A New Approach to Risk Assessment

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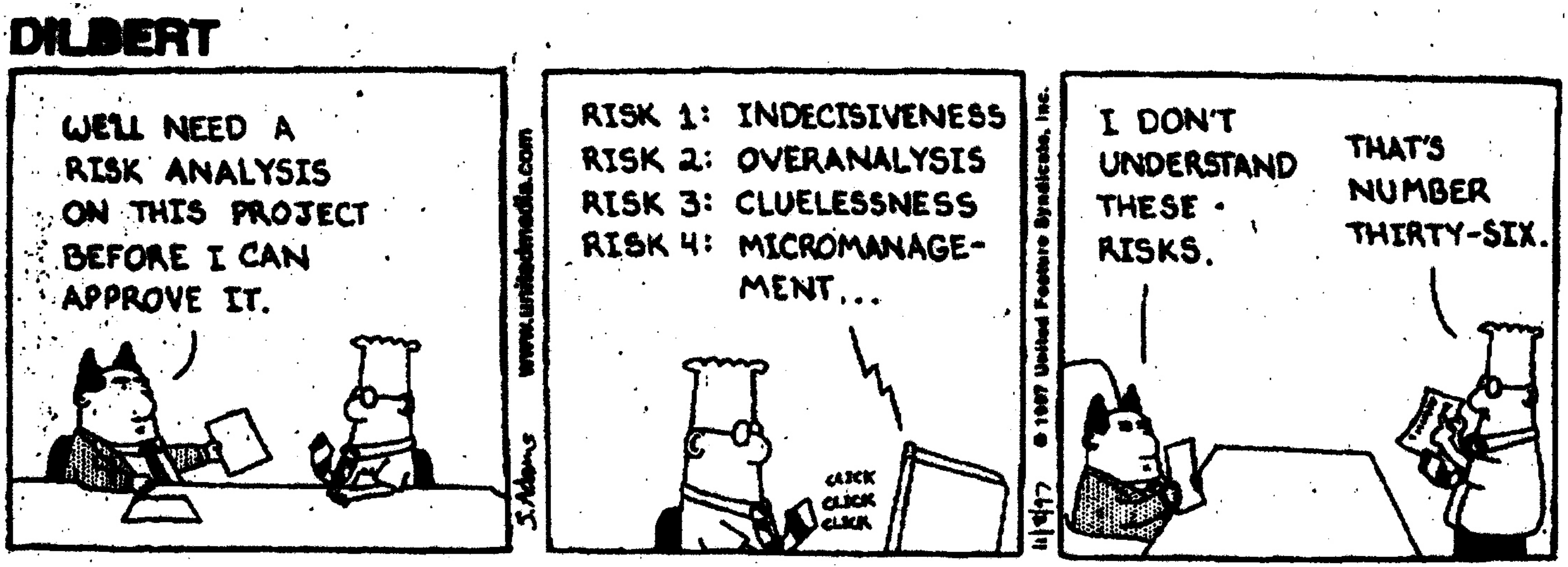
Introduction



Outline

- Uncertainty and risk
  - Objective risk
  - Subjective risk
- A new methodology
  - Fuzzy set approach
- Examples
  - Water supply risk
  - Flood disaster risk
- Conclusions

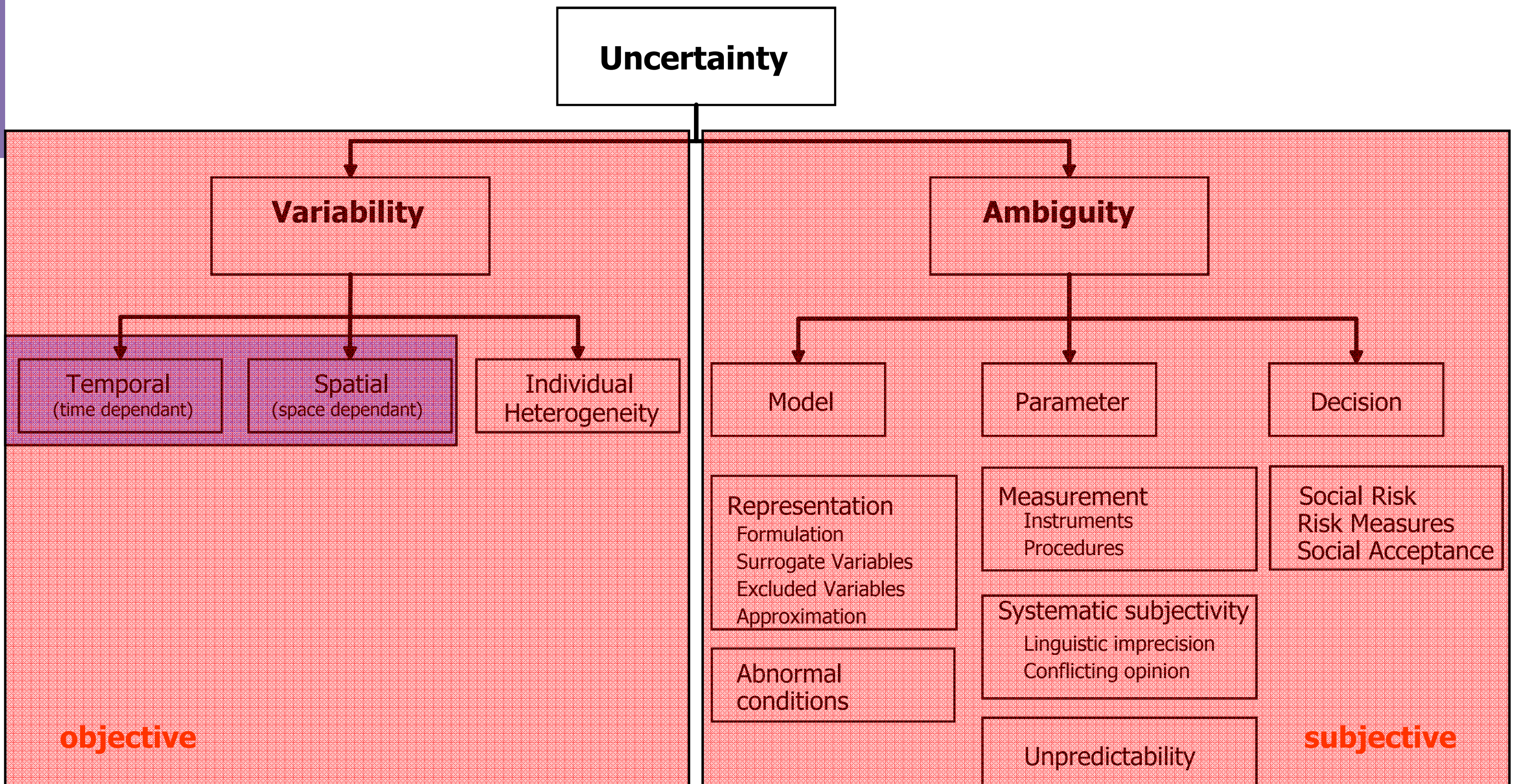
Uncertainty

- Current context
  - The dangers are more difficult to understand
  - Technical, social, economic and environmental systems are becoming increasingly complex
  - Information is shared much more rapidly
- Consequences
  - Larger damage
  - Instead of gradual and local damage much more widespread loss accumulation
  - Need for more active dialogue among stakeholders

Uncertainty

- Uncertainty – lack of certainty
- Implication is risk
  - Significant potential unwelcome effects of system performance
  - Knowledge of potential losses
- Risk reduction
  - Understanding the nature of the underlying threats in order to identify, assess and manage the risk
  - Understanding the value systems that define the risk perception

Uncertainty taxonomy



Risk dilemma

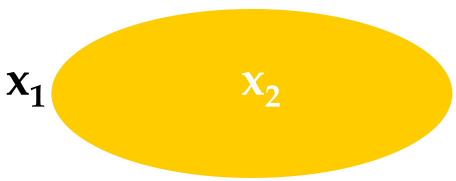
- Three fundamental types of risk
  - Objective – the property of real physical systems
  - Subjective – the degree of belief in a statement (not the property of real system)
  - Perceived – an individual's feeling of fear in the face of an undesirable possible event
- This is perhaps the most important misconception that blocks the way toward more effective societal risk management
- The ways society manages risks appear to be dominated by considerations of perceived and subjective risks, while it is objective risks that kill people, damage the environment and create property loss.

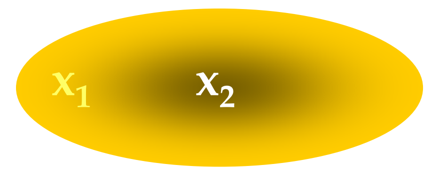
Research context

- The main objective is development of the possible methodology for the reliability analysis of water resources systems that will be capable of:
  - (a) addressing water resources uncertainty caused by variability and ambiguity;
  - (b) integrating objective and subjective risk; and
  - (c) assisting the water resources management based on better understanding of temporal and spatial variability of risk.

Changing paradigm

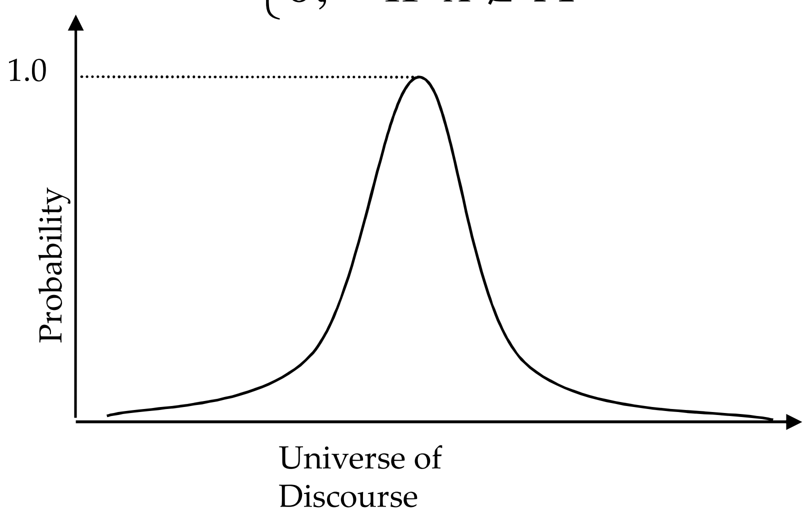
Ordinary set	Fuzzy set
(Probability Theory)	(Fuzzy Set Theory)

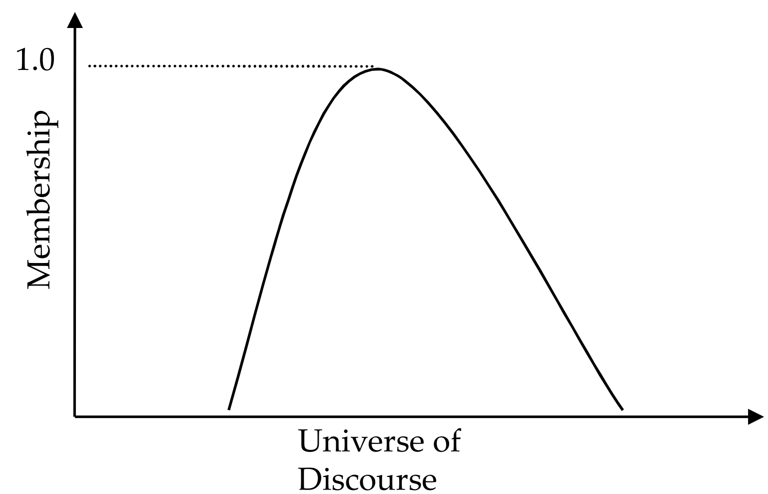




$$\mu_A(x) = \begin{cases} 1, & \text{if } x \in A \\ 0, & \text{if } x \notin A \end{cases}$$

$$\mu_A : X \rightarrow [0,1]$$





System performance indices

$$P_S = P(\hat{X} > \hat{Y})$$ probability of satisfactory performance

$$P_F = P(\hat{X} < \hat{Y})$$ probability of failure

$$\hat{M} = \hat{X} - \hat{Y}$$ margin of safety

$$\hat{\Theta} = \frac{\hat{X}}{\hat{Y}}$$ factor of safety

Fuzzy sets

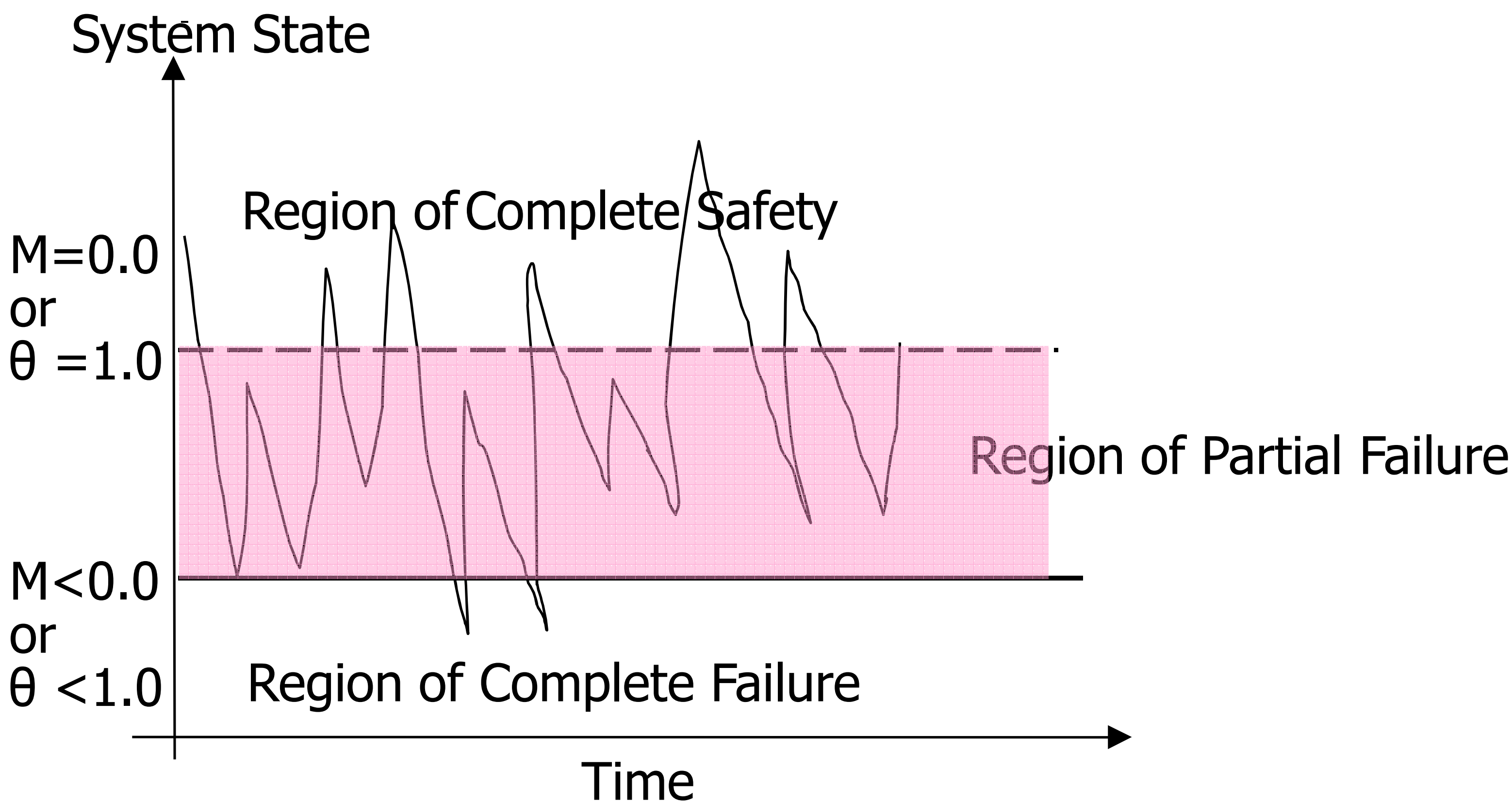
A fuzzy set is one which assigns grades of membership *between 0* and *1* to objects within its universe of discourse. If *X* is a universal set whose elements are *{x}*, then, a fuzzy set A is defined by, its membership function,

$$\mu_A : X \rightarrow [0,1]$$

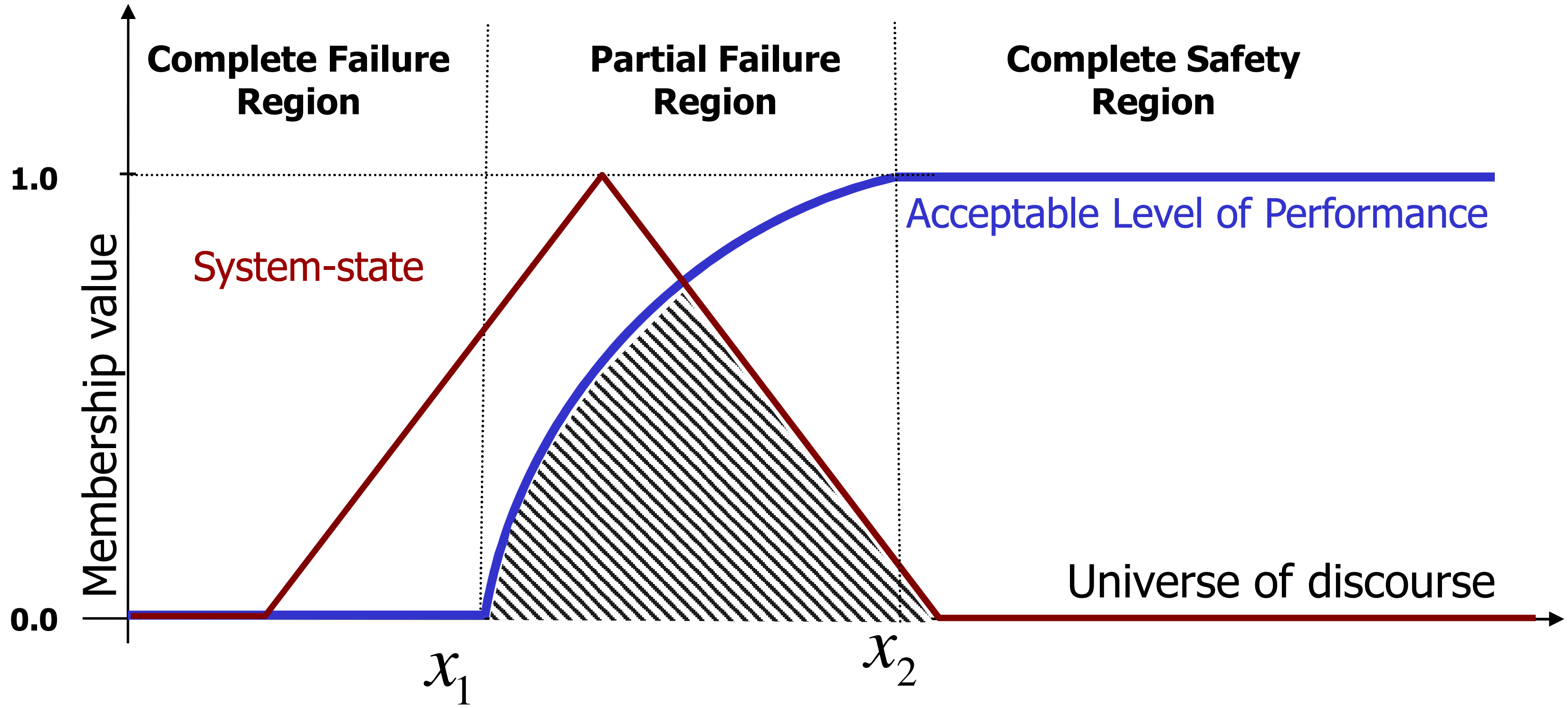
which assigns to every *x* a degree of membership in the interval *[0,1]*.

$$A = \{(x, \mu_A(x))\}, \quad x \in X$$

New definition of failure



Fuzzy risk analysis



Fuzzy risk analysis

System state

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

Acceptable level of performance

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

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Fuzzy risk analysis

The compatibility measure

$$CM_{S,L} = \frac{WOA_{S,L}}{WA_S}$$

- provides information about system reliability and vulnerability
- measure of proximity (overlap)

Fuzzy risk analysis

$$\text{Reliability Index} = \frac{\max\limits_{i \in K}\{CM_1, CM_2, \ldots\ldots CM_i\} \times LR_{max}}{\max\limits_{i \in K}\{LR_1, LR_2, \ldots\ldots LR_i\}}$$

$$\text{Robustness Index} = \frac{1}{CM_1 - CM_2}$$

$$\text{Resilience Index} = \left[\frac{\int_{t_1}^{t_2} t\, \tilde{T}(t)\, dt}{\int_{t_t}^{t_2} \tilde{T}(t)\, dt} \right]^{-1}$$

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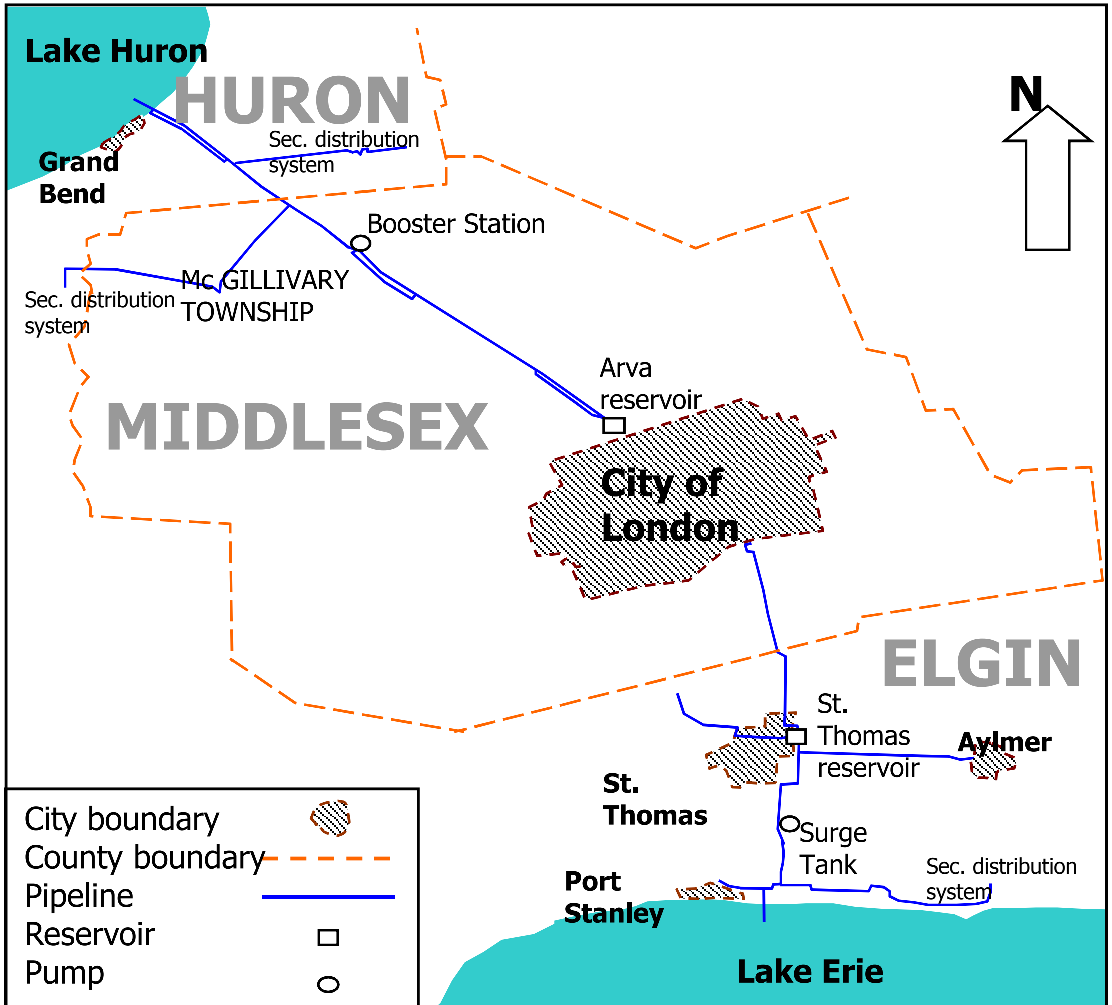
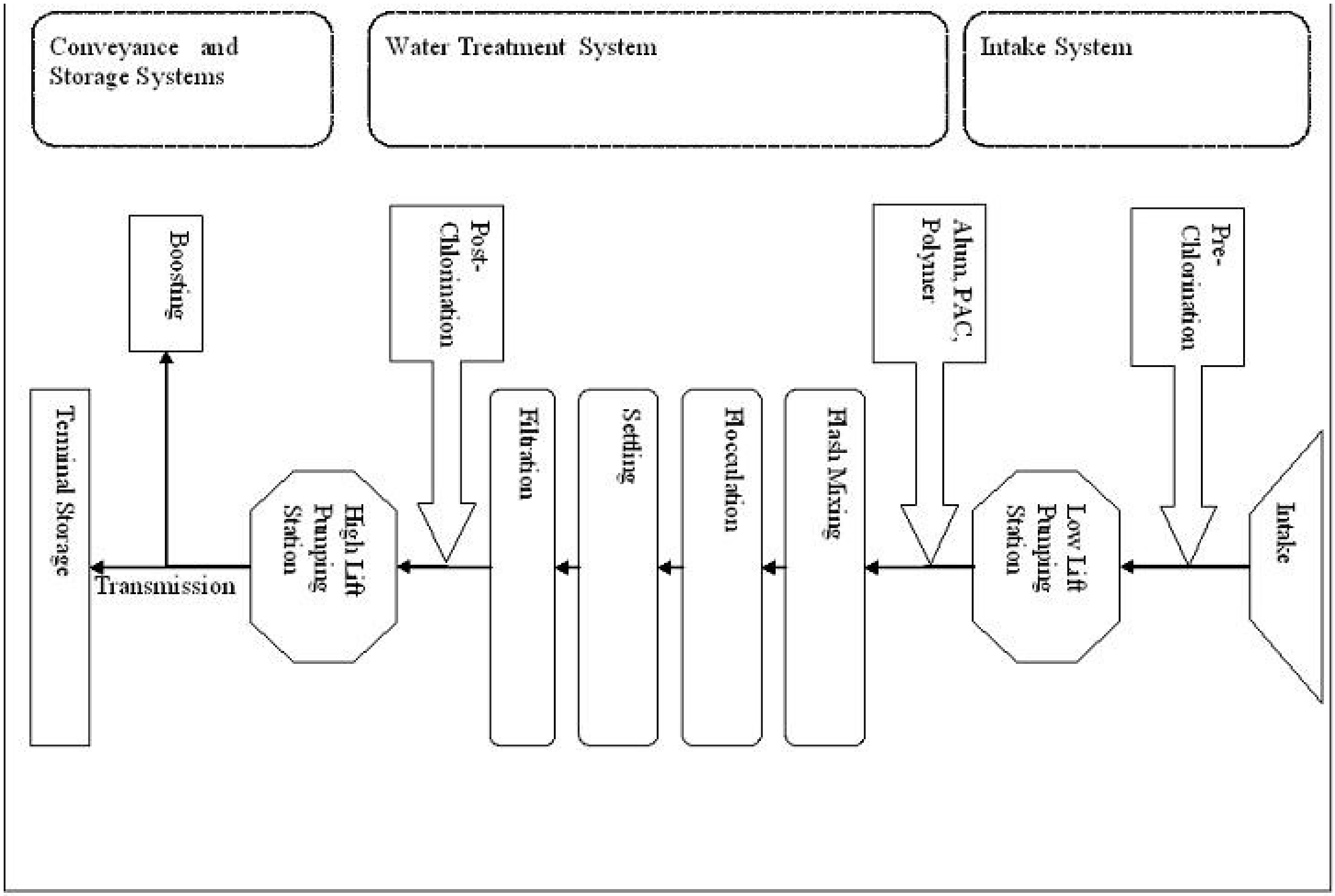
Implementation example 1



London region water supply



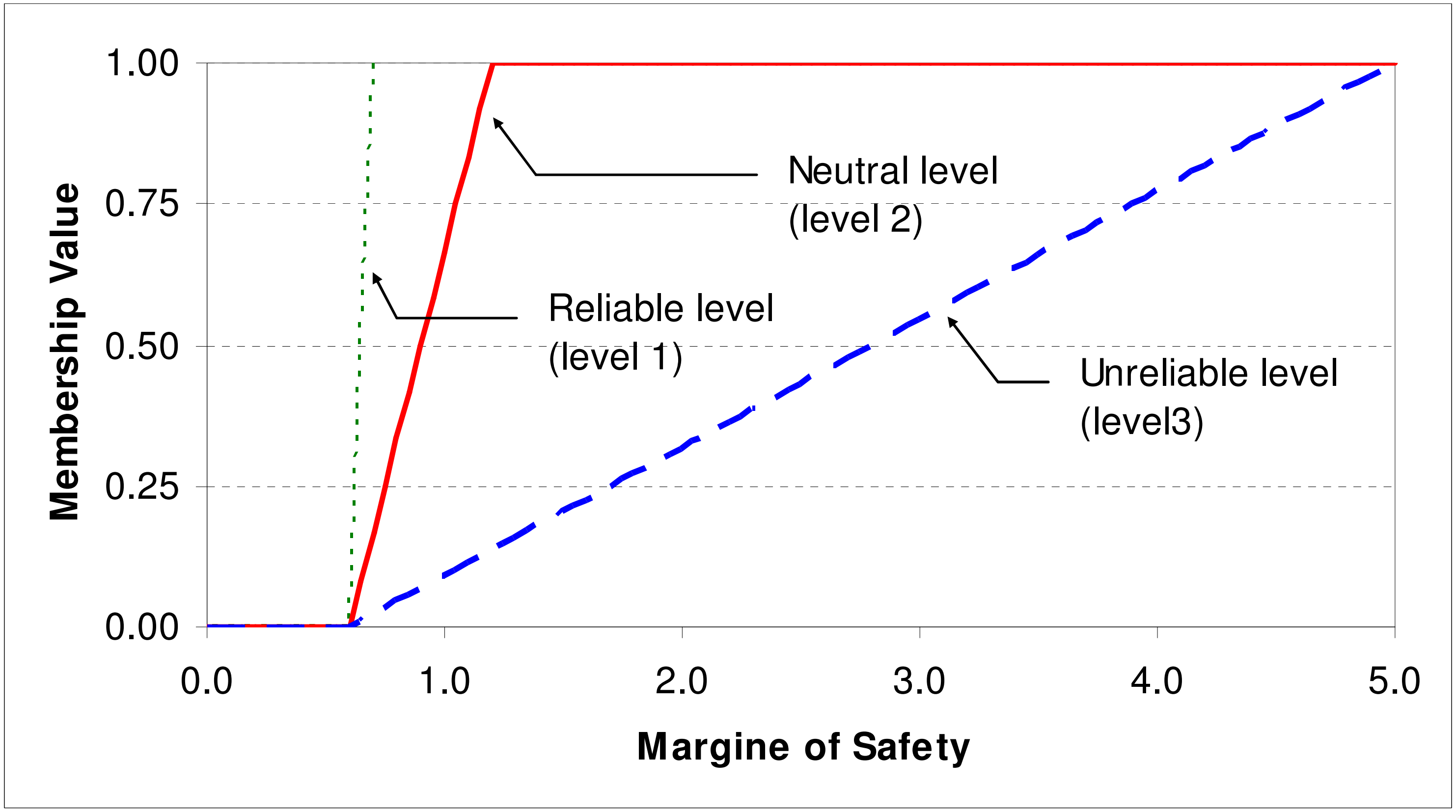
London region water supply

Microsoft Excel - Case Study-Calculation(LH).xls

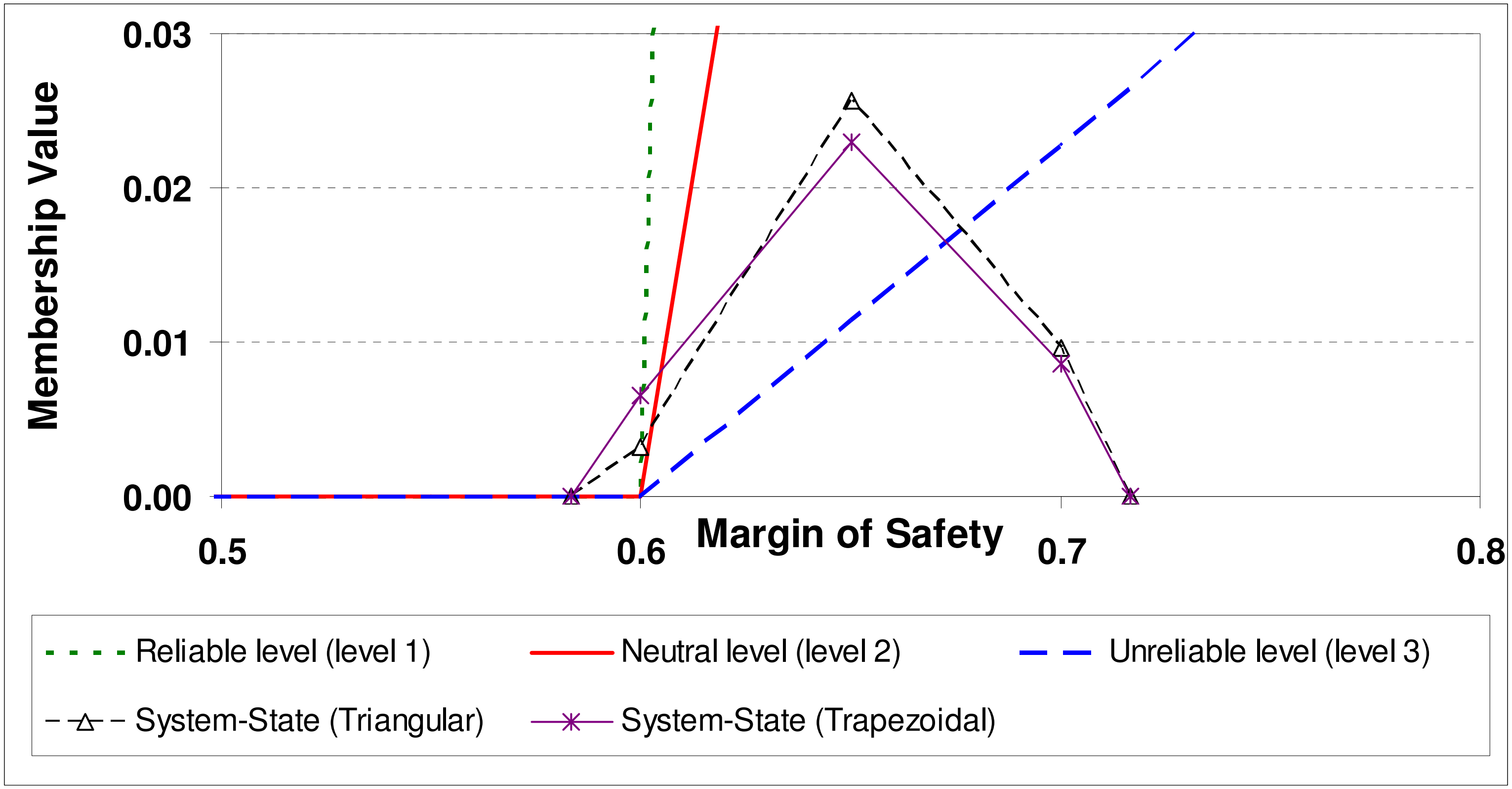
	A	B	H	I	J	K	L	M	N
4		System	Units	Capacity			Requirment		
5				Average Daily flow	Design Capacity	Maximum Overload	Yearly Min	Yearly Avg	Yearly Max
6	Intake Crib	Intake System	MLD	157.3	340.0	454.6	53.0	157.3	255.7
7	Chlorinator I		Kg/d	360.0	630.0	900.0	24.5	72.0	130.0
8	RC Intake Pipe		MLD	157.3	340.0	454.6	53.0	157.3	255.7
9	Traveling Screens	Low Lifting System	MLD	157.3	340.0	454.6	53.0	157.3	255.7
10	Pumping Wells		MLD	157.3	340.0	454.6	53.0	157.3	255.7
11	Chlorinator II		Kg/d	360.0	630.0	900.0	24.5	72.0	130.0
12	Single Speed Pump 1		MLD	49.9	75.0	100.0	16.8	49.0	81.2
13	Variable Speed Pump		MLD	57.4	86.2	115.0	19.3	49.0	93.4
14	Single Speed Pump 2		MLD	49.9	75.0	100.0	16.8	49.0	81.2
15	Single Speed Pump 1 (Back-up		MLD	49.9	75.0	100.0	16.8	49.0	81.2
16	Variable Speed Pump (Back-up		MLD	57.4	86.2	115.0	19.3	49.0	93.4
17	Single Speed Pump 2 (Back-up		MLD	49.9	75.0	100.0	16.8	49.0	81.2

	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP
4	Element-State (Tri-MoS)			Element-State (Trap-MoS)				Element-Failure (Tri)			Element-Failure (Trap)			
5	a	b	c	a	b	c	d	a	b	c	a	b	c	d
6	-0.22	0.40	0.88	-0.22	0.09	0.41	0.88	0.08	0.13	0.17	0.08	0.11	0.14	0.17
7	0.26	0.62	0.97	0.26	0.44	0.74	0.97	0.01	0.01	0.01	0.01	0.01	0.01	0.01
8	-0.22	0.40	0.88	-0.22	0.09	0.41	0.88	0.08	0.13	0.17	0.08	0.11	0.14	0.17
9	-0.22	0.40	0.88	-0.22	0.09	0.41	0.88	0.04	0.08	0.50	0.04	0.19	0.35	0.50
10	-0.22	0.40	0.88	-0.22	0.09	0.41	0.88	0.00	0.50	1.00	0.00	0.33	0.67	1.00
11	0.26	0.62	0.97	0.26	0.44	0.74	0.97	0.01	0.01	0.01	0.01	0.01	0.01	0.01
12	-0.31	0.26	0.83	-0.31	-0.03	0.22	0.83	0.02	2.51	5.00	0.02	1.68	3.34	5.00
13	-0.31	0.32	0.83	-0.31	0.01	0.32	0.83	0.02	2.51	5.00	0.02	1.68	3.34	5.00
14	-0.31	0.26	0.83	-0.31	-0.03	0.22	0.83	0.02	2.51	5.00	0.02	1.68	3.34	5.00
15	-0.31	0.26	0.83	-0.31	-0.03	0.22	0.83	0.02	2.51	5.00	0.02	1.68	3.34	5.00
16	-0.31	0.32	0.83	-0.31	0.01	0.32	0.83	0.02	2.51	5.00	0.02	1.68	3.34	5.00
17	-0.31	0.26	0.83	-0.31	-0.03	0.22	0.83	0.02	2.51	5.00	0.02	1.68	3.34	5.00

London region water supply



London region water supply



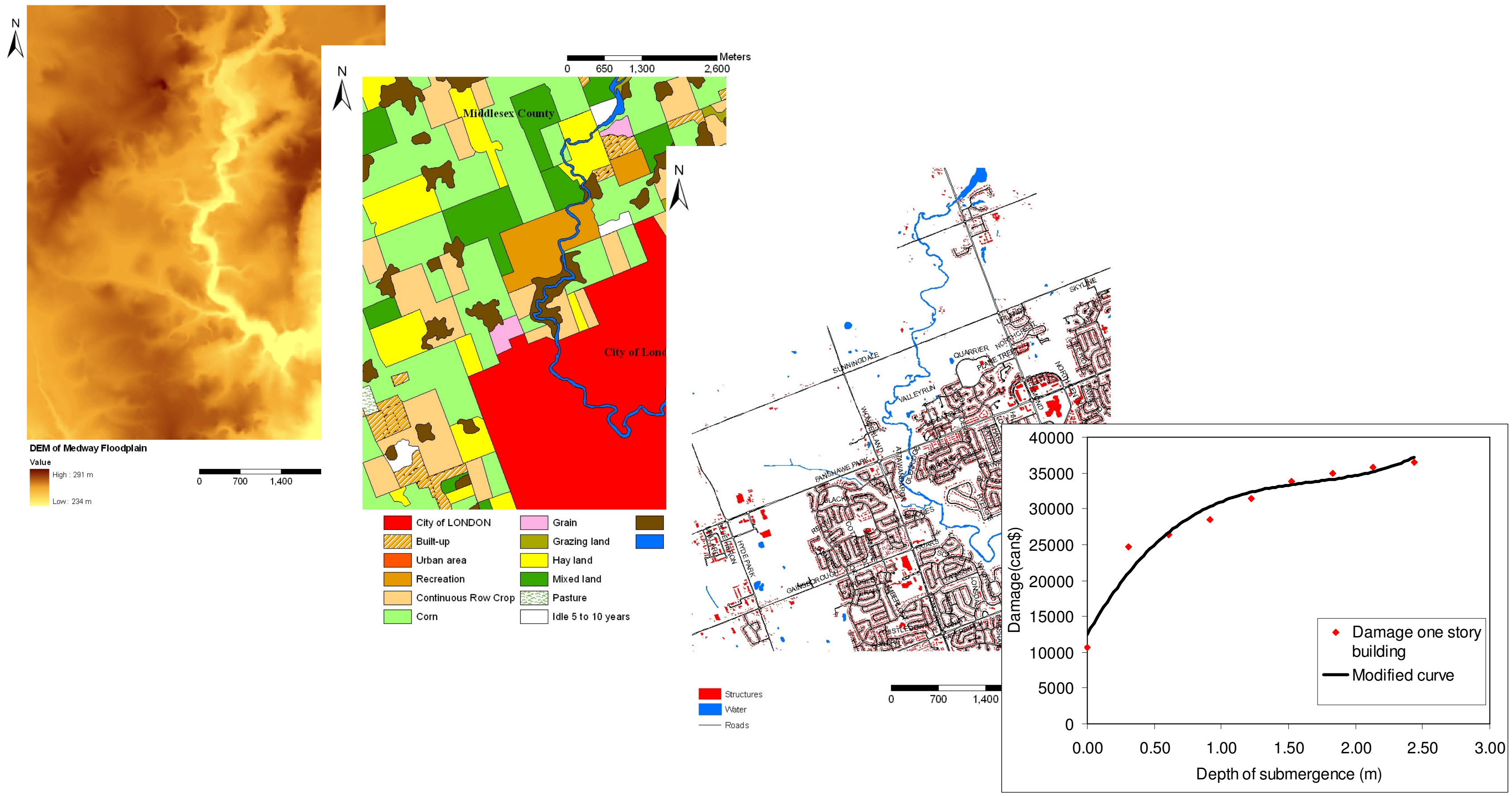
London region water supply

Fuzzy Performance Index	LHPWSS		EAPWSS	
	Triangular	Trapezoidal	Triangular	Trapezoidal
Combined Reliability-Vulnerability	0.699	0.642	0.042	0.017
Robustness (level 2 – level 1)	NA	NA	1.347	3.314
Robustness (level 3 – level 1)	-2.120	-2.473	NA	NA
Robustness (level 3 – level 2)	-2.120	-2.473	-1.347	-3.314
Resiliency	0.017	0.017	0.054	0.054

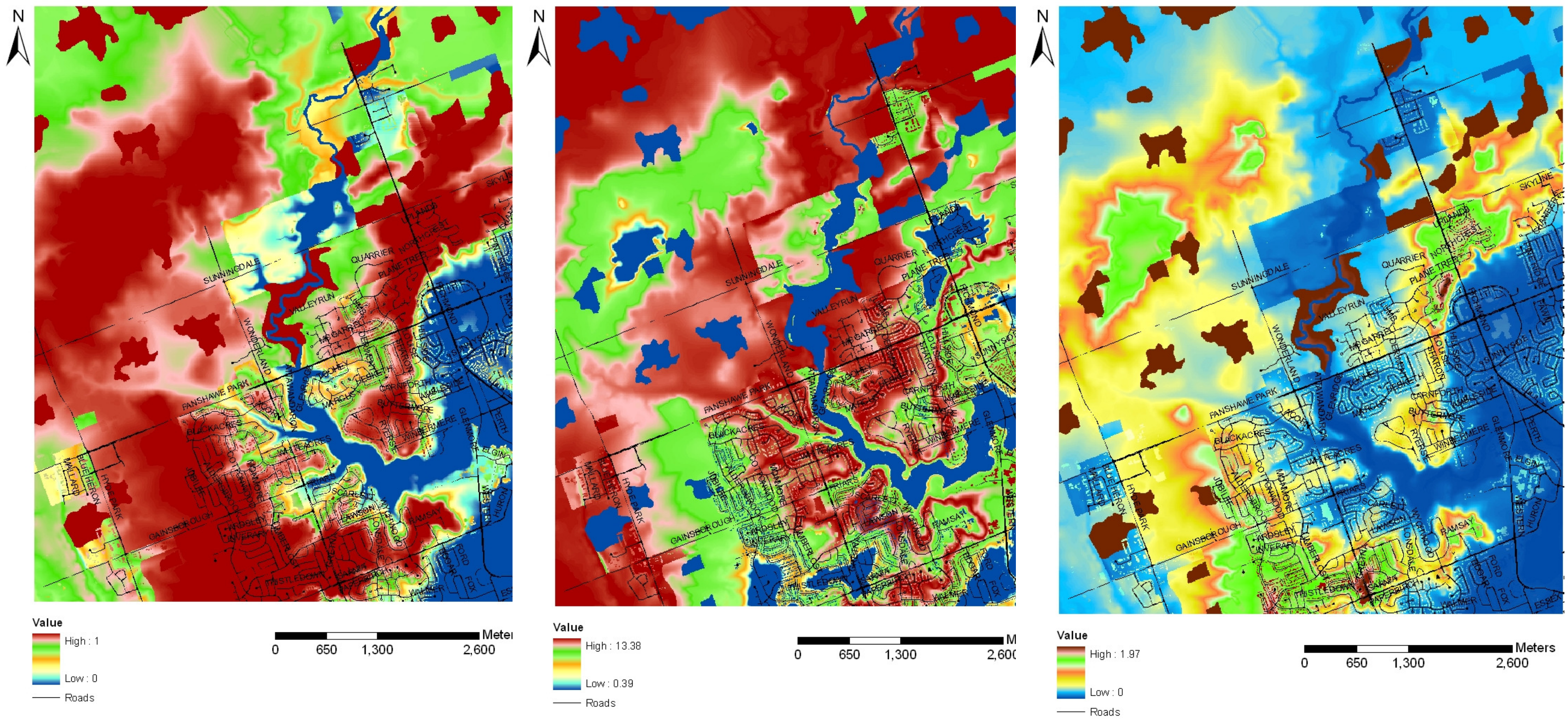
Implementation example 2

- Extension of fuzzy risk analysis to spatial problems
- Integration of GIS and fuzzy risk analysis
- Medway Creek Flooding– North London

Medway Creek flooding case study



Medway Creek flooding case study



Instead of conclusions

- One possible methodology for risk analysis capable of:
  - addressing uncertainty caused by variability and ambiguity;
  - integrating objective and subjective risk; and
  - assisting in risk management based on better understanding of temporal and spatial variability of risk.

Instead of conclusions

- Fuzzy risk analysis provides for addressing uncertainty caused by variability and ambiguity.
- Risk is described using a combined fuzzy reliability and vulnerability, fuzzy robustness and fuzzy resiliency.
- Fuzzy risk analysis has been successfully extended into a spatial fuzzy risk analysis.

Research

- Over 10 years (postdoctoral fellows, PhD and MSc cadidates)
- Support:
  - National Sciences and Engineering Research Council (NSERC)
  - Public Safety and Emergency Preparedness Canada (PSEP)
  - ICLR
- Resource:

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