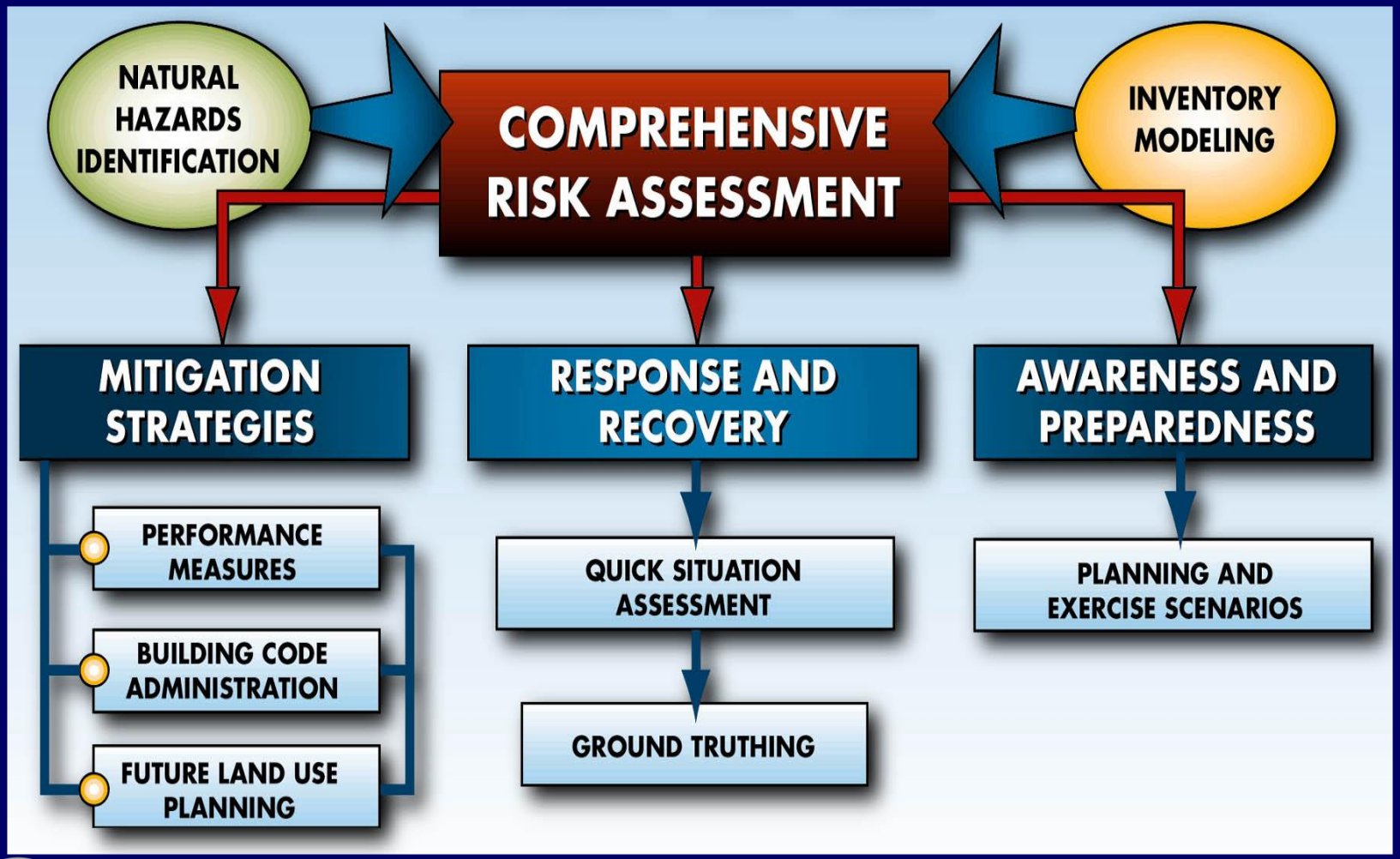
HAZUS Applications



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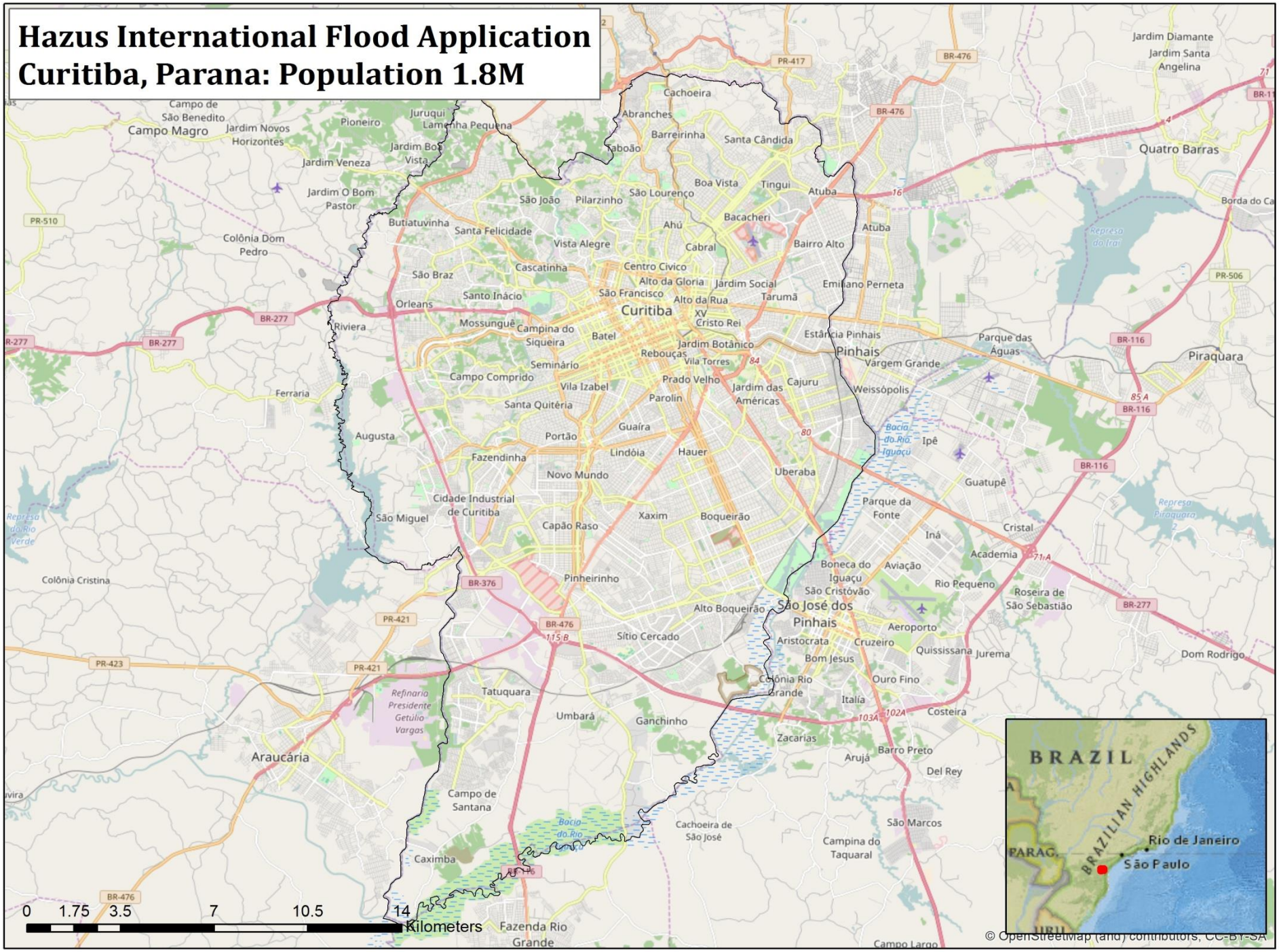
Hazus International Flood Application
Curitiba, Parana: Population 1.8M



Building Inventory – US Model Data

- **Demographics** – Population, Employment, Housing
- **Building Stock** – Residential, Commercial, Industrial
- **Essential Facilities** – Hospitals, Schools, Police Stations, Fire Stations
- **Transportation** – Highways, Bridges, Railways, Tunnels, Airports, Ports and Harbors, Ferry Facilities
- **Utilities** – Waste Water, Potable Water, Oil, Gas, Electric Power, Communication Facilities
- **High Potential Loss Facilities** – Dams and Levees, Nuclear Facilities, Hazardous Material Sites, Military Installations

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Building Inventory – Curitiba Model Data

- **Demographics** – Population, Employment, Housing
- **Building Stock** – Residential, Commercial, Industrial
- **Essential Facilities** – Hospitals, Schools, Police Stations, Fire Stations
- **Transportation** – Highways, Bridges, Railways, Tunnels, Airports, Ports and Harbors, Ferry Facilities
- **Utilities** – Waste Water, Potable Water, Oil, Gas, Electric Power, Communication Facilities
- **High Potential Loss Facilities** – Dams and Levees, Nuclear Facilities, Hazardous Material Sites, Military Installations

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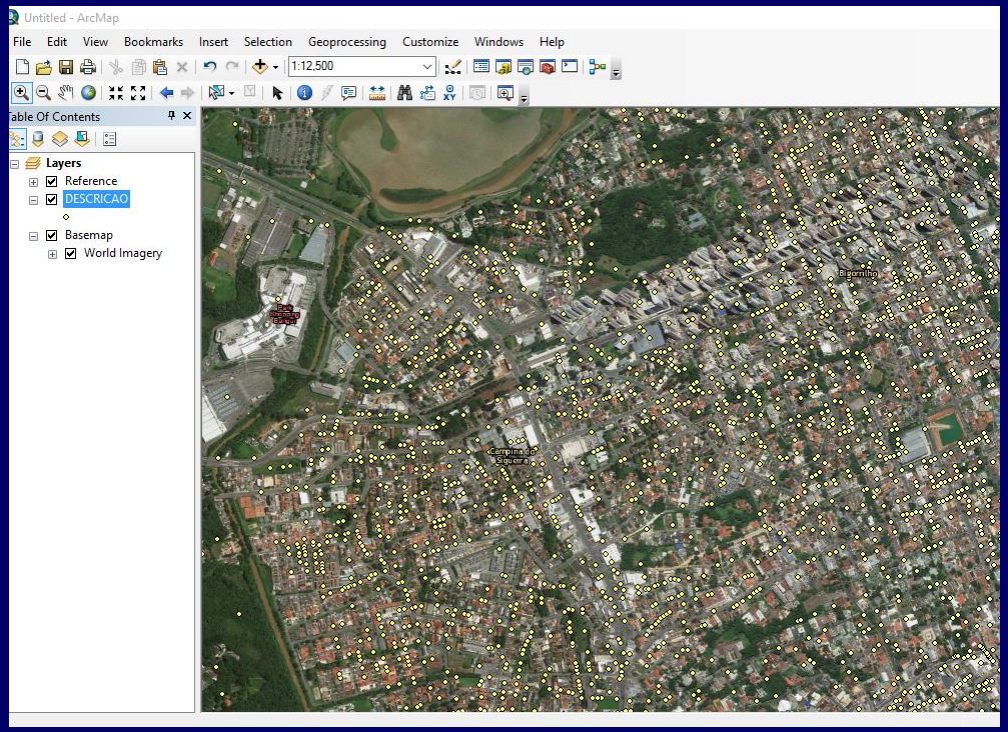
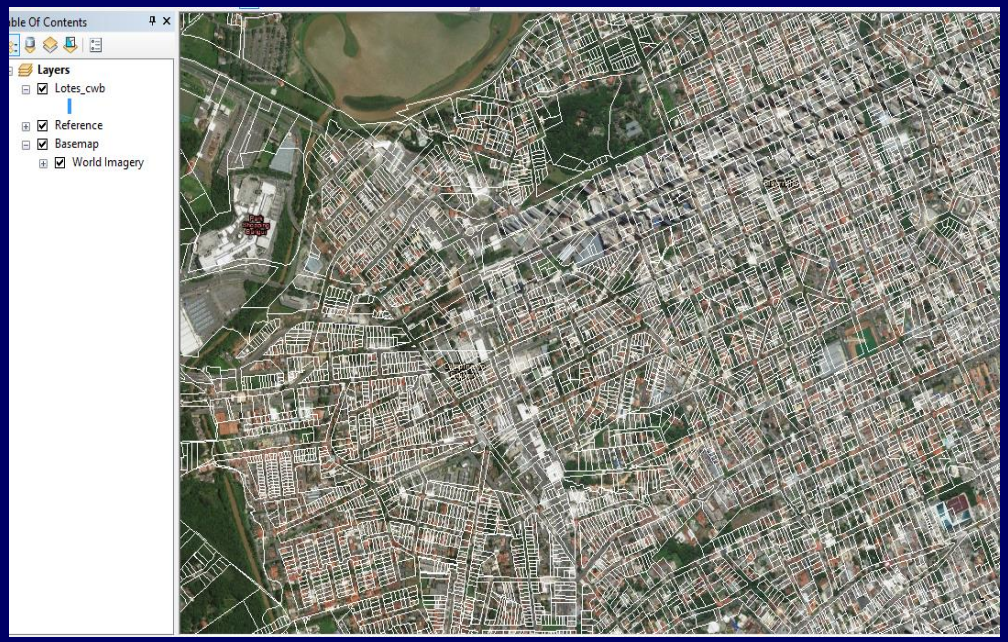
Building Inventory

- Building Points, Parcels
- Citywide inventory, over 335,000 structures

Hazus Structure Specific Attributes Required:

- Occupancy type
- Number of stories
- First Floor Height
- Foundation Type
- Building Value, Contents (optional)





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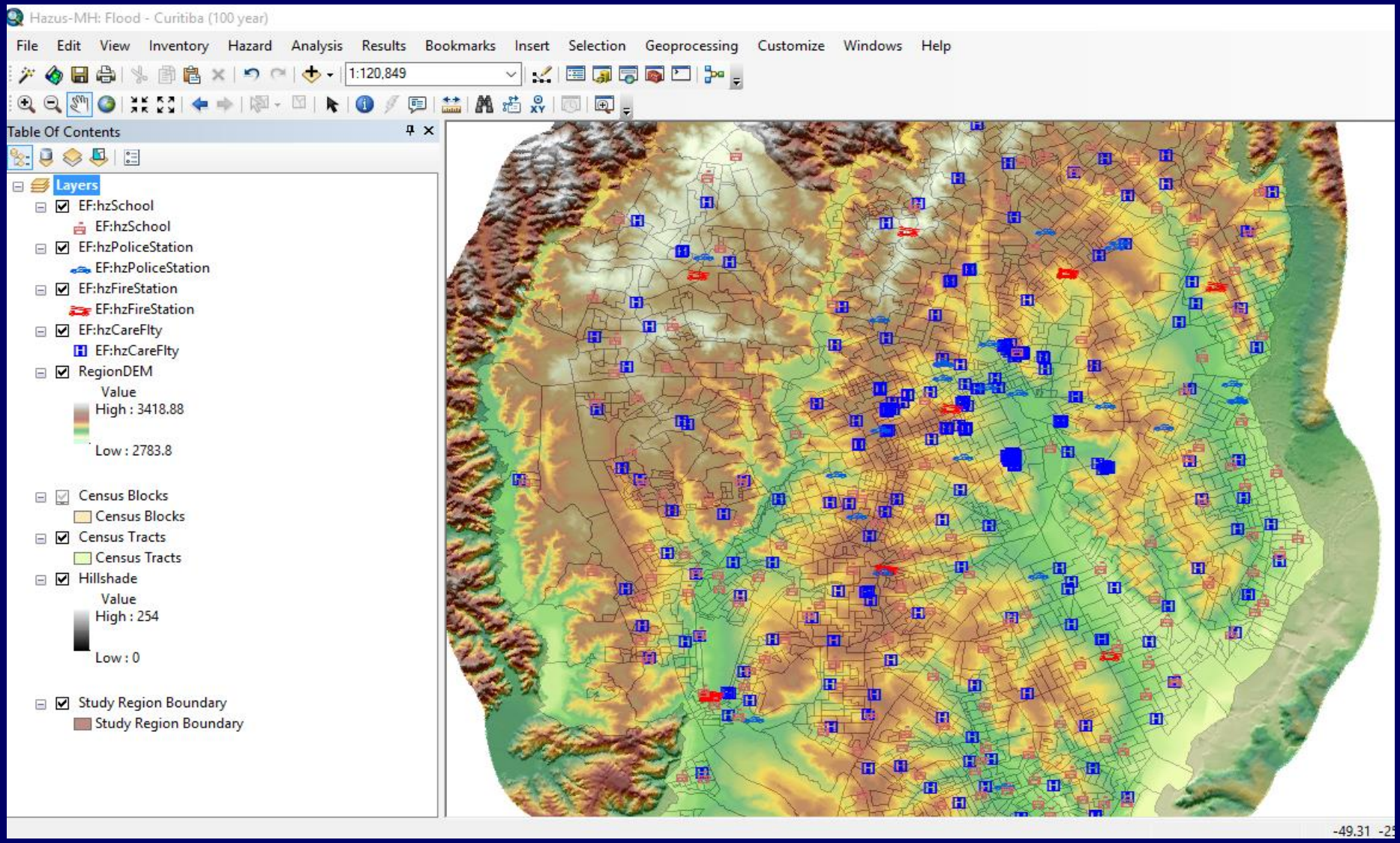
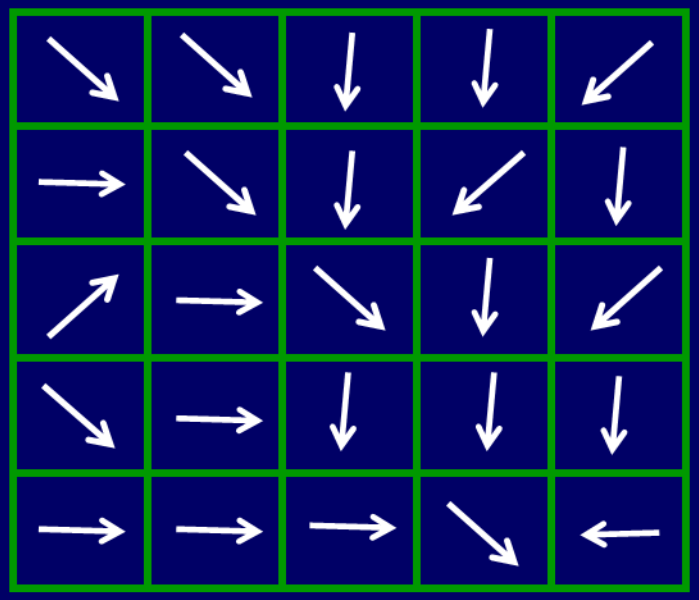
Essential Facilities

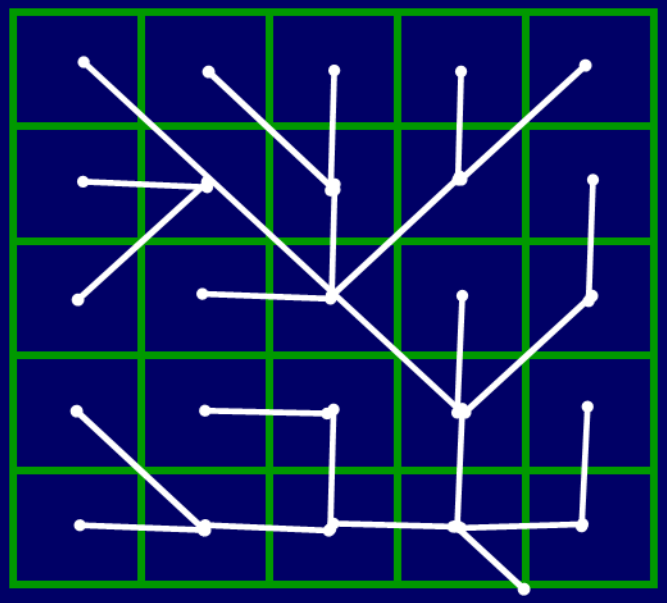


Hydrologic and Hydraulic Model

Hazus Flood Stream Delineation – Flow Direction

- Direction in which water would flow if poured at that cell onto the terrain
- 8-direction pour point model: steepest downslope neighbor





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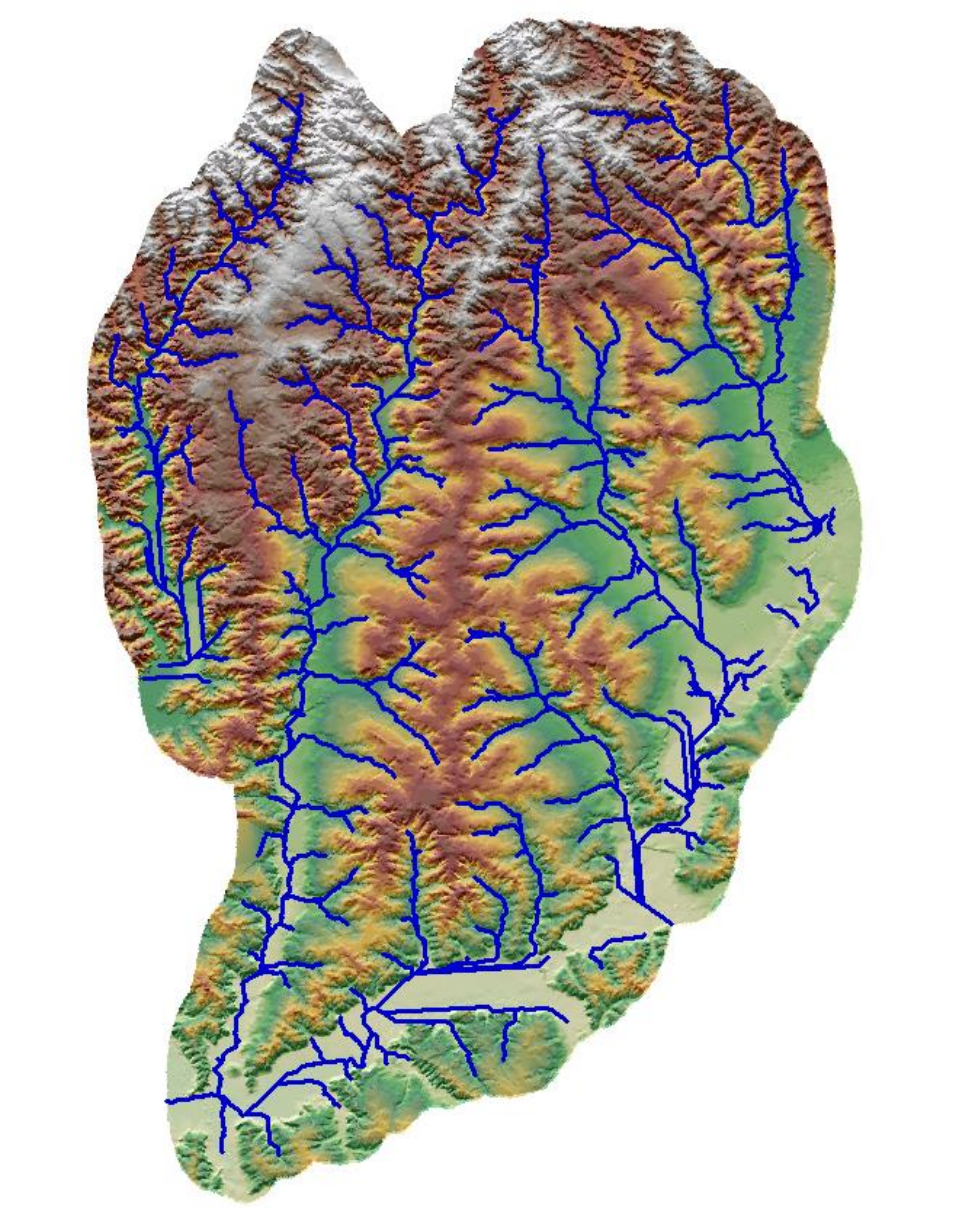
Curitiba Stream Network

- Stream network is created using Hazus H&H pour point model
- 10 meter DEM from AguasParana
- Plans to incorporate LIDAR soon



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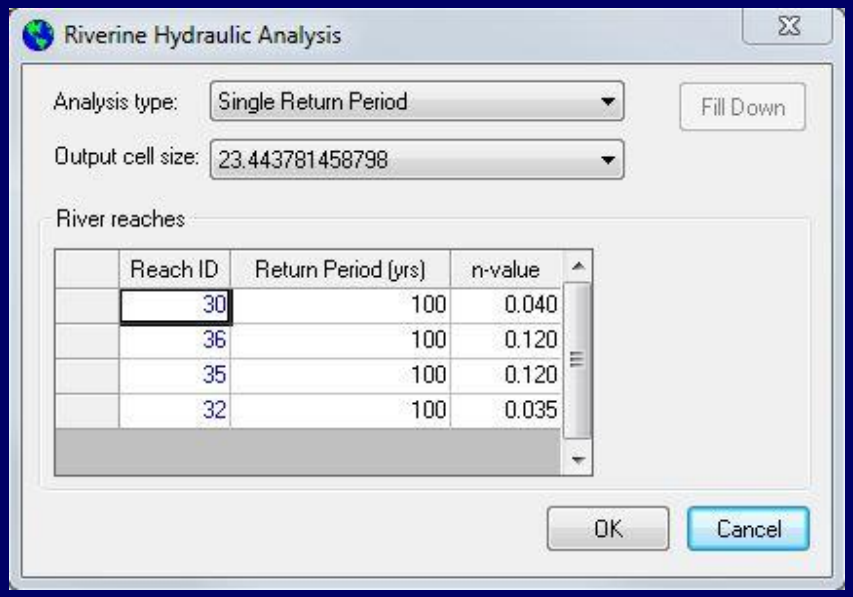
Hydraulic Analysis Options

- Select level of flood to analyze for each selected stream reach.

Numbered stream reaches



Analysis Options:

- Suite of return periods
- Single return period
- Single discharge

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Manning's (n) Examples

Manning Coefficient (n) Value	Material Description
0.011 - 0.015	Concrete
0.025 - 0.040	Rock cuts
0.028 - 0.035	Gravel
0.040 - 0.070	Cobbles with large boulders
0.080 - 0.140	Dense brush

Lower value → Higher value

Smoother → Rougher

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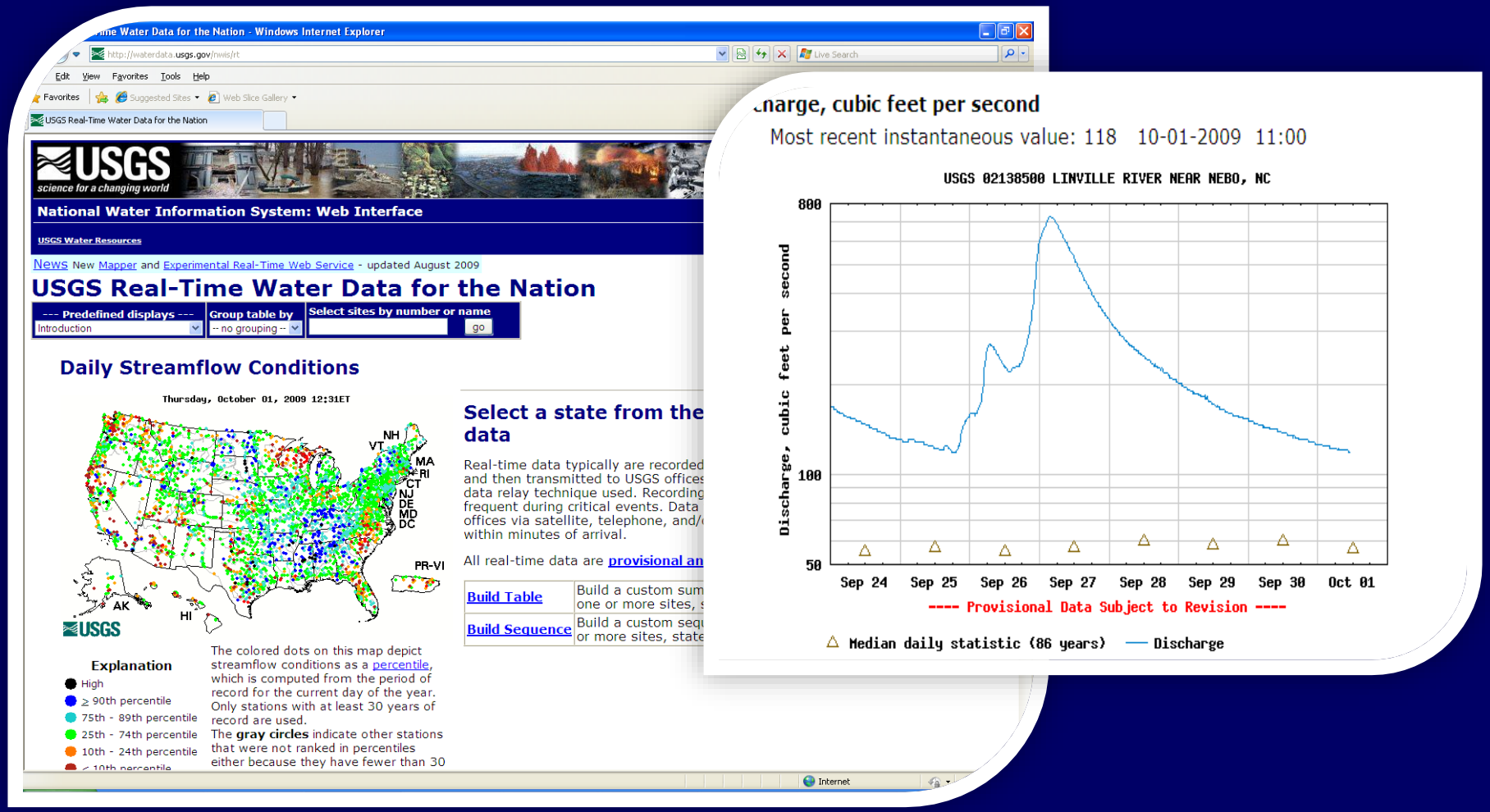
Discharge Values Sources – USGS



http://waterdata.usgs.gov/nwis/rt

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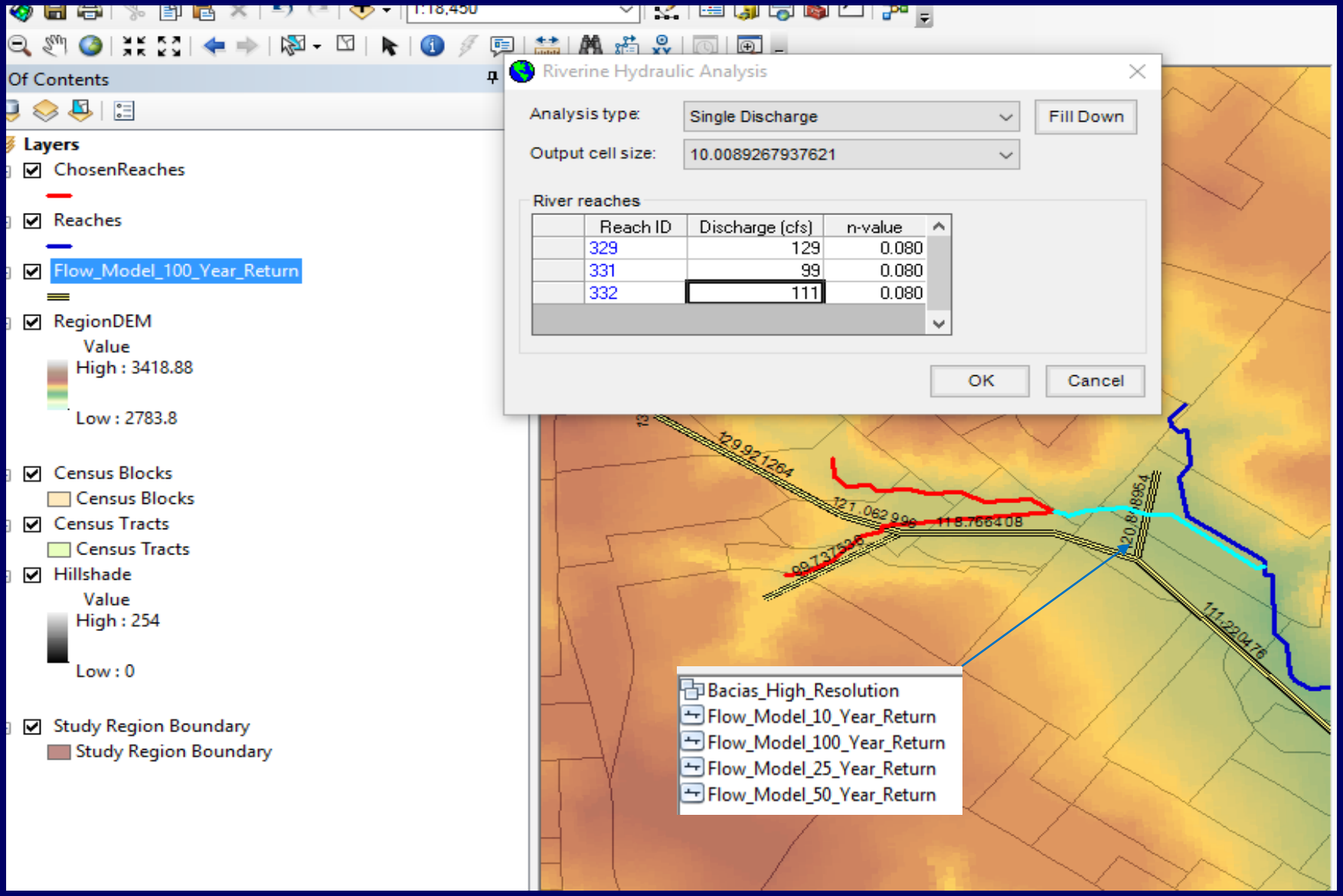
Curitiba Discharge Values Sources – Institute of Research and Planning (IPPUC)



Hazus Structural Flood Loss Method

Specific Occupancy Depth Damage Functions

Based on flood depth at location and flood vulnerability attributes

- Occupancy type
- Number of stories
- First Floor Height
- Foundation Type
- Building Value, Contents (optional)

General Building Stock Depth-Damage Functions

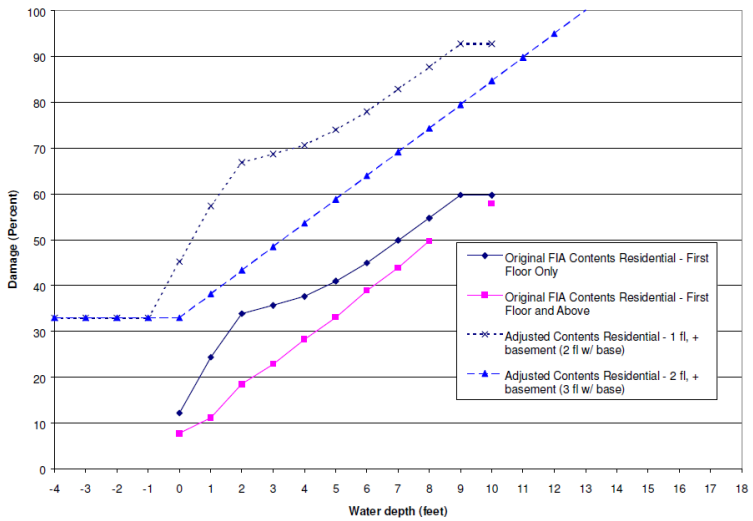
Structure | Contents | Inventory

Static c2

Riverine | RES1

	-3 ft	-2 ft	-1 ft	0 ft	1 ft	2 ft
1	0.00	0.00	3.00	13.00	23.00	32.00
2	0.00	14.00	19.00	26.00	32.00	39.00
3	0.00	0.00	0.00	11.00	12.00	14.00
4	4.00	8.00	14.00	19.00	21.00	26.00
5	0.00	0.00	0.00	5.00	8.00	12.00
6	3.00	6.00	10.00	12.00	14.00	20.00
7	0.00	0.00	0.00	3.00	9.00	13.00
8	6.00	9.00	14.00	15.00	24.00	27.00

Figure 5.4 FIA-Based Structure Depth-Damage Curve Split Level, Basement-Modified



General Building Stock Depth-Damage Functions

Structure | Contents | Inventory

Static c2

Riverine | RES1

	Occupancy	SpecificOccupId	Source	Description	Stories	Comment
1	RES1	R11N	USACE - IWR	one story, no baseme	1 Story	
2	RES1	R11B	BCAR - Jan 2011	one story, w/ baseme	1 Story	RAMPP Inserted
3	RES1	R12N	FIA	two floors, no baseme	2 Story	
4	RES1	R12B	FIA (MOD.)	two floors, w/ baseme	2 Story	
5	RES1	R13N	FIA	three or more floors, n	3 Story	
6	RES1	R13B	FIA (MOD.)	three or more floors, w	3 Story	
7	RES1	R1SN	FIA	split level, no baseme	Split Level	
8	RES1	R1SB	FIA (MOD.)	split level, w/ baseme	Split Level	

US Hazus Model Loss Estimation Outputs

	Earthquake Ground Shaking Ground Failure	Flood Frequency Depth Discharge Velocity	Hurricane Pressure | Missile | Rain
Direct Damage			
General Building Stock	✓	✓	✓
Essential Facilities	✓	✓	✓
High Potential Loss Facilities	✓		
Transportation Systems	✓	✓	
Utility Systems	✓	✓	
Induced Damage			
Fire Following	✓		
Hazardous Materials Release			
Debris Generation	✓	✓	✓
Direct Losses			
Cost of Repair	✓	✓	✓
Income Loss	✓	✓	✓
Crop Damage		✓	
Casualties	✓	Generic Output	
Shelter Needs	✓	✓	✓
Indirect Losses			
Supply Shortages	✓	✓	
Sales Decline	✓	✓	
Opportunity Costs	✓	✓	
Economic Loss	✓	✓	

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Curitiba, Brazil Hazus Model Loss Estimation Outputs

	Earthquake Ground Shaking Ground Failure	Flood Frequency Depth Discharge Velocity	Hurricane Pressure | Missile | Rain
Direct Damage			
General Building Stock	✓	✓	✓
Essential Facilities	✓	✓	✓
High Potential Loss Facilities	✓		
Transportation Systems	✓	✓	
Utility Systems	✓	✓	
Induced Damage			
Fire Following	✓		
Hazardous Materials Release			
Debris Generation	✓	✓	✓
Direct Losses			
Cost of Repair	✓	✓	✓
Income Loss	✓	✓	✓
Crop Damage		✓	
Casualties	✓	Generic Output	
Shelter Needs	✓	✓	✓
Indirect Losses			
Supply Shortages	✓	✓	
Sales Decline	✓	✓	
Opportunity Costs	✓	✓	
Economic Loss	✓	✓	

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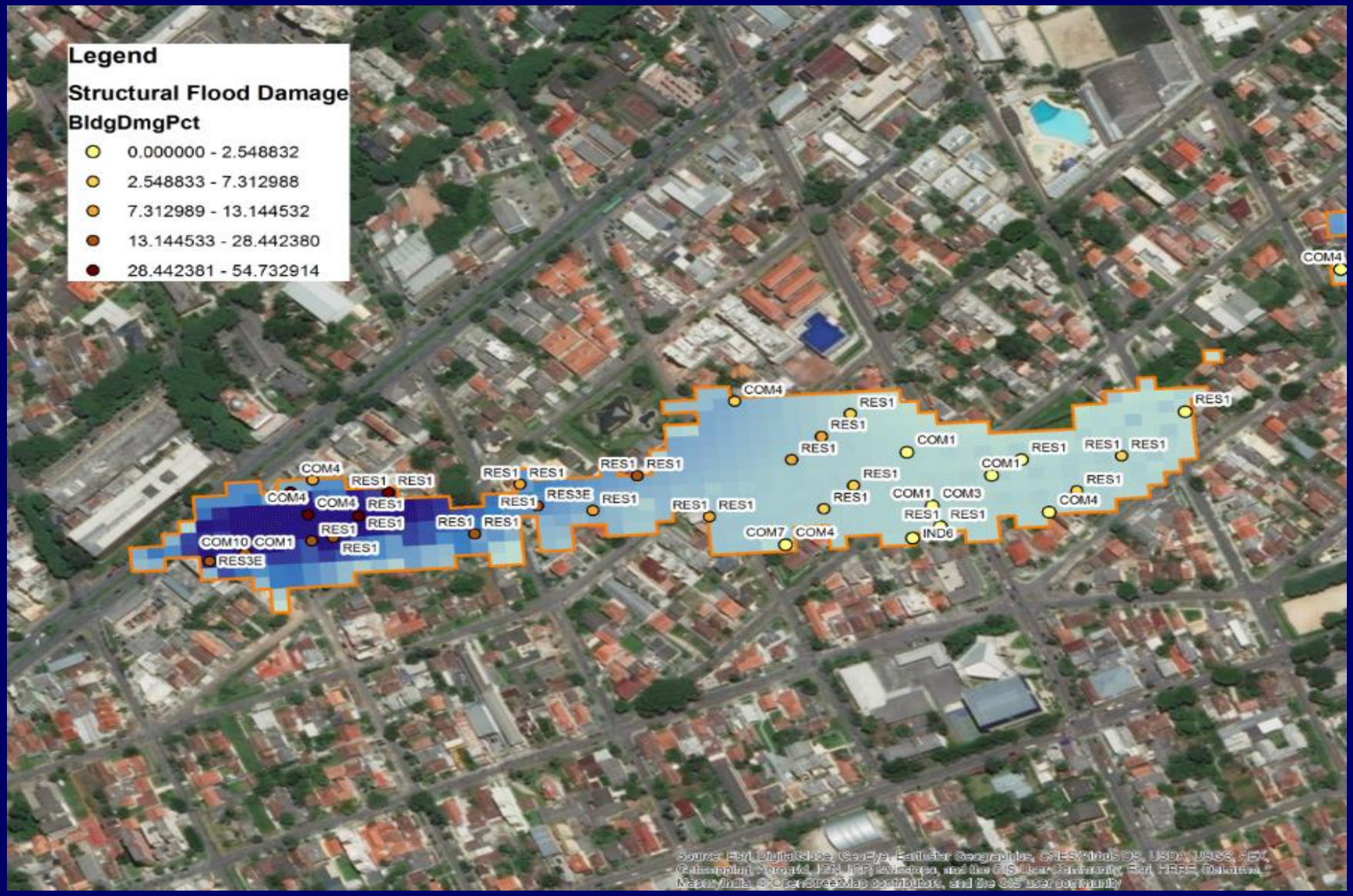
Flood Model Results



Future Enhancements/Next Steps

- Review of depth damage functions for Brazil
- Review of occupancy types assigned
- Addition of building/content values for economic analysis
- Incorporation of LIDAR
- Assignment of Manning's-N values using land use/land cover data
- Development of various planning scenarios, comparison to recent large scale events for calibration

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Questions?

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