DEFINING RISK AND ITS ROLE IN DISASTER MANAGEMENT

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YORK UNIVERSITÉ UNIVERSITY

Since 2005

FIDS 25 CELEBRATING 1989 - 2014

2000-02


RISK
Hazard or threat and uncertainty
Expected loss
Probability, impact
Probability, vulnerability, social factors
Likelihood and exposure to hazard
Frequency, consequences, preparedness
Uncertainty, elements at risk, community perception

CONVENTIONAL APPROACH

$$R = H \times V$$

Here,
R = risk;
H = hazard, determined as a probability (or likelihood) of the occurrence of hazard;
V = vulnerability (also loss, impact or consequences).

Risk evaluation equation	Variable other than probability and impact	Proposed by
$R = p \cdot L^x$	x (> 1) = people's perception	Whyte and Burton (1982)
$R = P \cdot S$	S = severity	Government of Michigan (2001)
$R = p \cdot V \cdot n$	n=social consequences	Ferrier and Haque, 2003
$Risk = \frac{H \cdot L}{preparedness\,(mitigation)}$	Preparedness or mitigation are measurable measures	Smith (2004)
$R = p \cdot L \cdot f(x)$	$f(x)$ = risk aversion factor	Schneider (2006)
$R = H \cdot V \cdot M$	M = manageability or ability of humans	Noson (2009)
$R = H \cdot Elements\ at\ Risk \cdot V$	$Elements\ at\ Risk$ = physically exposed assets	Smith and Petley (2009)
$R = H \cdot (V \cdot cp)$	cp = community perception	Nirupama (2012)

Encyclopedia of Earth Sciences Series
2013

Encyclopedia of Natural Hazards

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DISASTER RISK MANAGEMENT

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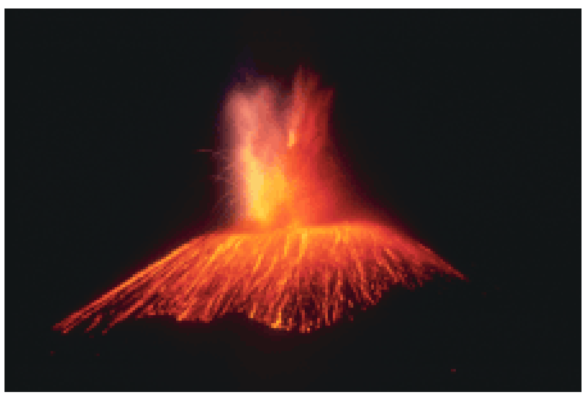
Threat recognition - risk and vulnerability identification

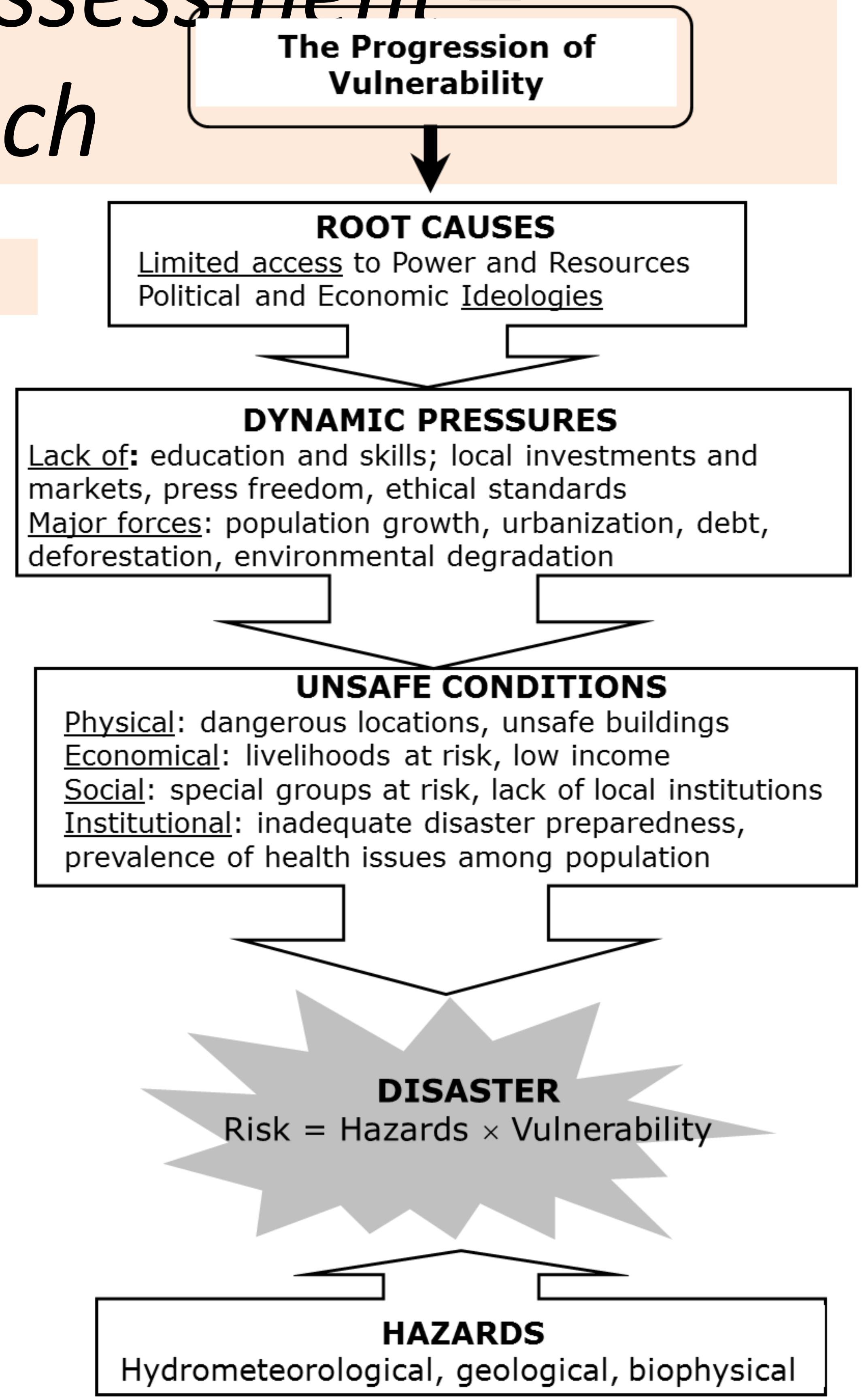
Risk from natural and technological hazards

Recognizing vulnerabilities



Risk analysis and assessment – Qualitative approach

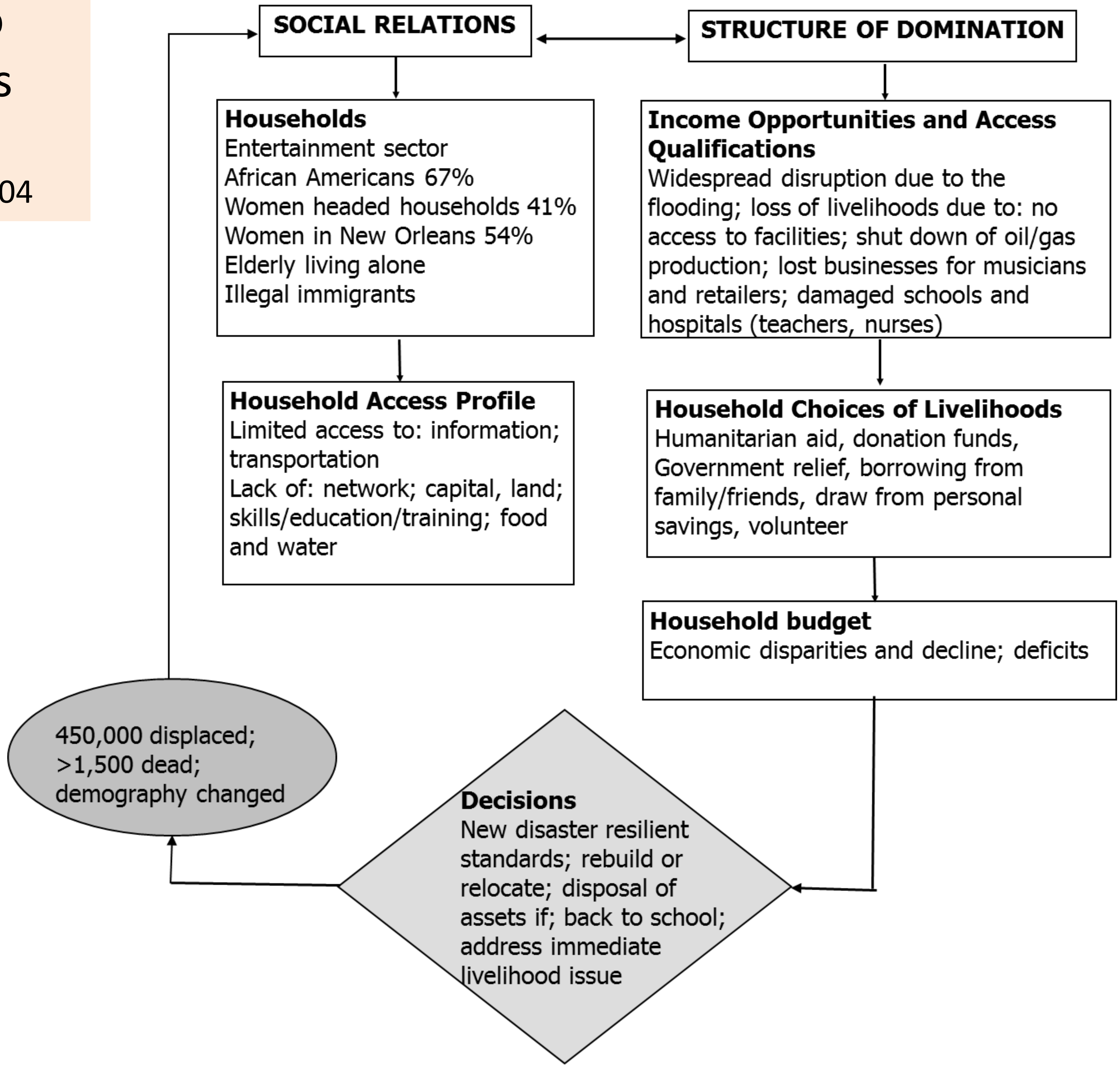
Pressure and Release Model (Wisner et al 2004)



Nirupama, N. (2012). Risk and Vulnerability Assessment – A Comprehensive Approach, *International Journal of Disaster Resilience in the Built Environment*, Emerald, **3**:2.

Access to Resources Model

Wisner et al 2004



Quantitative Approaches
HRVA - Hazard Risk Vulnerability Assessment

British Columbia

Hazard, Risk and Vulnerability Analysis Tool Kit

2004

Ministry of Public Safety and
Solicitor General
Provincial Emergency Program

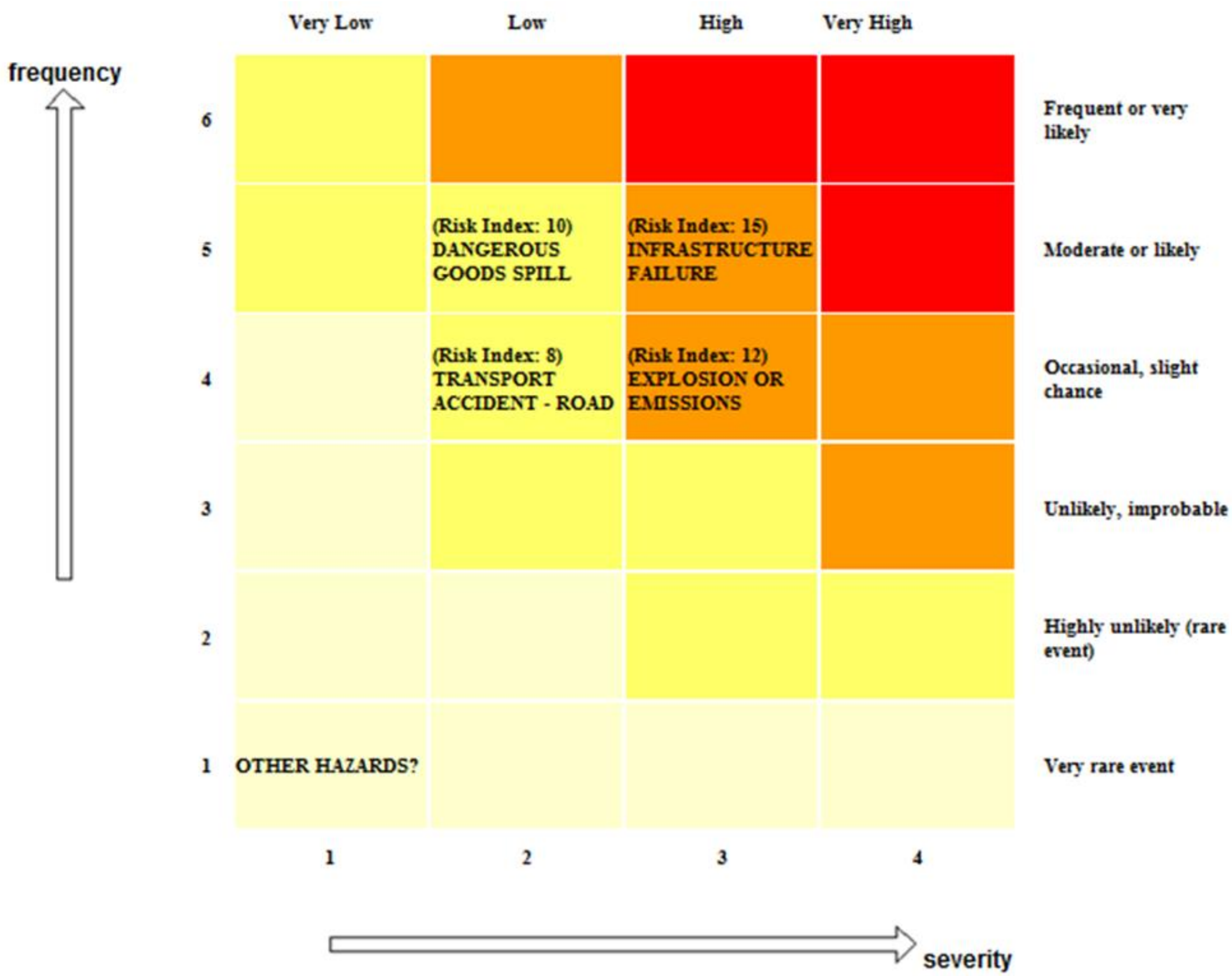
BRITISH COLUMBIA

Understanding the magnitude, frequency of occurrence, and severity of consequences and prioritization of risks

Measuring Impact

Category	Rank	Description	Criteria
Fatality	1	Very Low	0-4 deaths: 2 reported
Injury	2	Low	4-50 people: 24 reported
Critical Facility	3	High	Evacuation <10,000 people: 12,500 reported
Lifelines	2	Low	Disruption 1-2 days without Gas & Electricity
Property Damage	3	High	Localized Severe Damage: Contained to a 2 km radius and involved over 580 Homes
Environmental Impact	3	High	Localized Severe Damage: Smoke, Asbestos and Burning Metal affected residents homes & businesses
Economic/Social Impact	3	High	Extended & Widespread: Lawsuits continue for properties damaged, area residents experienced trauma and fear from threat of asbestos contamination

Risk Prioritization



HIRA – Hazard Identification and Risk Analysis

Hazard Identification and Risk Assessment for the Province of Ontario

Emergency Management Ontario
Ministry of Community Safety and Correctional Services
2011

Risk = Frequency*Consequence*Changing Risk
Changing Risk = Change in Frequency + Change in Vulnerability

Measuring Impact

- Social Impacts
- Property Damage
- Critical Infrastructure Service Disruptions/Impact
- Environmental Damage
- Business/Financial Impact
- Psychosocial Impacts

Risk Prioritization

Level of Risk	Description	Hazards
>50	Extreme	
41 - 50	Very High	
31 - 40	High	
21 - 30	Moderate	
11 - 20	Low	
<10	Very Low	

FEMA – FEDEARL EMERGENCY MANAGEMENT AGENCY

<table>
<tr><th colspan="2">Category</th><th>Rating</th><th colspan="2">Score</th><th>Weight</th><th>Total</th></tr>
<tr><td colspan="2">History</td><td>High</td><td colspan="2">10</td><td>2</td><td>20</td></tr>
<tr><td rowspan="2">Vulnerability</td><td>People</td><td>Medium</td><td>5</td><td rowspan="2">15/2 = 7.5</td><td rowspan="2">5</td><td rowspan="2">37.5</td></tr>
<tr><td>Property</td><td>High</td><td>10</td></tr>
<tr><td colspan="2">Max Threat</td><td>High</td><td colspan="2">10</td><td>10</td><td>100</td></tr>
<tr><td colspan="2">Probability</td><td>Medium</td><td colspan="2">5</td><td>7</td><td>35</td></tr>
<tr><td colspan="6">Total Risk</td><td>192.5</td></tr>
</table>

Risk Prioritization

Total Risk =100

Develop risk reduction plans for these hazards

No immediate need to develop risk reduction plans

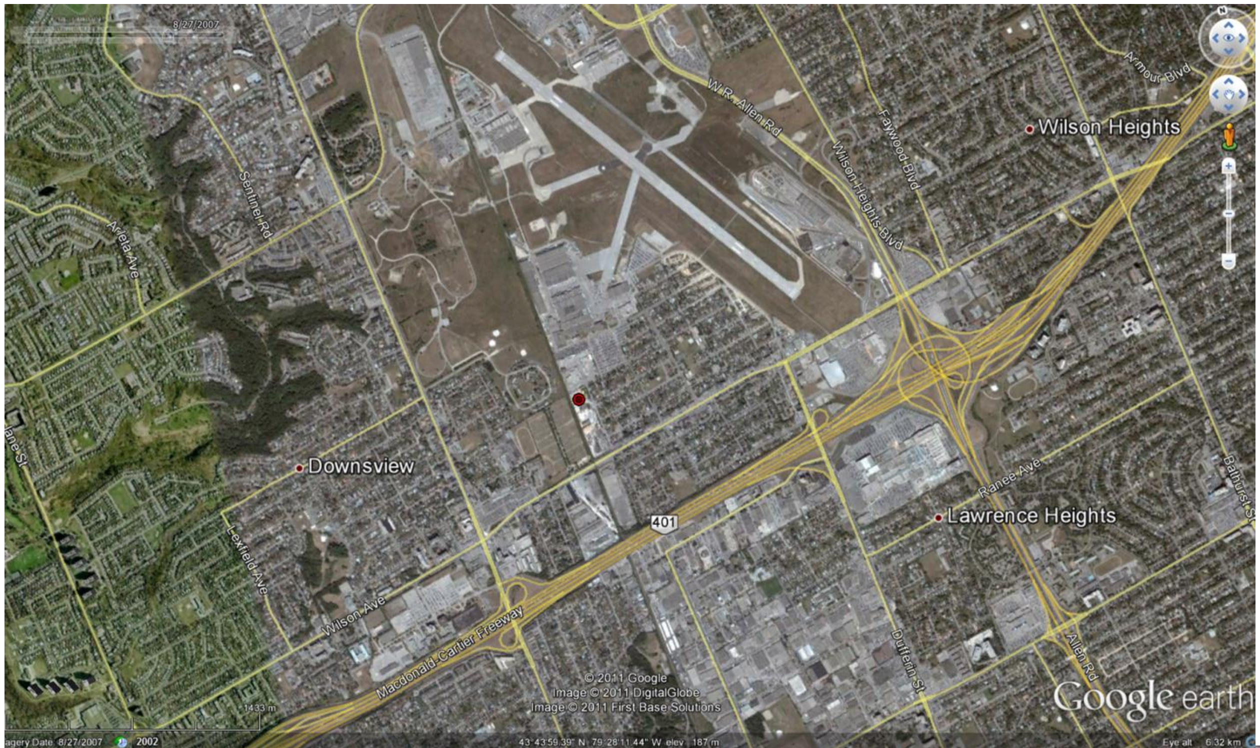
SMUG – SERIOUSNESS, MANAGEABILITY, URGENCY, GROWTH

SMUG RATINGS

Seriousness	High = 4-5	Medium = 2-3	Low = 0-1
Manageability	High = 7+	Medium = 5-7	Low = 0-4
Urgency	High = >20 yrs	Medium = <20	Low = 100 yrs
Growth	High = 3	Medium = 2	Low = 1

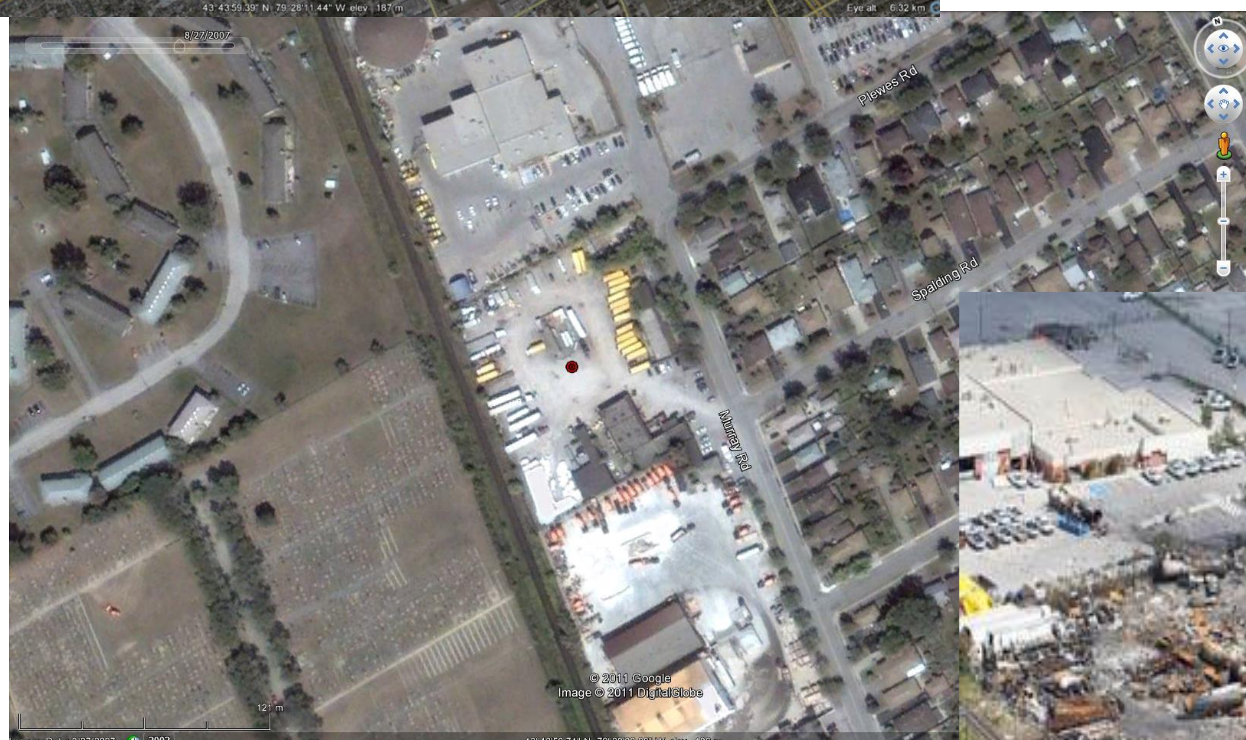
SMUG Ratings

Hazard	S	M	U	G	Total
Utility Failure - Communications	3	6	3	3	15
Flooding	3	4	3	3	13
Public Health Emergency	3	5	2	2	12
Utility Failure - Power	2	4	3	3	12
Storm Surge	2	3	2	2	9
Transportation - Road	2	1	3	2	7
Civil Unrest	1	3	1	1	6



Risk Analysis

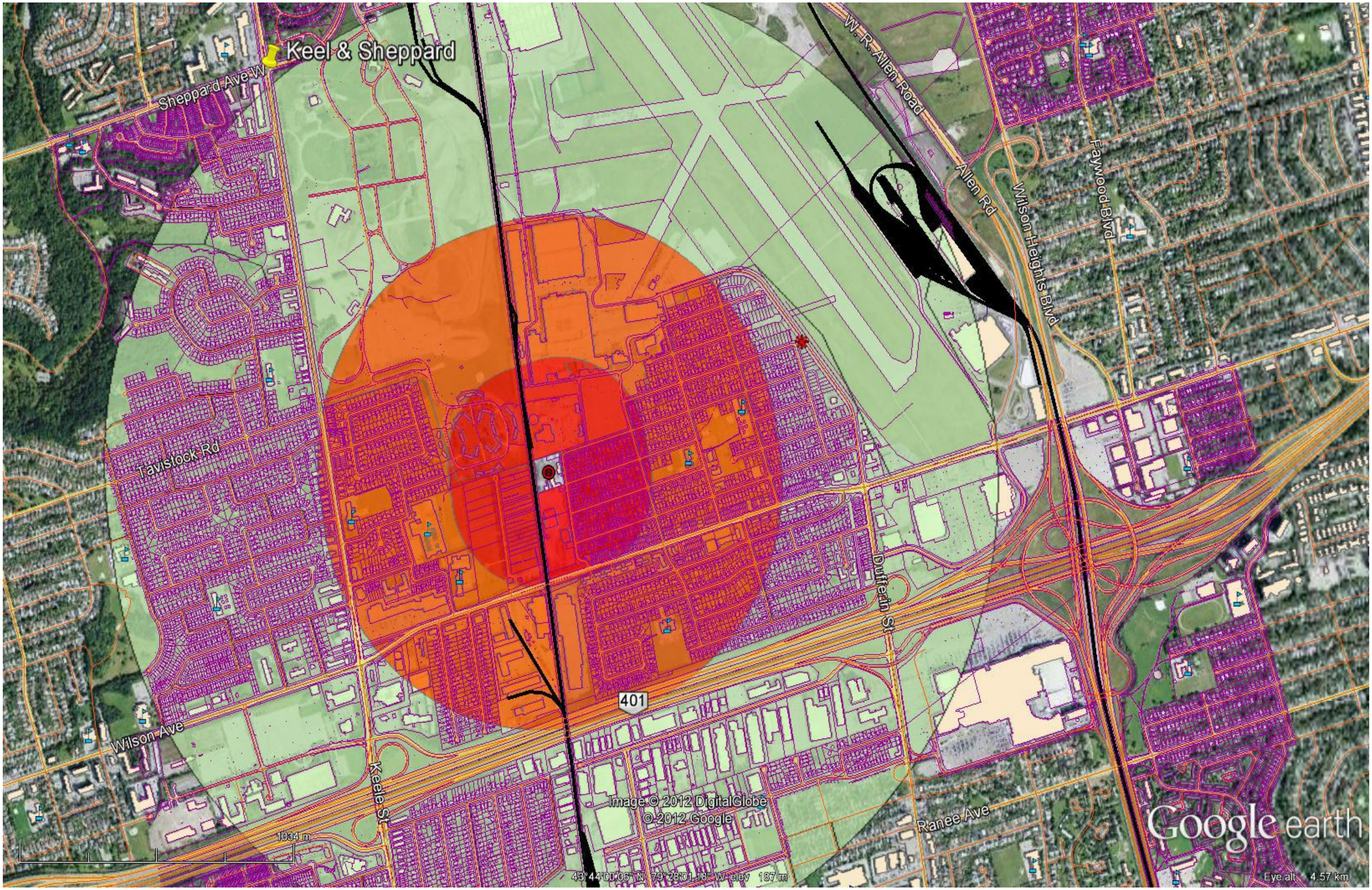
the 2008 Toronto Propane Explosion Case



Armenakis, C. and Nirupama, N. (2013). Estimating spatial disaster risk in urban environments, Geomatics, Natural Hazards and Risk, Taylor & Francis, 4 (4): 289-298.

HAZARD ZONING

- For an explosion caused by a propane storage tank of up to 9.5 tonne (5,000 USWG) capacity, the projectile distance is about 320m.
- The recommended evacuation zone is 2.5 times the projectile distance.

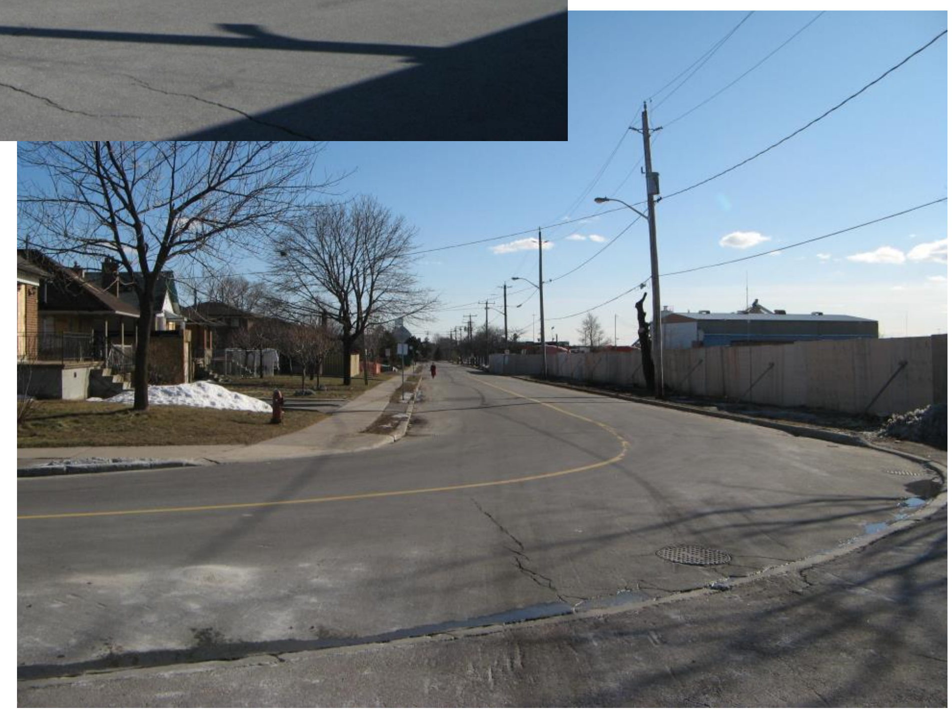


Keel & Sheppard
Sheppard Ave W
W. R. Allen Road
Allen Rd
Wilson Heights Blvd
Faywood Blvd
Tavistock Rd
Dufferin St
401
Wilson Ave
Keele St
Ranee Ave
Image © 2012 DigitalGlobe
© 2012 Google
Google earth

VULNERABILITIES

- **Social**
- **Physical**
- **Economic**
- **Critical Infrastructure**
- **Environmental**

PHYSICAL



$$PV_{ji} = \frac{(MJ + C)_{\%DA_i}}{\sum_{i=1}^{n} D(Zone_j \%DA_i)}$$

where MJ is dwellings requiring major repairs, C represents construction of the dwellings and other buildings prior to 1960, D is the number of buildings in $\%DA$ polygonal area, i = number of DA per zone; j = number of zones.

ECONOMIC

$$EV_{ji} = \frac{(UE + F\_50)_{\%DA_i}}{\sum_{i=1}^{n} POP(Zone_j\,\%DA_i)}$$

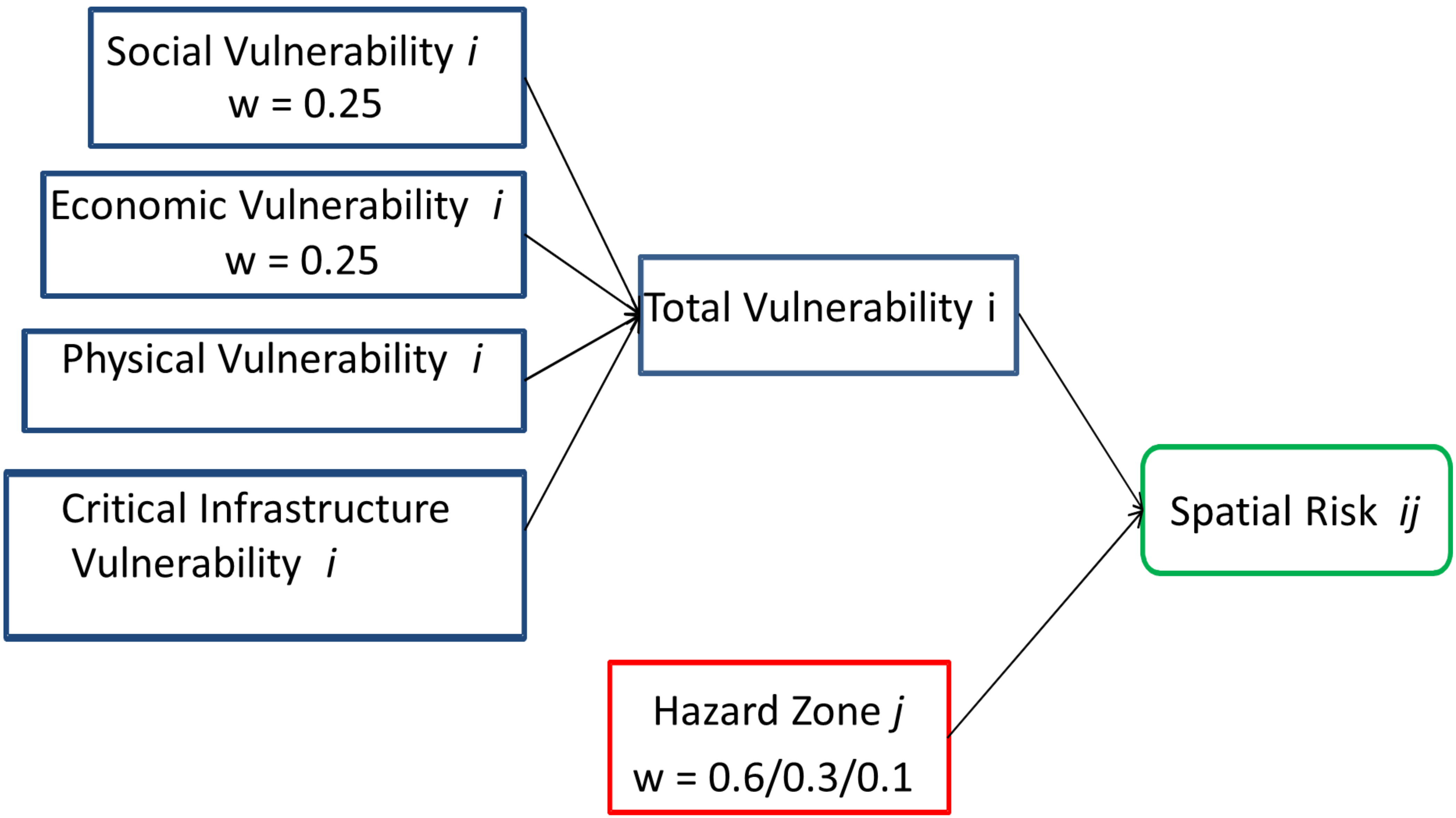
where i = number of DA per zone, j = number of zones.

CRITICAL INFRASTRUCTURE

$$CI_{ji} = CI_j \times \frac{\%DA_{ij}}{A_j}$$

where CI_j is the number of critical infrastructure elements in Zone j, $\%DA_{ij}$ is the polygonal area of $\%DA_i$ in Zone j, and A_j is the polygonal area of Zone j.

SPATIAL RISK ASSESSMENT MODEL



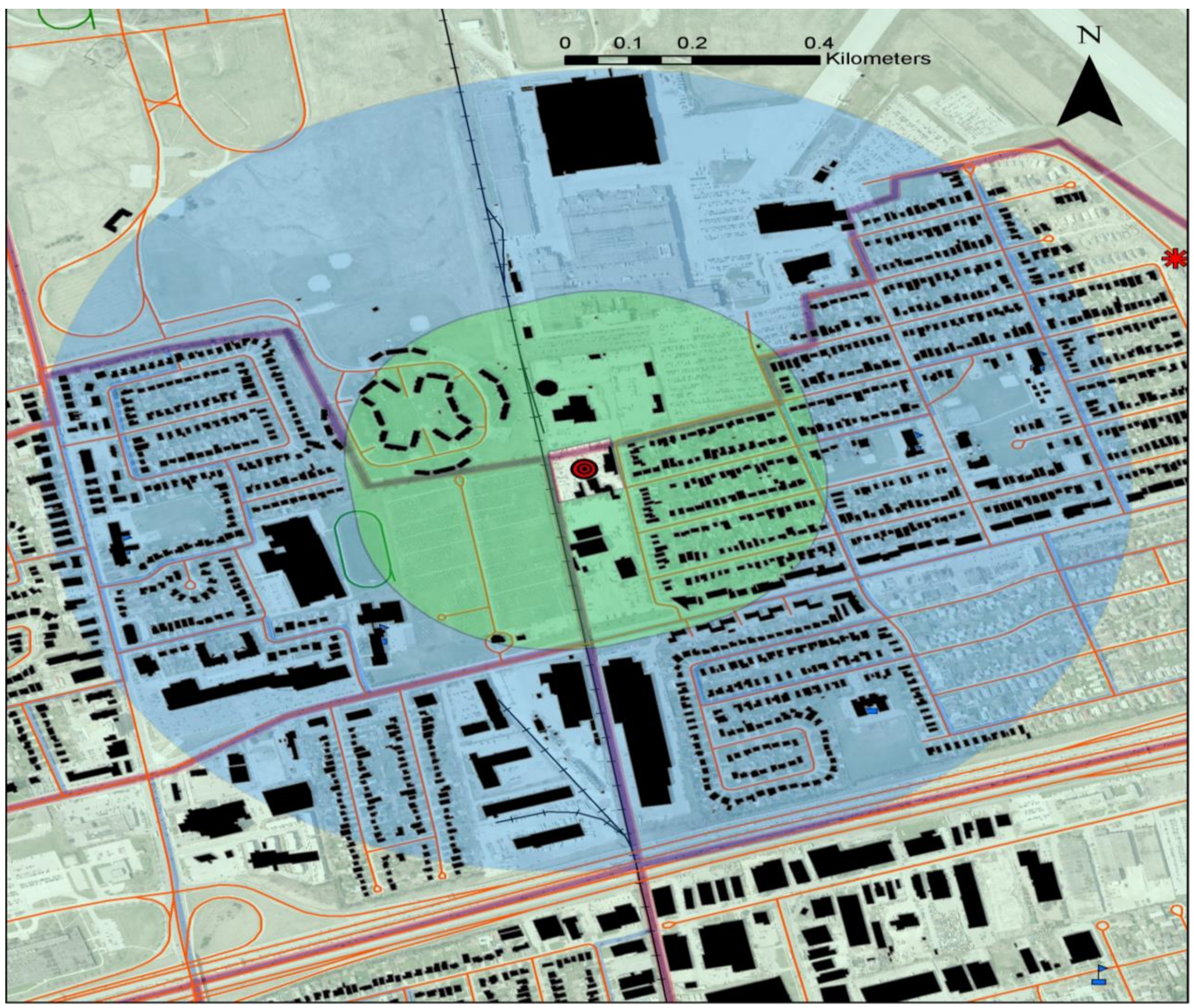
RISK ESTIMATION

$$R_{nj} = H_j \times 0.25 \sum_{j=1}^{3} \sum_{i=1}^{n} (SV_{ji} + EV_{ji} + PV_{ji} + CI_{ji}).$$

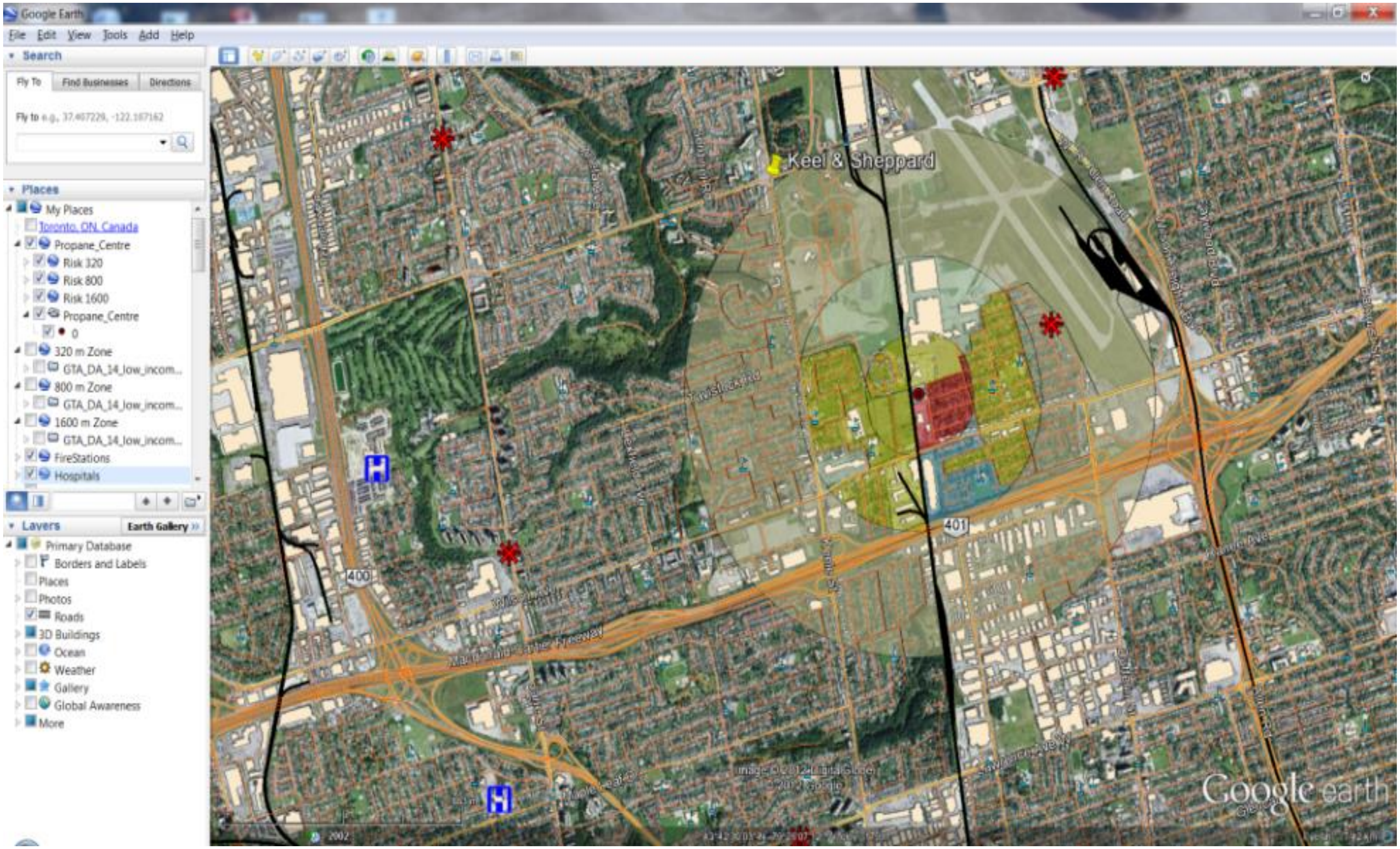
i = DA, j = hazard zone, and n is the number of DAs in each zone;
Rnj = spatial risk index of all DAs located in zone j;
Hj = relative hazard zone index;
SVji = social vulnerability component;
EVji = economic vulnerability component;
PVji = physical vulnerability component;
CIji = critical infrastructure component;
0.25 = average of the total four individual vulnerability types.

Table 1. Spatial risk estimation for Zone 1 ($j = 1$).

DA ID	DA_i	Total V_{ji}	R_{ji}; $H_j = 0.6$
352,021,159	4.638	0.2659	0.1596
352,021,160	0.140	0.0485	0.0291
352,021,162	0.187	0.0197	0.0118
352,021,165	0.309	0.0313	0.0188
352,021,166	0.167	0.9409	0.5645
352,021,167	0.325	0.3932	0.2359
352,021,182	0.358	0.0000	0.0000



Risk Prioritization



(red = very high risk; yellow = high risk; blue = medium risk; greyish green = low risk)

CONVENTIONAL APPROACH APPLIED TO ONTARIO HAZARDS

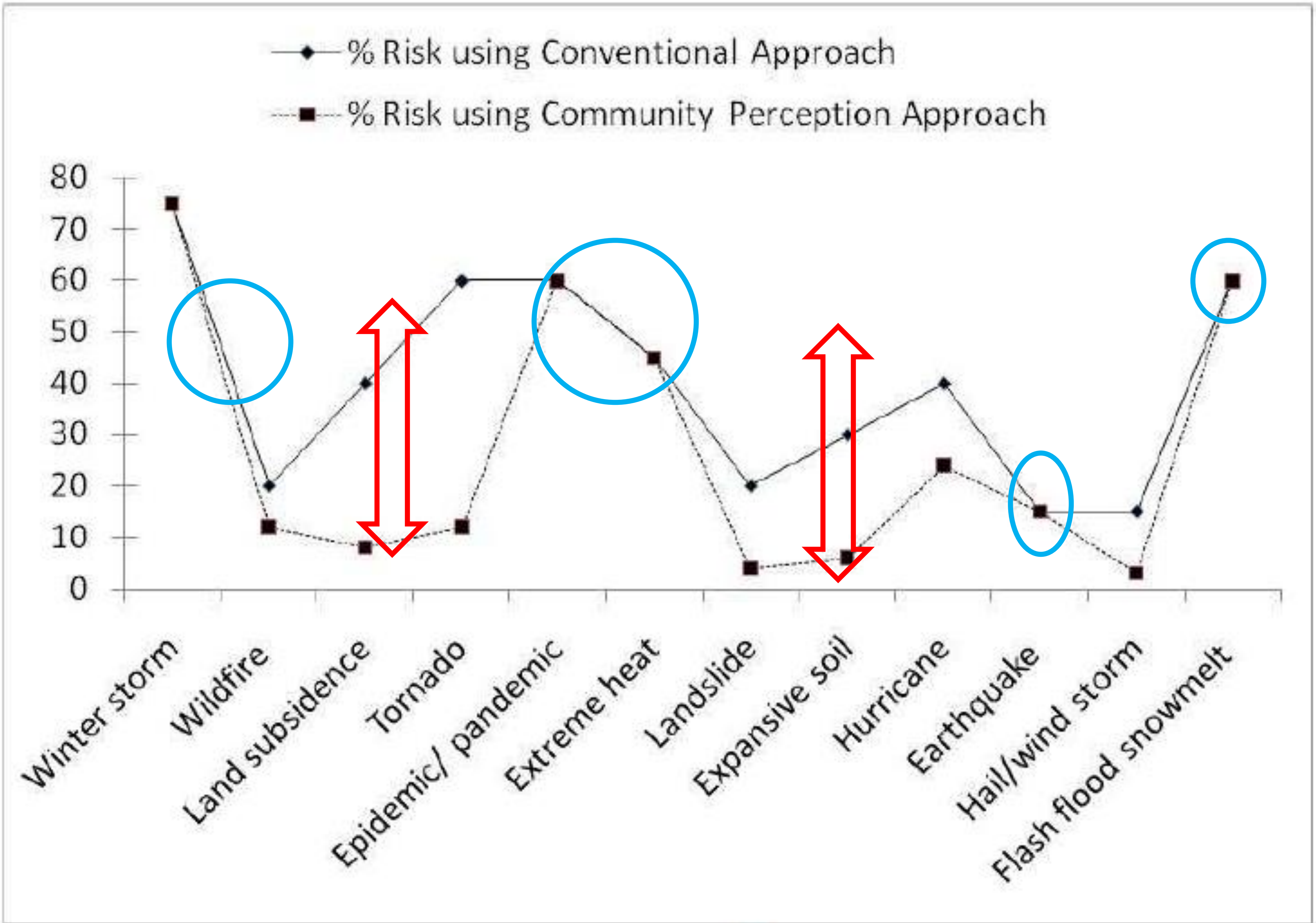
SN	Hazard	Likelihood (1)	Impact (2)	Risk Index (*RI*) (1)×(2)= (3)	*RI* (%) (3)÷20*×100 =(4)
1	Winter storm	5	3	15	75
2	Wildfire	4	1	4	20
3	Land subsidence	4	2	8	40
4	Tornado	4	3	12	60
5	Epidemic/ pandemic	3	4	12	60
6	Extreme heat	3	3	9	45
7	Landslide	2	2	4	20
8	Expansive soil	2	3	6	30
9	Hurricane	2	4	8	40
10	Earthquake	1	3	3	15
11	Hail storm/ wind storm	3	1	3	15
12	Flash flood from snowmelt	3	4	12	60
* max value of *RI*, based on max ranks of Likelihood =5 (Table 2) and Impact = 4 (Table 1)					

Nirupama, N. (2012). Risk and Vulnerability Assessment – A Comprehensive Approach, *International Journal of Disaster Resilience in the Built Environment*, Emerald, **3**:2.

ACCOUNTING FOR COMMUNITY PERCEPTION

SN	Hazard	Likelihood (1)	Impact (2)	Community Perception (cp) (3)	Risk Index (RI_{cp}) (1)×(2×3) (4)	RI_{cp} (%) (4)÷100*×100 (5)
1	Winter storm	5	3	5	75	75
2	Wildfire	4	1	3	12	12
3	Land subsidence	4	2	1	8	8
4	Tornado	4	3	1	12	12
5	Epidemic/ pandemic	3	4	5	60	60
6	Extreme heat	3	3	5	45	45
7	Landslide	2	2	1	4	4
8	Expansive soil	2	3	1	6	6
9	Hurricane	2	4	3	24	24
10	Earthquake	1	3	5	15	15
11	Hail storm/ wind storm	3	1	1	3	3
12	Flash flood from snowmelt	3	4	5	60	60

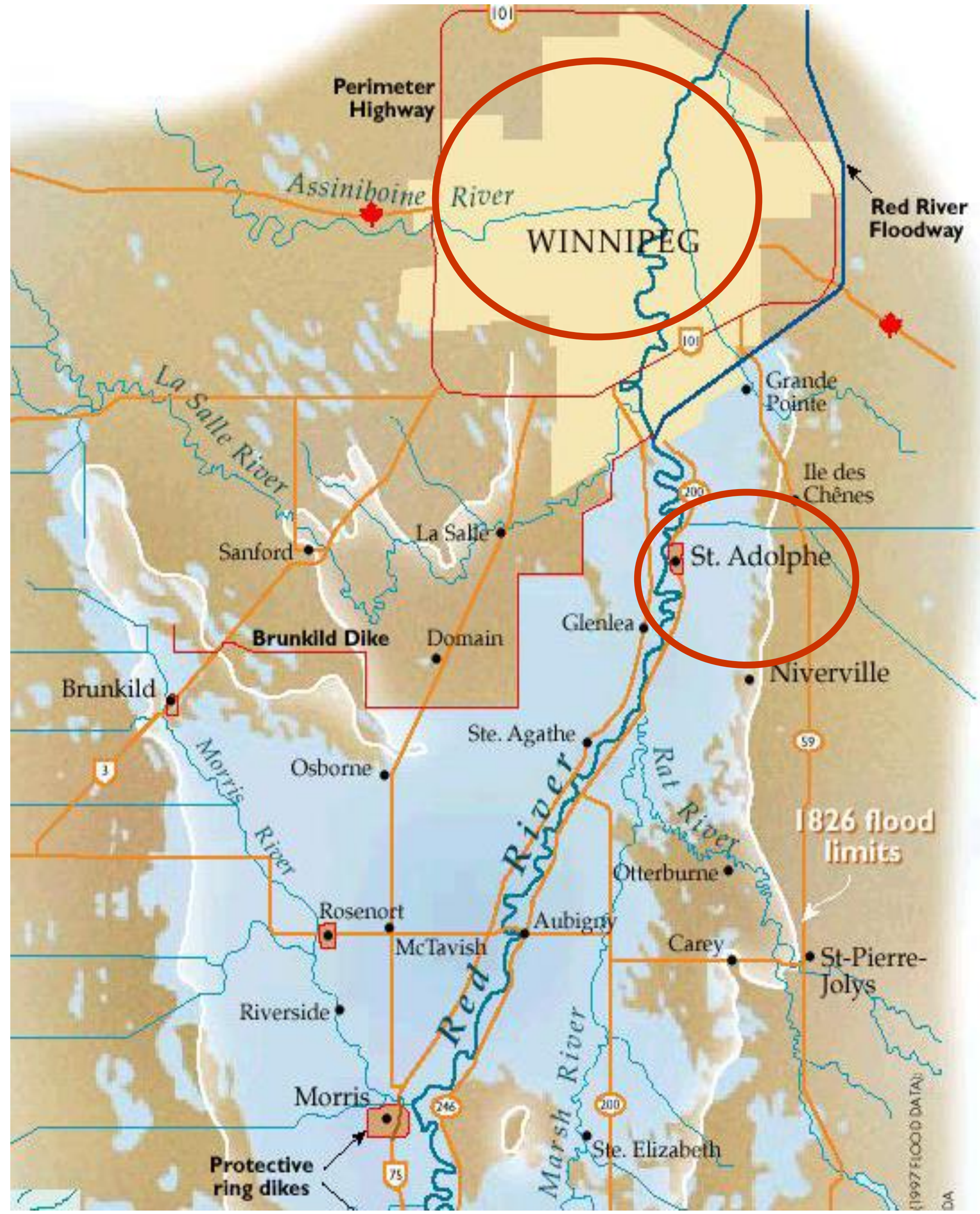
* max value of RI_{cp} - based on max ranks of Likelihood = 5, Impact = 4, and cp = 5



% Risk using Conventional Approach
% Risk using Community Perception Approach
80
70
60
50
40
30
20
10
0
Winter storm
Wildfire
Land subsidence
Tornado
Epidemic/ pandemic
Extreme heat
Landslide
Expansive soil
Hurricane
Earthquake
Hail/wind storm
Flash flood snowmelt

Risk control options - structural, non structural, cost/benefit analysis

The 1997 Red River Flood



Simonovic, S. and Nirupama (2005). A Spatial Multi-Objective Decision Making under Uncertainty for Water Resources Management, *Journal of Hydroinformatics*, 7 (2), 117-133.

Criteria

#1: Minimize flood depth

#2: Minimize damage - buildings, roads, crops

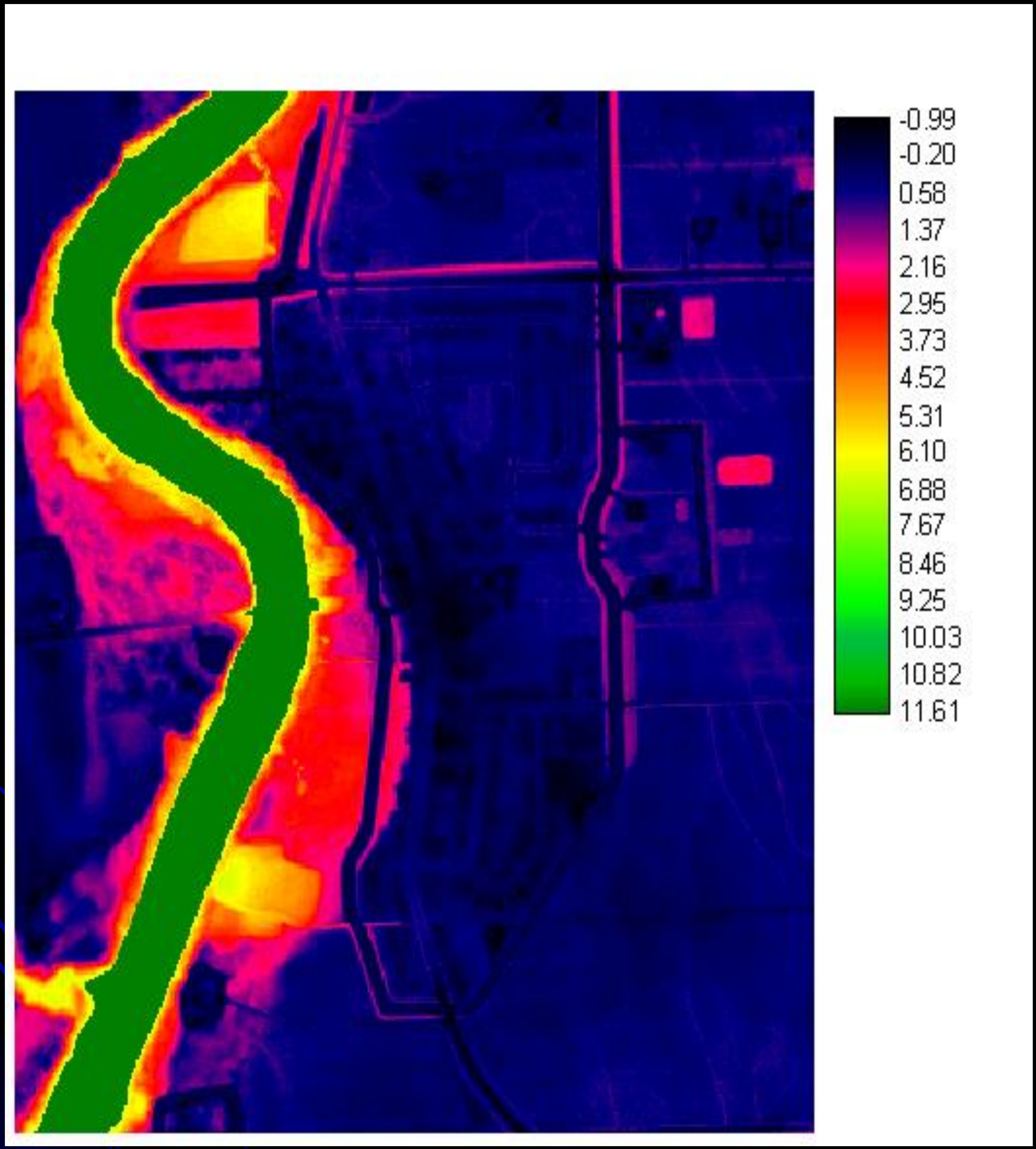
Alternatives

1: Dike to protect the City of St. Adolphe.
2: Raise floodway gate by 1m.
3: Lower floodway gate by 1m.

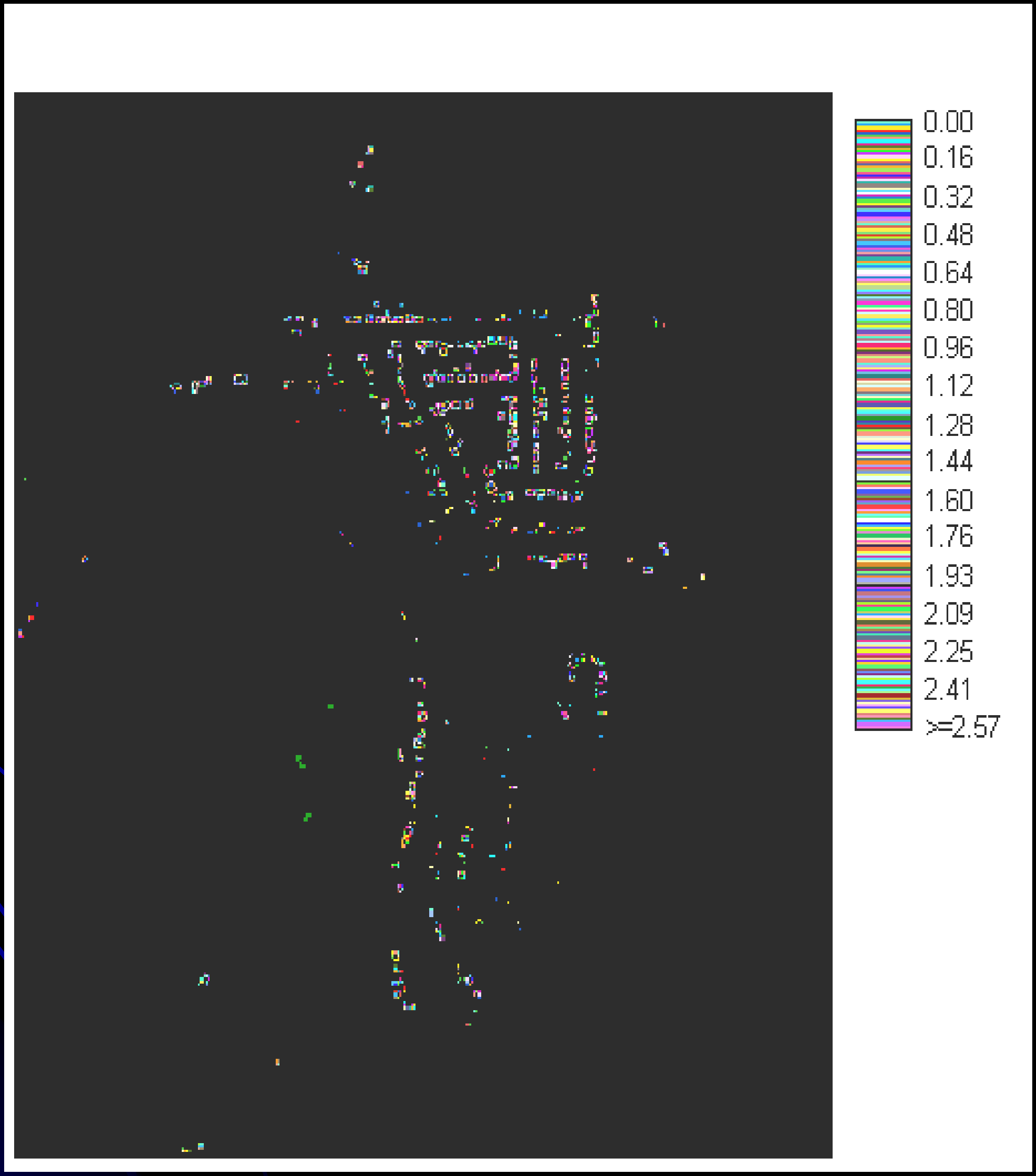
Multiple decision makers' preferences

Criteria	Decision Maker's Preference (W_i)		
	Weight set #1	Weight set #2	Weight set #3
Flood depth	0.5	0.1	0.9
Damage	0.5	0.9	0.1

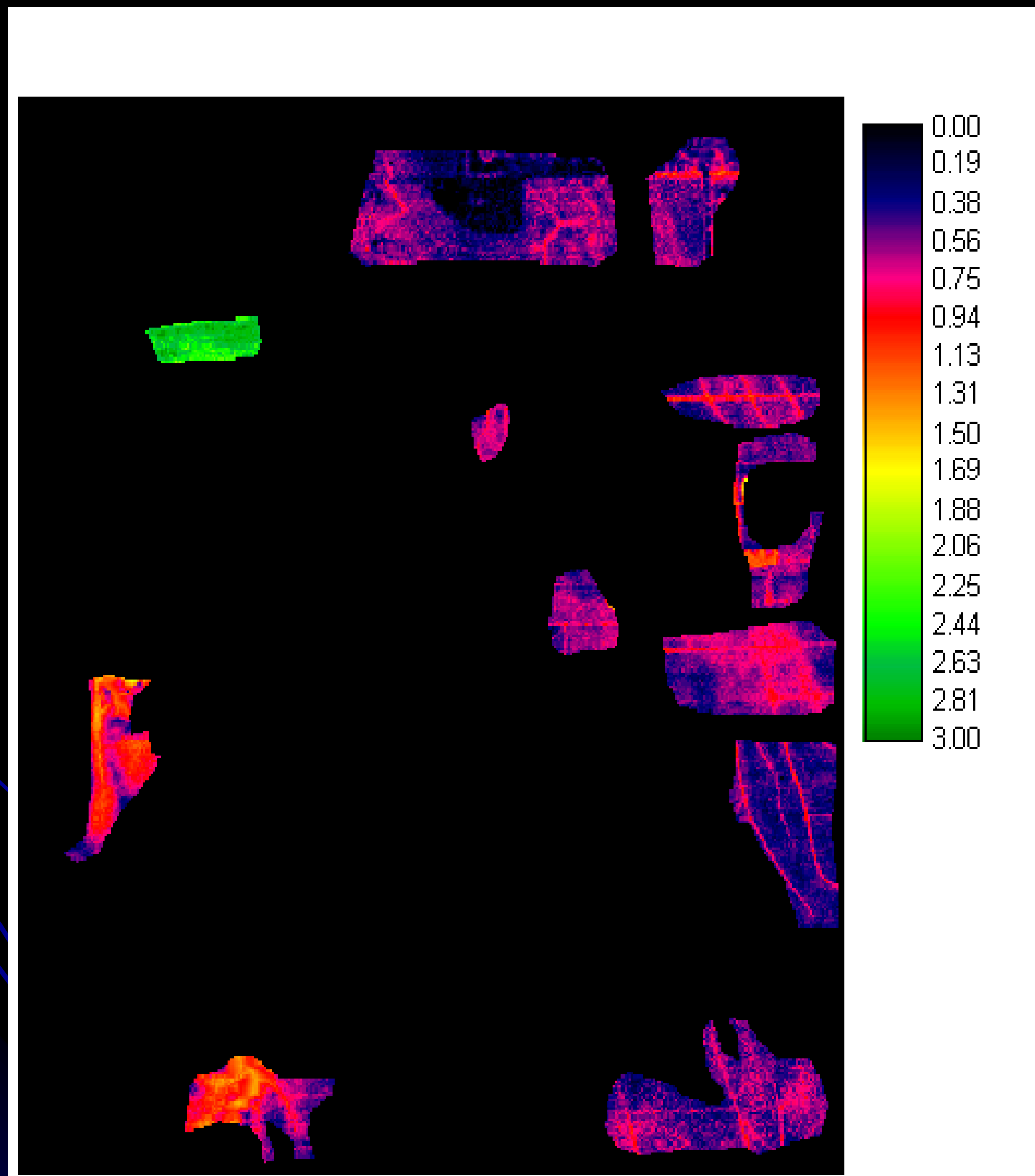
Flood depth for simulated alternative #2



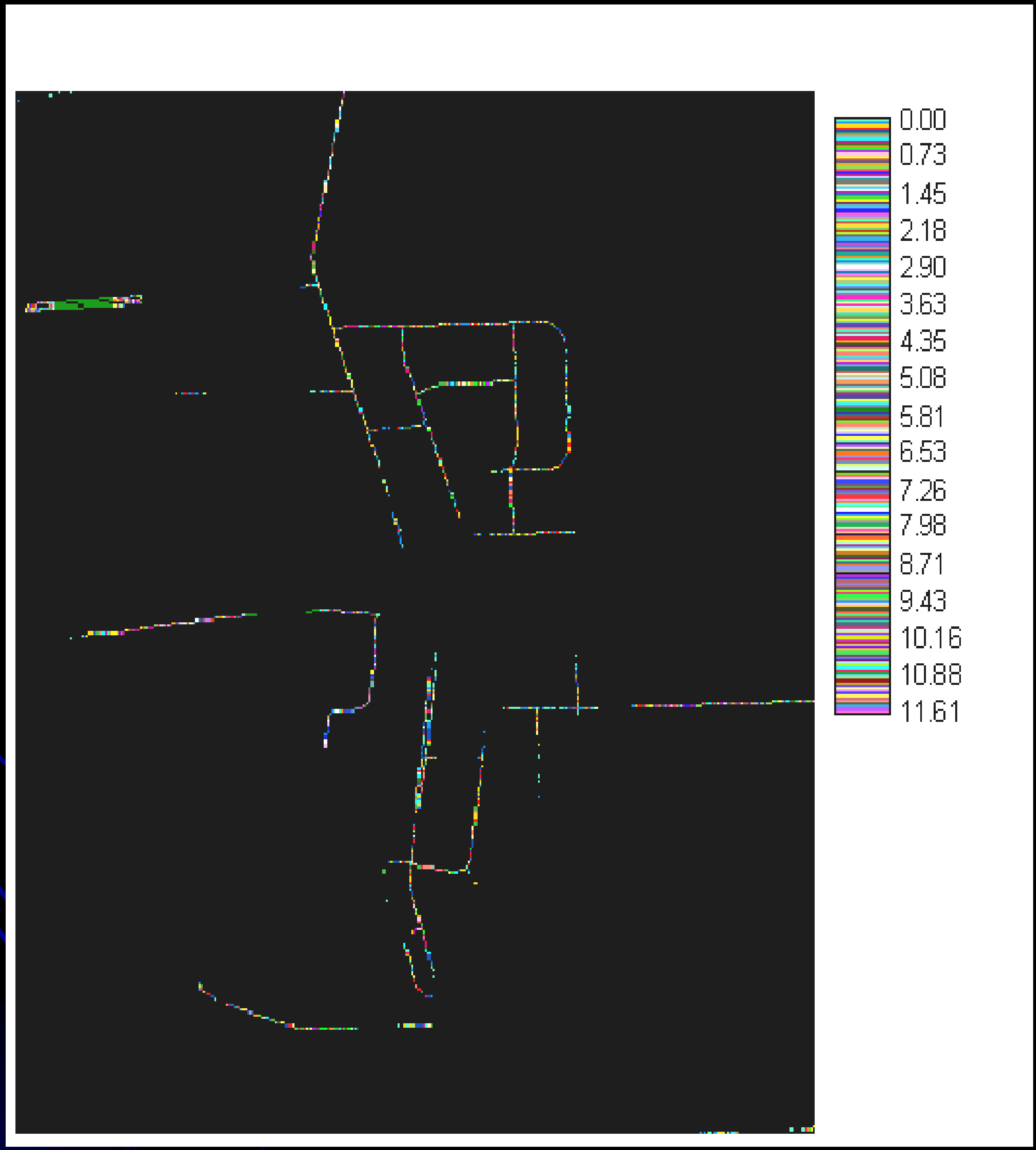
Flooded buildings for simulated flood protection alternative #2



Flooded fields for simulated flood protection alternative #2



Flooded roads for simulated flood protection alternative #2



$ Damage

Buildings

$$y = 76879x^3 - 344873x^2 + 470283x + 538659$$

Roads

$$rd = 18.889L^2 + 261.25L + 300000$$

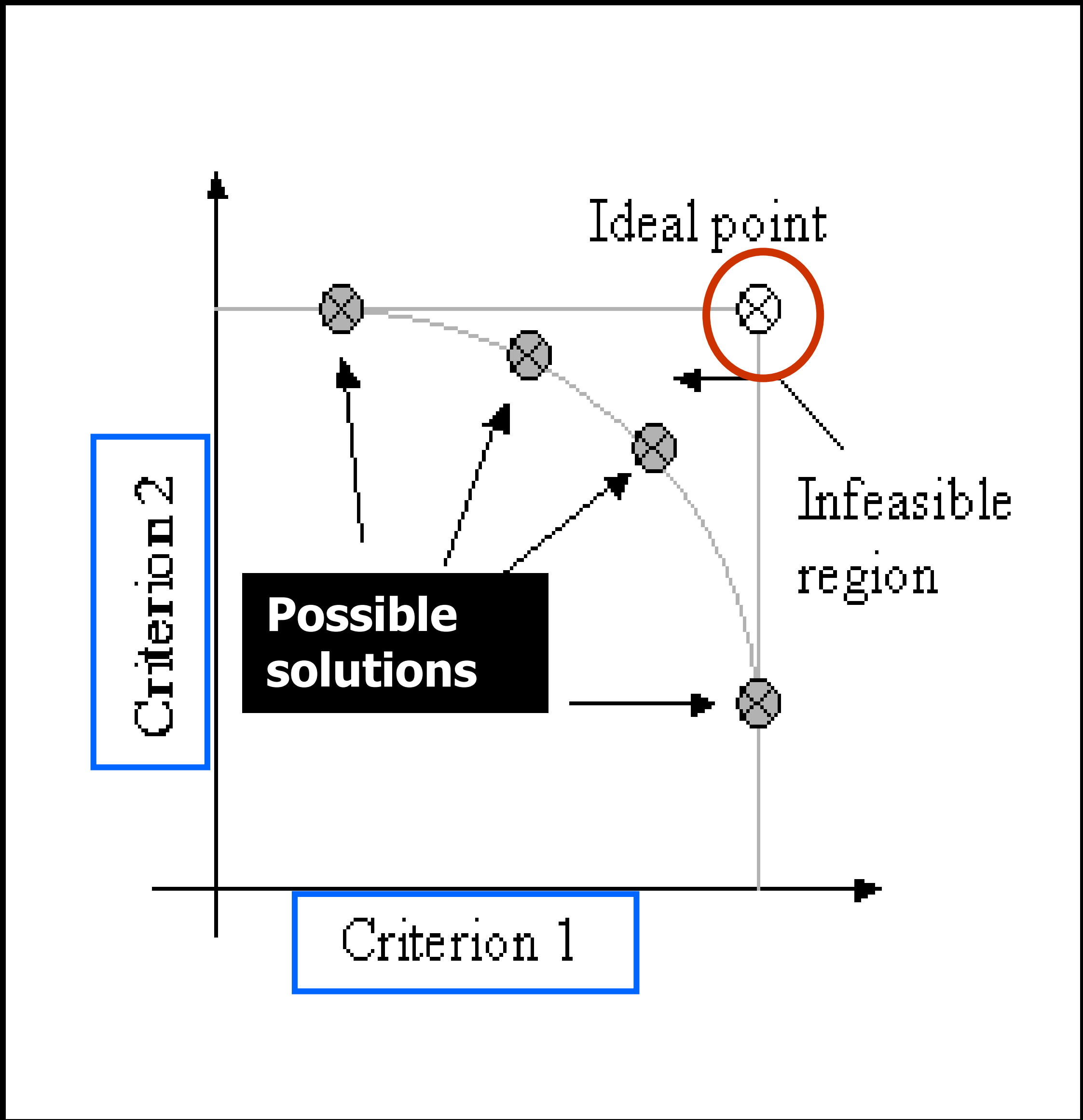
Crops

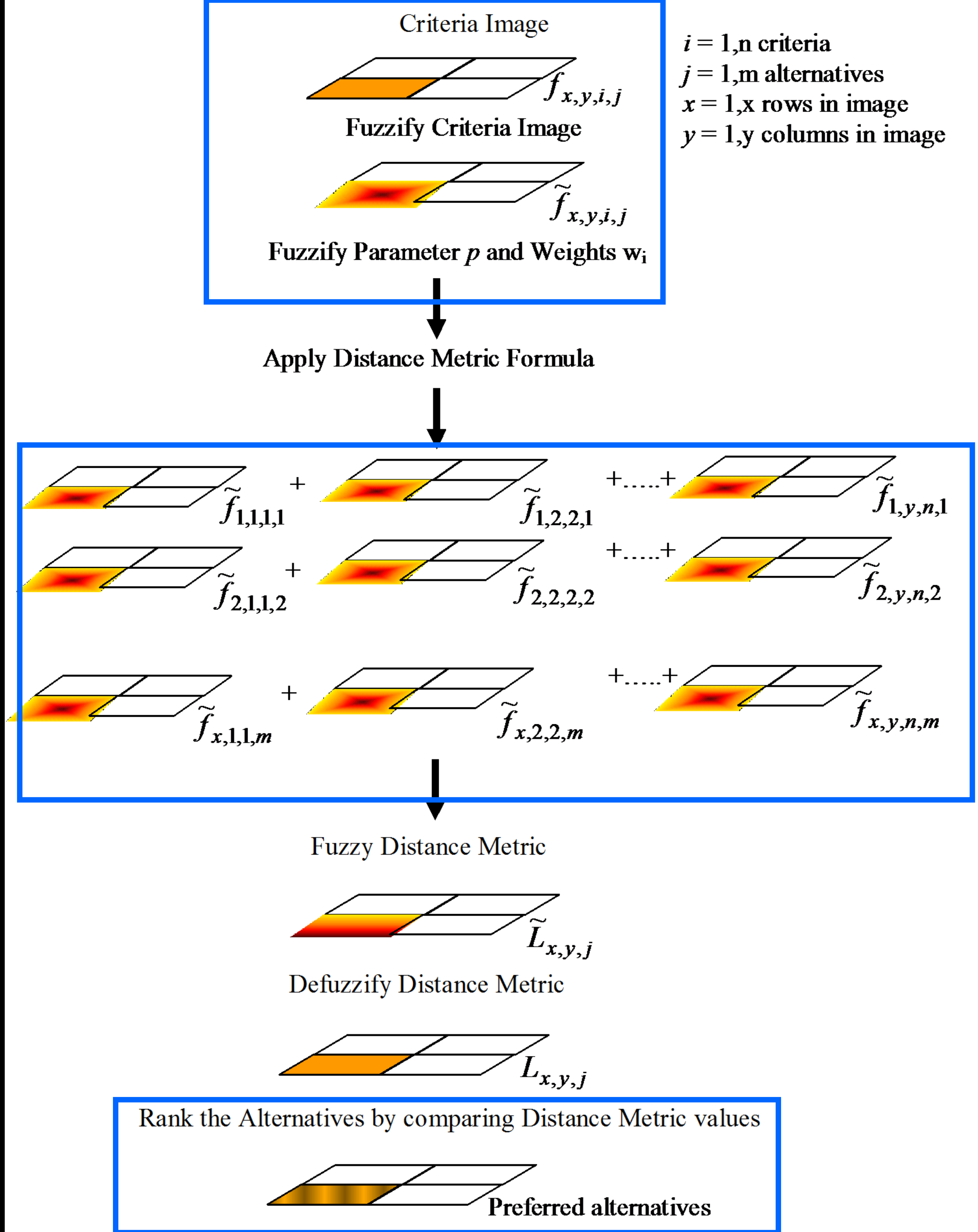
$$ad = \sum\left[(1 - yield) * (cp) * A * price\right]$$

Water surface elevation for three alternatives

Alternative	Total discharge at floodway entry point (m^3/sec)	Water surface elevation (m)
Dike	3650	232.89
Floodway 1	4730	233.83
Floodway 2	2900	231.71

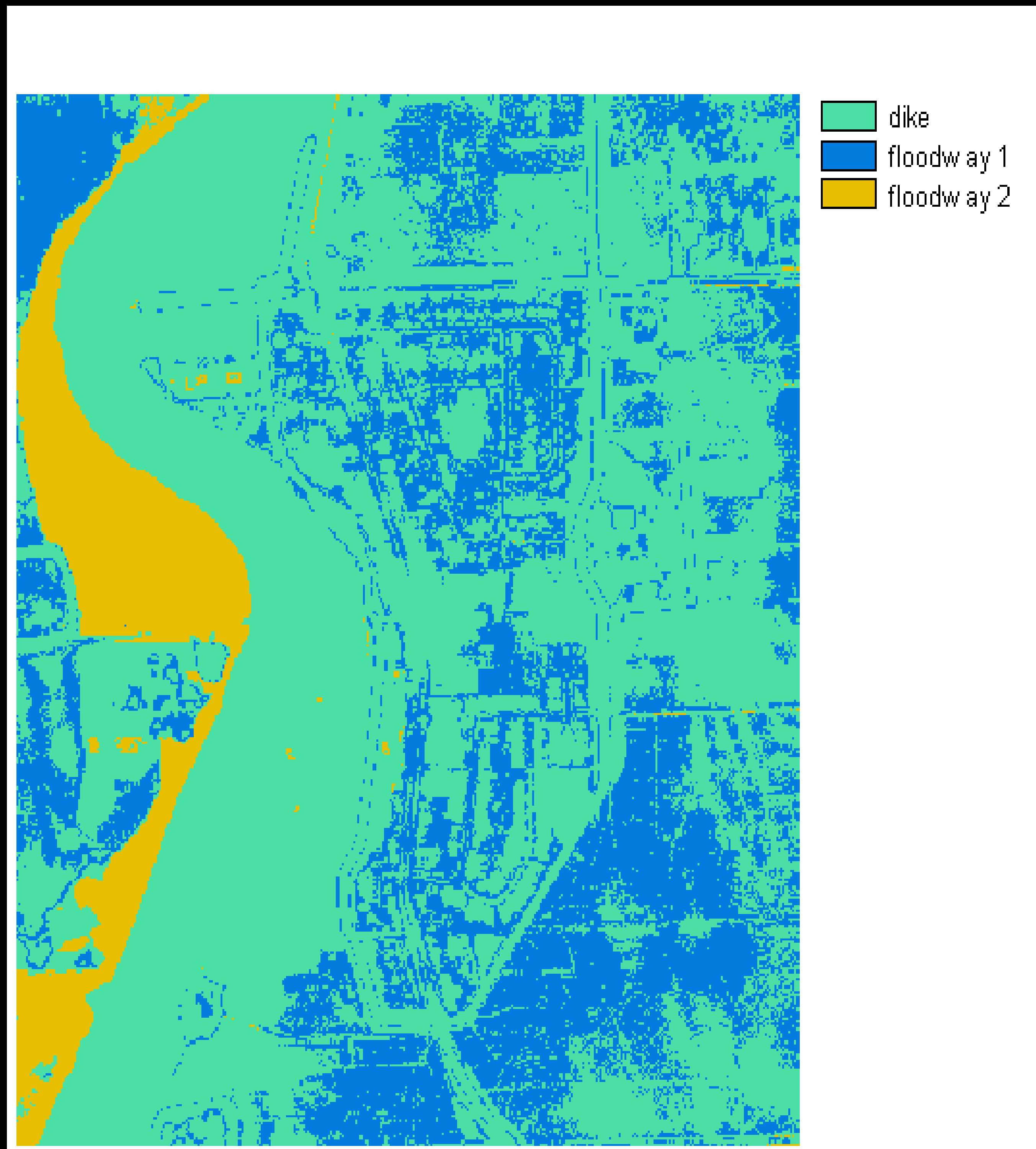
Multi-Criteria Decision Making using Compromise Programming



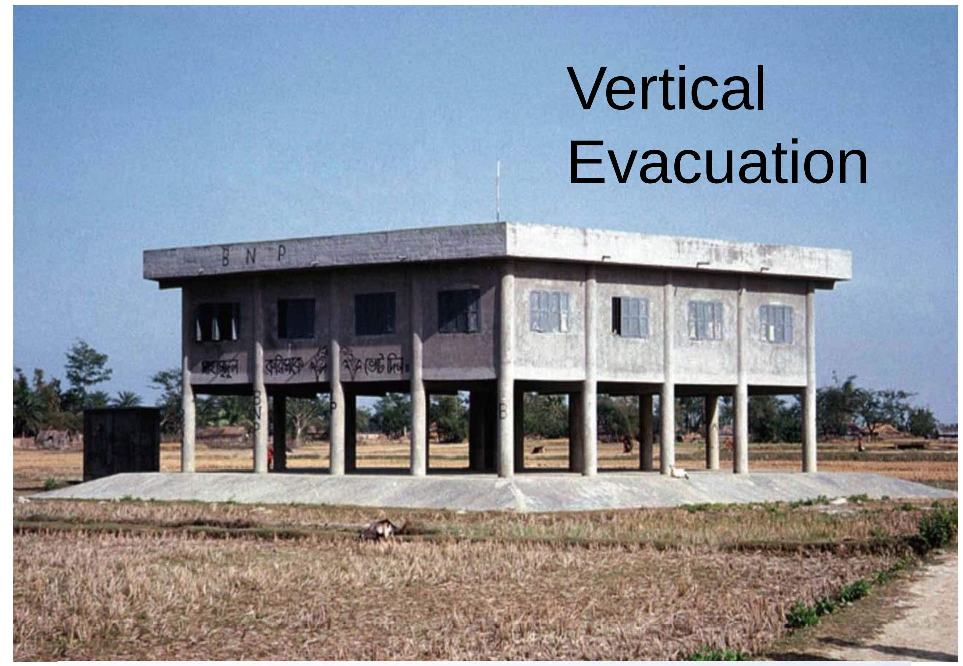


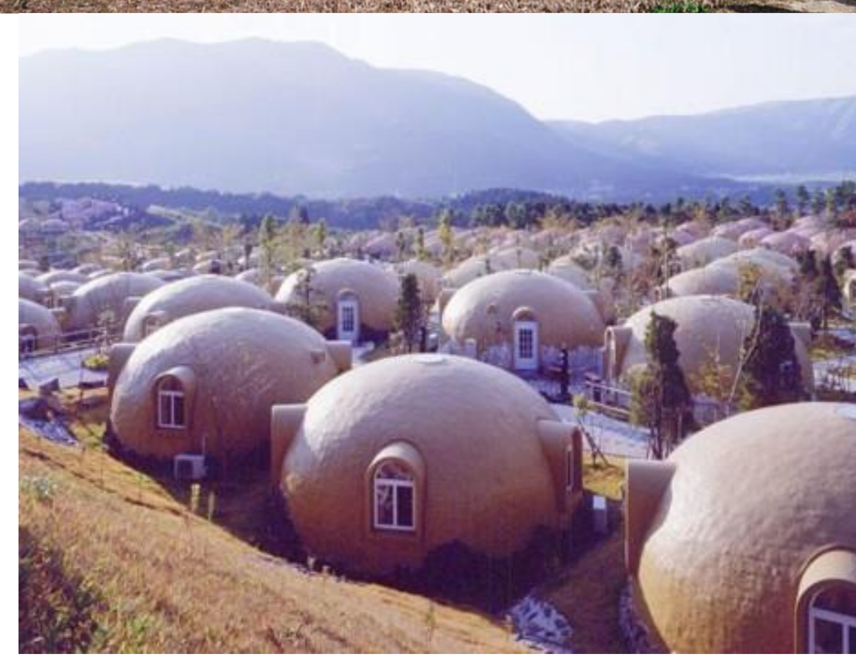
Criteria Image
$f_{x,y,i,j}$
Fuzzify Criteria Image
$\tilde{f}_{x,y,i,j}$
Fuzzify Parameter p and Weights w_i
i = 1,n criteria
j = 1,m alternatives
x = 1,x rows in image
y = 1,y columns in image
Apply Distance Metric Formula
$\tilde{f}_{1,1,1,1}$ + $\tilde{f}_{1,2,2,1}$ +.....+ $\tilde{f}_{1,y,n,1}$
$\tilde{f}_{2,1,1,2}$ + $\tilde{f}_{2,2,2,2}$ +.....+ $\tilde{f}_{2,y,n,2}$
$\tilde{f}_{x,1,1,m}$ + $\tilde{f}_{x,2,2,m}$ +.....+ $\tilde{f}_{x,y,n,m}$
Fuzzy Distance Metric
$\tilde{L}_{x,y,j}$
Defuzzify Distance Metric
$L_{x,y,j}$
Rank the Alternatives by comparing Distance Metric values
Preferred alternatives

Ranking of Alternatives



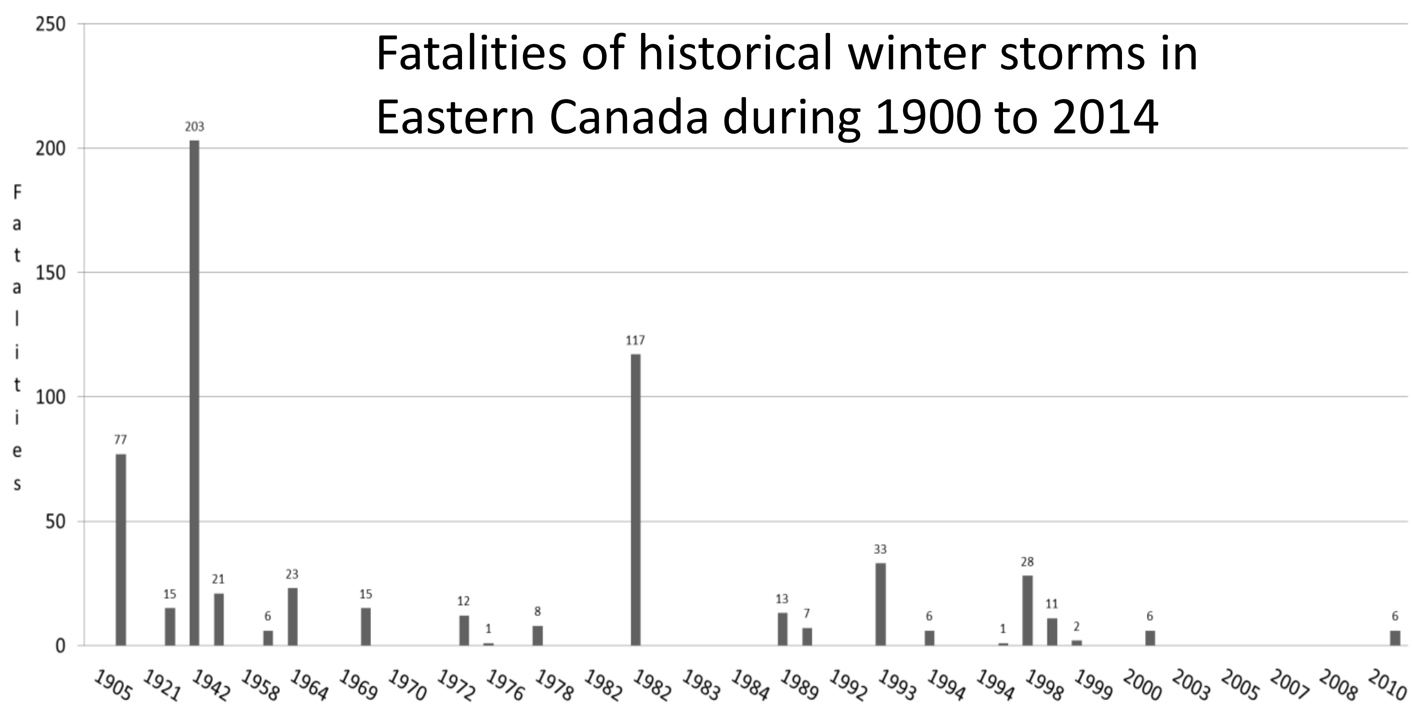
Strategic planning - economic, political and institutional support considerations

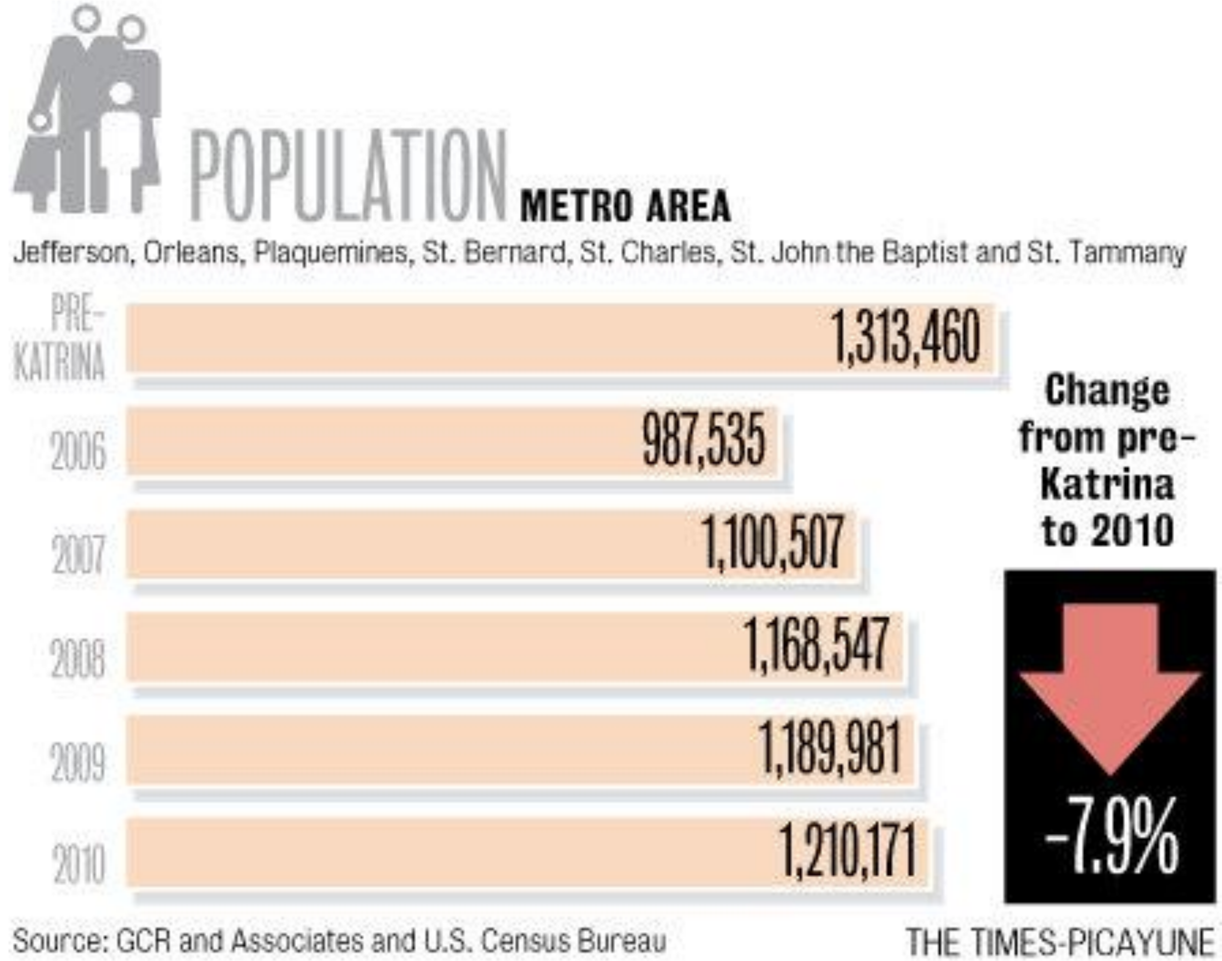


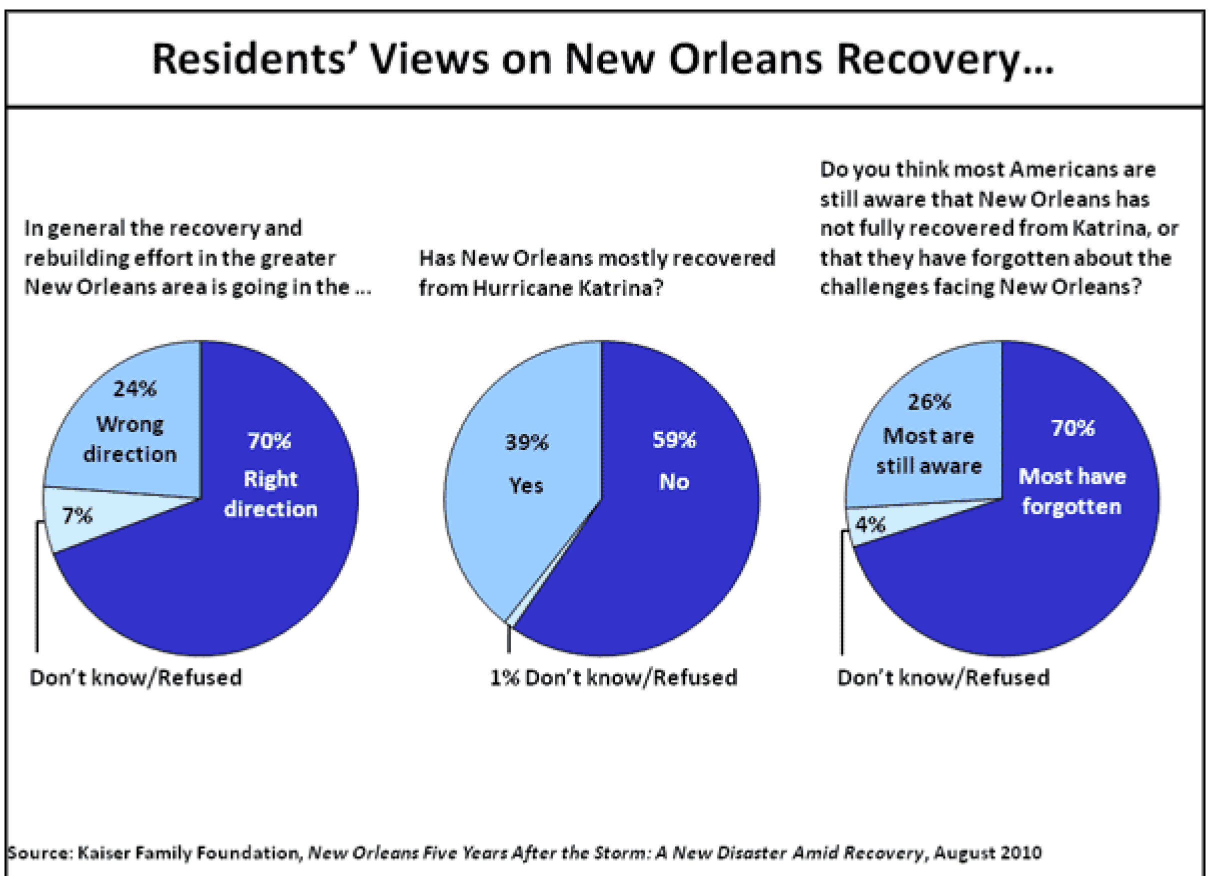


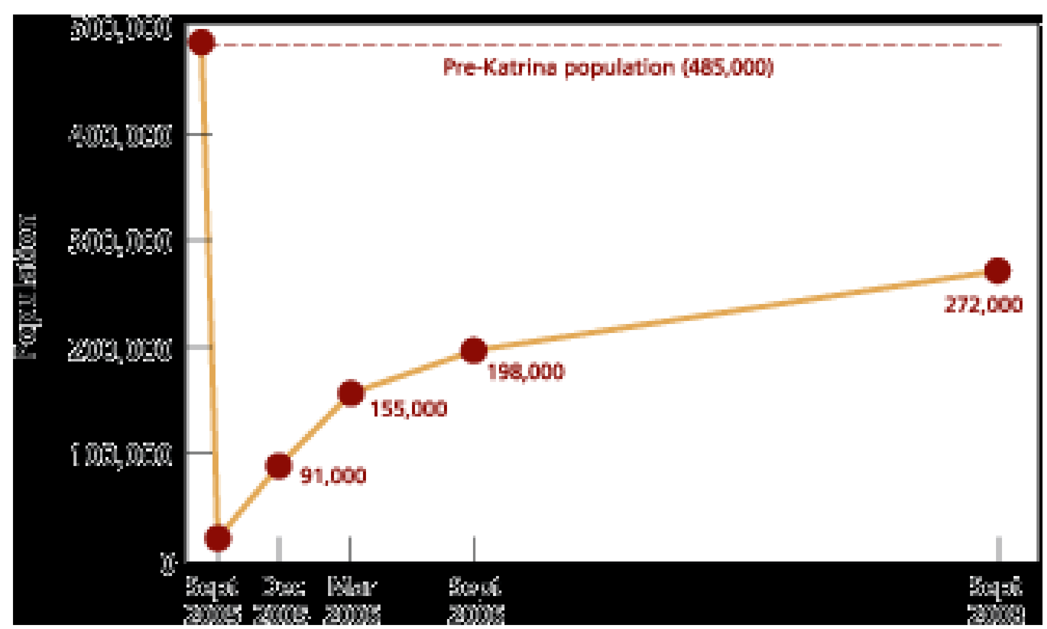
Nirupama, N. (2013). Vertical evacuation during cyclones: suitable for developing countries. *Natural Hazards*. 69:1137-1142

Response, recovery, reconstruction, and rehabilitation




POPULATION METRO AREA
Jefferson, Orleans, Plaquemines, St. Bernard, St. Charles, St. John the Baptist and St. Tammany
PRE-KATRINA 1,313,460
2006 987,535
2007 1,100,507
2008 1,168,547
2009 1,189,981
2010 1,210,171
Change from pre-Katrina to 2010
-7.9%
Source: GCR and Associates and U.S. Census Bureau
THE TIMES-PICAYUNE


Residents' Views on New Orleans Recovery…
In general the recovery and rebuilding effort in the greater New Orleans area is going in the …
24% Wrong direction
70% Right direction
7%
Don't know/Refused
Has New Orleans mostly recovered from Hurricane Katrina?
39% Yes
59% No
1% Don't know/Refused
Do you think most Americans are still aware that New Orleans has not fully recovered from Katrina, or that they have forgotten about the challenges facing New Orleans?
26% Most are still aware
70% Most have forgotten
4%
Don't know/Refused
Source: Kaiser Family Foundation, *New Orleans Five Years After the Storm: A New Disaster Amid Recovery*, August 2010


Pre-Katrina population (485,000)
91,000
155,000
198,000
272,000

Knowledge management and sustainable development

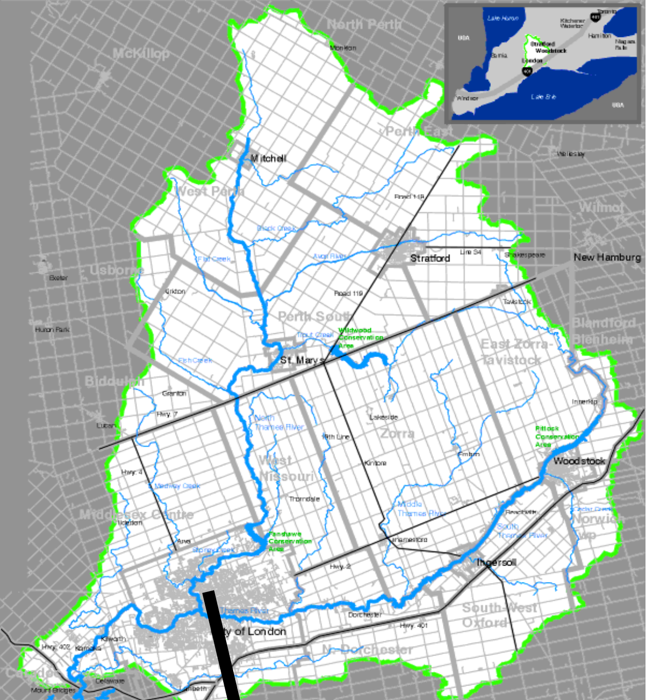
$$RMI = (RMI_{RI} + RMI_{RR} + RMI_{DM} + RMI_{FP})/4$$

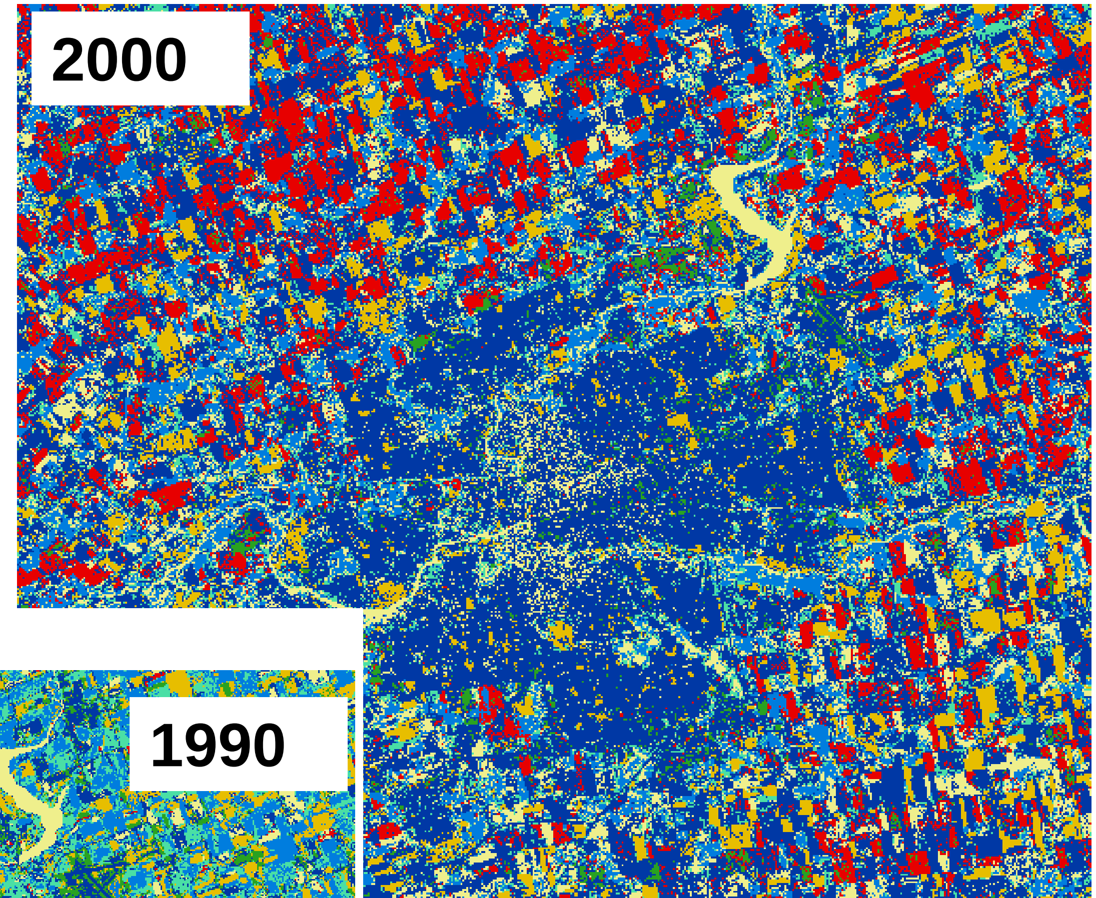
RMI = Risk Management Index

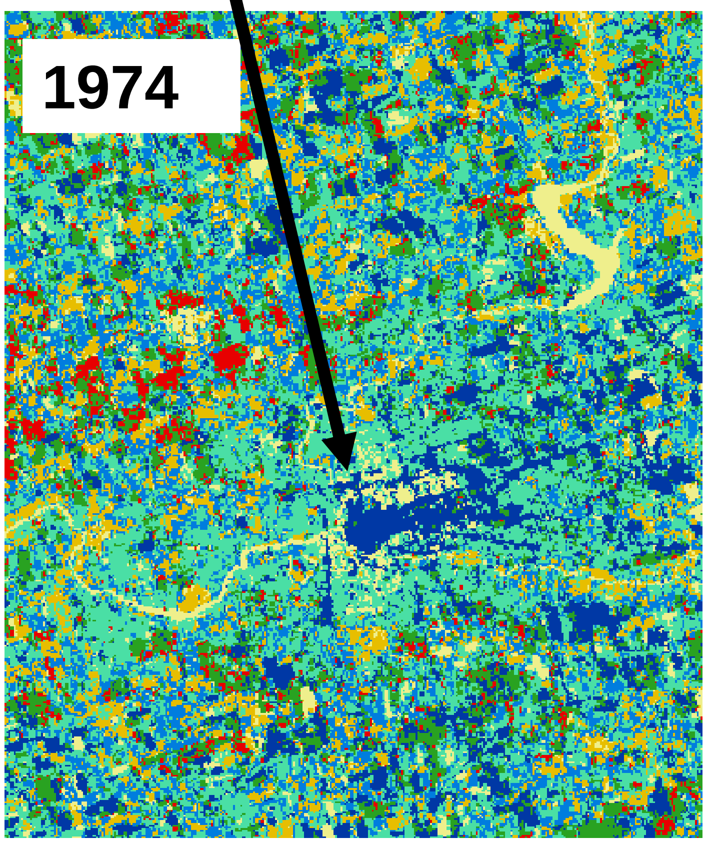
RMI_{RI} = risk identification, includes objective and perceived risks;
RMI_{RR} = risk reduction measures including prevention and mitigation;
RMI_{DM} = measures of response and recovery; and
RMI_{FP} = governance and financial protection measures.

Cardona (2002)

Upper Thames River Watershed



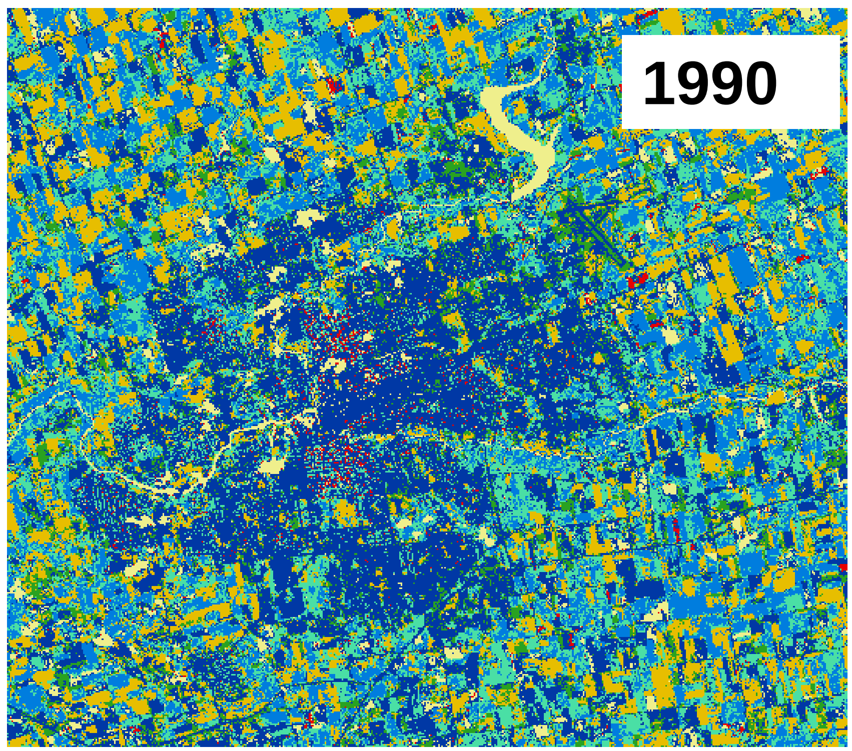




Meter
4681.53

- wood
- row crops and legume grasse
- small grain or grasses
- fallow
- urban
- homestead
- water

Nort



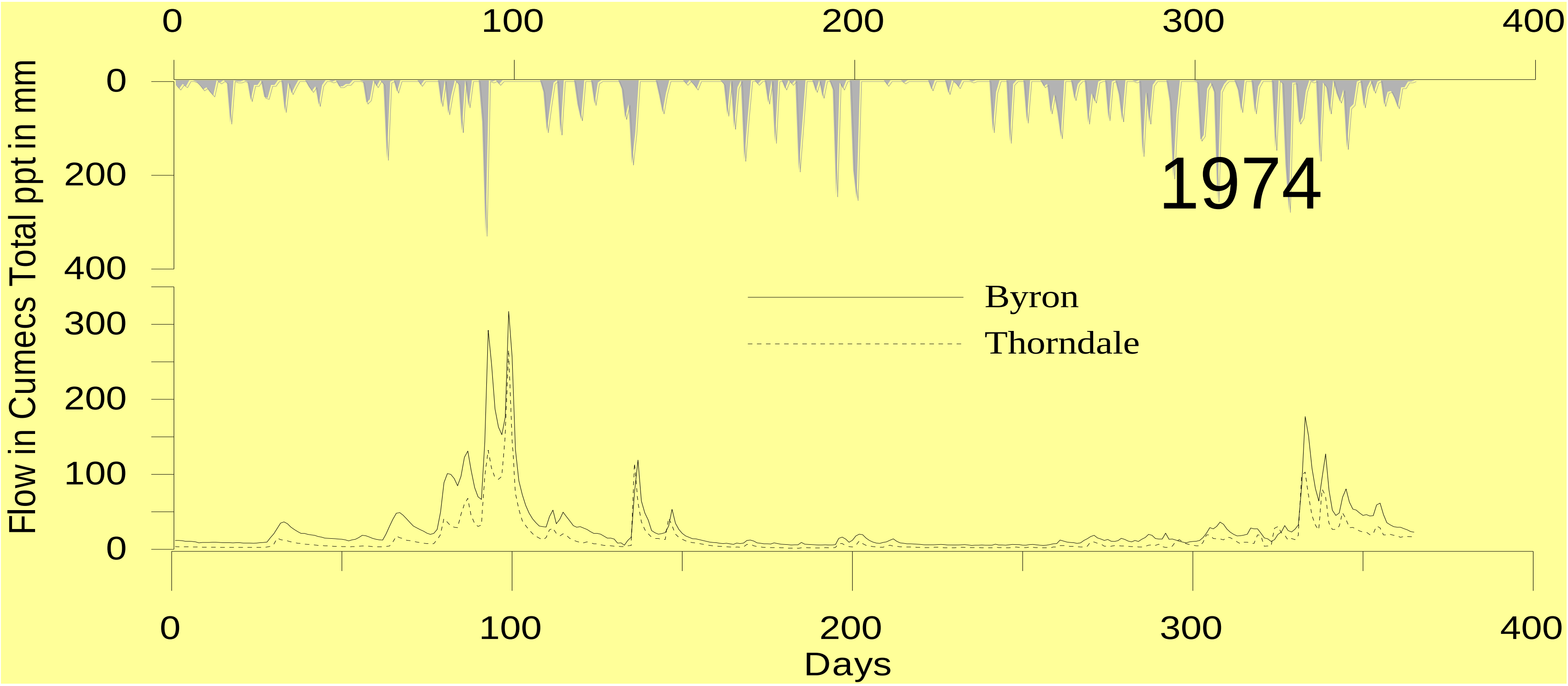
Meter
4634.51

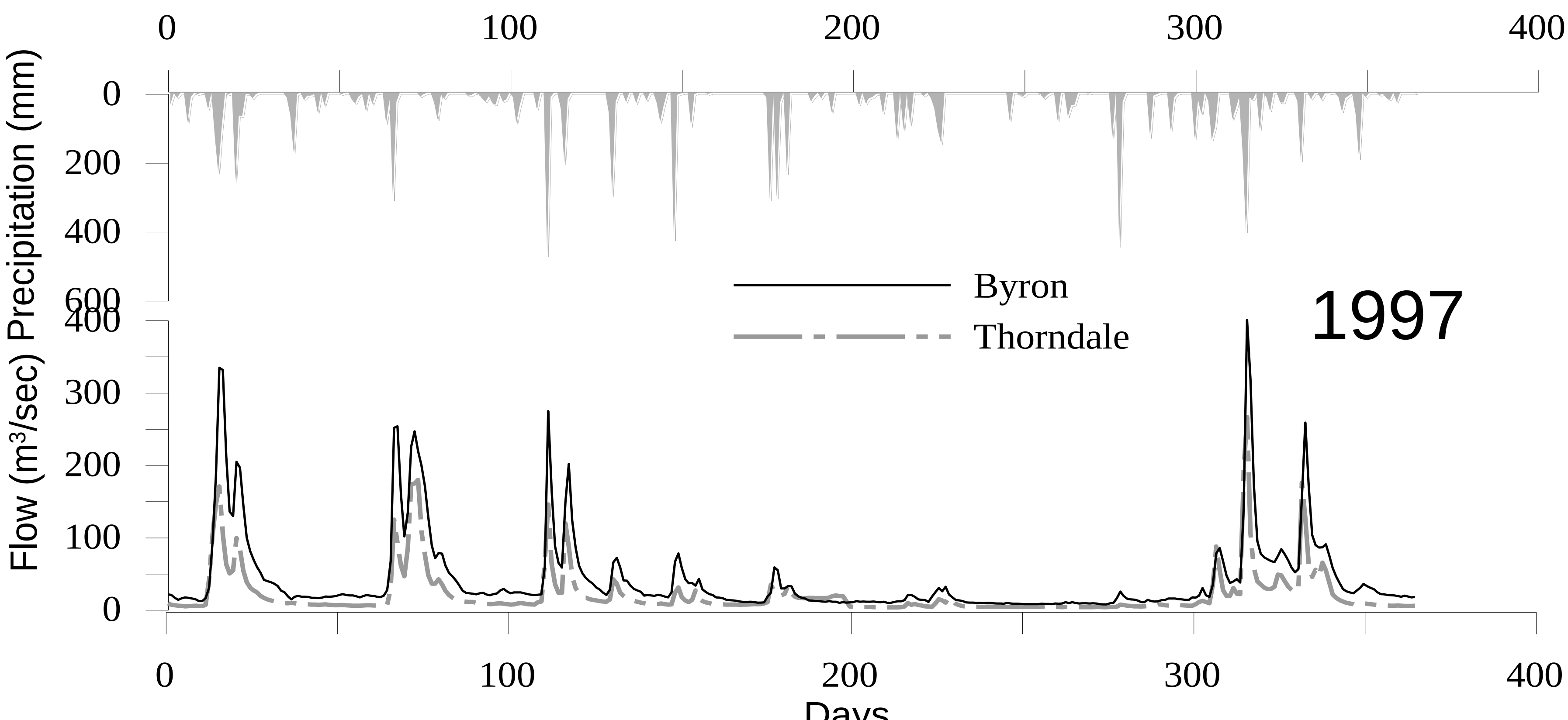
North

- wood
- row crops and legume grasses
- small grain or grass
- fallow
- urban
- homestead
- water

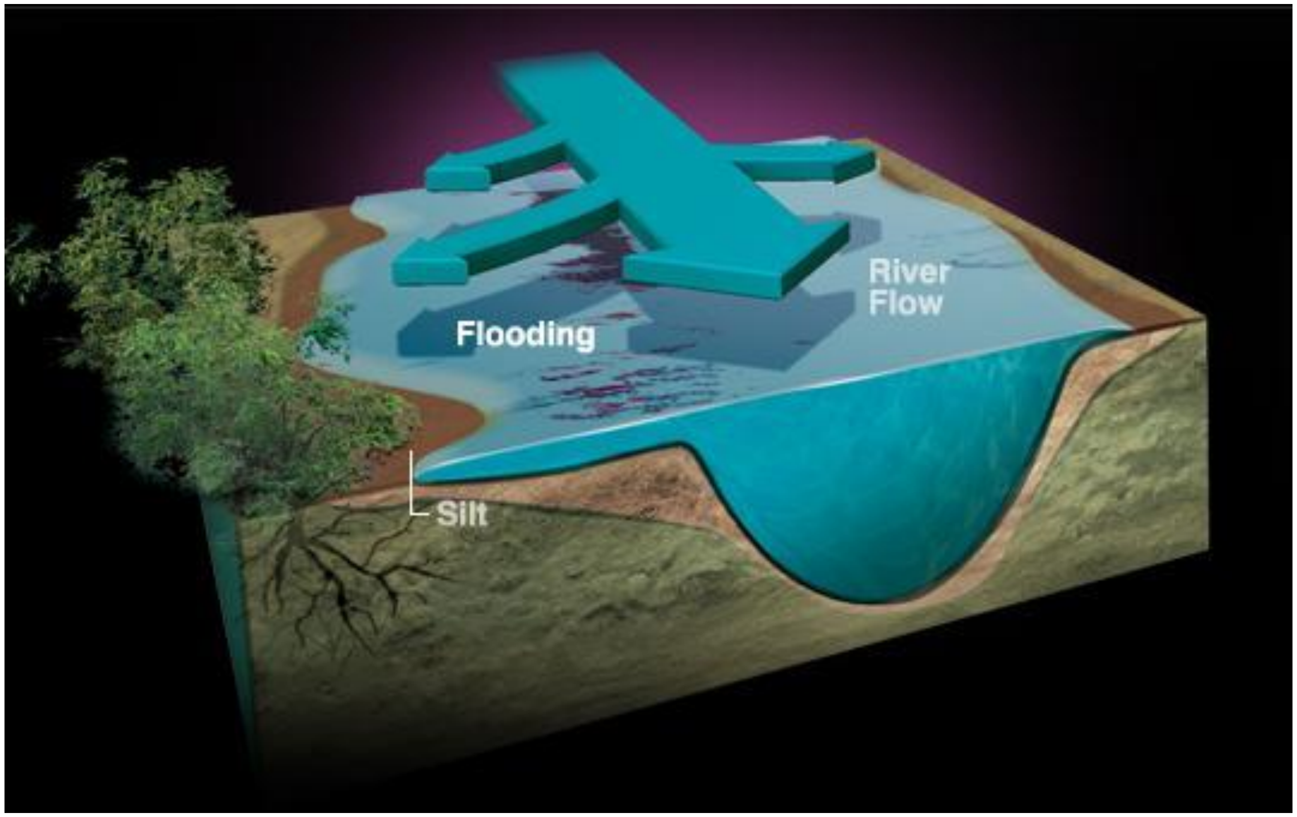
- wood
- row crops and legume grasses
- small grain or grasses
- fallow
- urban
- homestead
- water

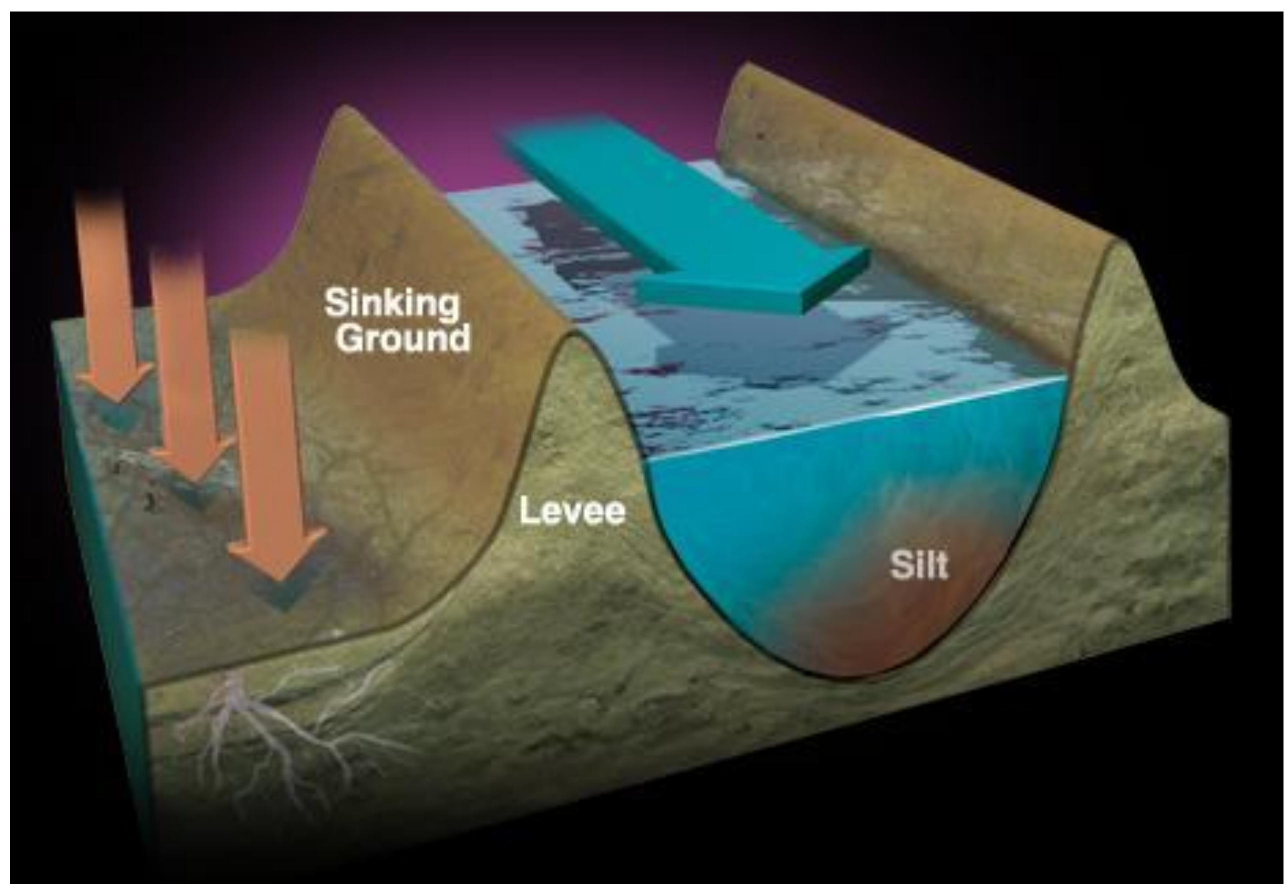
Land Use Classes	LANDSAT-1 MSS Jul 7, 1974 (%)	LANDSAT-5 TM Jul 23, 1990 (%)	LANDSAT-7 ETM Oct 30, 2000 (%)
Woods	24.01	11.98	13.06
Row Crops & Legume Grasses	22.78	29.18	13.20
Small Grains or Grass	31.56	34.91	16.84
Fallow Land	4.79	2.34	30.06
Urban	10.07	16.72	22.25
Homestead	3.14	2.05	1.86
Water	3.65	2.82	2.73





Nirupama, N. and S.P. Simonovic (2007). Increase of Flood Risk due to Urbanisation: A Canadian Example, *Natural Hazards*, Springer, 40, 25-41.


River
Flow
Flooding
Silt


Sinking
Ground
Levee
Silt

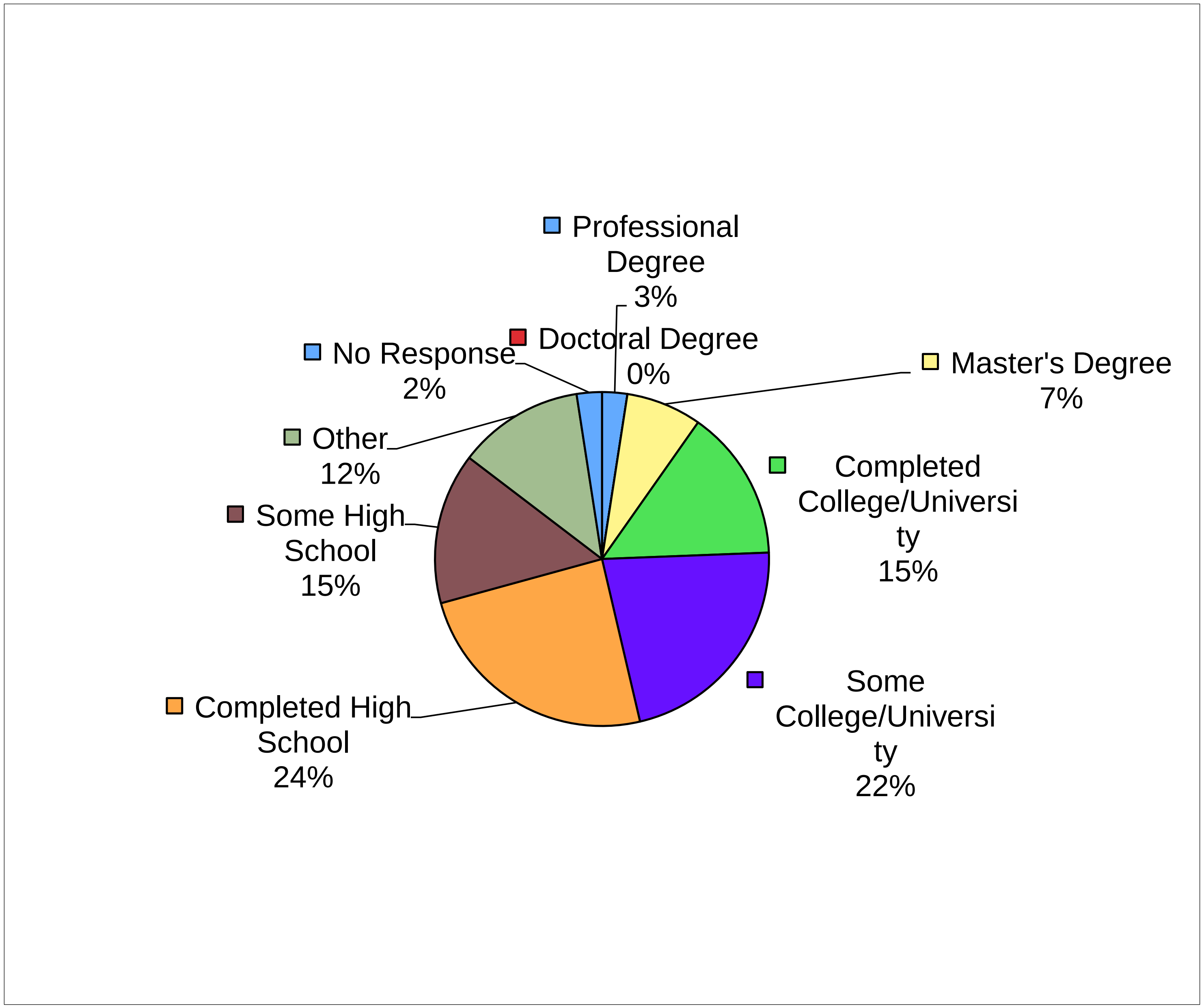
Resilience building and community participation

ENGAGING PUBLIC FOR BUILDING RESILIENT COMMUNITIES TO REDUCE DISASTER IMPACT

Nirupama, N. and Maula, A. (2013). Engaging Public for Building Resilient Communities to Reduce Disaster Impact, Special Issue on Sociological Aspects of Natural Disasters Springer, *Natural Hazards*. 66:51-59.

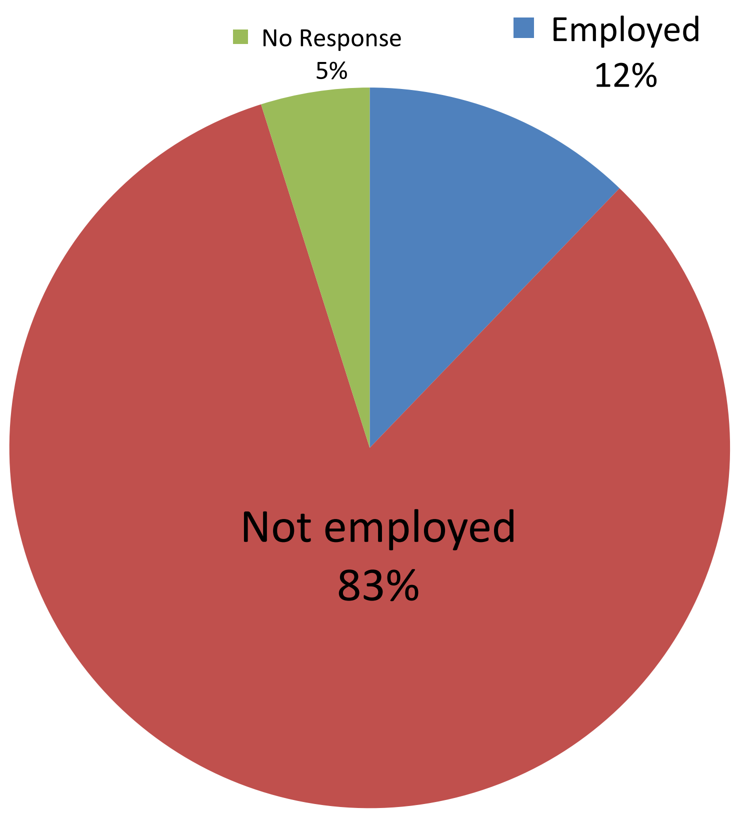
Nirupama, N. and Etkin, D. (2012). Institutional Perception and Support in Emergency Management in Ontario, Canada, *Disaster Prevention and Management*, Emerald, 21(5).

Education

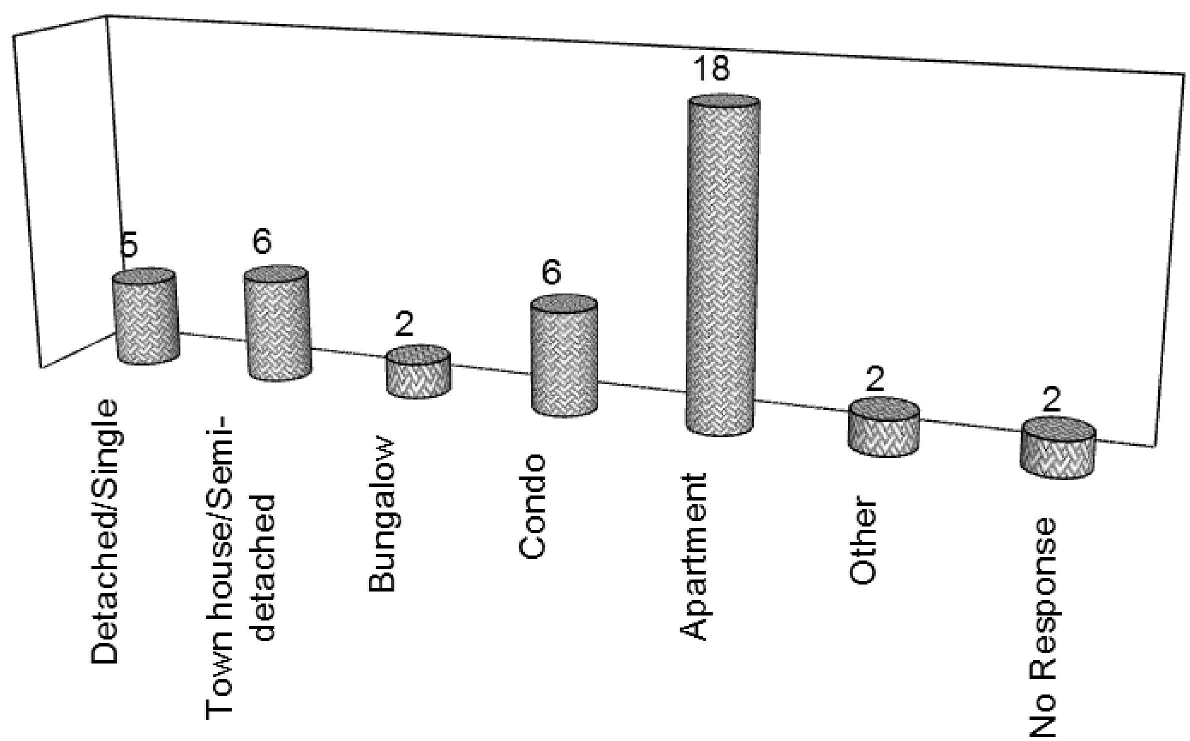


Professional Degree 3%
Doctoral Degree 0%
Master's Degree 7%
No Response 2%
Other 12%
Completed College/University 15%
Some High School 15%
Some College/University 22%
Completed High School 24%

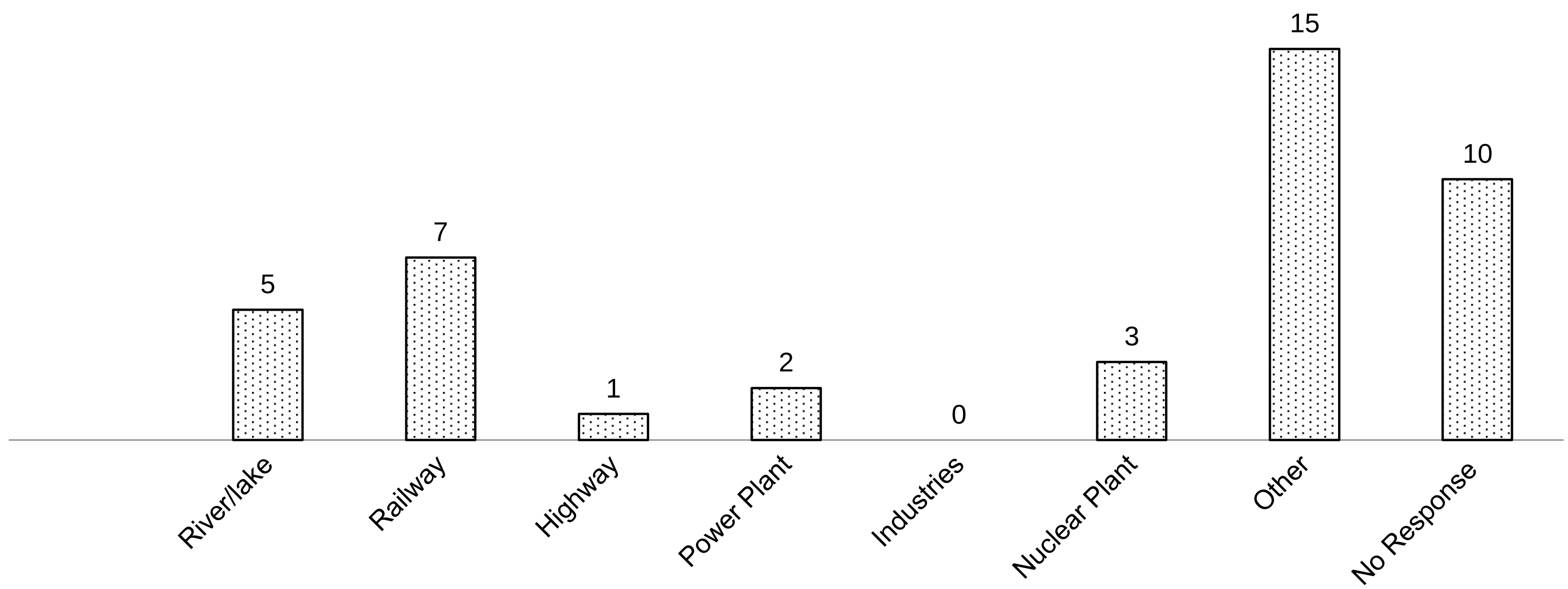
Employment



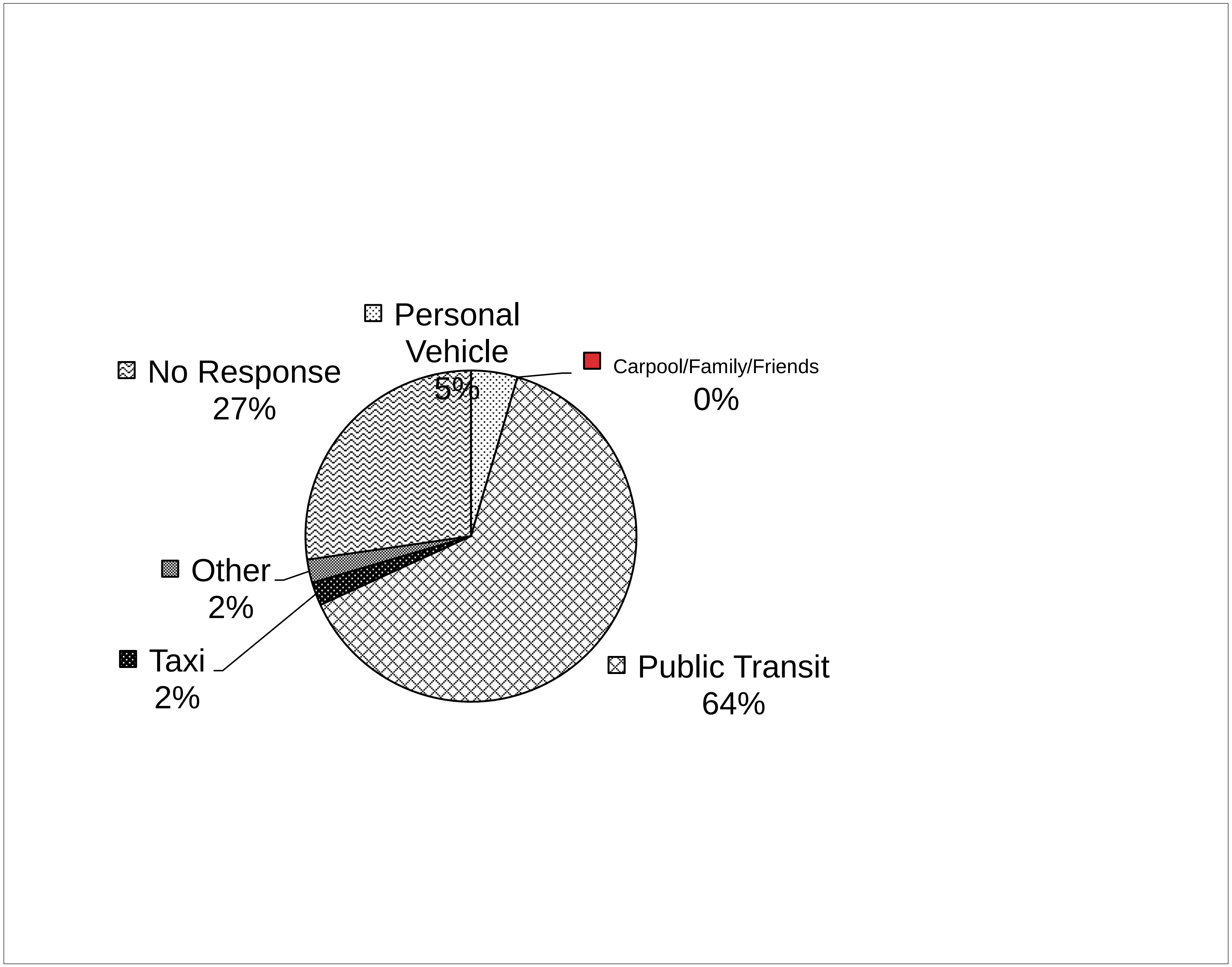
Type of Housing Occupied by the Participants



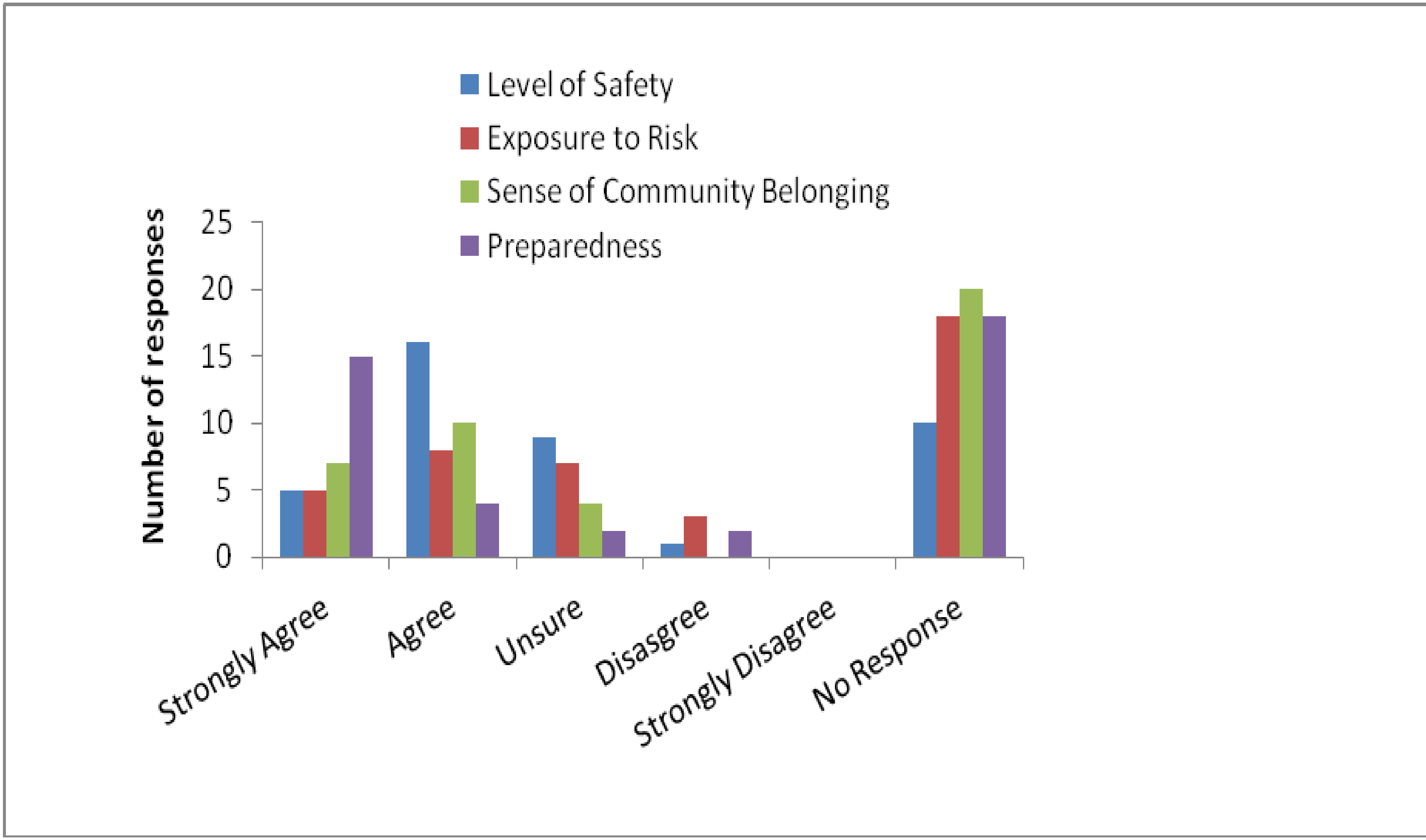
Proximity to Potential Risks



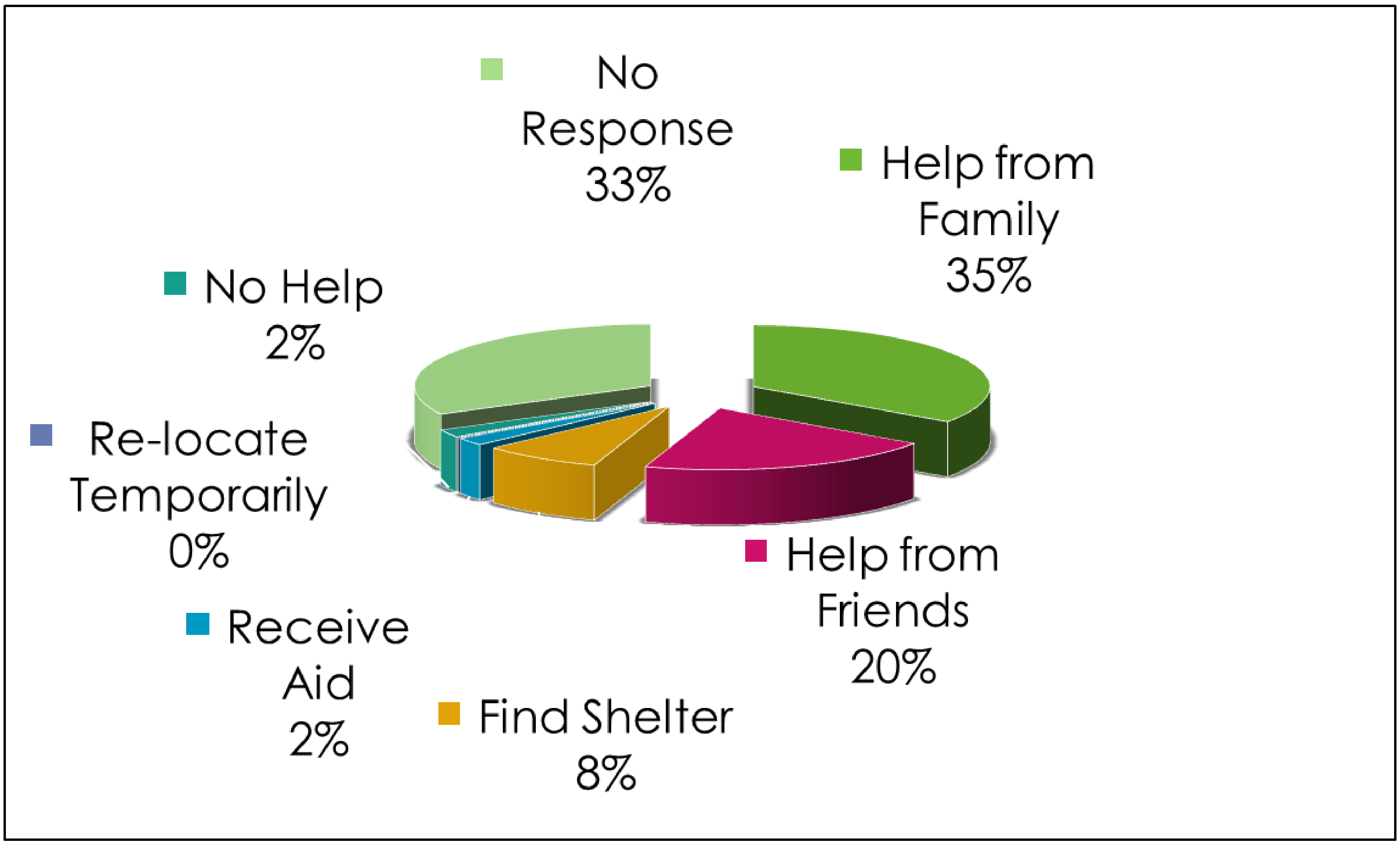
Transportation



People's perception of their safety, exposure to risk or threat, sense of belonging with their community, and preparedness to deal with emergencies



Preferences for Seeking help when Faced with Emergencies



CONGRATULATIONS FIDS

FIDS

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CELEBRATING
1989 - 2014