2-D Hydrodynamic Modelling for Evaluation of Flood Risk in Space and Time

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Presented by
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Presentation outline

- Red River Flood of 1997
- 2D Hydrodynamic Modelling
- Spatial and temporal variation of risk
- Uncertainty in floodplain management
- Fuzzy set theory
- Fuzzy risk measures : (1) Combined reliability and vulnerability index
  (2) Robustness index
  (3) Resiliency index
- Methodology for spatial and temporal representation of fuzzy risk measures
- Conclusion

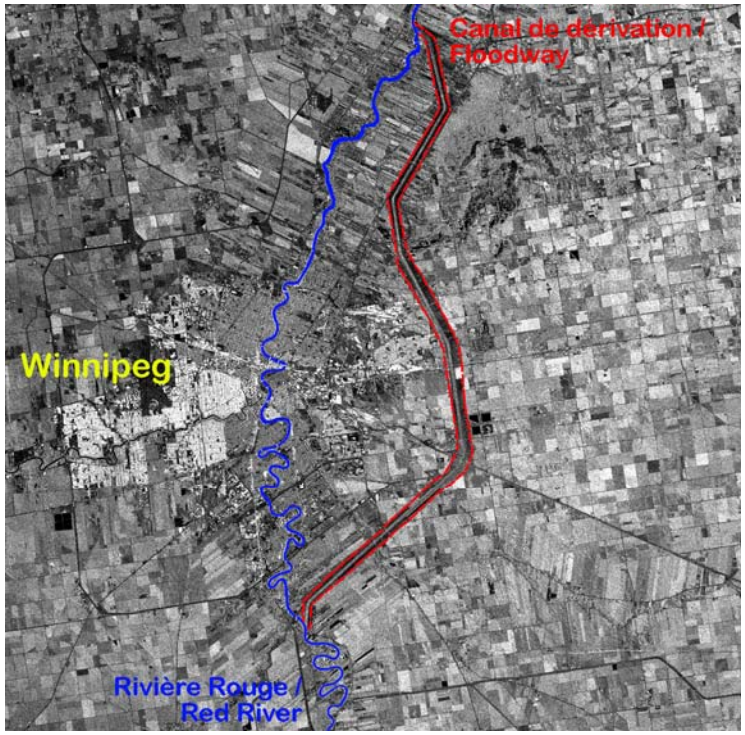
Project objectives

- Methodology to represent spatial and temporal variation of risk in floodplain management
- Methodology to spatially and temporally represent risk associated with uncertainty

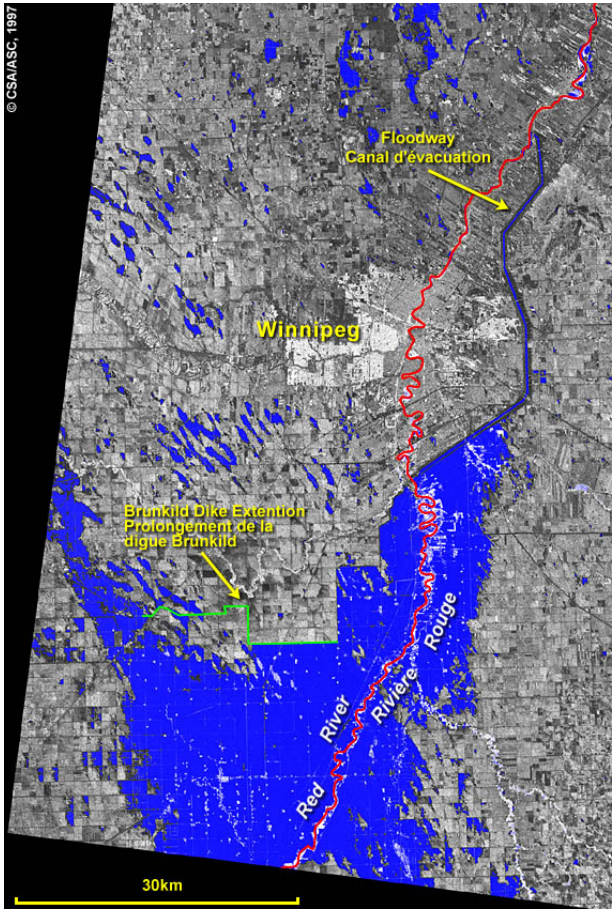
Research contributions

- Introduce spatial and temporal variability in flood risk assessment

Red River Flood 1997



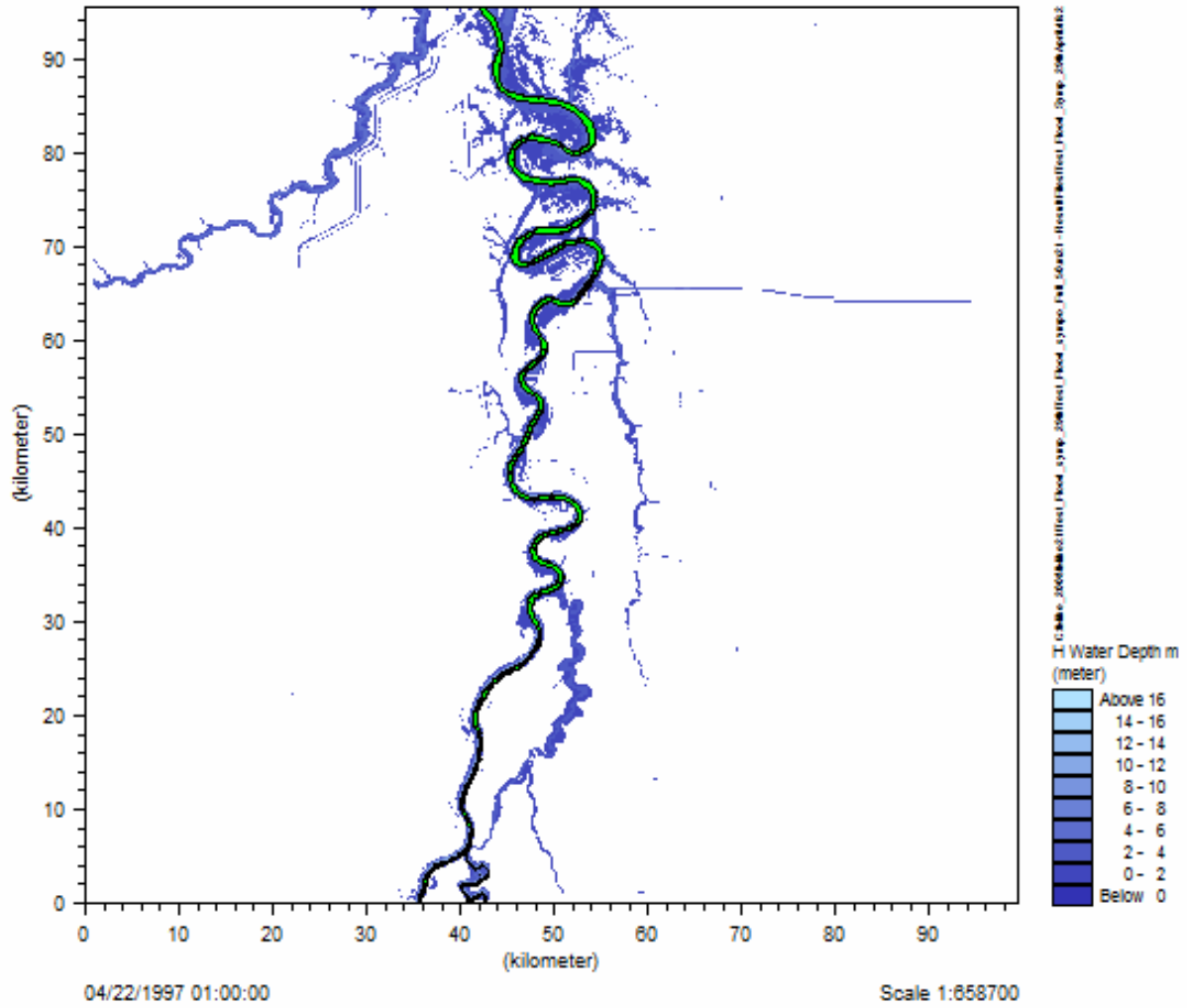
RADARSAT1 Image, Spring, 1997



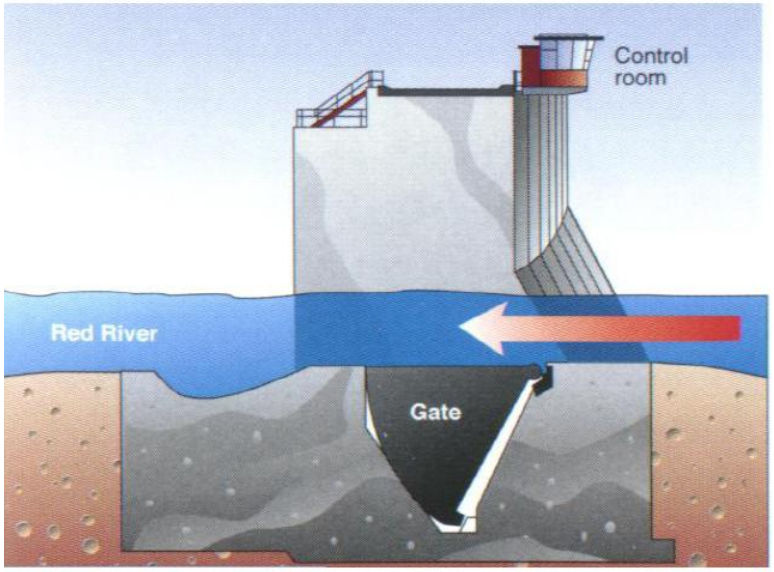
RADARSAT1 Image, May 01, 1997

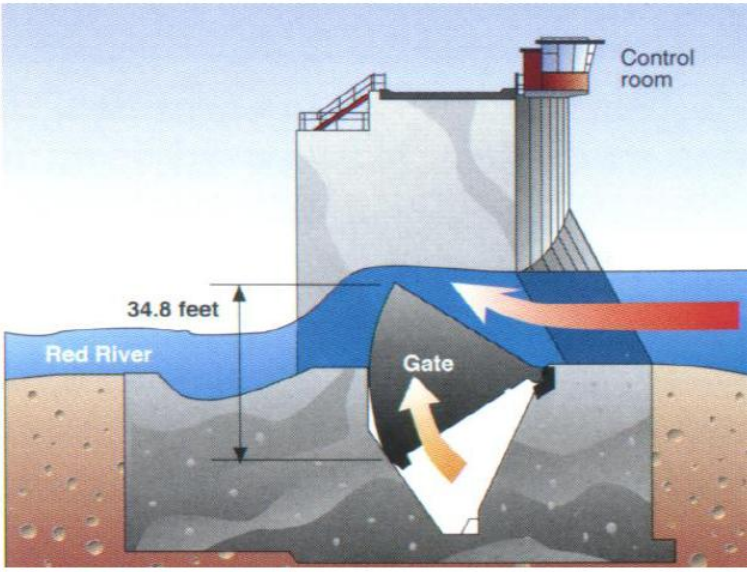
Inlet Structure and Floodway

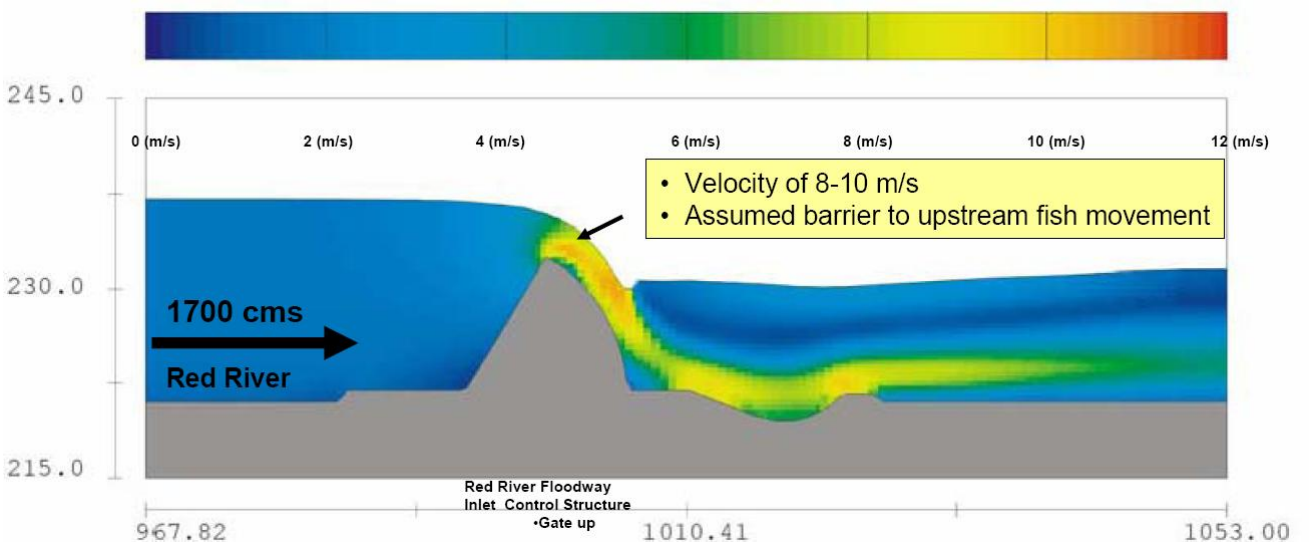
2D Hydrodynamic Modelling



Operation of Inlet Control Structure



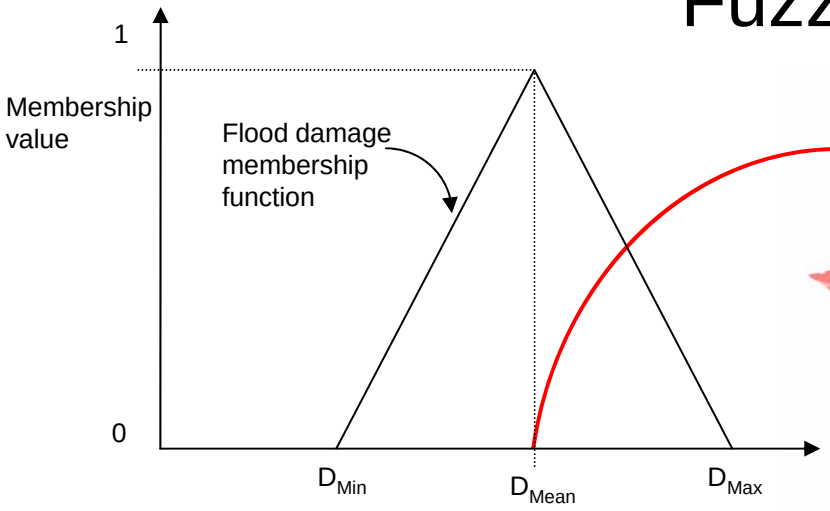




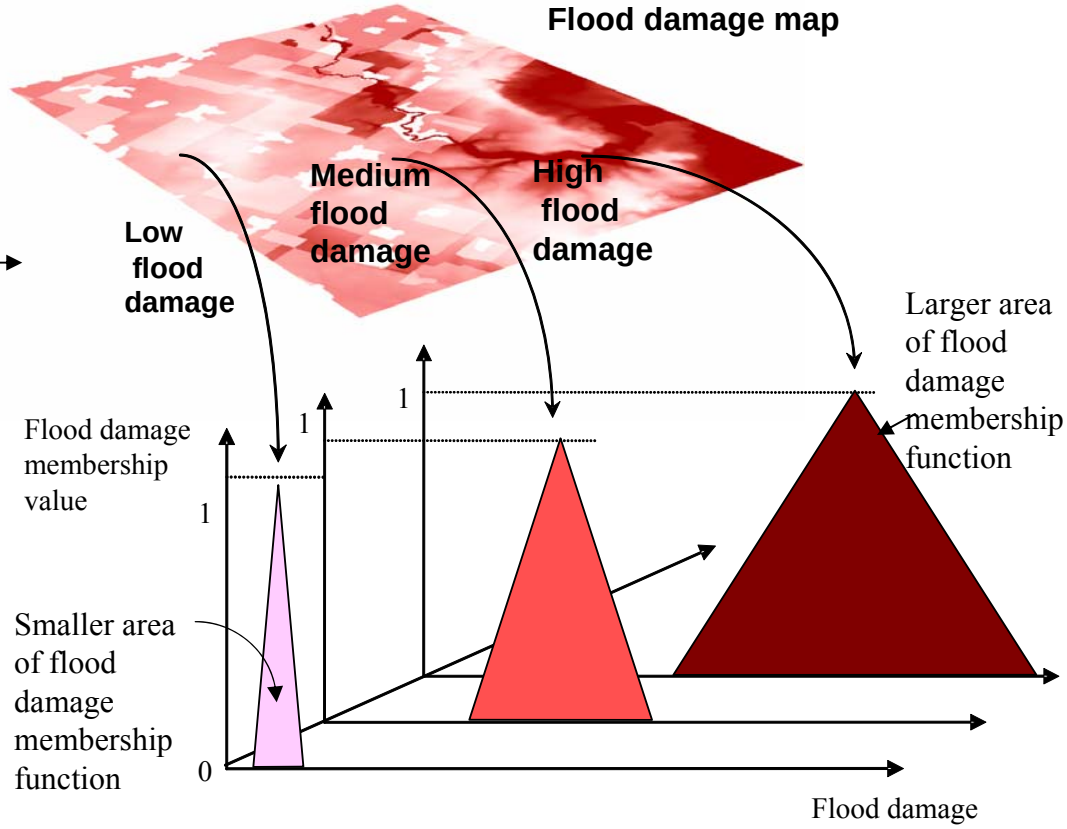
Uncertainty associated with flood risk management

- Lack of data and ambiguity
- Hydrologic uncertainty
- Hydraulic uncertainty
- Economic uncertainty
- Structural uncertainty
- Spatial and temporal uncertainty
- Individual heterogeneity
- Precise knowledge of goals, constraints and consequences
- Lack of knowledge in representation of mathematical model

Fuzzy set theory

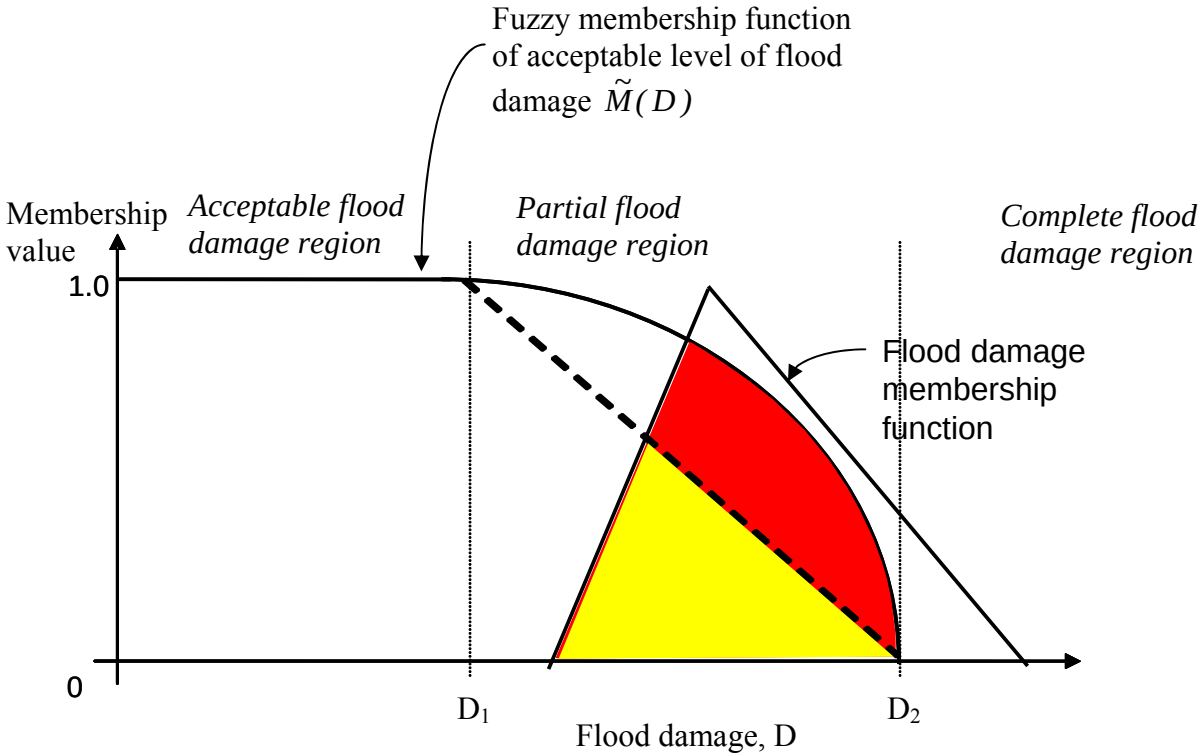


$$\widetilde{S}(D) = \begin{cases} 0 & if\ D \le D_{Min} \\ \dfrac{D - D_{Min}}{D_{Mean} - D_{Min}} & if\ D \in [D_{Min}, D_{Mean}] \\ \dfrac{D_{Max} - D}{D_{Max} - D_{Mean}} & if\ D \in [D_{Mean}, D_{Max}] \\ 0 & if\ D \ge D_{Max} \end{cases}$$



Fuzzy risk measures

Combined reliability & vulnerability Index



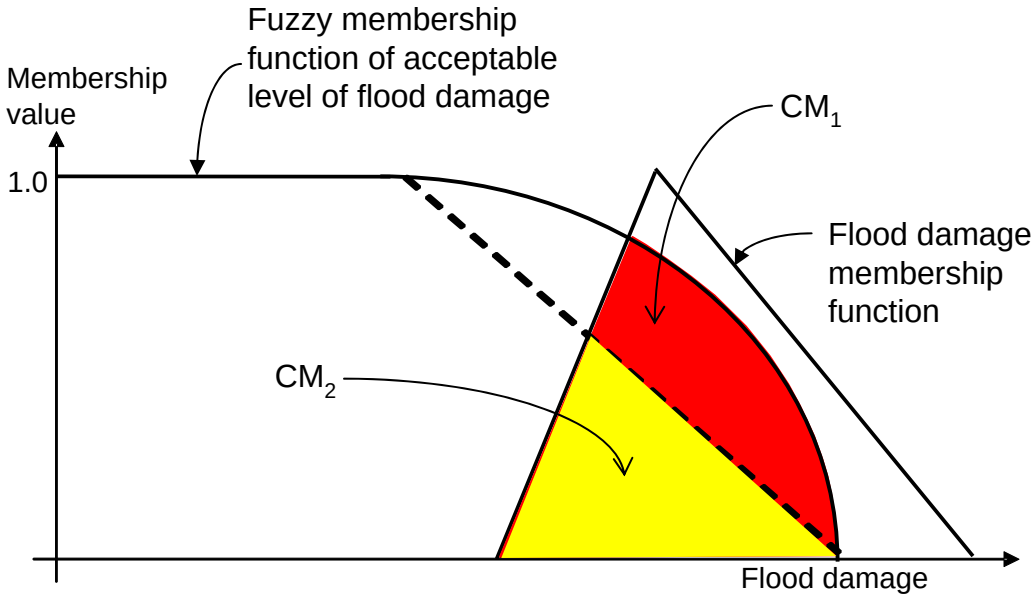
$$\tilde{M}(D) = \begin{Bmatrix} 1 & if\ D \le D_1 \\ \theta(D) & if\ D \in [D_1, D_2] \\ 0 & if\ D \ge D_2 \end{Bmatrix}$$

$$Compatibility\ Measure\ (CM) = \frac{Weighted\ Overlap\ area}{Weighted\ area\ of\ system\ state\ function}$$

$$RE_f = \frac{\max\limits_{i \in K}\{CM_1, CM_2, ...CM_i\} \times LR_{max}}{\max\limits_{i \in K}\{LR_1, LR_2, ...LR_i\}}$$

Fuzzy risk measures

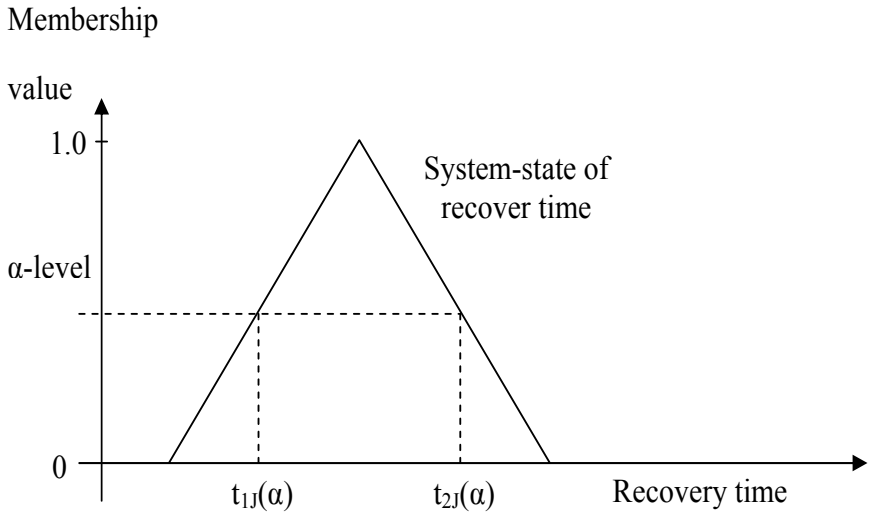
Robustness Index

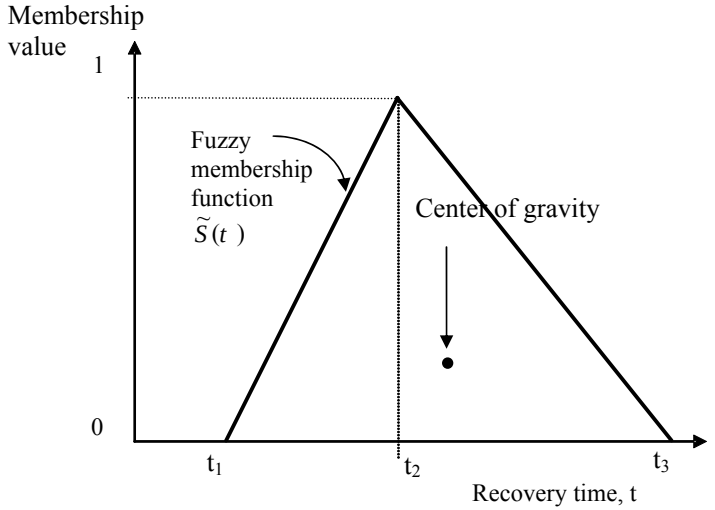


$$RO_f = \frac{1}{CM_1 - CM_2}$$

Fuzzy risk measures

Resiliency Index



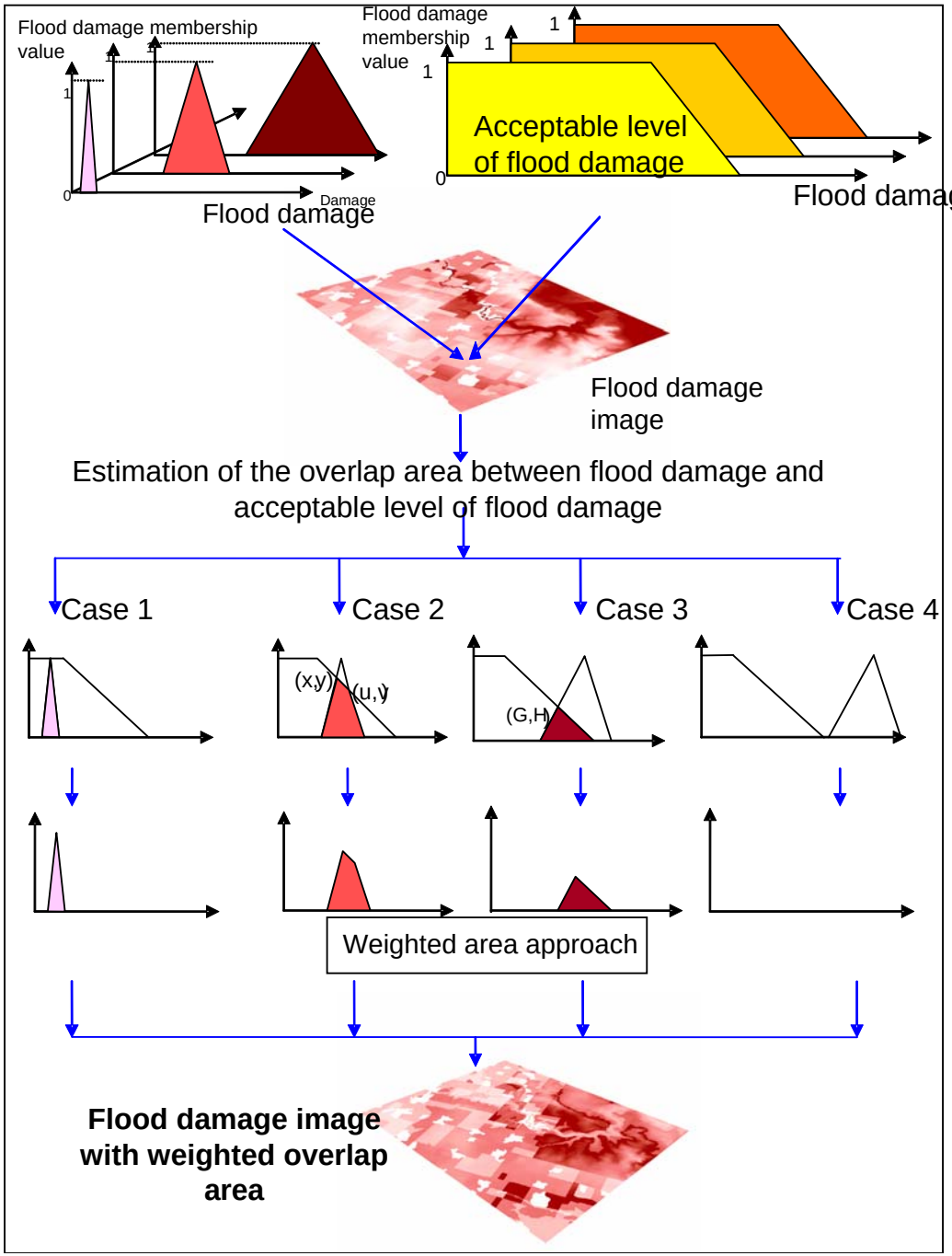


$$\tilde{T}(\alpha) = \left(\max_{j \in J}[t_{1_1}(\alpha), t_{1_2}(\alpha), \ldots\ldots, t_{1_j}(\alpha)], \max_{j \in J}[t_{2_1}(\alpha), t_{2_2}(\alpha), \ldots\ldots, t_{2_j}(\alpha)] \right)$$

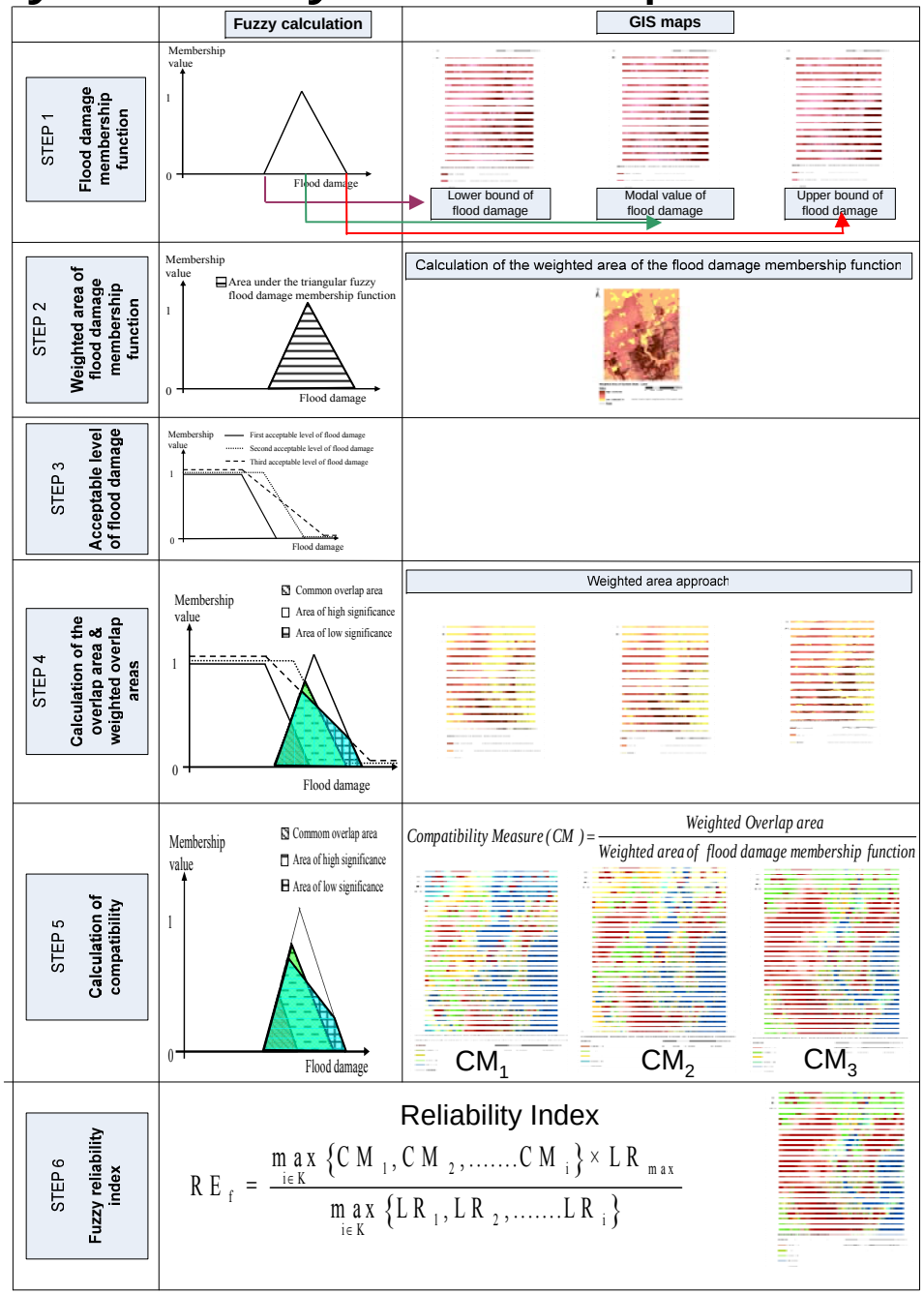
CGi is the center of gravity of the recovery time membership

$$RS_i = [CG_i]^{-1} = \left[\frac{\int_{t_1}^{t_3} t\tilde{T}(t)dt}{\int_{t_1}^{t_3} \tilde{T}(t)dt} \right]^{-1}$$

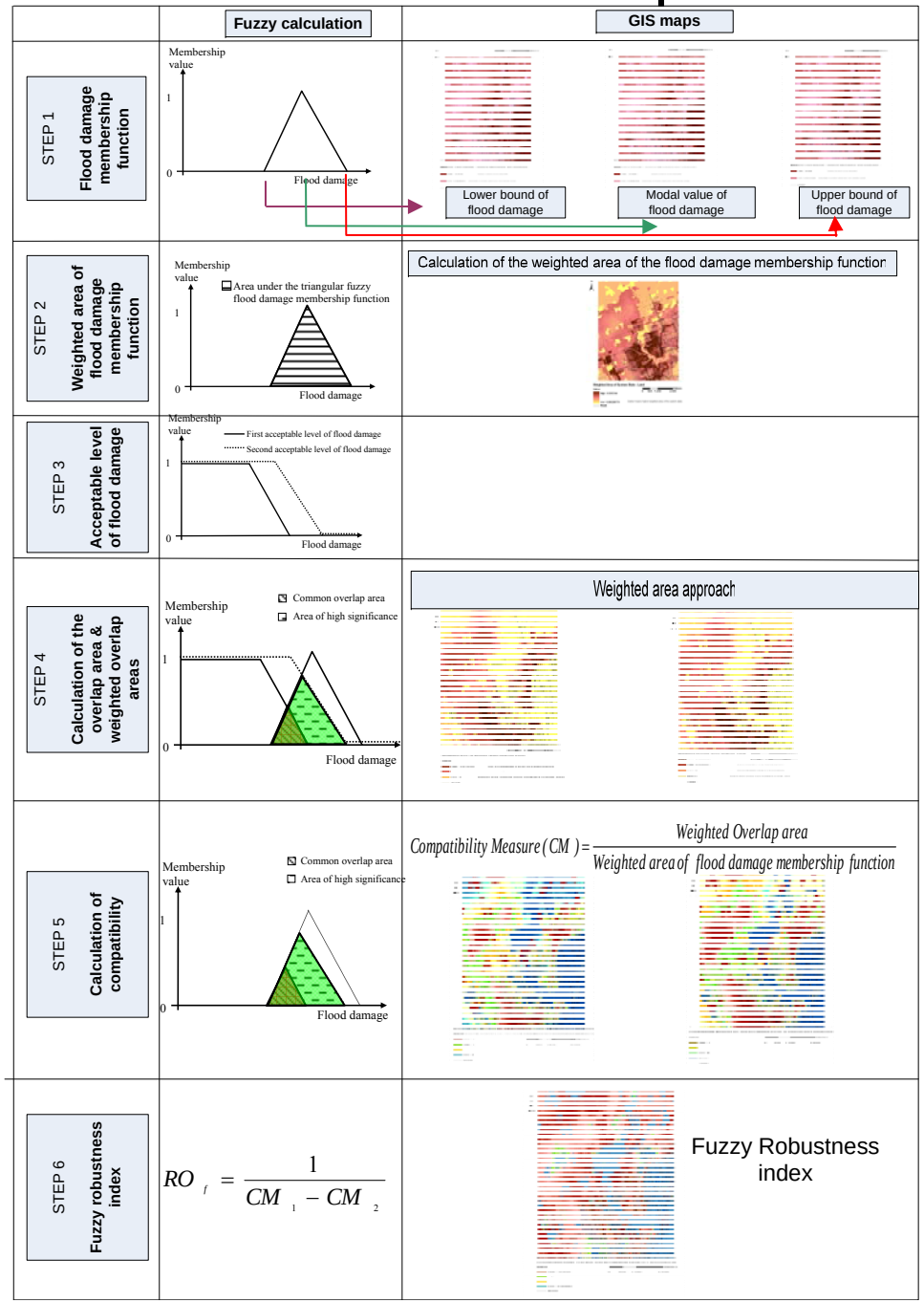
Spatial and temporal representation of fuzzy risk measures



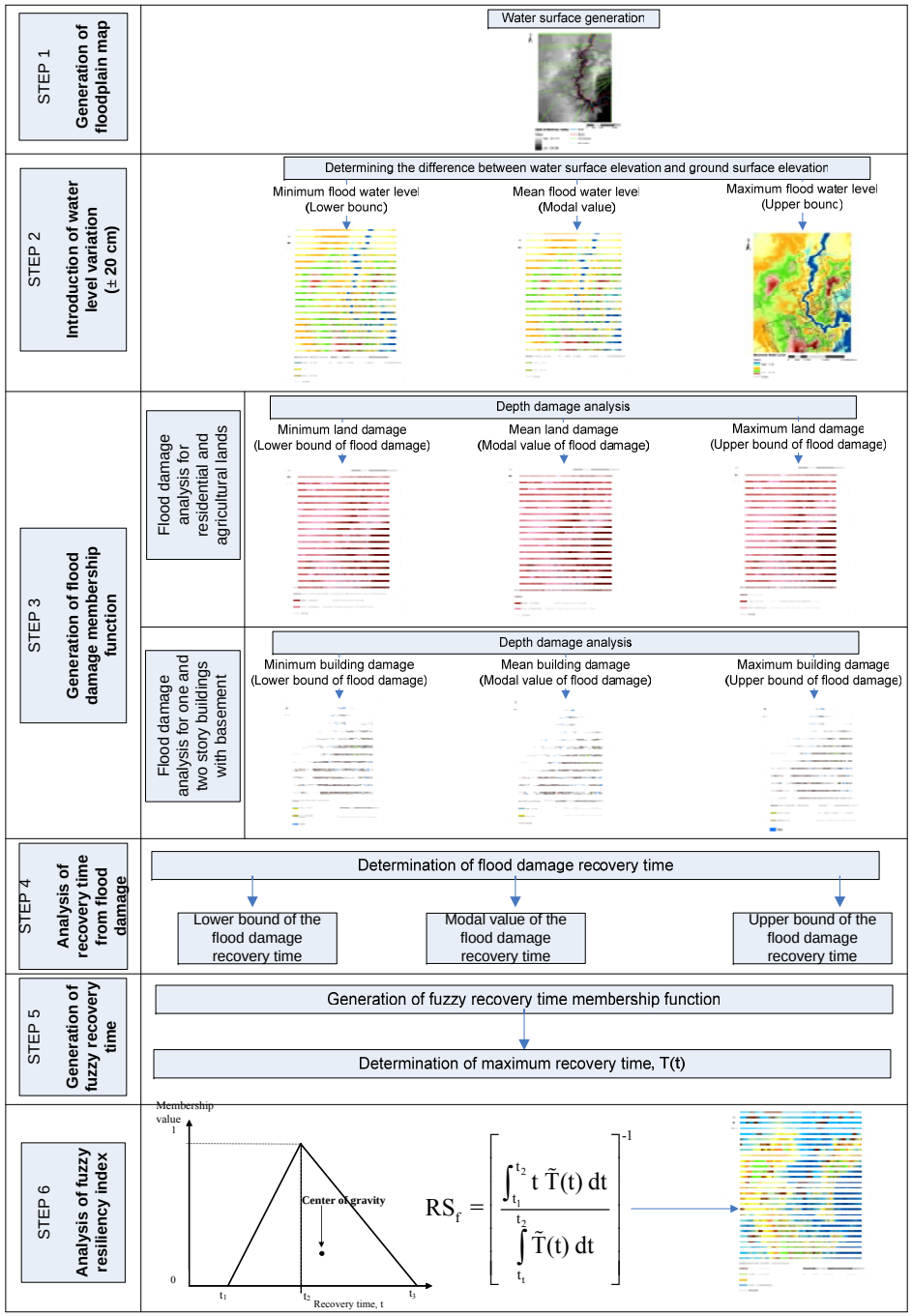
Fuzzy reliability index in space and time



Fuzzy robustness index in space and time



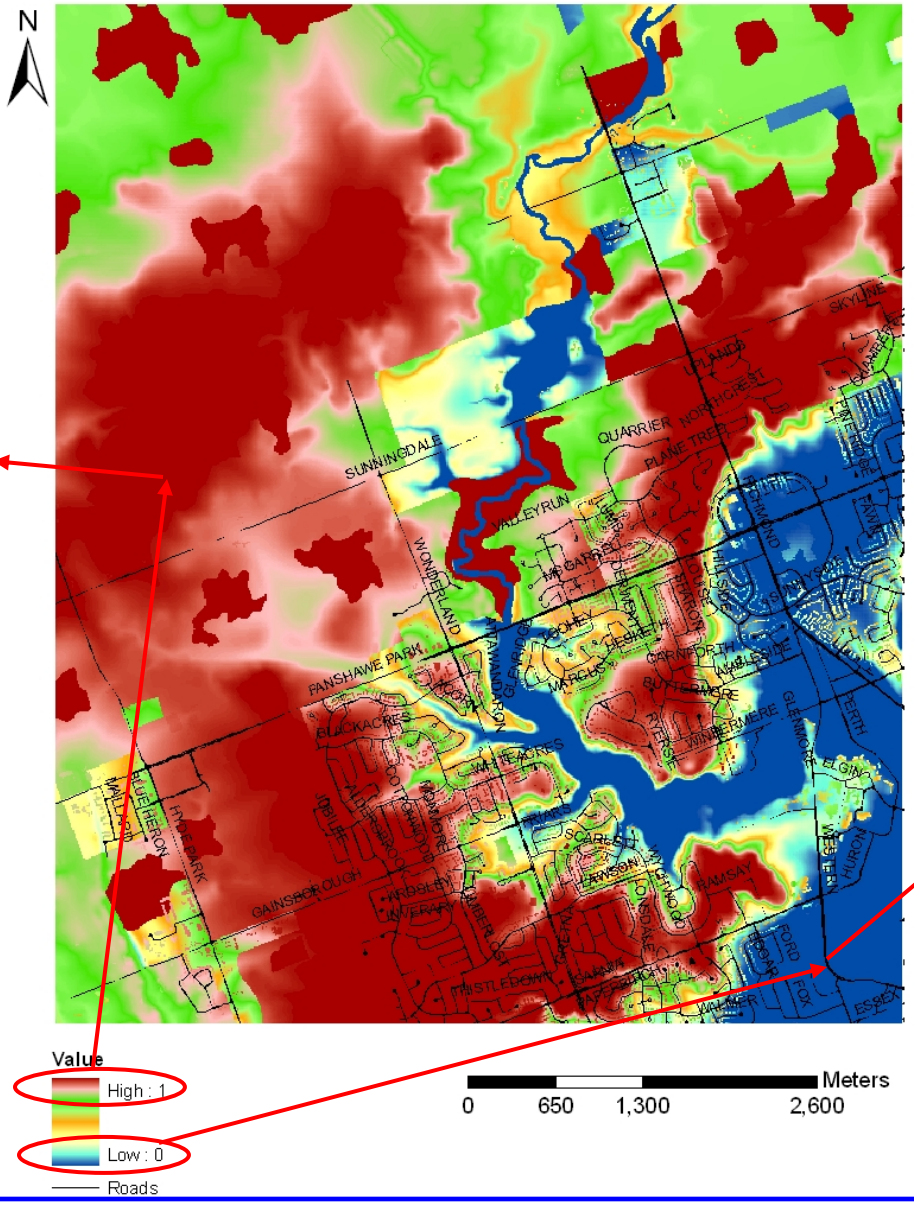
Fuzzy resiliency index in space and time



Results (London Ontario)
Spatial reliability-vulnerability index

High reliability

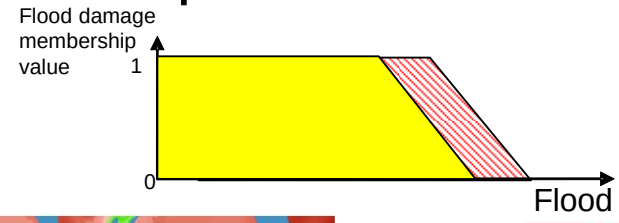
Less vulnerability

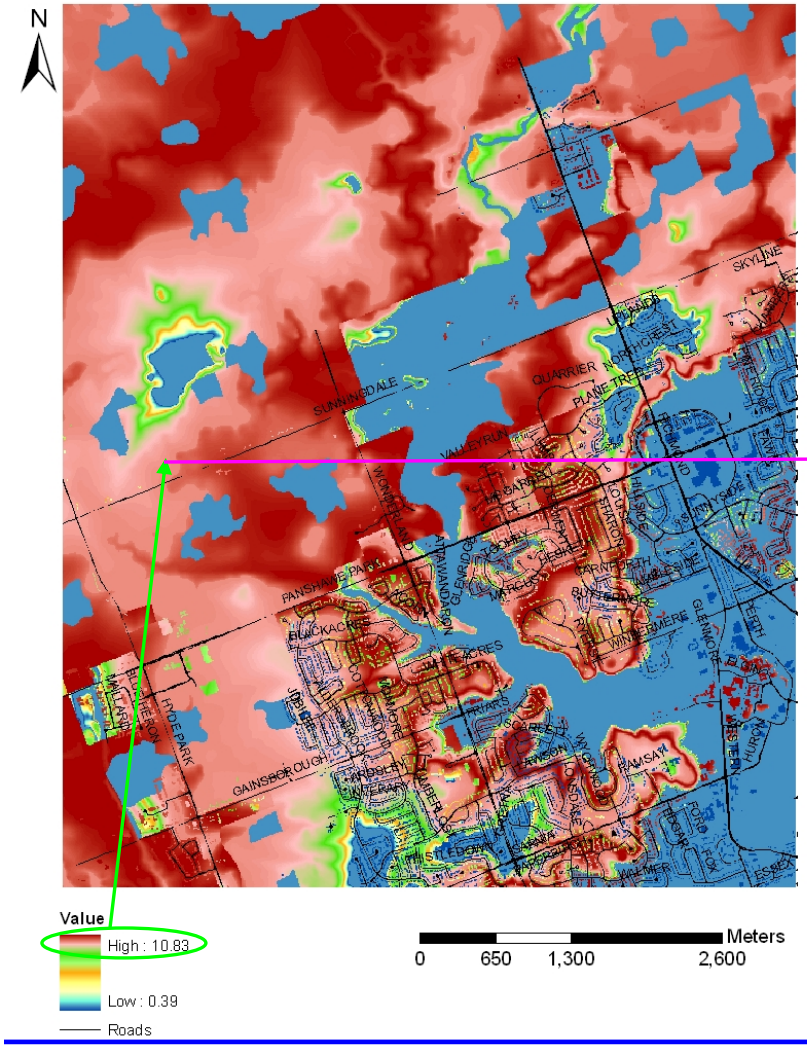


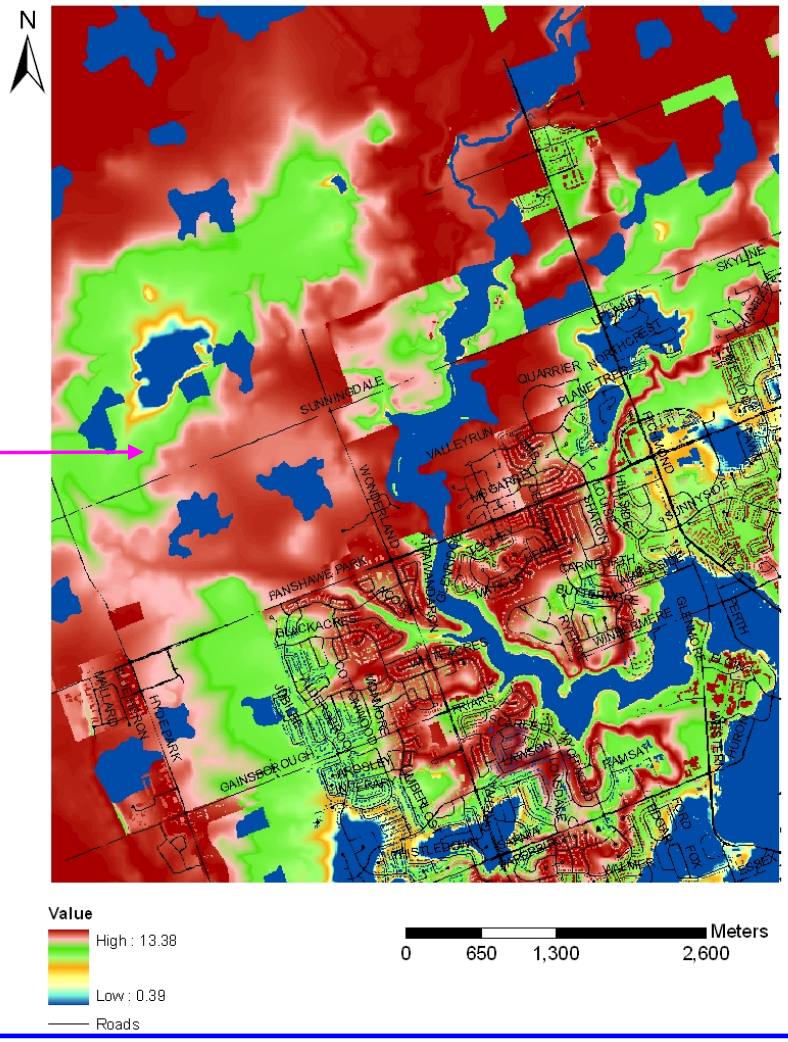
Low reliability

High vulnerability

Results (London Ontario)
Spatial robustness index

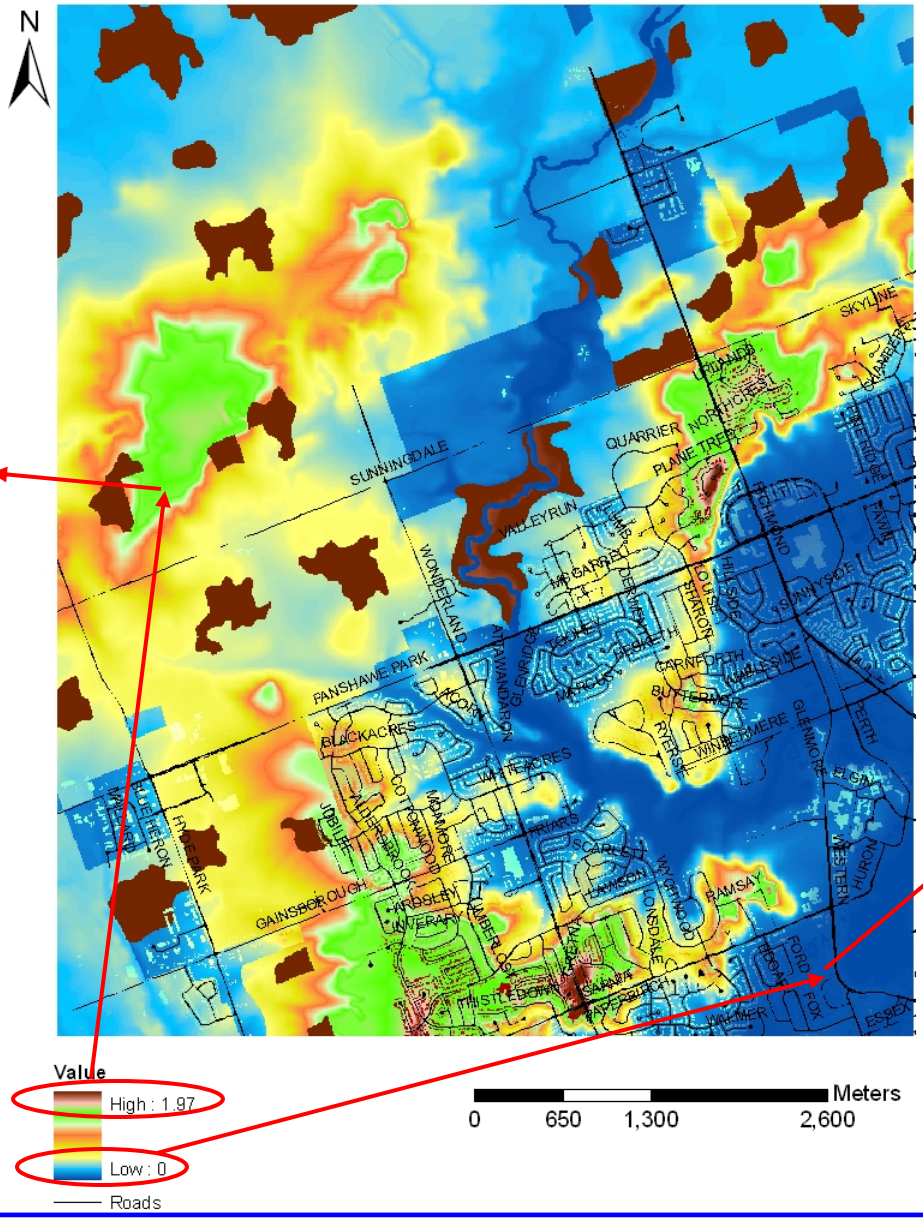






Results (London Ontario)

Spatial resiliency index



Conclusions

- Represents spatial and temporal uncertainty
- Spatial and temporal variation of flood risk under uncertainty
- Assessment of reliability and vulnerability of area under flooding
- Ability to adapt
- Recovery time
- Minimize flood damage

Thank you