Assessment of Climate Change Risk to Municipal Infrastructure - City of London

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Key messages

- Municipal infrastructure is vulnerable to climate change
- Adaptation cost can be very high
- Adaptation = Risk management
- Comprehensive risk assessment methodology is required to gather and examine available data in order to develop an understanding of the relevant climate effects and their interactions with infrastructure.
- Time to act is now

Outline

- Methodology introduction and data
  - Climate modelling
  - Hydrologic modelling
  - Hydraulic modelling
- Risk assessment
- Conclusions

Study team

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- Donald H. Burn, Professor (UW)
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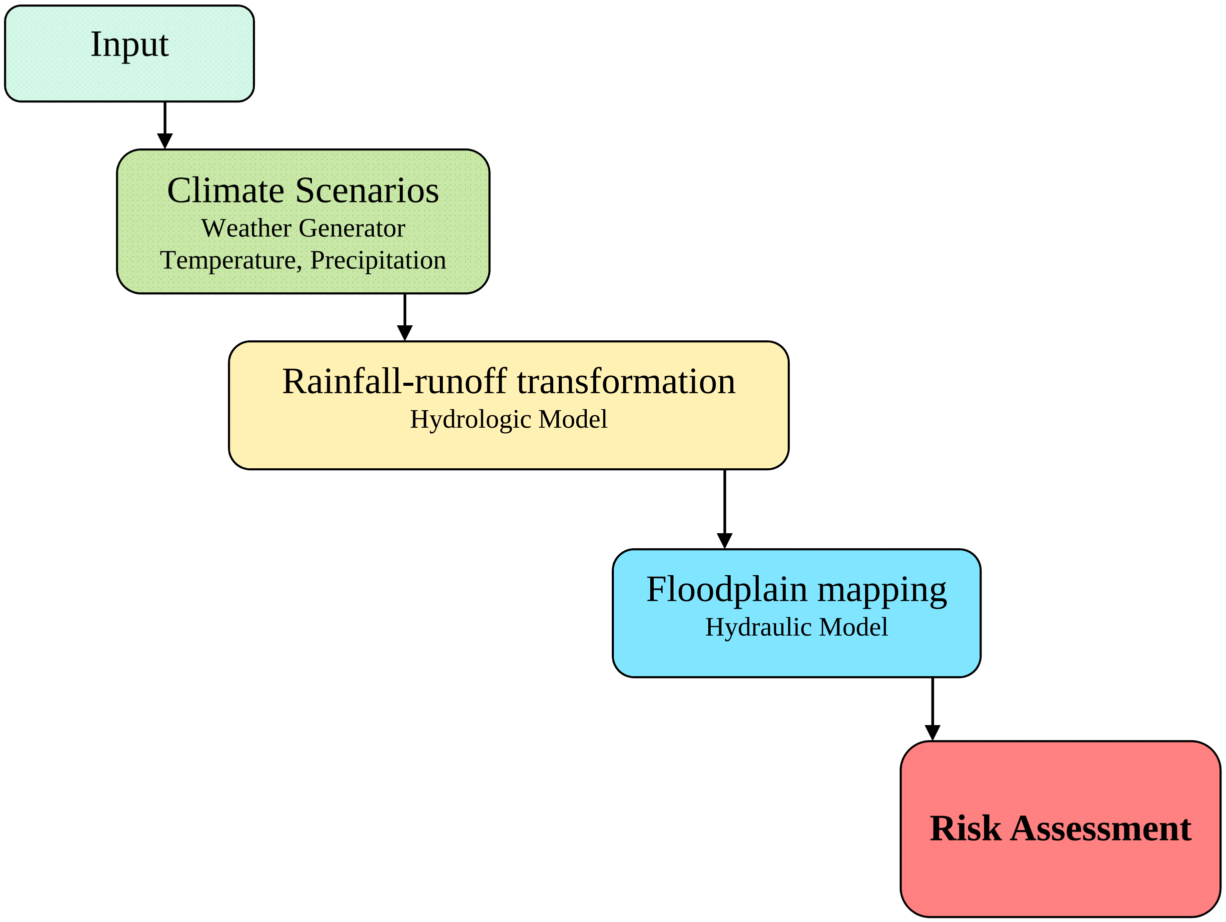
Research methodology



Research methodology

- Data Input
  - Inventory of infrastructure components;
  - Data gathering and sufficiency analysis;
- Climate Modelling
  - Existing climate scenario
  - Wet climate scenario
- Hydrologic Modelling
  - HEC-HMS model
- Hydraulic Modelling
  - HEC-RAS model
- Risk Assessment
  - Qualitative vulnerability assessment;
  - Quantitative vulnerability assessment; and
- Prioritization of the infrastructure components based on the level of risk

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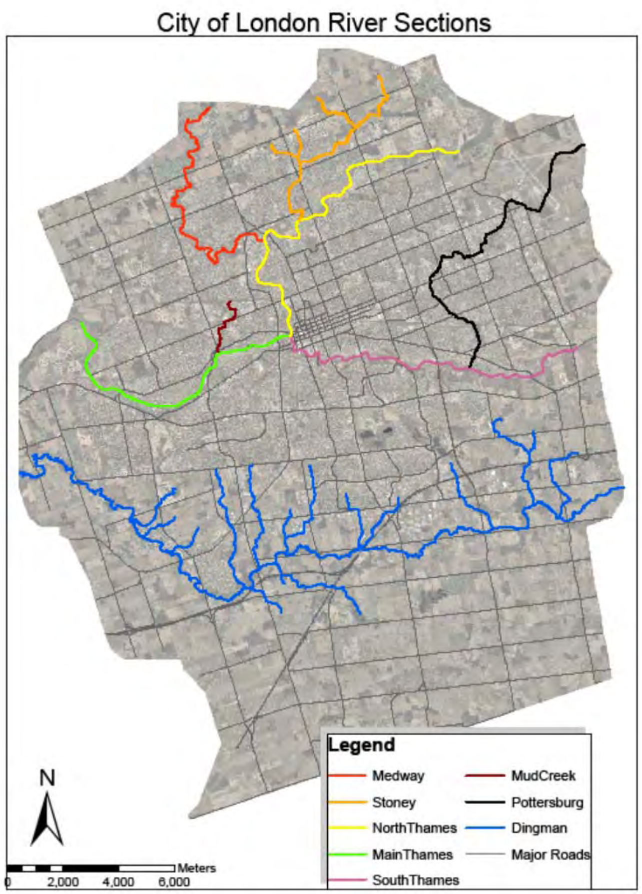
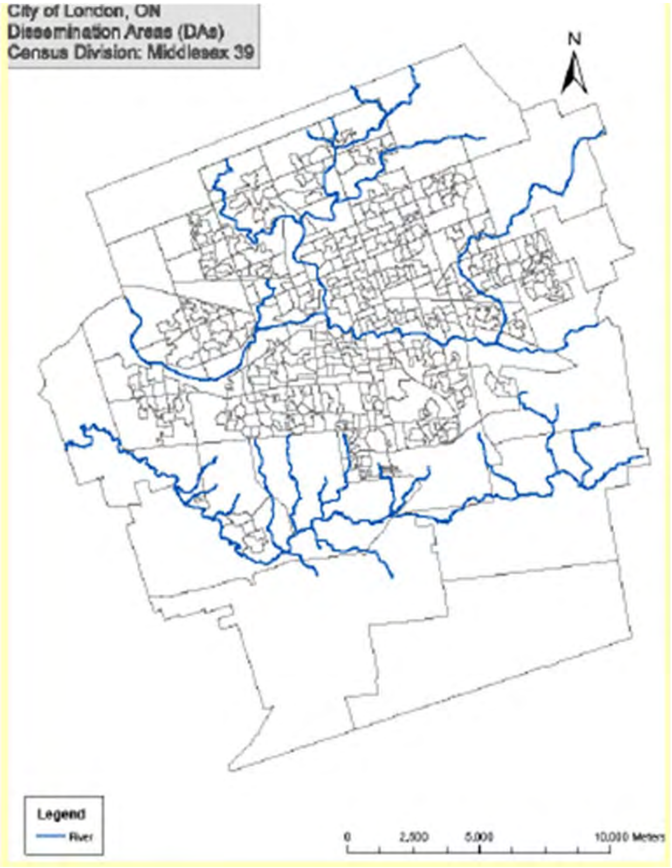
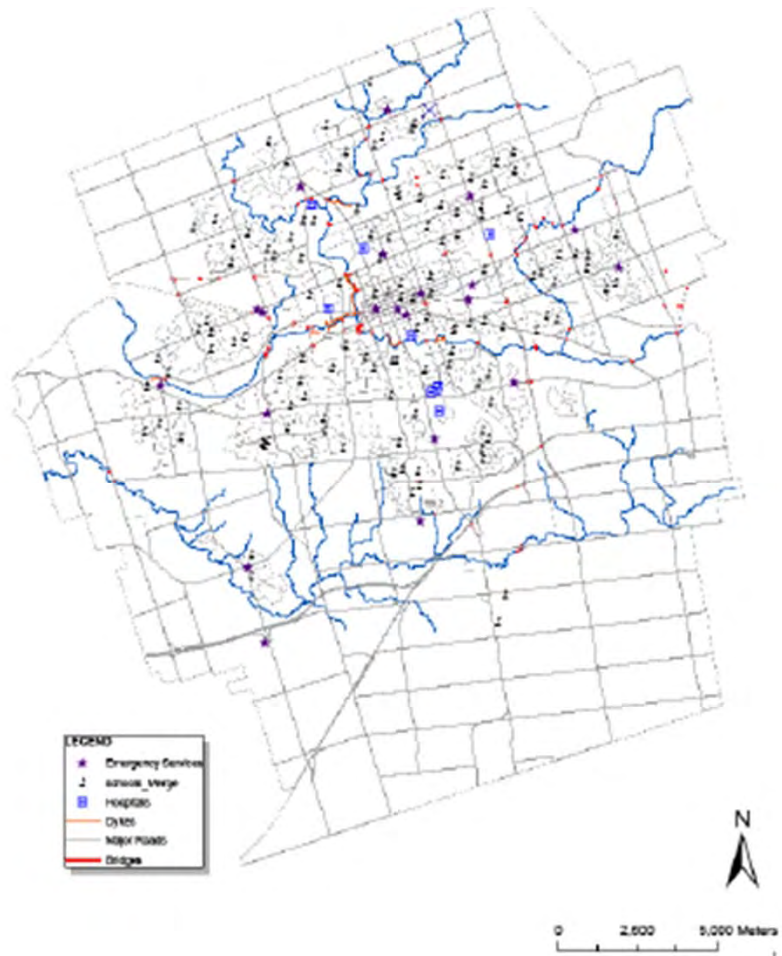
Spatial data





Infrastructure data input

- Buildings
- Transportation
  - Roadways
  - Bridges
- Critical Infrastructure
  - Schools
  - Hospitals and Emergency Services
- Barriers
  - Dams, Dikes, Other flood control infrastructure
- Sewer Infrastructure
  - Wastewater Treatment Plants
  - Outlets
  - Sanitary and Storm Systems



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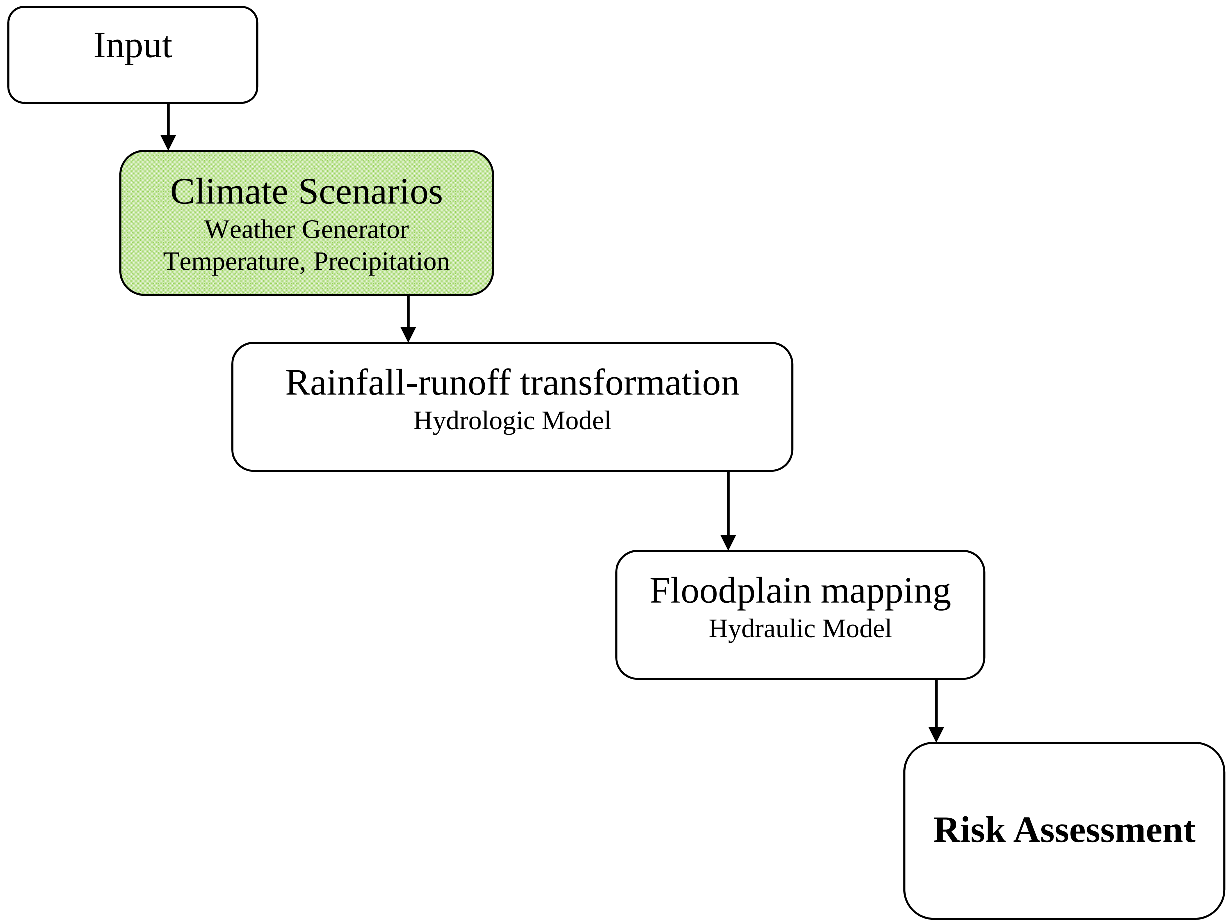
Climate modelling



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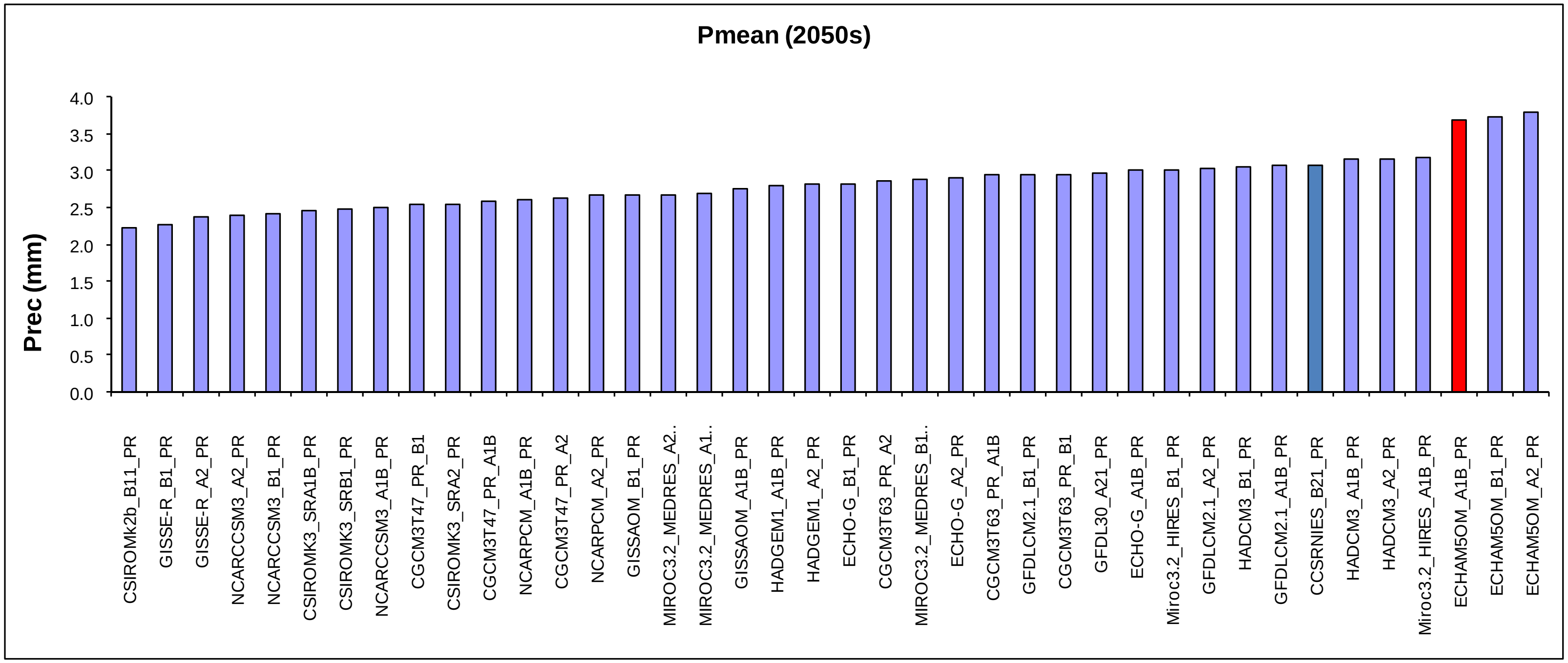
Climate scenarios

- Lower bound climate scenario
  - No modifications due to climate change and future emissions
  - Weather generator with perturbation of historical data
- Upper bound climate scenario
  - Recommended by the previous study
  - Data modified by GCM

Choice of climate scenario



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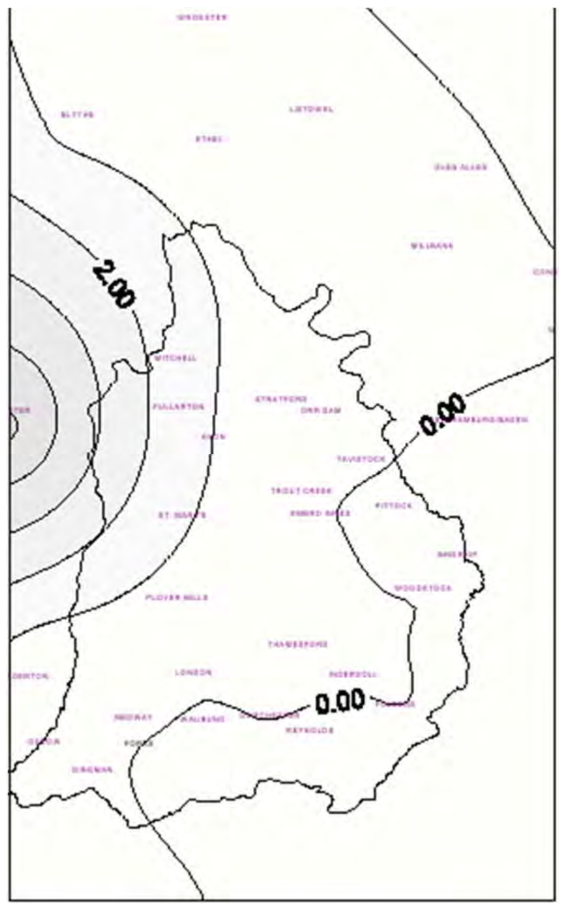
Weather generator

- K-NN model
  - Successful applications (Yates, 2003; Sharif and Burn, 2006)
  - Ability to generate meteorological variables out of the historical range
  - Combined with Principle Component Analysis to reduce computational burden
  - Use of 15 stations and 3 variables (precipitation, maximum and minimum temperature)

Building Resilient Communities
Pour construire des communautés solides

Weather generator



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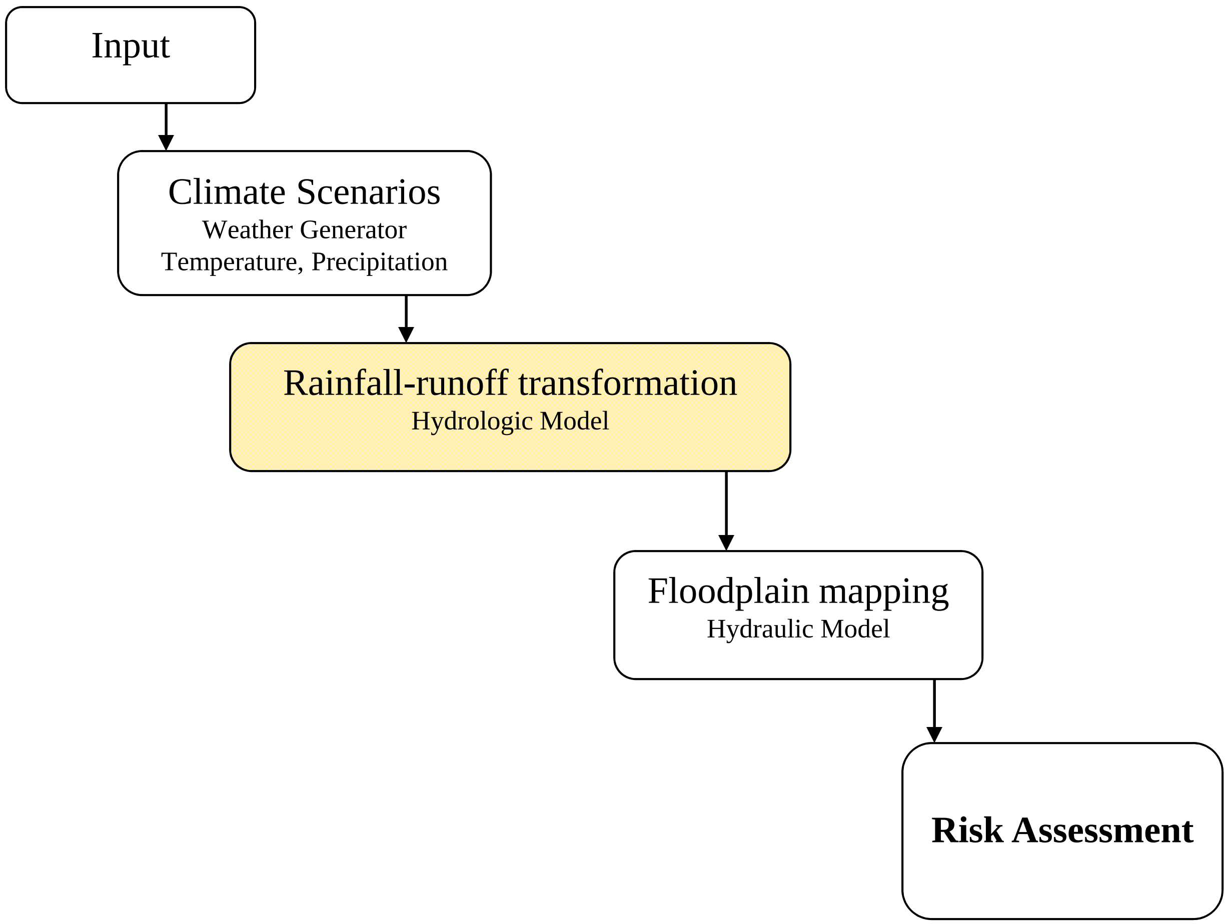
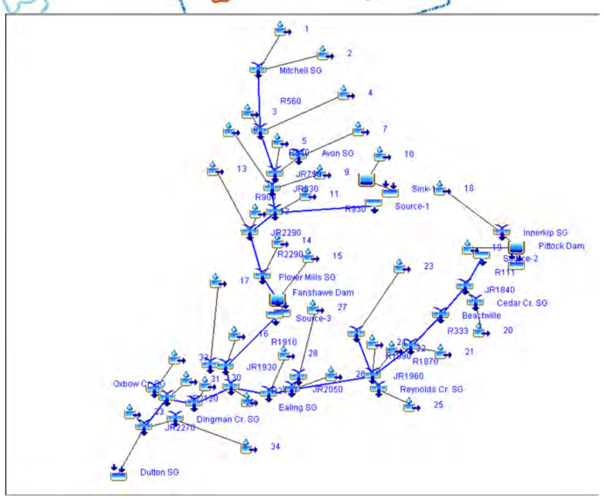
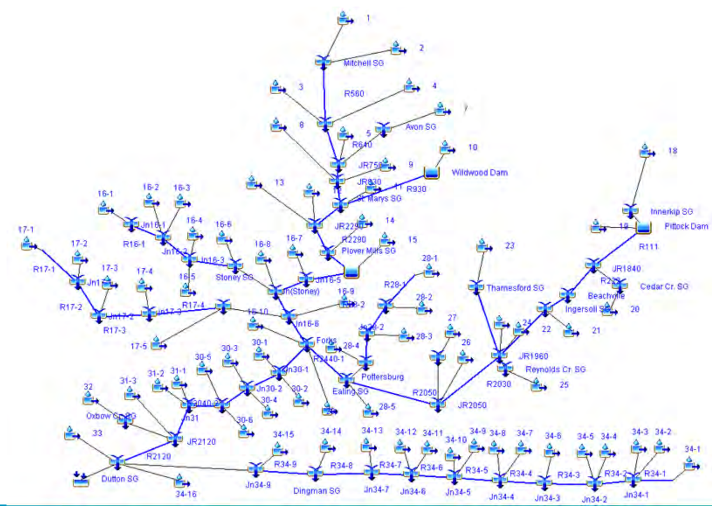
Hydrologic modelling



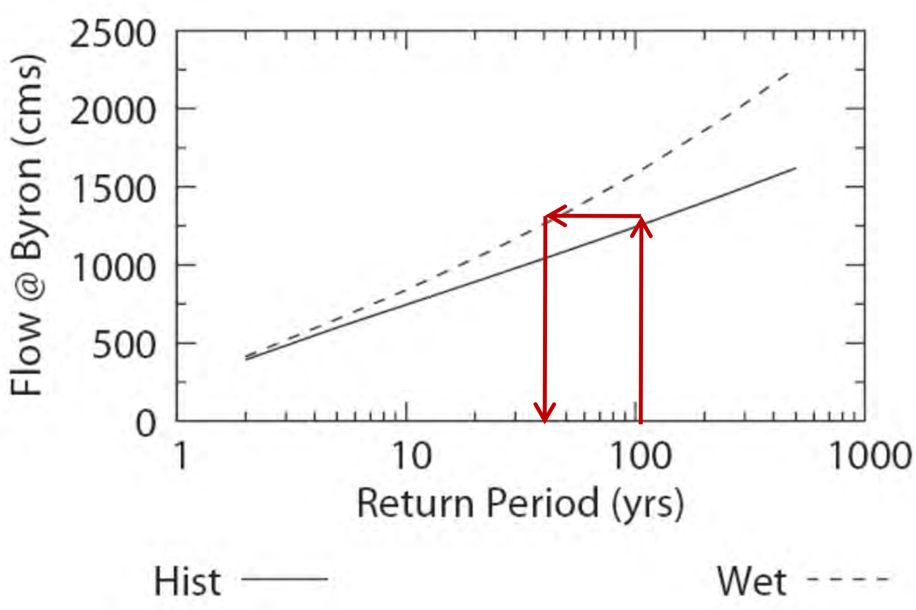
Hydrologic modelling

- Modification of HEC-HMS
- Nesting of sub-basins
  - Medway (5 sub-basins)
  - Stoney (6 sub-basins)
  - Pottersburg (4 sub-basins)
  - Dingman (16 sub-basins)





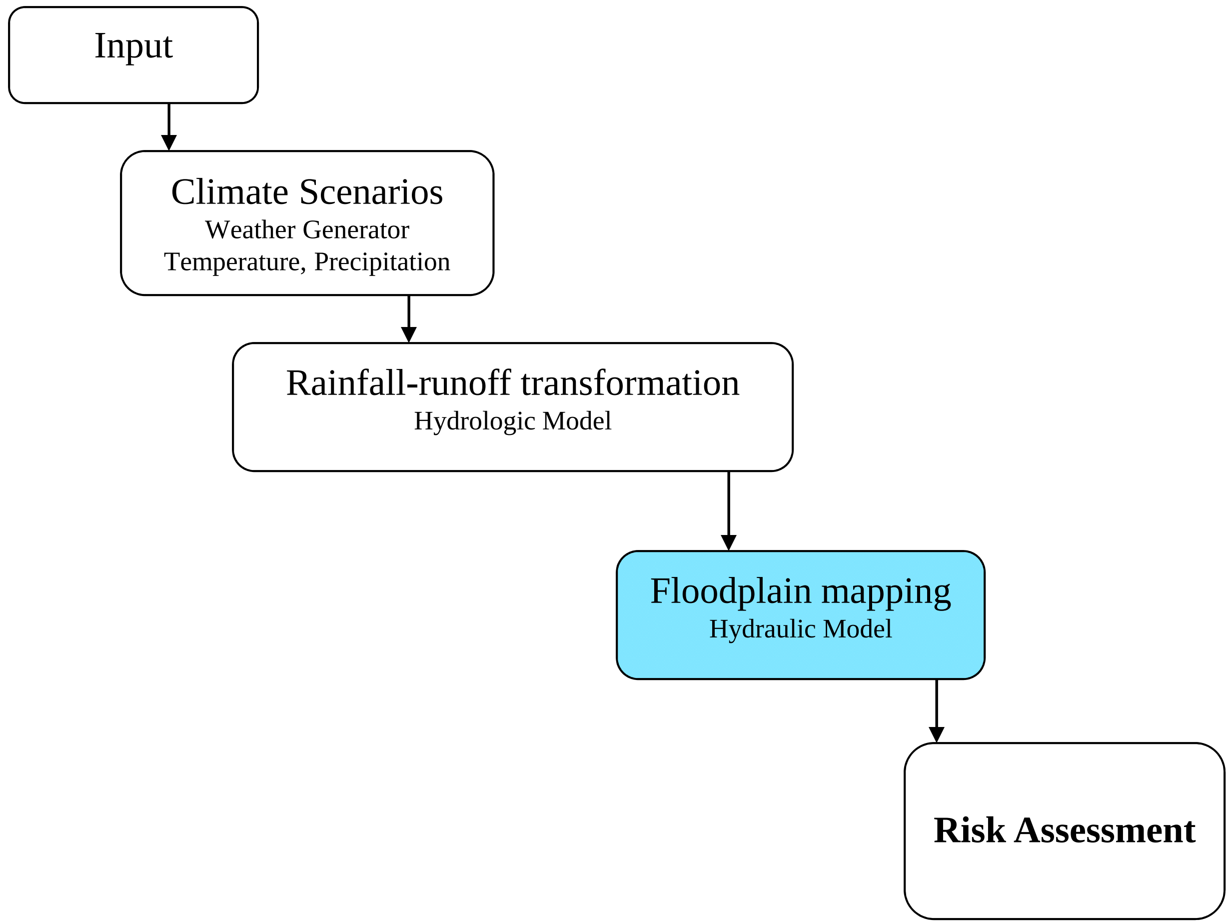
Hydrologic modelling



More frequent flooding

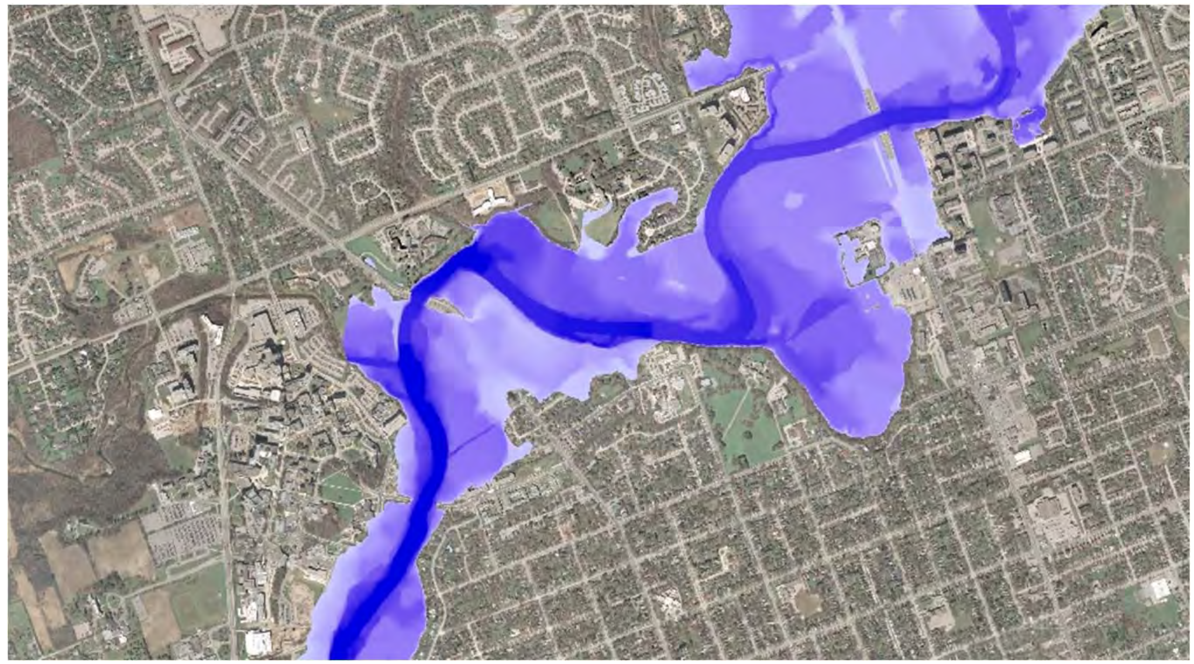
More severe floods

Hydraulic modelling



Hydraulic modelling

- Input: Streamflows from hydrologic model
- HEC-RAS and HEC-GeoRAS
- Output: floodplains to represent flood extent and depth for use in risk analysis



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Hydraulic modelling

100 yr

250 yr

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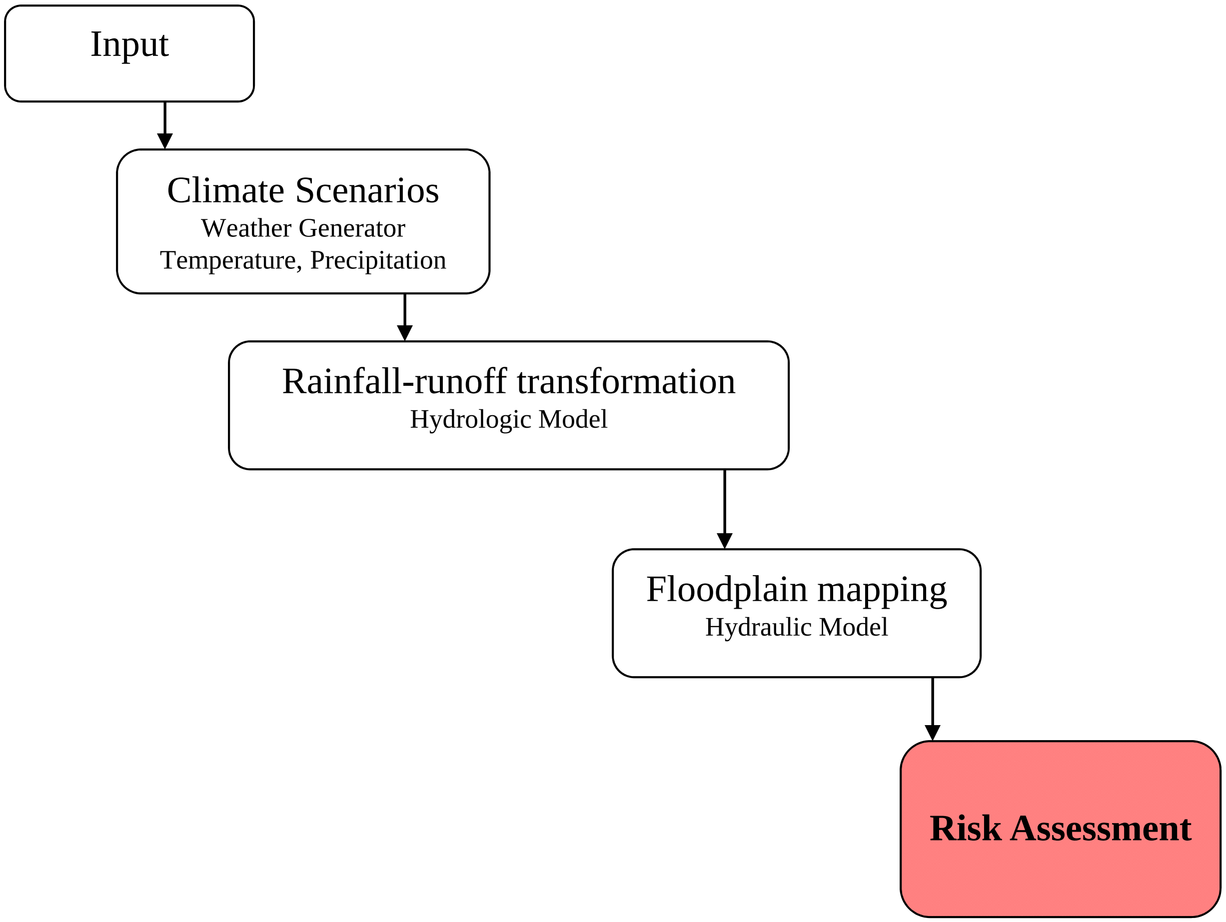
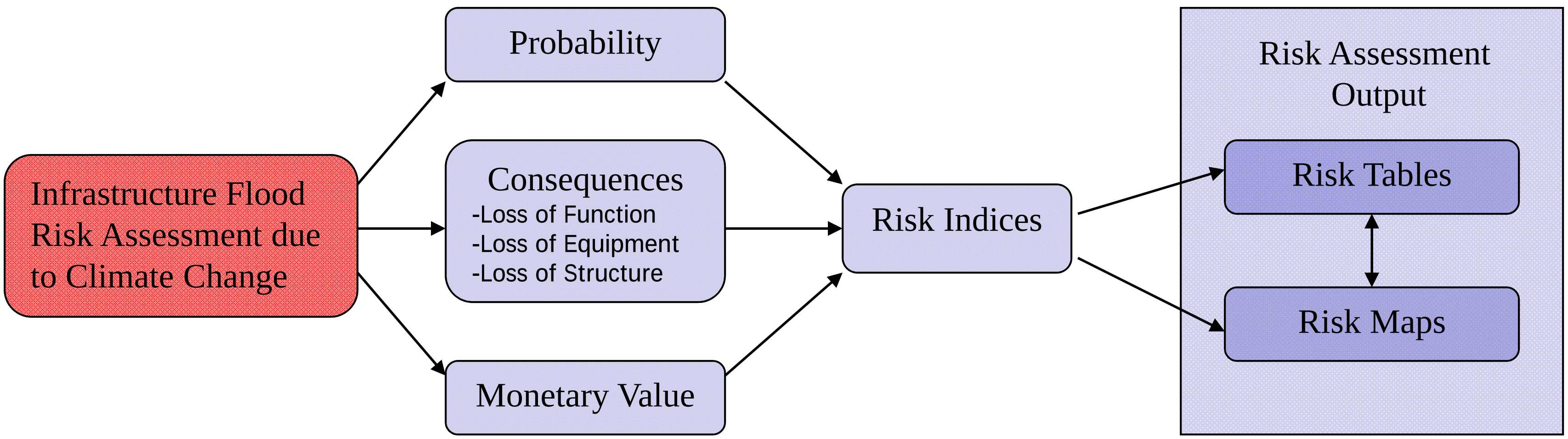
Risk assessment



Risk assessment



Risk = Probability of hazard x Σ[Monetary damage value x Consequence]

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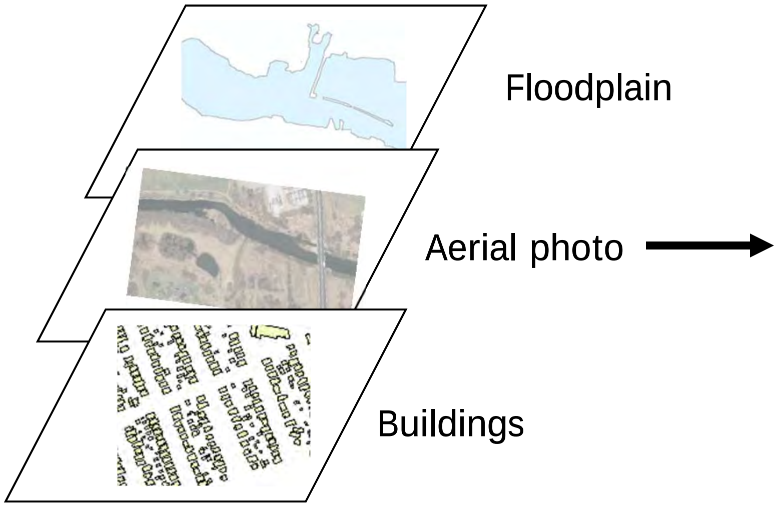
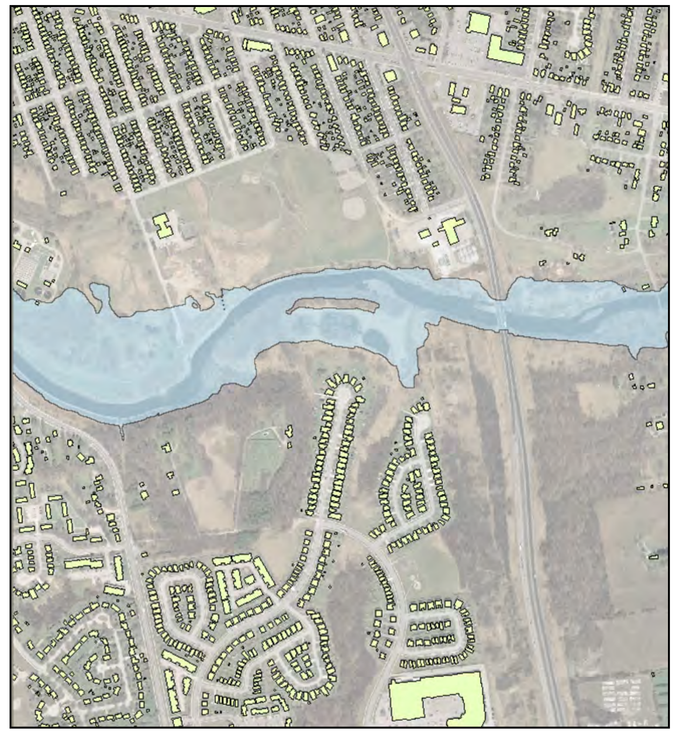
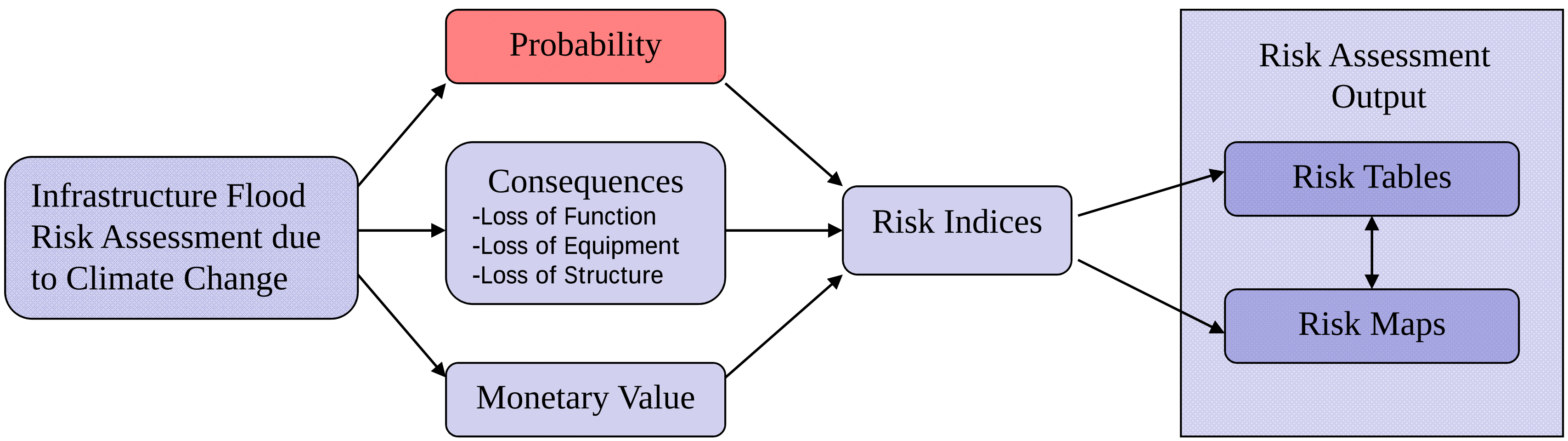
Risk assessment





Identify inundated infrastructure

Risk assessment



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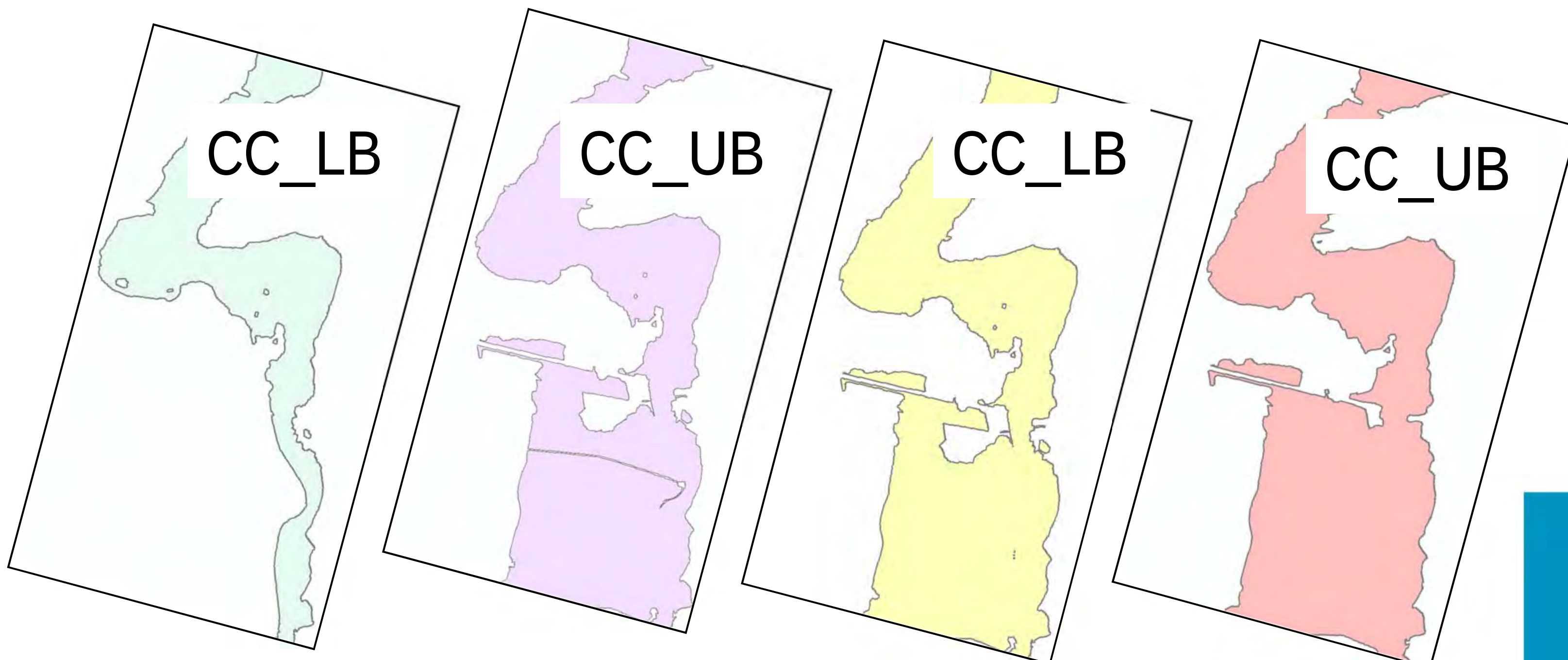
Risk assessment

- Probability - The likelihood that a particular flood event will occur in a given year



100yr RP 100yr RP 250yr RP 250yr RP

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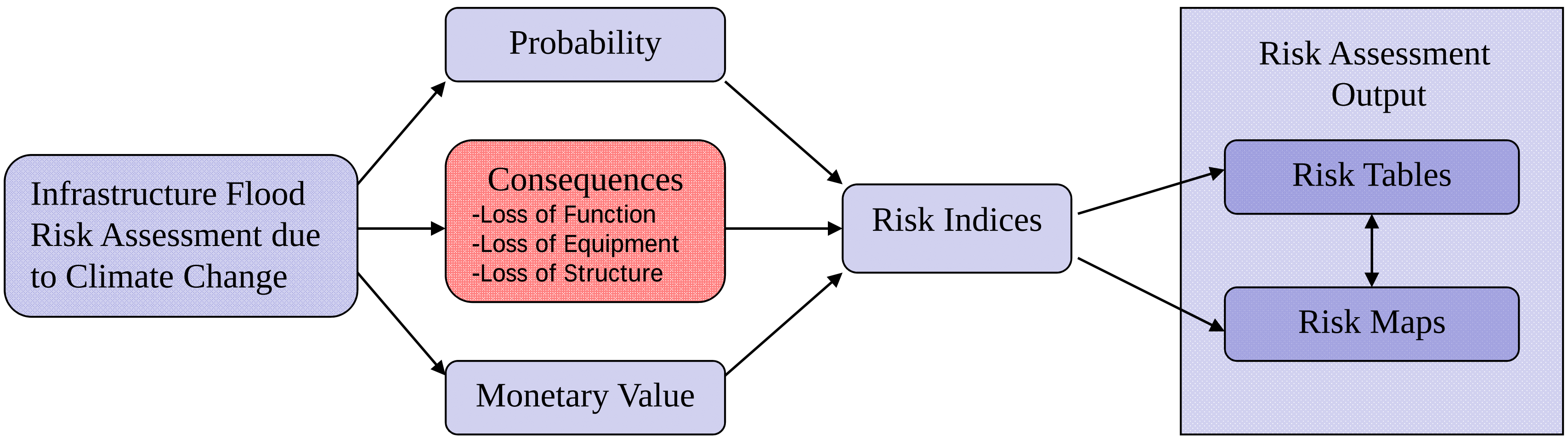
Risk assessment



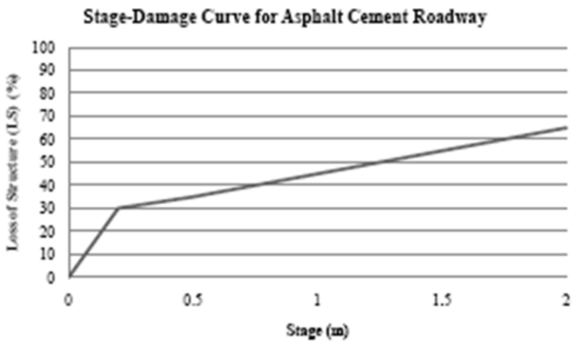
Risk assessment

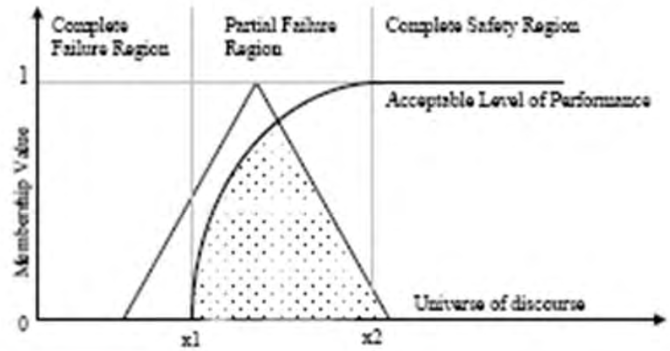
- Flood Consequence Multipliers
  - Loss of Function (IM_1) - a fraction of the damage an infrastructure incurs as a result of losing its function during a flood event [0,1]
  - Loss of Equipment (IM_2) - a fraction of the damage to any equipment related to the infrastructure as a result of a particular flood event [0,1]
  - Loss of Structure (IM_3) - a level of damage to the infrastructure itself which may need repair or replacement as a result of a particular flood event

Risk assessment

- Deterministic (quantitative) and fuzzy (qualitative) damage measures are combined to describe loss of structure (IM_3)

$$\mathrm{IM}_3(\mathrm{CM}) = \begin{cases} 1, & CM = 0 \\ \mathrm{Min}\left(1, \mathrm{LS} \times \dfrac{1}{\mathrm{CM}}\right), & CM > 0 \end{cases}$$





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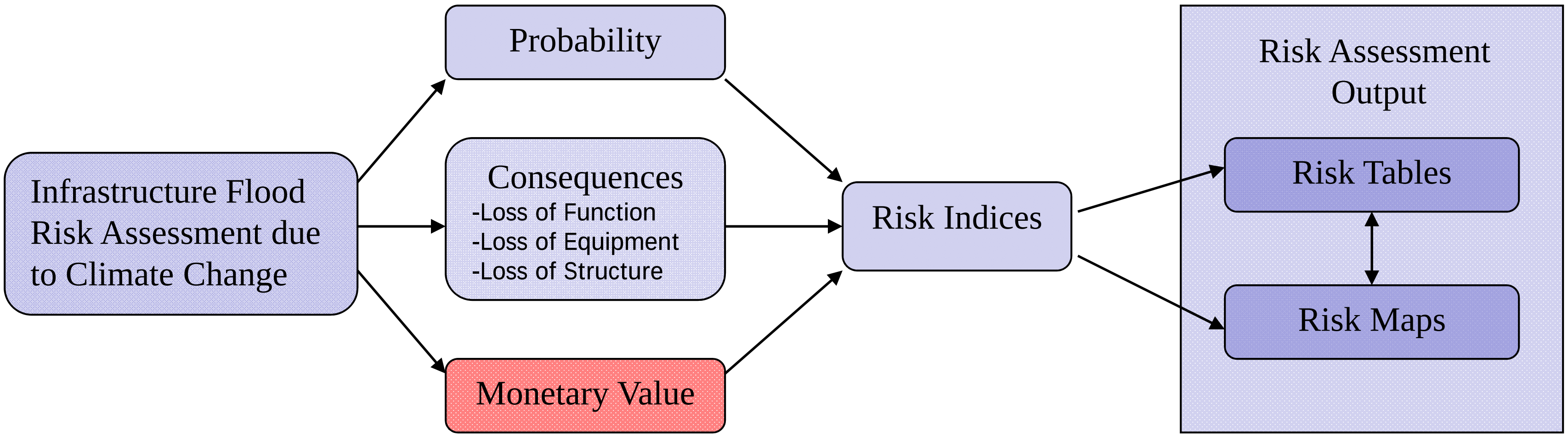
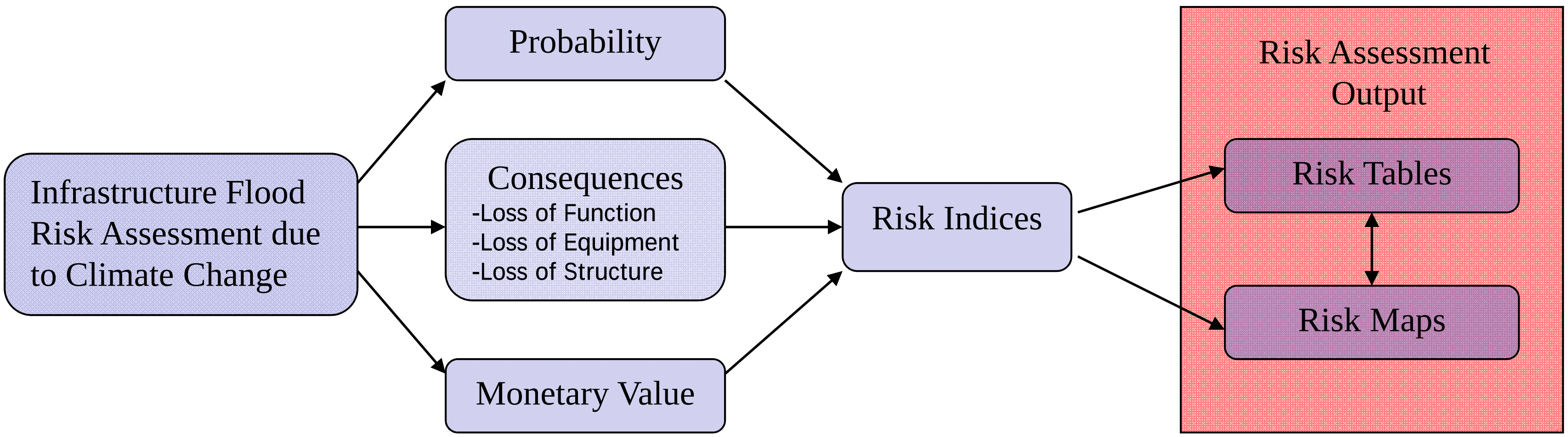
Risk assessment



Risk assessment



$$\text{Risk Index} = P \times \sum_{i=1}^{3} (D_i \times IM_i)$$

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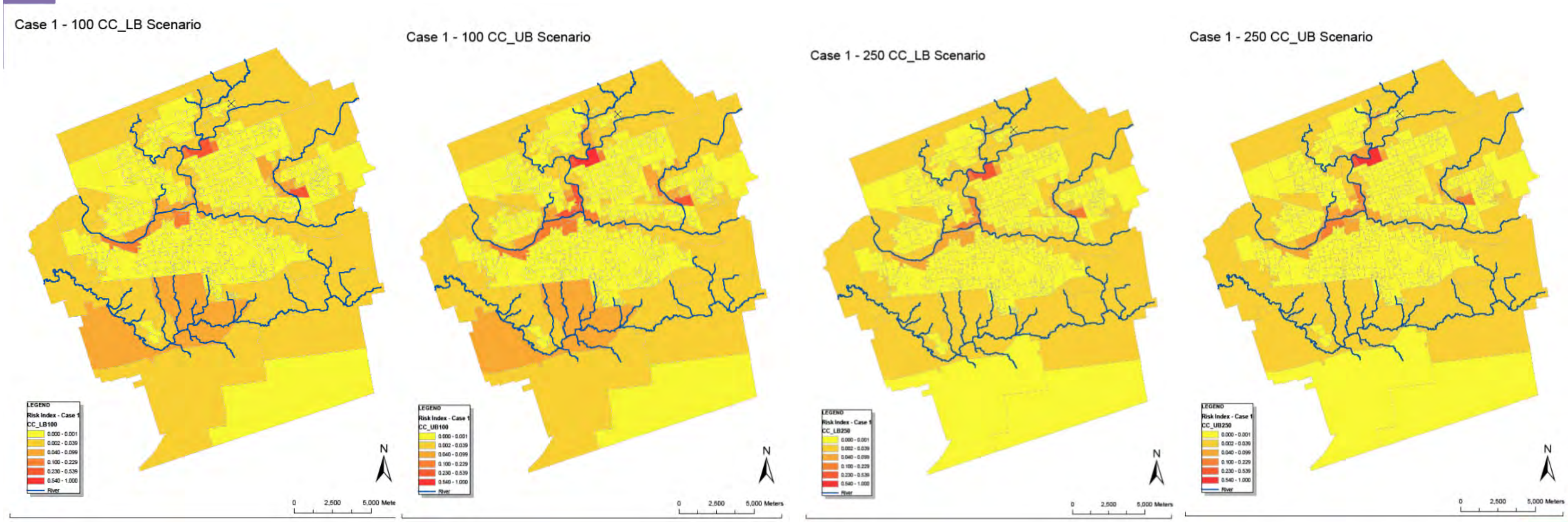
Risk assessment



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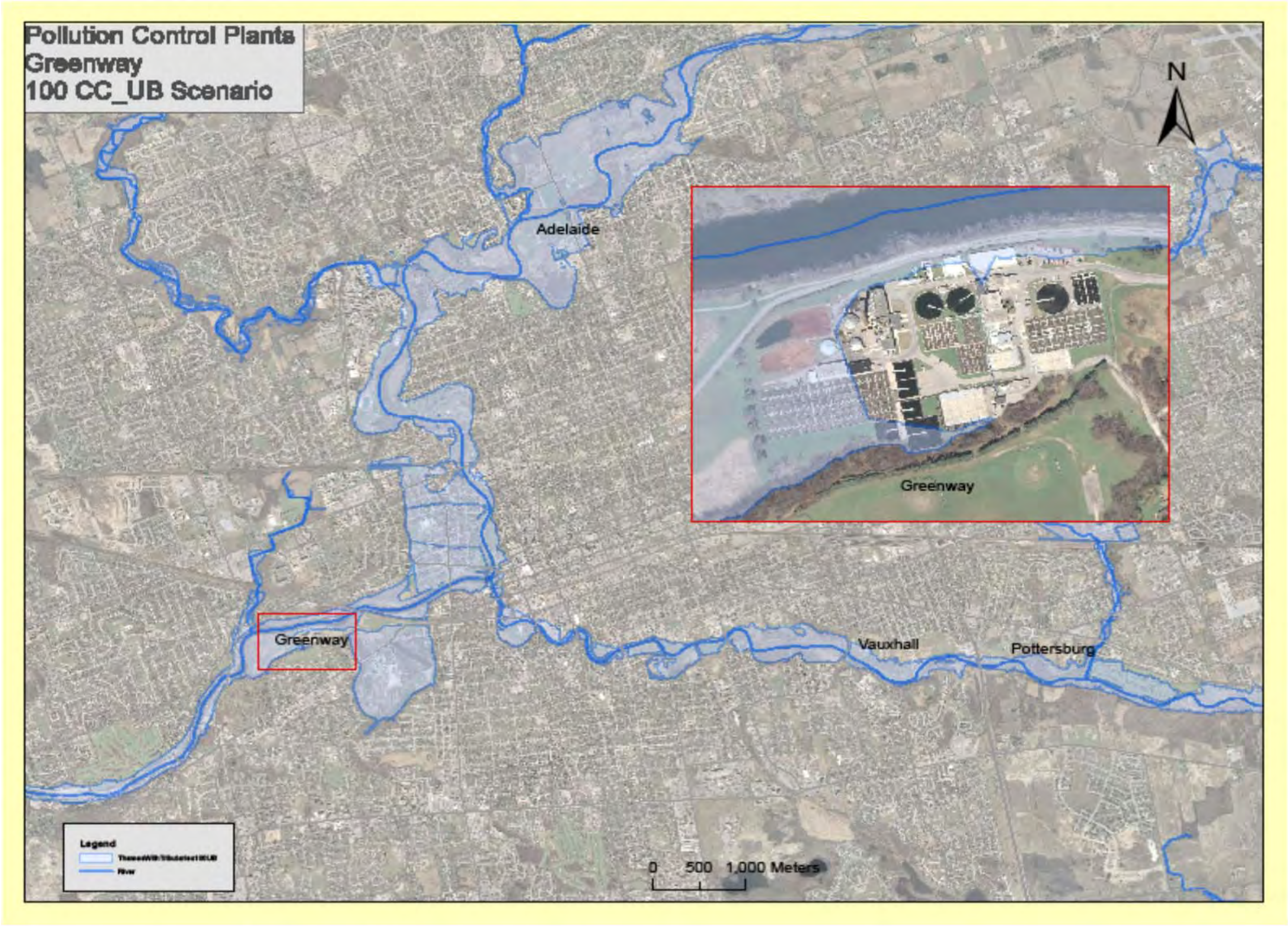
Risk assessment



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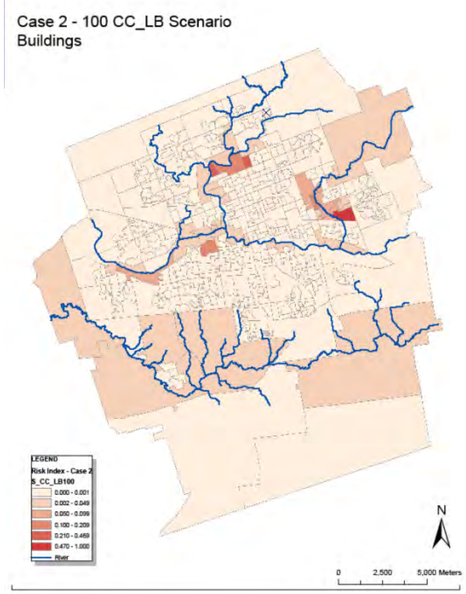
Risk assessment

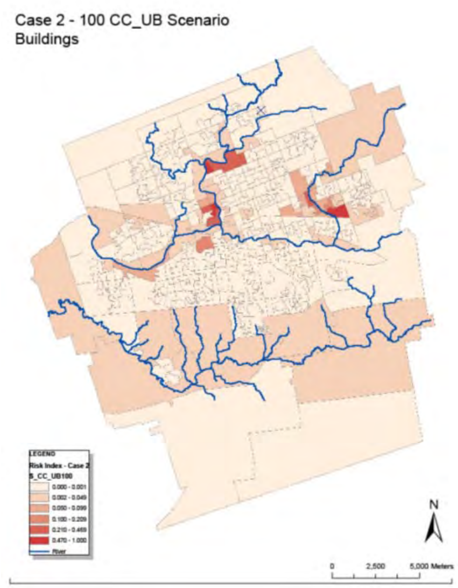
100 CC_ LB	100 CC_ UB	250 CC_LB	250 CC_UB
Total risk			
573,000,000	984,000,000	917,000,000	1,252,000,000
0.00	0.61	0.51	1.00
5,730,000	9,840,000	3,668,000	5,004,000
0.33	**1.00**	**0.00**	**0.22**

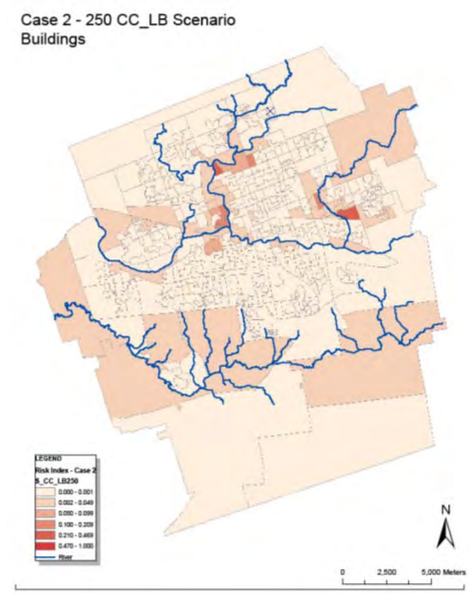
Risk assessment

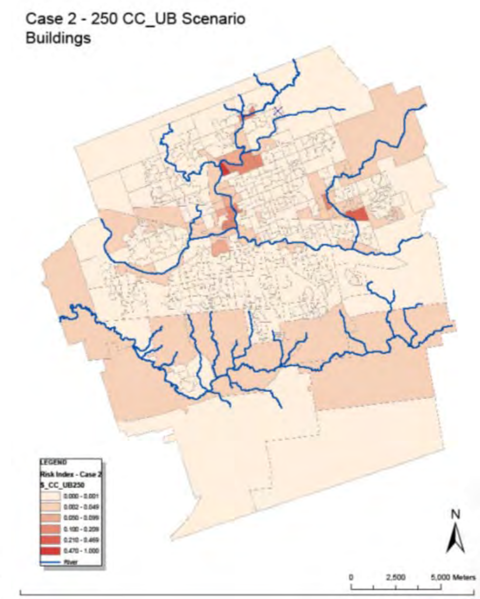
250 UTRCA	250 CC_LB	250 CC_UB
797,000,000	917,000,000	1,252,000,000
0.00	0.26	1.00
3,188,000	3,668,000	5,004,000
0.00	**0.27**	**1.00**

Risk assessment

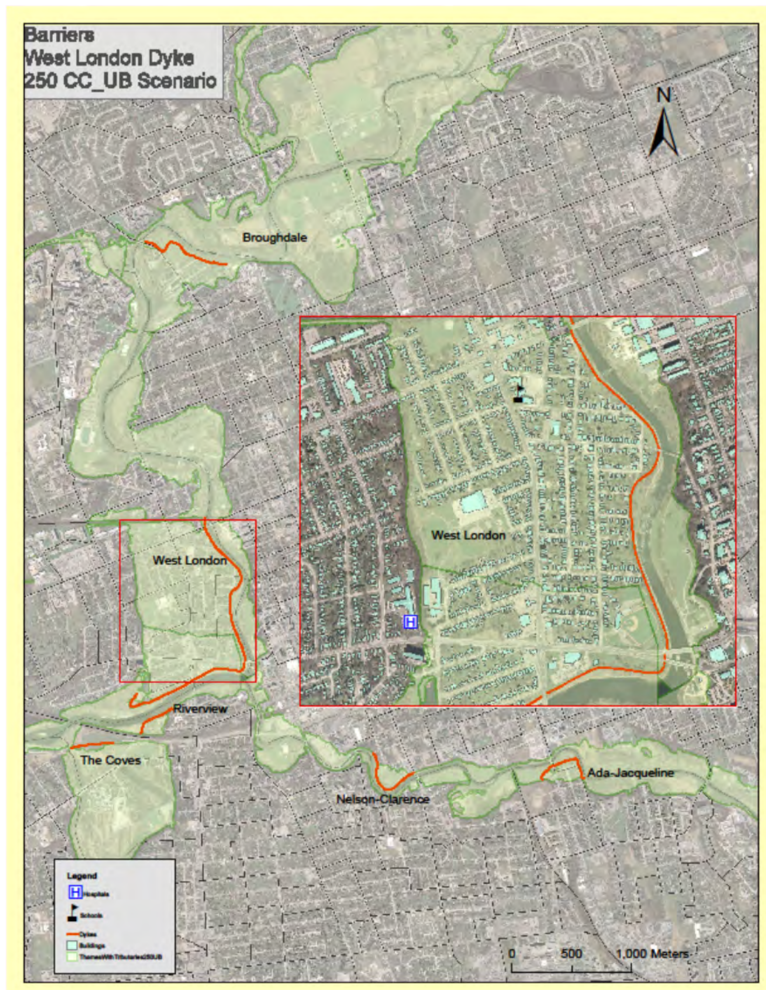








Risk assessment



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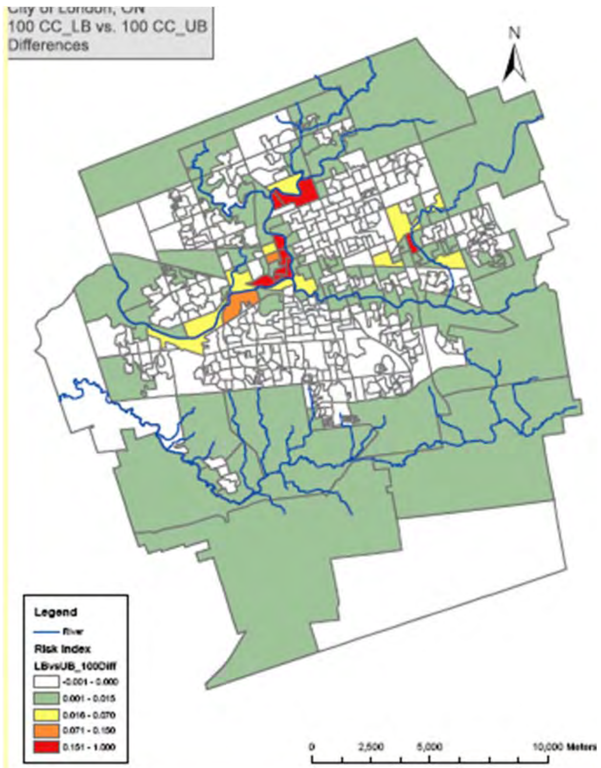
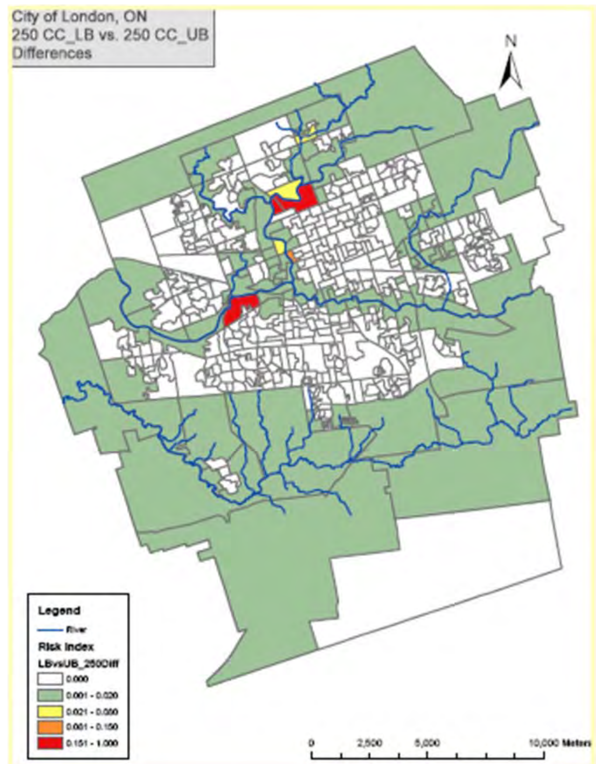
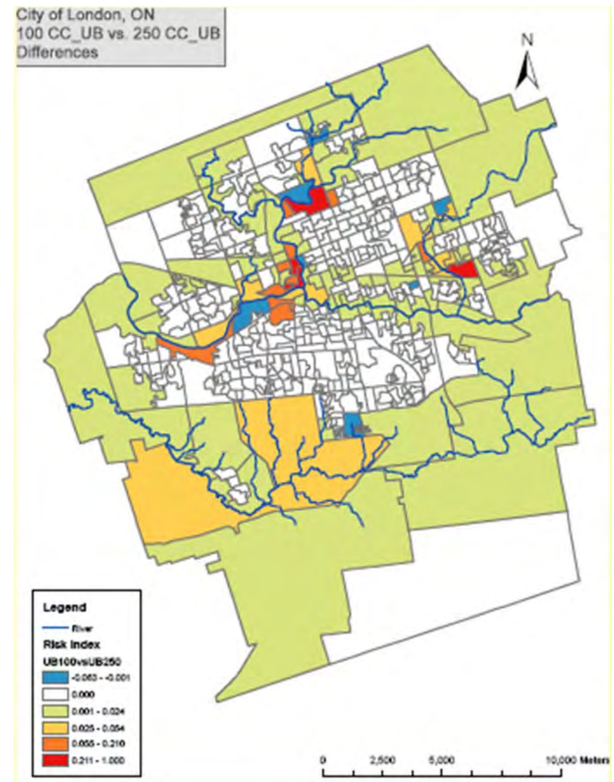
Risk assessment

100 CC_ LB	100 CC_ UB	250 CC_LB	250 CC_UB
Roads			
0.00	0.00	0.00	0.00
Bridges			
0.50	0.58	0.23	0.27
Buildings			
0.43	**1.00**	**0.37**	**0.55**
Pollution Control Plants			
0.57	0.62	0.24	0.30
Critical Facilities			
0.00	0.01	0.00	0.00
Barriers			
0.16	0.65	0.23	0.32

Risk assessment







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Conclusions

- Insights into climate change caused flood risk to municipal infrastructure
- Multiple recommendations (engineering, operational, policy)
- Input into adaptation policy development
- Prioritization of adaption action