A Profile of Earthquake Risk in Canada:

Knowledge to Inform a National Earthquake Resilience Strategy

Murray Journeay
Public Safety Geoscience Program
Land & Minerals Sector, NRCan

Contributing Authors: Vitor Silva, Anirudh Rao, Marco Pagani,
Trevor Allen, John Adams, Robert White, Mica Hilt, & the PSGP Risk Team

GLOBAL EARTHQUAKE MODEL 2018

A Step Toward Earthquake Resilience

5th of December 2018 | 0900h - 1800h | CAR College, Pavia, Italy

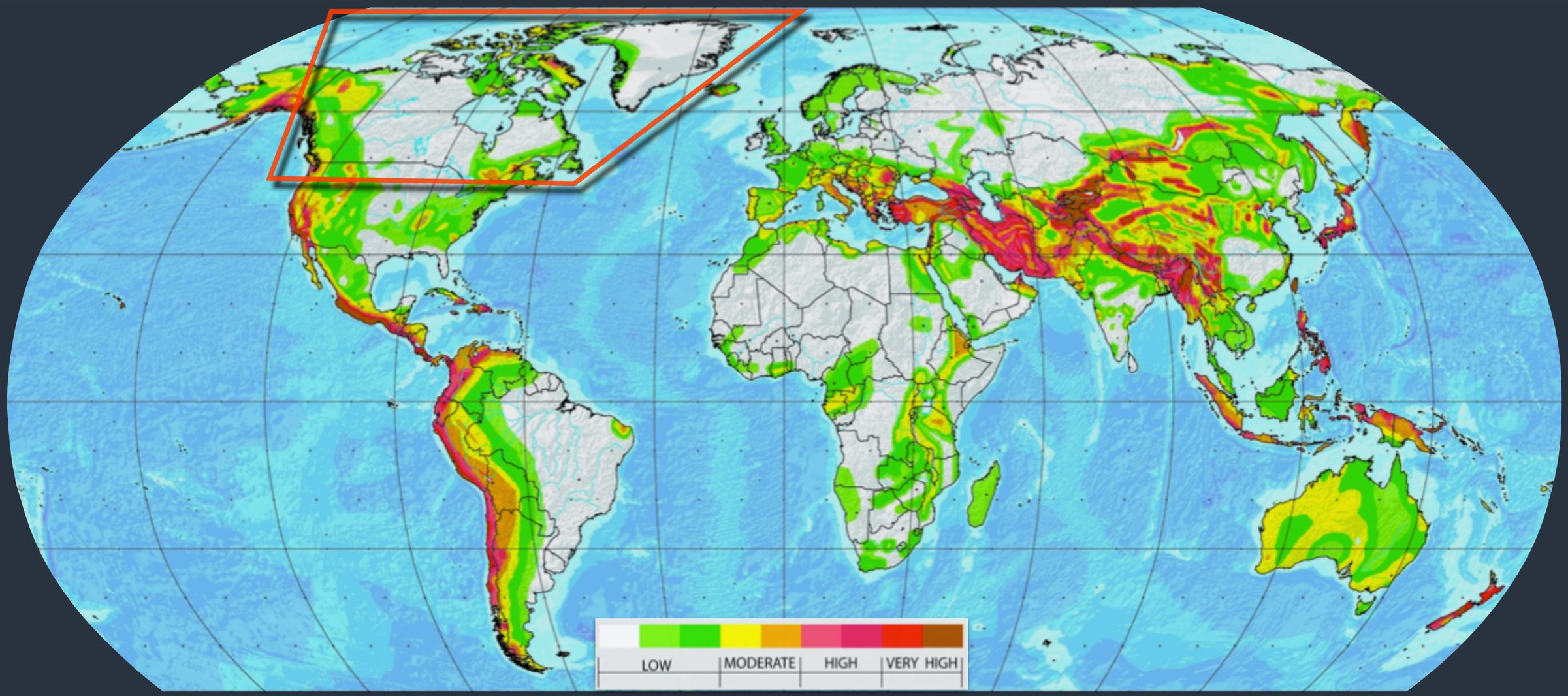
Natural Resources Canada | Ressources naturelles Canada | GEM Global Earthquake Model working together to assess risk | British Columbia | Emergency ManagementBC | OpenQuake | Institute for Catastrophic Loss Reduction | IBC | BAC | Defence R&D Canada | DRDC–RDDC | Public Safety Canada | Sécurité publique Canada

OPENQUAKE-CA

Global Earthquake Model

CANADA

C.D. Howe Report (C454) Anticipated economic losses caused by a catastrophic earthquake exceed current risk tolerance thresholds for private sector insurance markets **($42b)** and would likely overwhelm federal emergency backstop measures and existing capacities for recovery at all levels of government.



Emergency Management

Logan Simpson

Community Planning

Financial Planning

understanding risk → *disaster resilience planning*

NIBS 2017: Mitigation Saves

Riverine Flood	7:1	5:1
Hurricane Surge	Too few grants	7:1
Wind	5:1	5:1
Earthquake	3:1	4:1
Wildland-Urban Interface Fire	3:1	4:1

Performance indicators as a bridge to disaster resilience planning

Disaster Resilience PlanningFramework

science-based decision making

Integrated Risk Assessment & Scenario Planning → **Policy Goals & Objectives** → **Baseline Risk Profile** → **Risk Reduction Pathways** → **Disaster Resileince Strategy**

Process

Assets of Concern

Risk Reduction Targets

Risk Identification

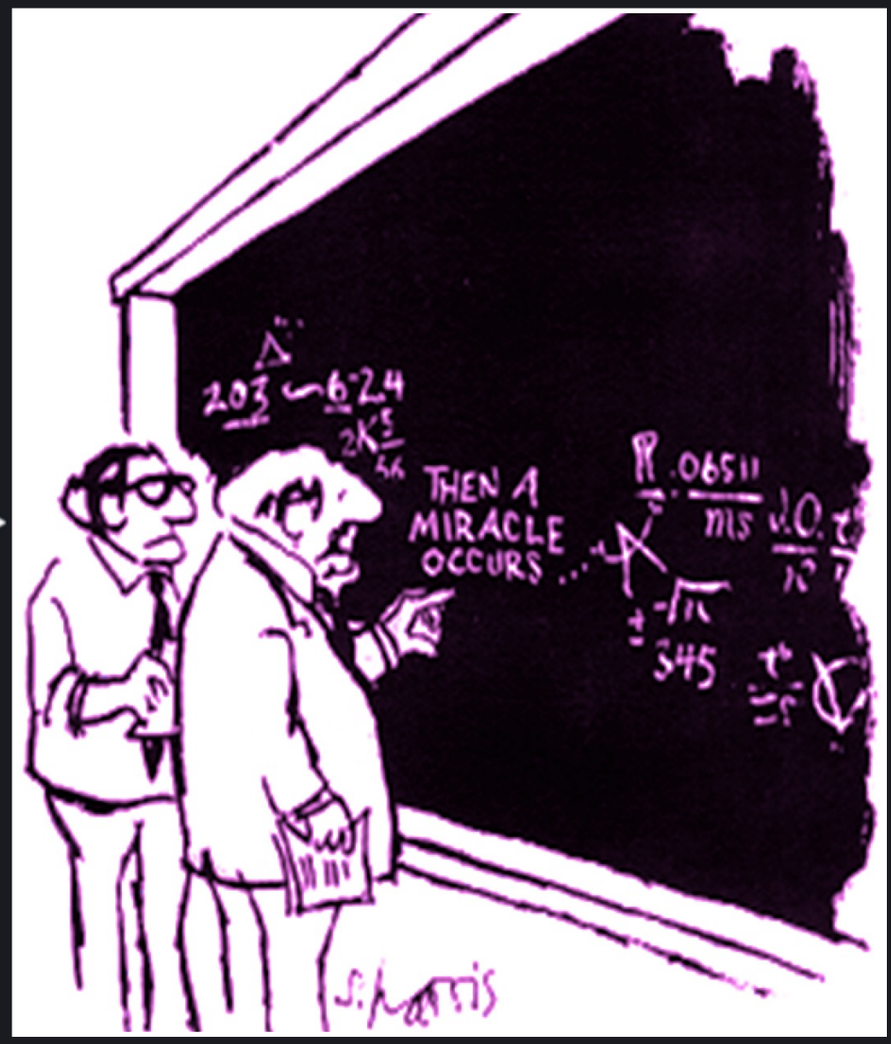
Risk Appraisal

Quantitative Risk Analysis

Baseline Risk Profile

Hazards of Concern

People



Disaster Resilience Strategy

Planners

Risk Analysts

Decision Makers

OPENQUAKE-CA

Disaster Resilience Planning Framework

science-based decision making

Integrated Risk Assessment & Scenario Planning

Policy Goals & Objectives

Baseline Risk Profile

Risk Reduction Pathways

Disaster Resileince Strategy

Process

Assets of Concern

Risk Reduction Targets

UNISDR

Policy Goals

Constraints

Risk Identification

Risk Appraisal

Quantitative Risk Analysis

Baseline Risk Profile

Hazards of Concern

GEM GLOBAL EARTHQUAKE MODEL

Physical Risk

Socioeconomic Vulnerability

Hazard Potential

Exposure

Physical Vulnerability

People

Scientists Engineers

Individuals Planners Regulators

Disaster Resilience Strategy

Planners

Risk Analysts

Decision Makers

OPENQUAKE-CA

Disaster Resilience Planning Framework

performance measures - from knowledge to action

cascading effects of lifeline system failures and implications for disaster recovery

Recovery Time

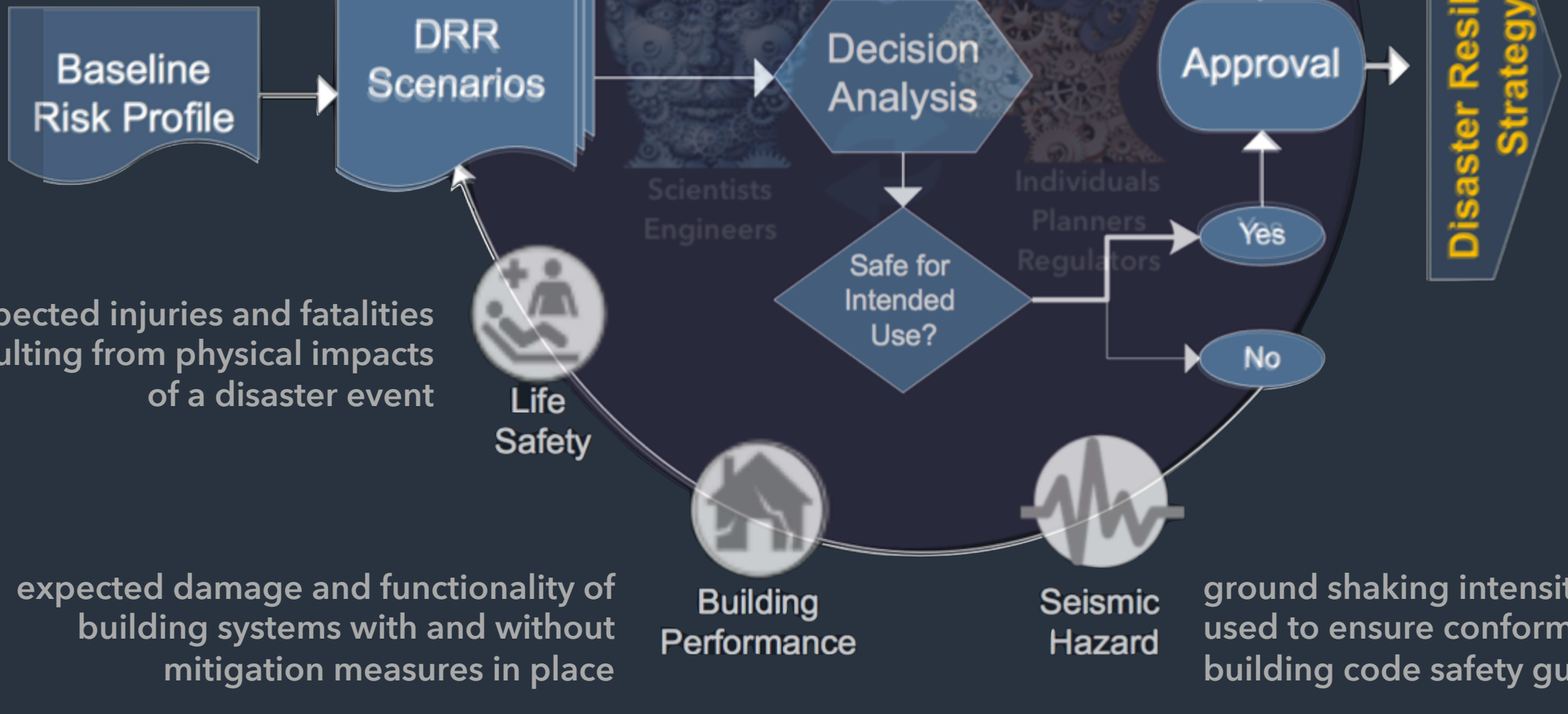
Economic Security

direct and indirect economic losses; expected return on proactive mitigation/adaptation investments

Social Displacement

extent and duration of disruption to people and business functions during disaster recovery process

Deliberative Dialog



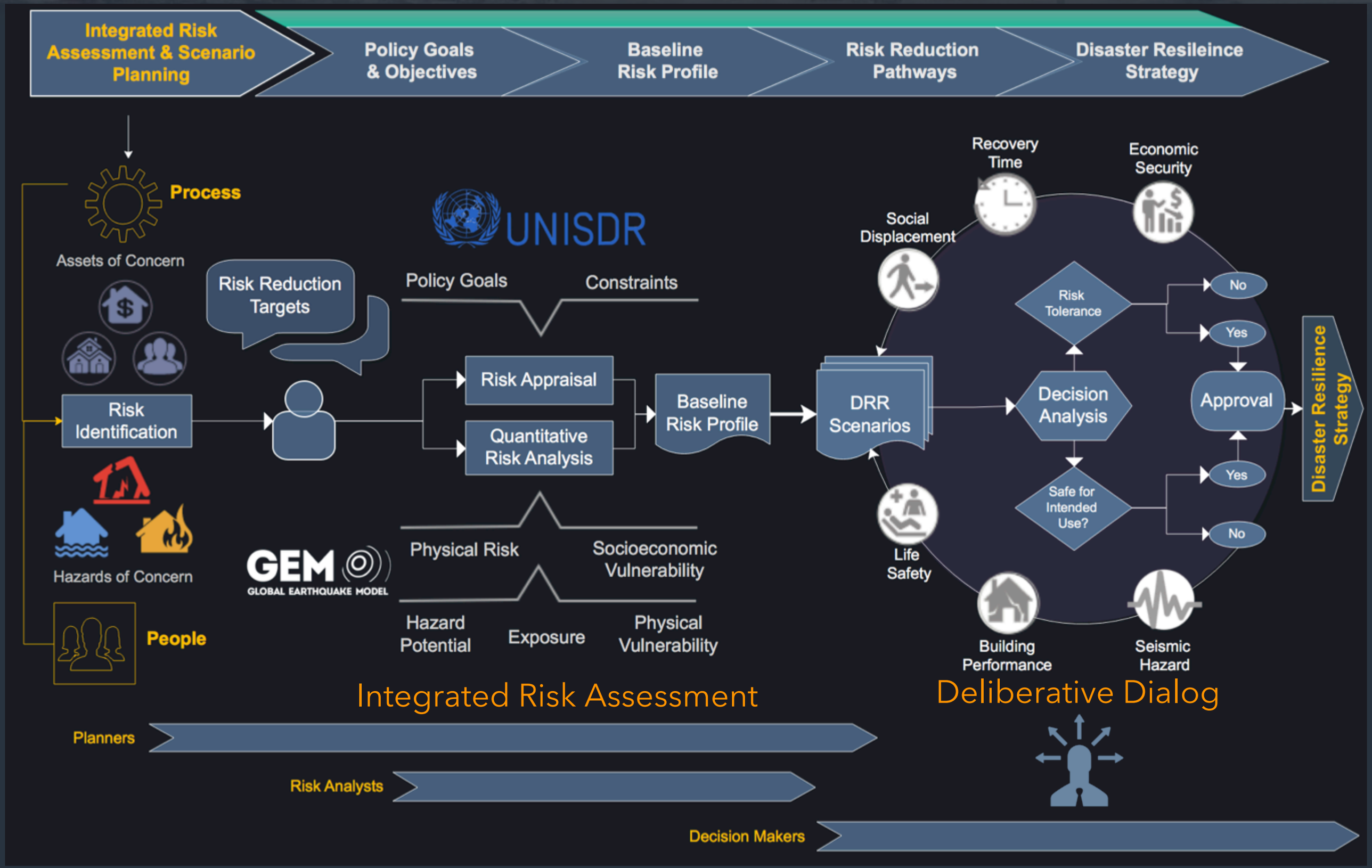
expected injuries and fatalities resulting from physical impacts of a disaster event

expected damage and functionality of building systems with and without mitigation measures in place

ground shaking intensity threshold used to ensure conformance with building code safety guidelines

Disaster Resilience Planning Framework

evidence-based decision making



Global Earthquake Model

Analytic Framework

INTEGRATED SEISMIC RISK

PHYSICAL SEISMIC RISK

Probability of damage and loss to people and structures due to earthquakes

SOCIO-ECONOMIC VULNERABILITY AND RESILIENCE

Vulnerability of society and economy and their capacity to cope with earthquake events

GEM
GLOBAL EARTHQUAKE MODEL

SEISMIC HAZARD

Probability of ground shaking due to earthquakes

EXPOSURE

Elements at risk

PHYSICAL VULNERABILITY

Vulnerability of structures and their occupants to seismic hazard

Scientific Framework

- unique approach
- cohesive pathway
- actionable solutions

Seismic Hazards in Canada

SEISMIC HAZARD

Probability of ground shaking due to earthquakes

EXPOSURE

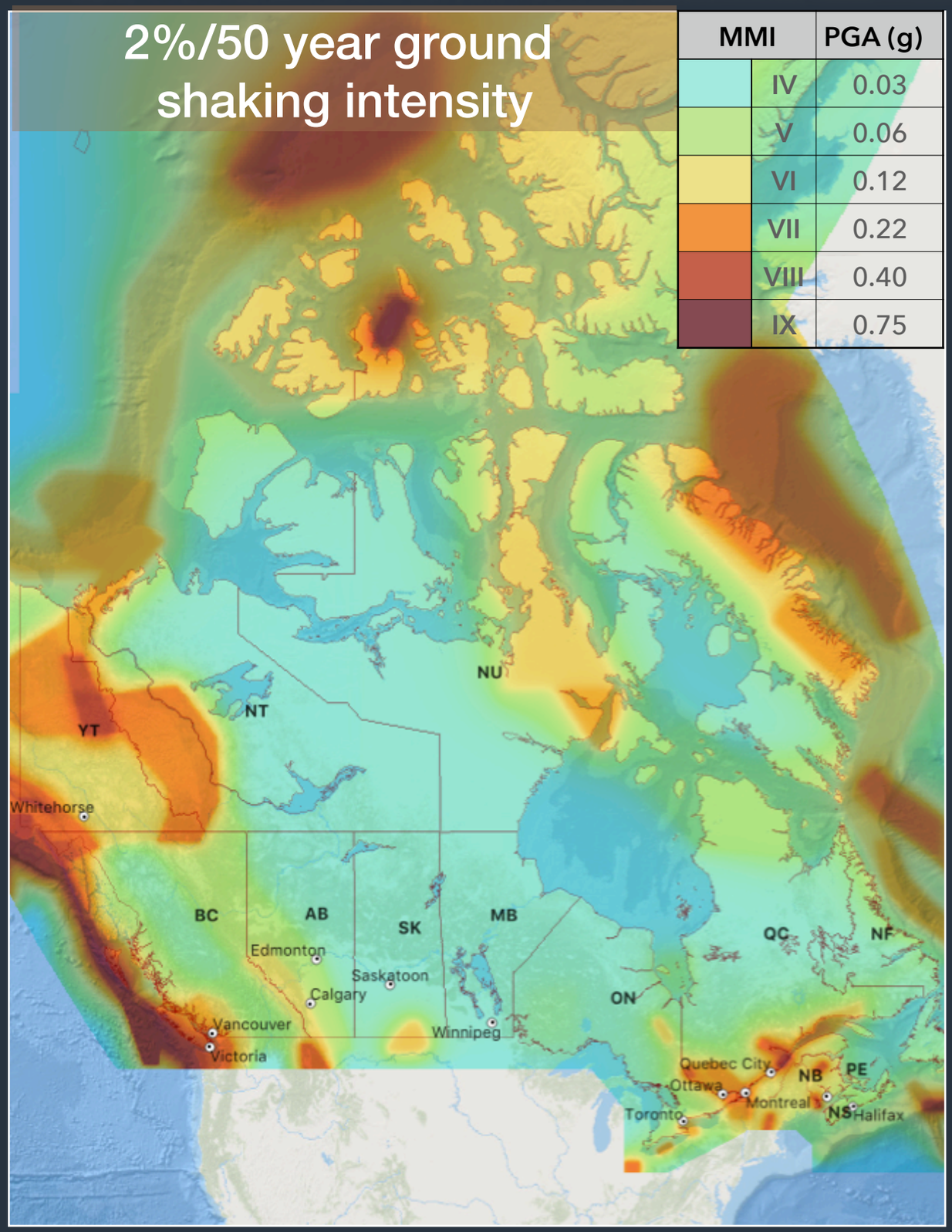
Elements at risk

PHYSICAL VULNERABILITY

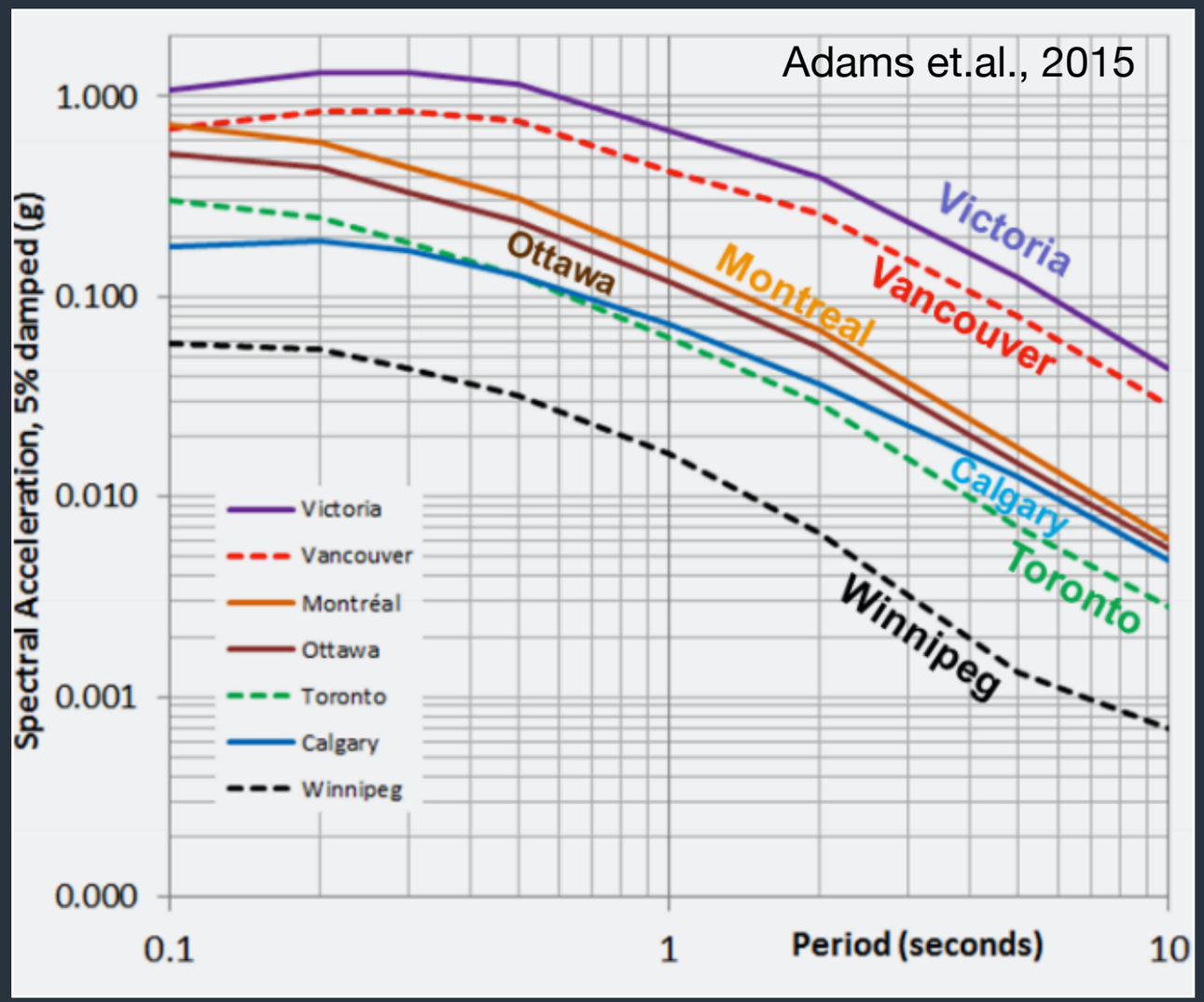
Vulnerability of structures and their occupants to seismic hazard

National Earthquake Risk Model

2015 National Seismic Hazard Model

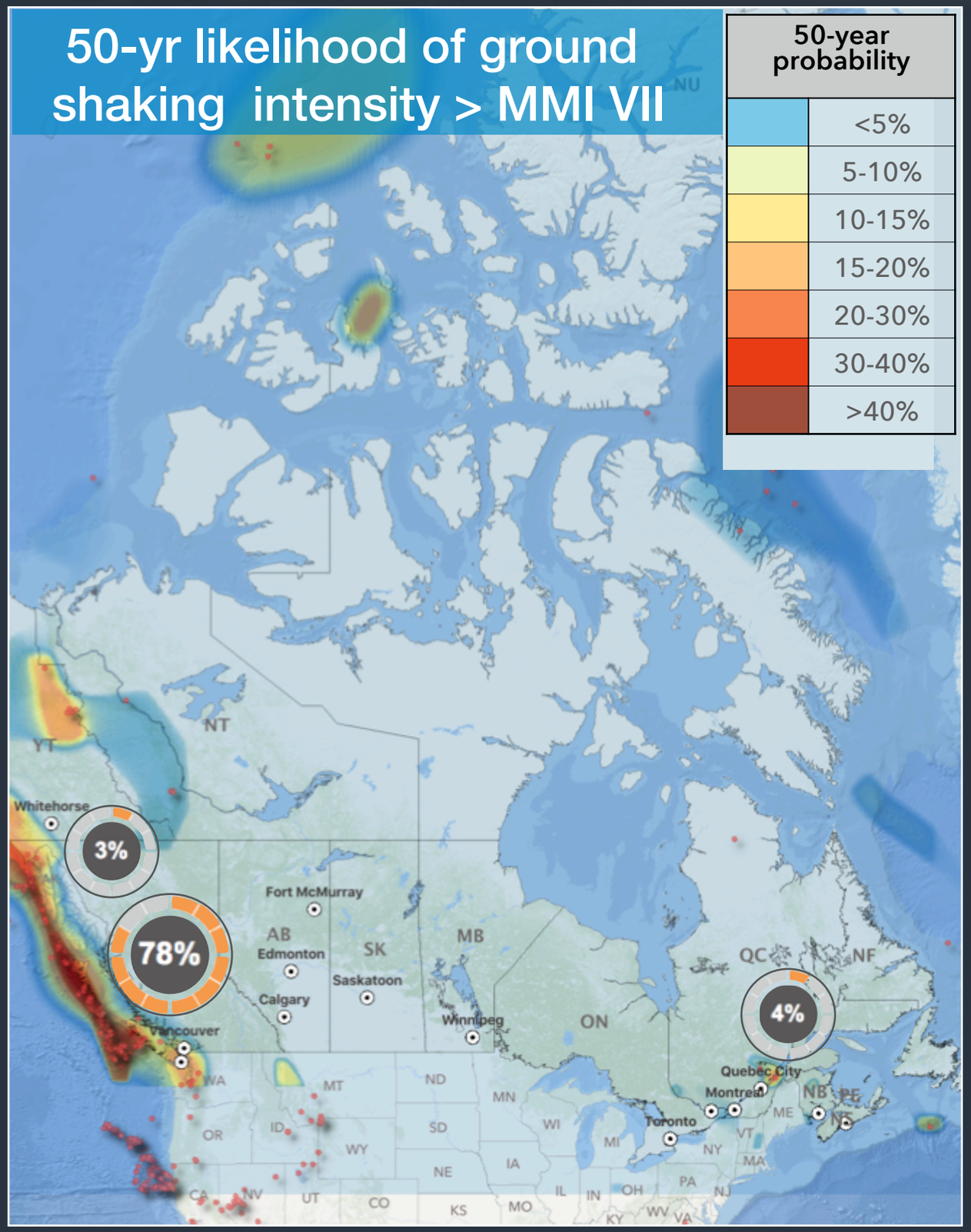


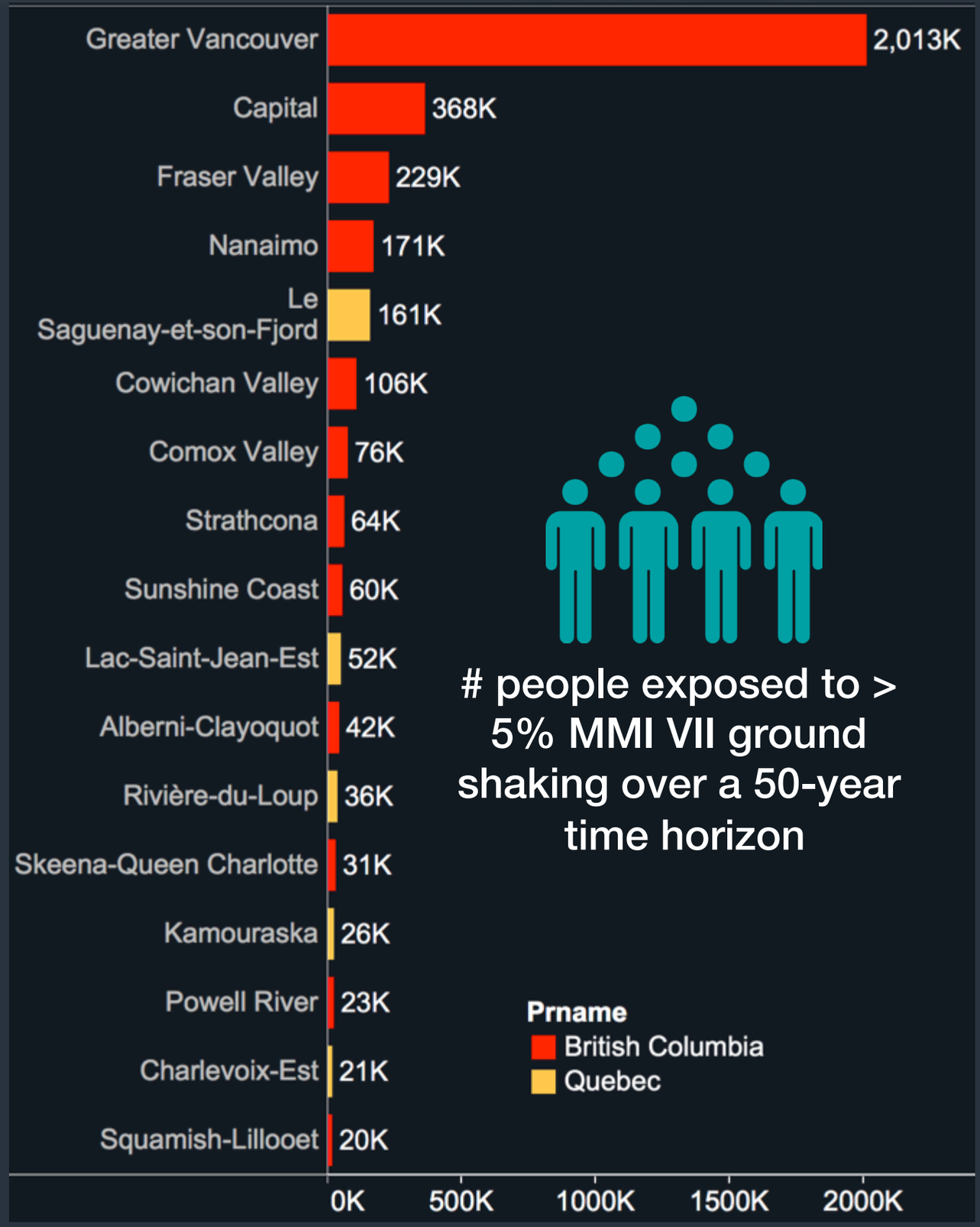
2%/50-year Uniform hazard spectra (UHS) derived from seismic hazard curves (i.e., spectral acceleration vs. exceedance probability) for relevant vibration periods. UHS curves for selected urban centers illustrate the range and period dependence of seismic hazards across Canada. UHS values are equivalent between Vancouver and Montreal at short periods. The UHS curve for Winnipeg is representative of many low-seismicity regions in Canada



National Earthquake Risk Model

likelihood of experiencing a catastrophic earthquake





Who and what are in harms way ?

SEISMIC HAZARD

Probability of ground shaking due to earthquakes

EXPOSURE

Elements at risk

PHYSICAL VULNERABILITY

Vulnerability of structures and their occupants to seismic hazard

OPENQUAKE-CA

National Earthquake Risk Model

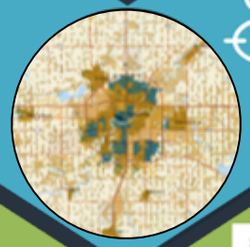
physical exposure of settled areas in Canada

1

Settled Area Boundaries

Spatial extent of human settlement as determined by remote sensing and satellite imagery

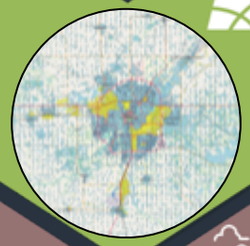
2



2016 National Census

Population, building counts and demographic characteristics of communities at neighborhood DA scale

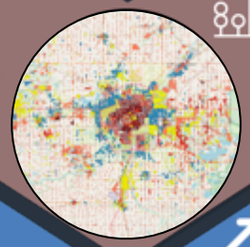
3



Land Use Classification

Form and character of built environment as inferred from population density and building function

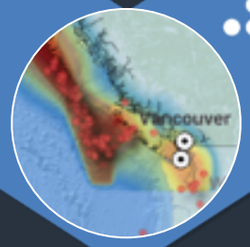
4



Built Environment

Allocation of buildings by construction typology and seismic design level based on land use class and reference inventories

5



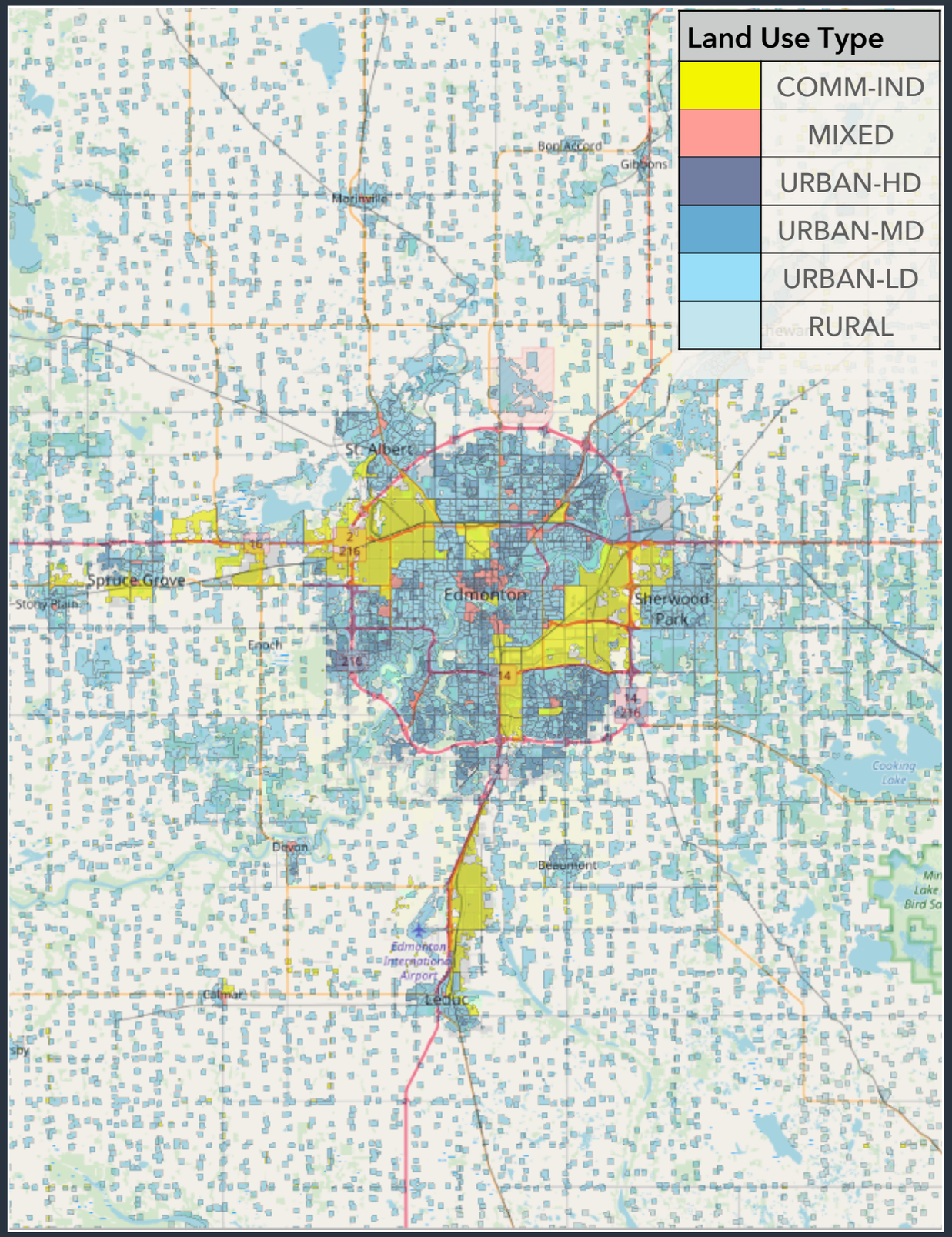
Risk Dynamics

Patterns of growth and development that drive physical and socioeconomic vulnerabilities over time

National Earthquake Risk Model

physical exposure of settled areas in Canada

OPENQUAKE-CA



3

Land Use

Form and character of built environment as inferred from population density and building function

Commercial-Industrial:
< 15 people/ha within designated commercial-industrial land use areas

Mixed Use
> 75 people/ha in mixed use residential/ commercial neighborhoods

Urban-High Density
> 75 people/ha in predominantly multi-family residential neighborhoods

Urban-Medium Density
35-75 people/ha in multi-family and single-family residential neighborhoods

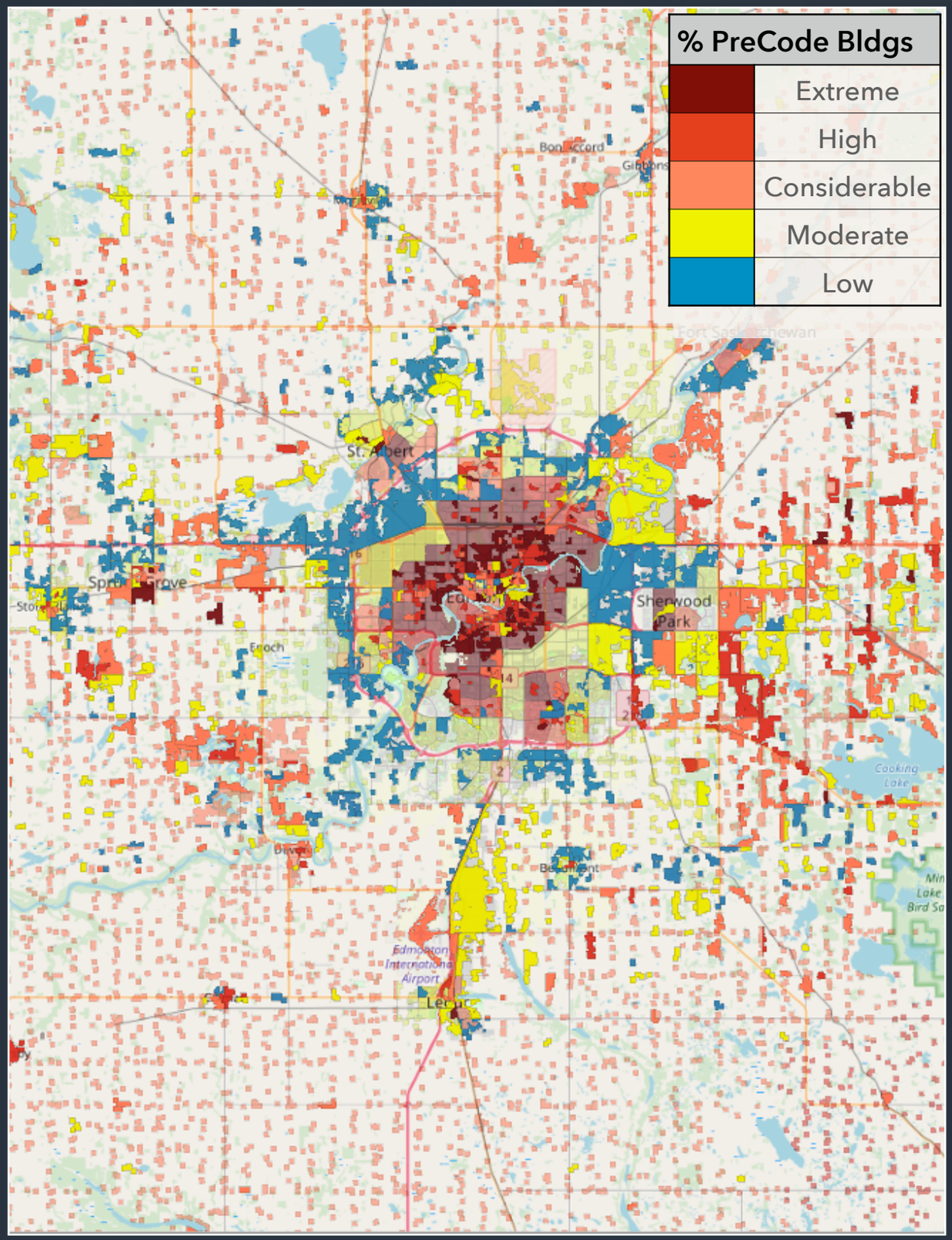
Urban-Low Density
< 35 people/ha in predominantly single-family residential neighborhoods

Rural
< 15 people/ha in single-family residential homes in rural and remote settings

OPENQUAKE-CA

National Earthquake Risk Model

physical exposure of settled areas in Canada



4

Built Environment

Allocation of buildings by construction typology and seismic design level based on land use class and reference inventories

Land Use	Building Count	Capital Assets	Daytime Population	Nighttime Population	% Pre Code Buildings
RES-LD	4,938,984	$3,291,715M	15,440,685	16,806,338	49.3%
RURAL	2,233,900	$1,196,995M	5,669,758	6,706,297	25.2%
RES-MD	1,647,968	$1,093,019M	5,137,025	5,370,169	14.1%
COMM-IND	409,542	$611,139M	4,207,445	2,475,838	4.4%
RES-HD	330,767	$622,218M	3,246,826	2,773,726	4.1%
MIXED	231,518	$203,739M	1,584,403	907,973	2.9%
Grand Total	**9,792,679**	**$7,018,825M**	**35,286,142**	**35,040,341**	**100.0%**

Physical Impacts on the Built Environment?

SEISMIC HAZARD

Probability of ground shaking due to earthquakes

EXPOSURE

Elements at risk

PHYSICAL VULNERABILITY

Vulnerability of structures and their occupants to seismic hazard

National Earthquake Risk Model - *physical vulnerability*

Backbone Fragility Models

Concrete

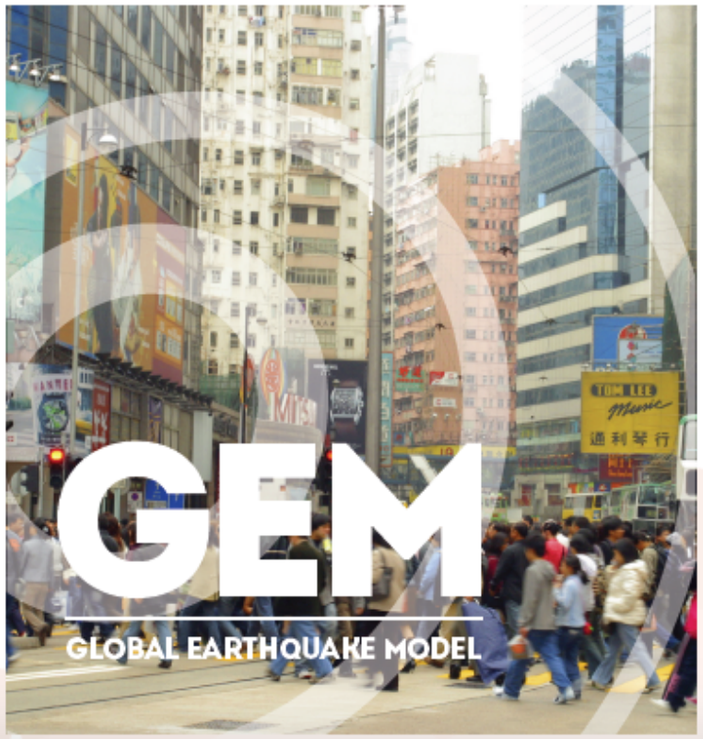
Masonry

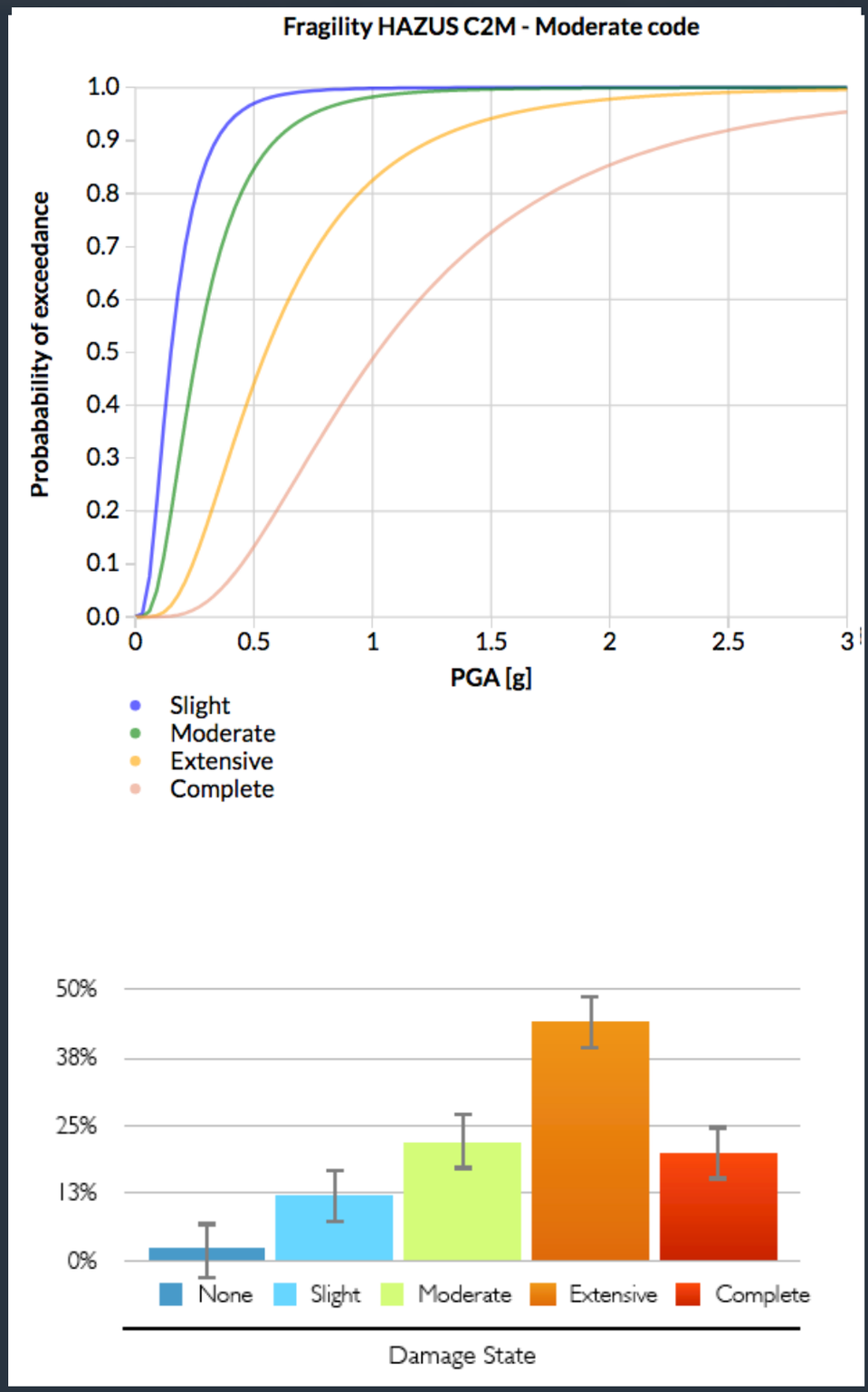
Steel

Wood

Guidelines for Analytical Vulnerability Assessment - Low/Mid-Rise

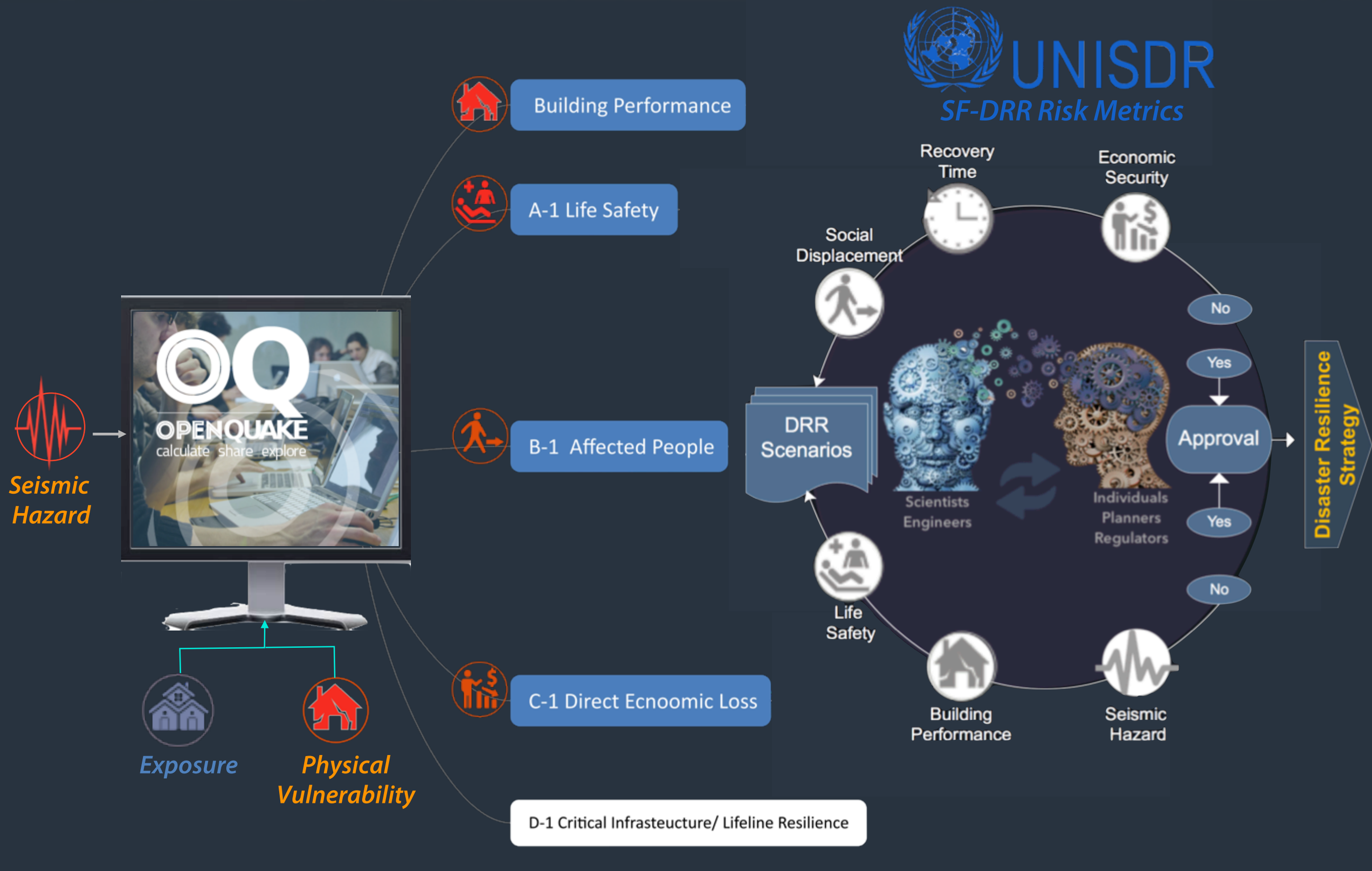
D'Ayala D., A. Meslem, D. Vamvatsikos, K. Porter, T. Rossetto and V. Silva





National Earthquake Risk Model

Performance - based risk metrics



BRITISH COLUMBIA | Emergency ManagementBC

PHYSICAL SEISMIC RISK

Probability of damage and loss to people and structures due to earthquakes

SOCIO-ECONOMIC VULNERABILITY AND RESILIENCE

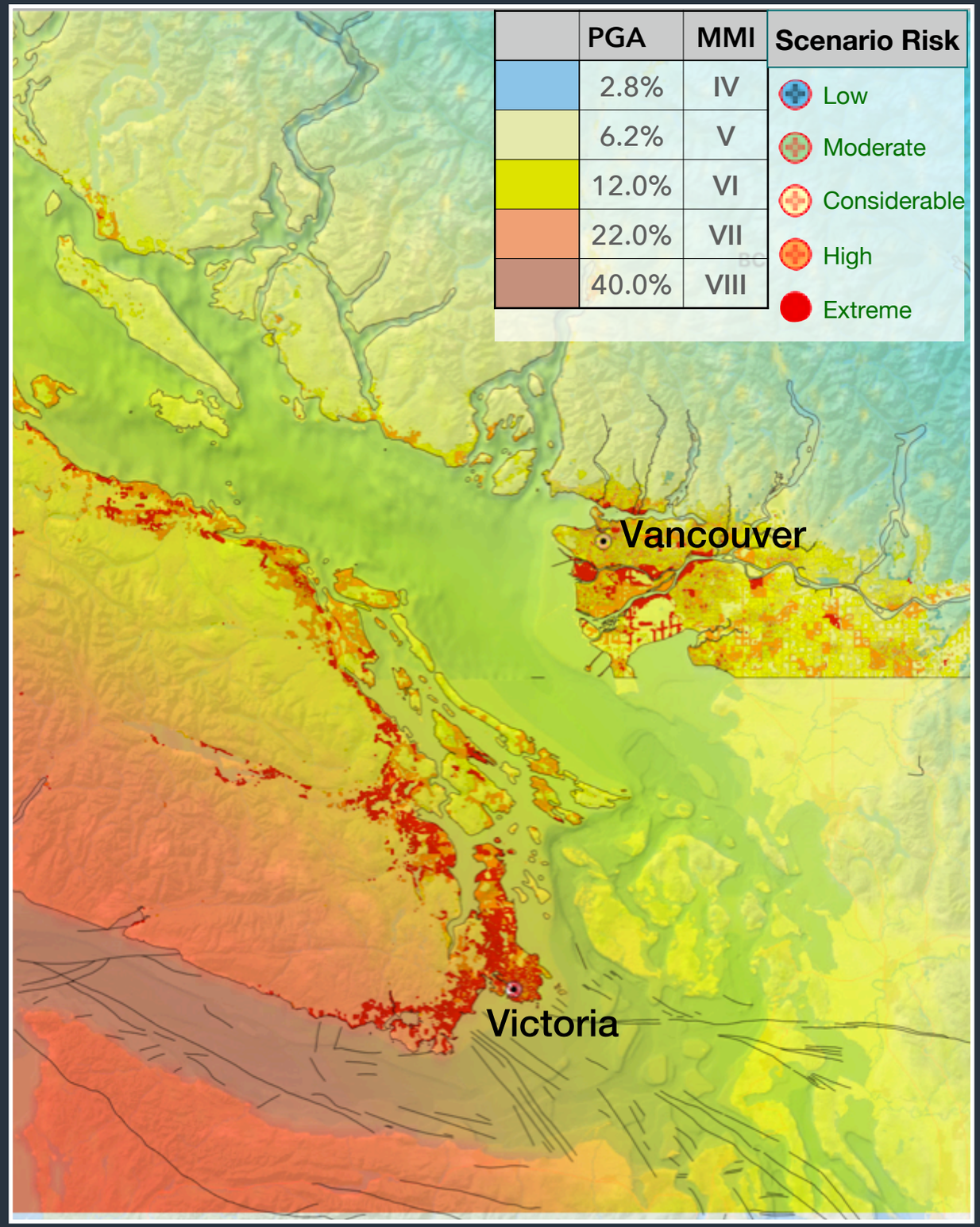
Vulnerability of society and economy and their capacity to cope with earthquake events

OPENQUAKE-CA

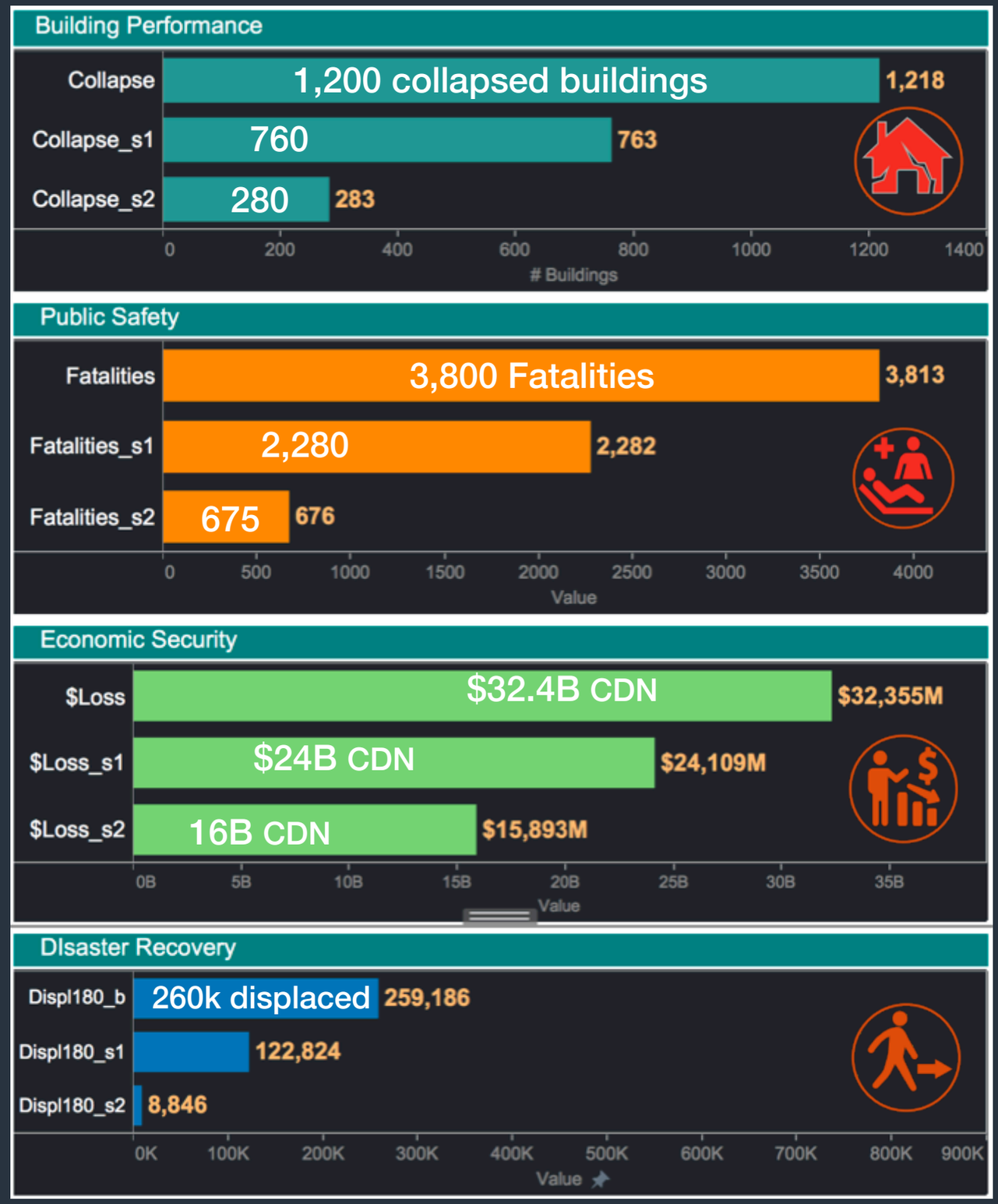
Emergency Management

deterministic earthquake planning scenarios

Cascadia (M9.0) Subduction Interface Rupture



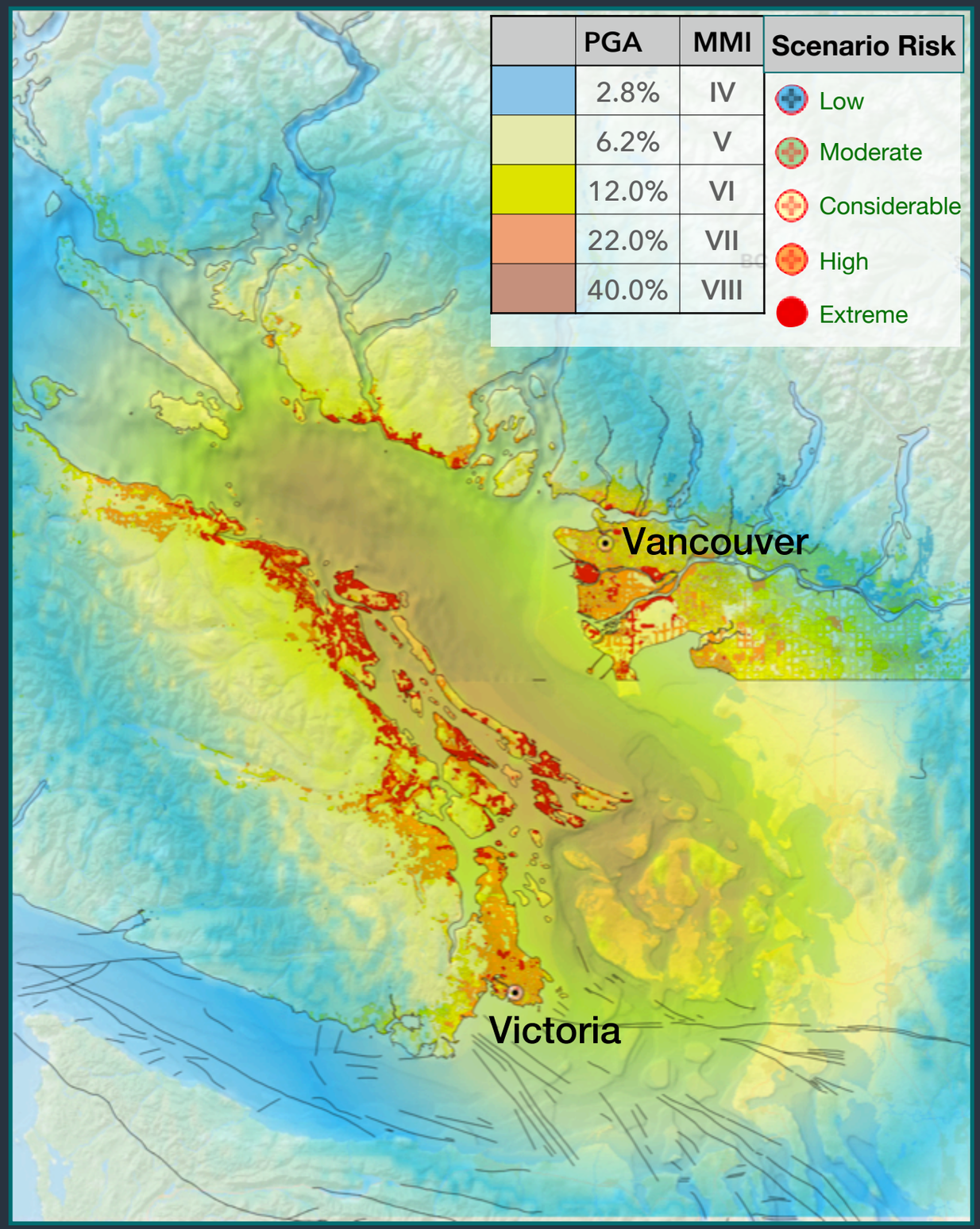
Risk Reduction Profile



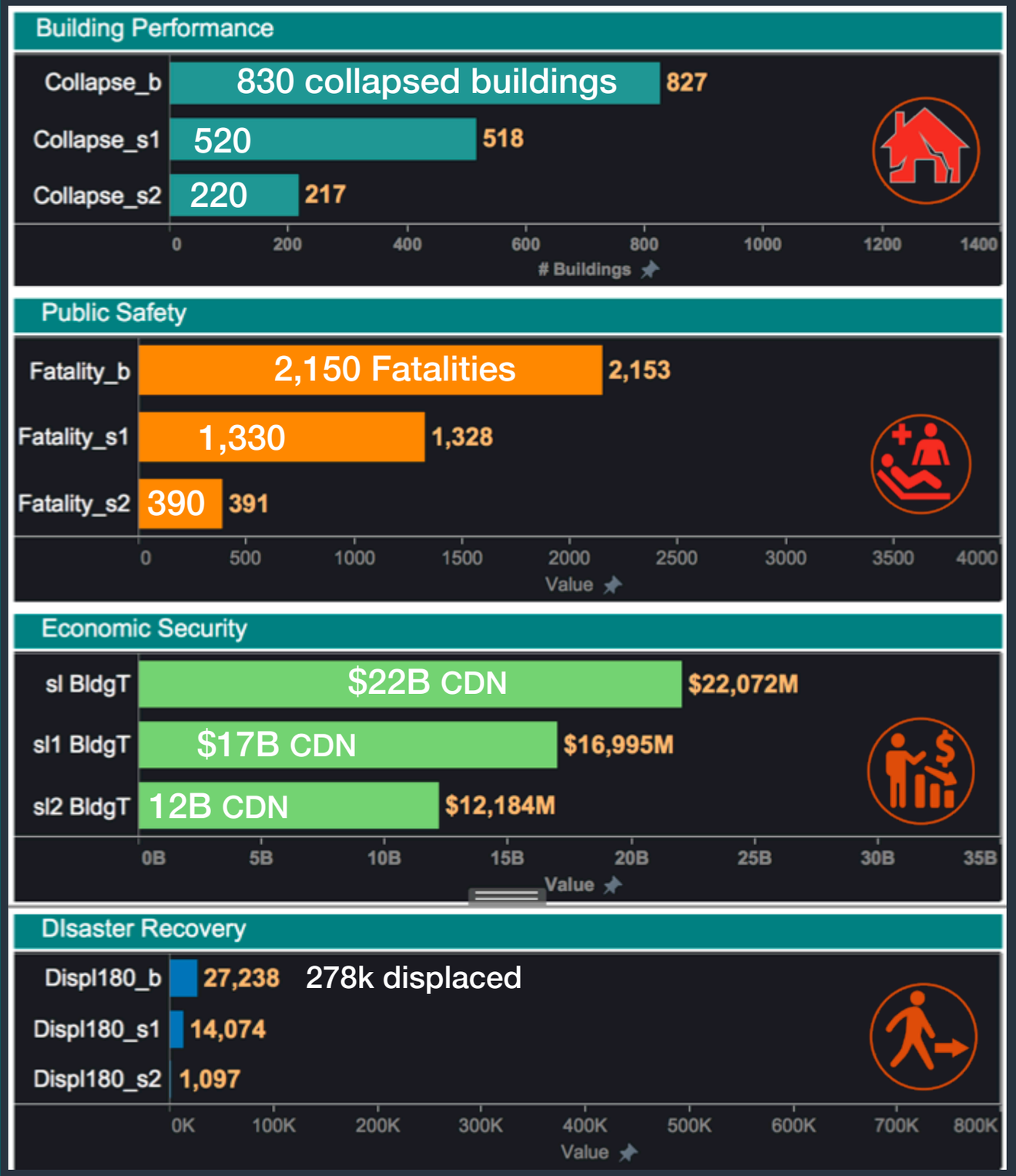
Emergency Management

deterministic earthquake planning scenarios

Juan de Fuca (M6.8) Inslab Rupture



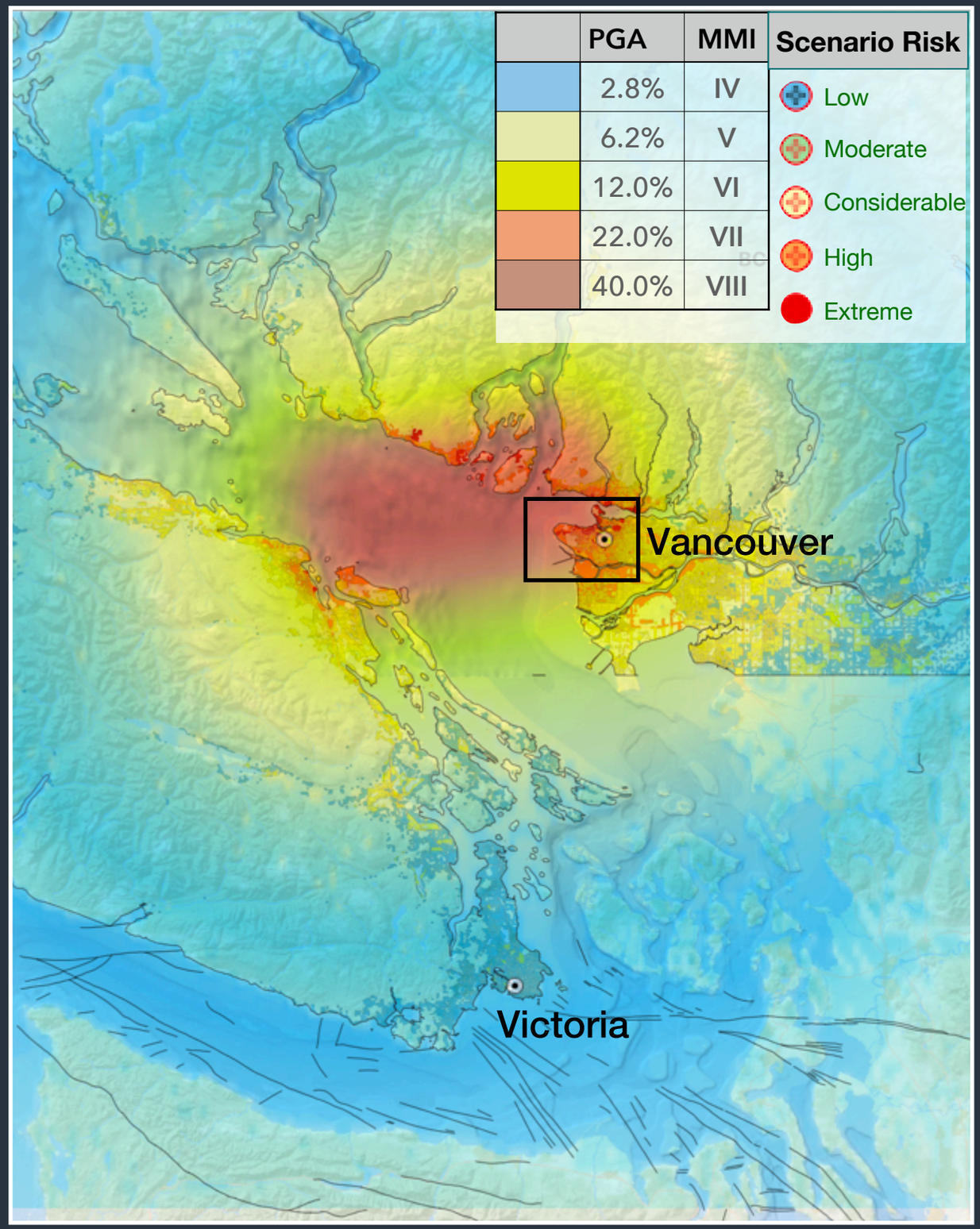
Risk Reduction Profile



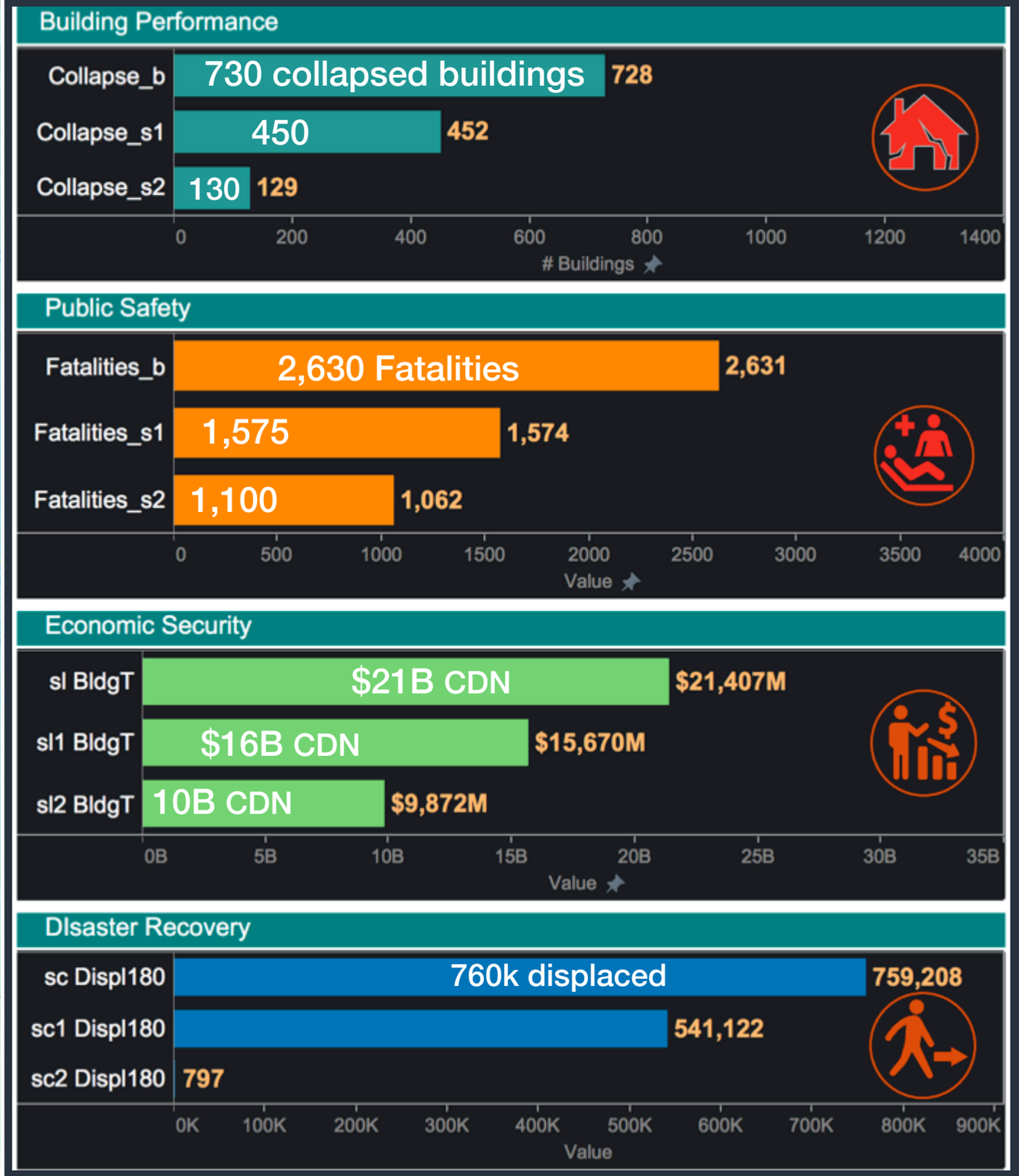
Emergency Management

deterministic earthquake planning scenarios

Georgia Strait (M7.3) Fault Rupture



Risk Reduction Profile



Disaster Resilience Planning

PHYSICAL SEISMIC RISK

Probability of damage and loss to people and structures due to earthquakes

SOCIO-ECONOMIC VULNERABILITY AND RESILIENCE

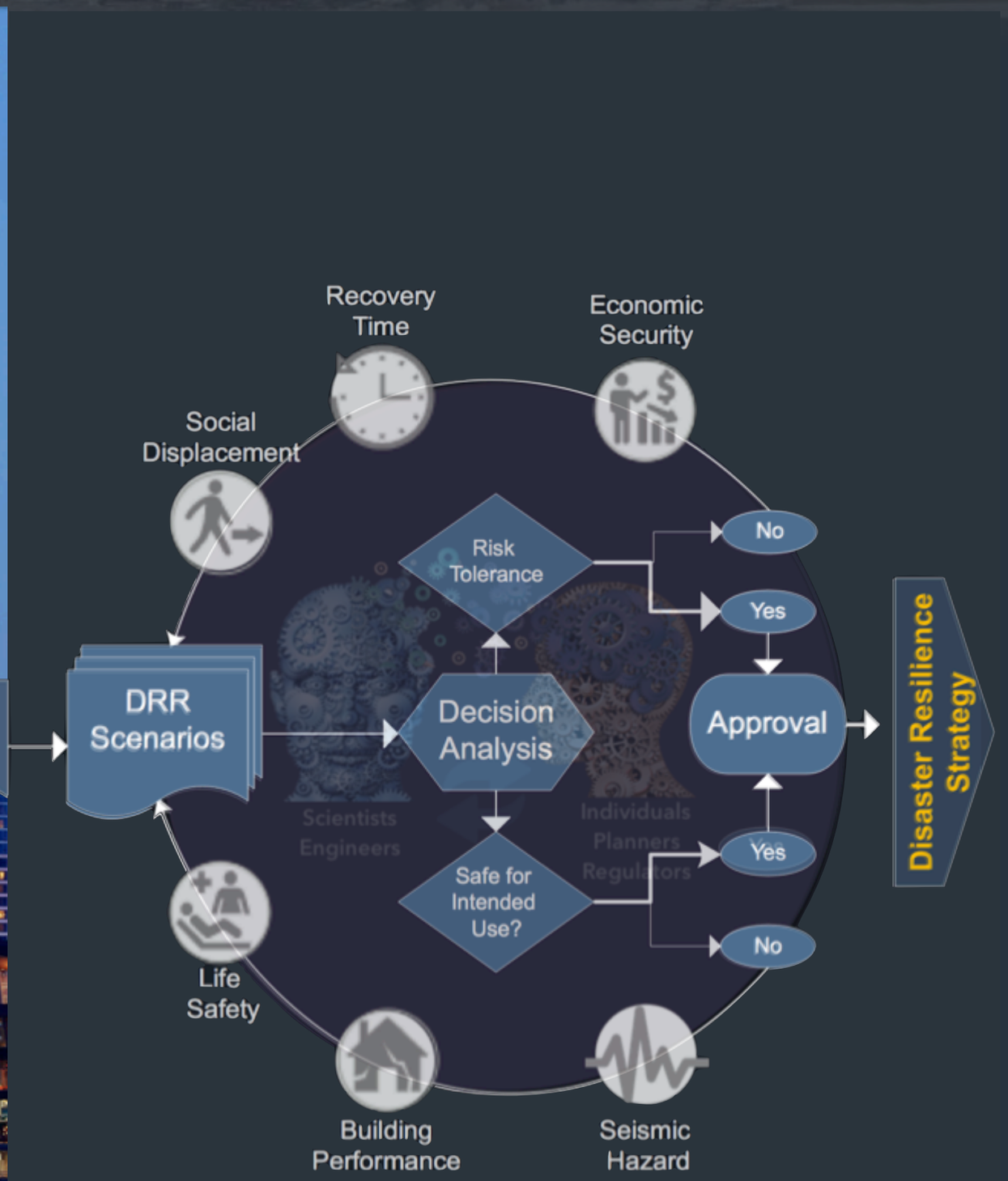
Vulnerability of society and economy and their capacity to cope with earthquake events

From Knowledge to Action

City of Vancouver Resilient Cities Initiative

From Knowledge to Action

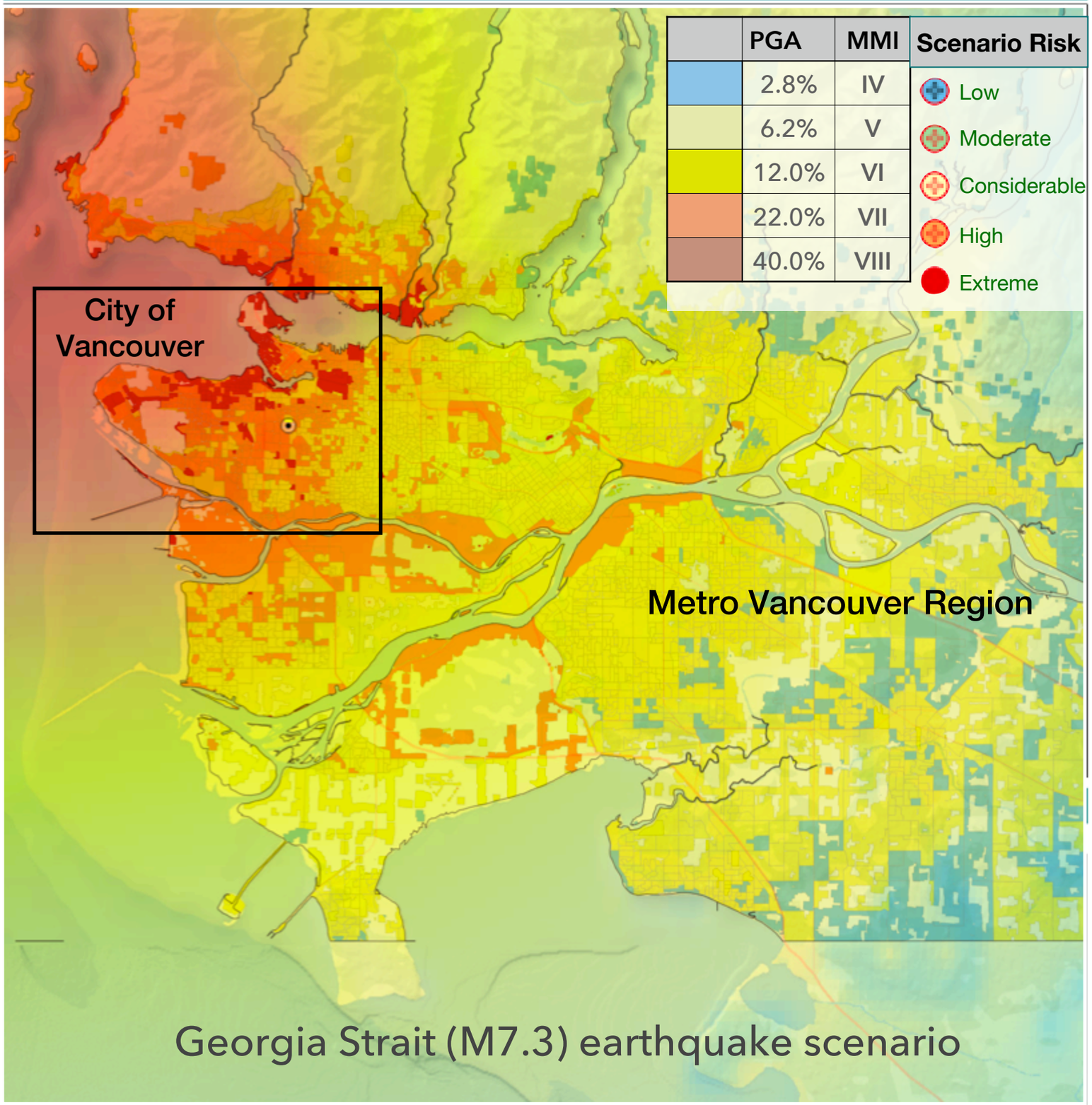
City of Vancouver Resilient Cities Initiative



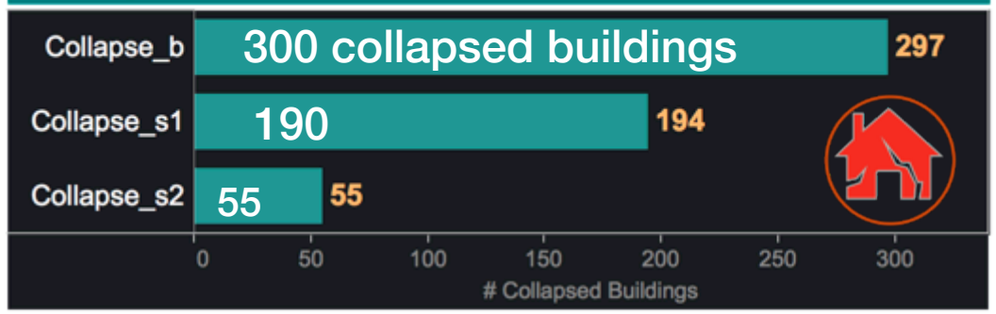
City of Vancouver Seismic Retrofit Policy Program

Integrated Risk Assessment & Scenario Planning

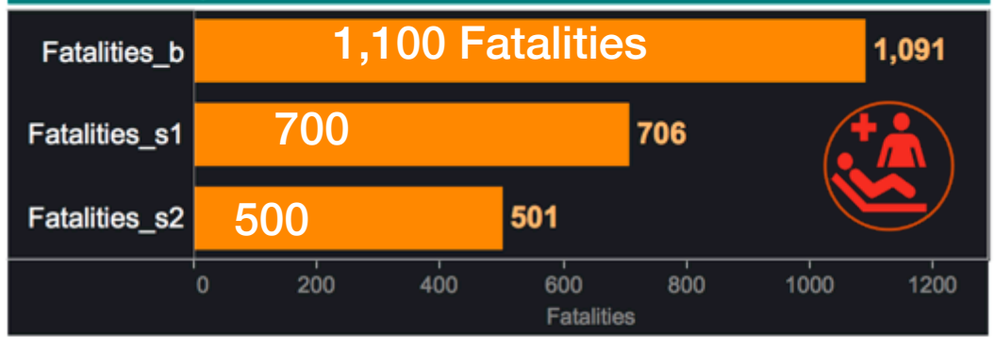
Loss Rate



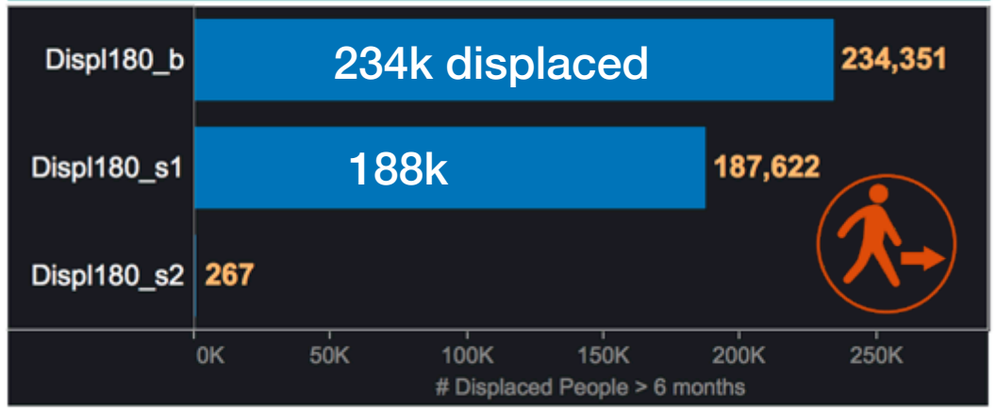
Building Performance



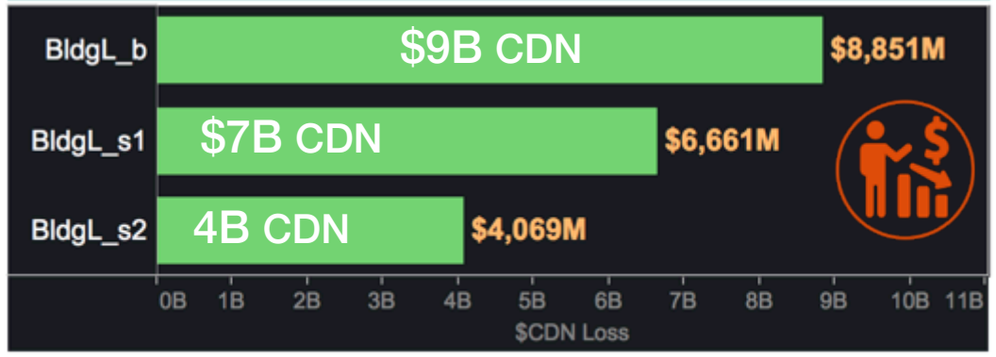
Public Safety



DIsaster Recovery



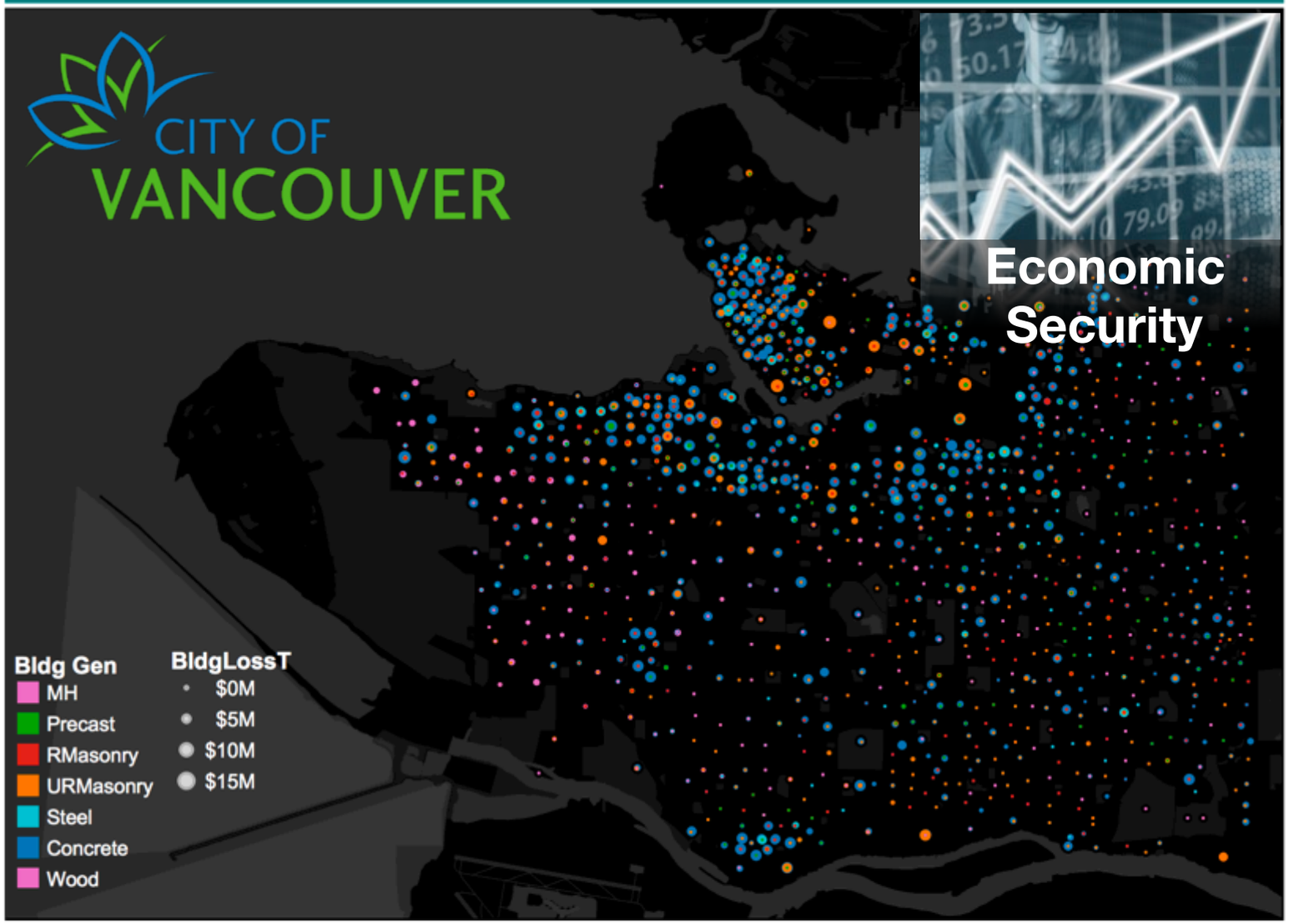
Economic Security



City of Vancouver Seismic Retrofit Policy Program

Integrated Risk Assessment & Scenario Planning

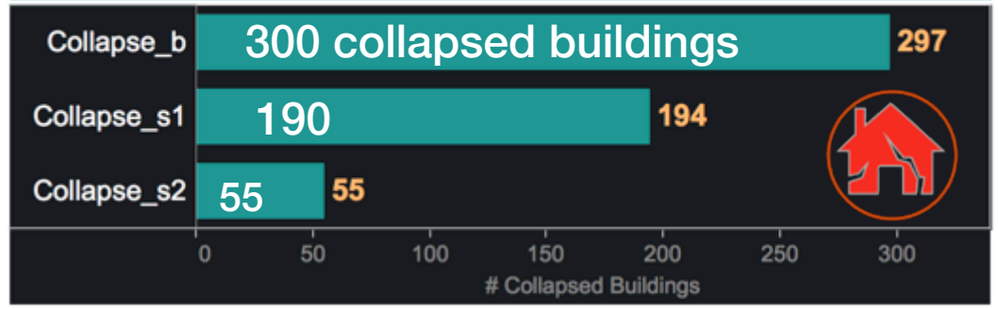
Loss Rate



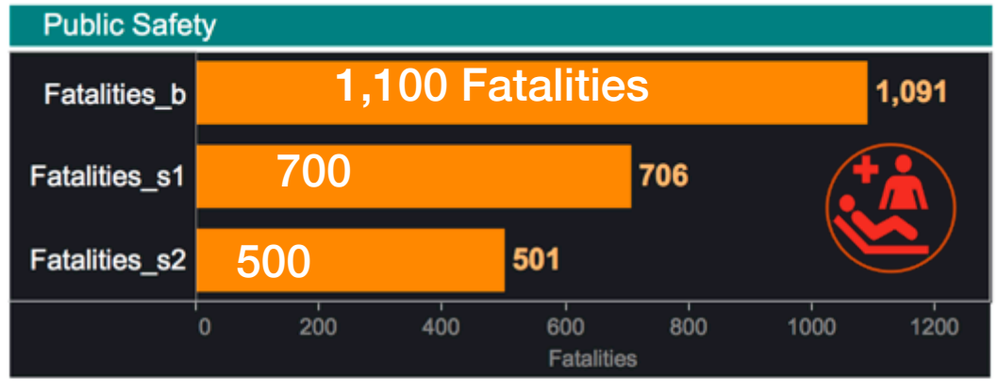
Seismic Retrofit Strategies

Bldg Gen	Bldg Nu..	BldgCos..	BldgL_b	BldgL_s1	BldgL_s2	BCR_s1	BCR_s2	BCR_ave	ROI_s1	ROI_s2	ROI_ave
Concrete	3,760	$48,886M	$4,927M	$3,581M	$1,958M	0.9	2.0	1.5	3.7	8.3	6.0
MH	167	$29M	$4M	$4M	$5M	0.2	-0.9	-0.3	0.5	-2.9	-1.2
Precast	237	$1,076M	$102M	$80M	$48M	0.7	1.7	1.2	2.6	6.1	4.4
RMasonry	856	$2,273M	$219M	$155M	$80M	0.9	2.0	1.5	3.4	7.4	5.4
Steel	980	$5,276M	$707M	$530M	$306M	1.1	2.5	1.8	4.5	9.6	7.0
URMasonry	2,692	$9,575M	$1,102M	$797M	$502M	1.1	2.1	1.6	2.7	6.9	4.8
Wood	86,868	$35,582M	$1,789M	$1,514M	$1,169M	0.3	0.6	0.4	1.6	3.2	2.4
Grand Total	95,560	########	$8,851M	$6,661M	$4,069M	0.7	1.6	1.1	2.5	5.4	3.9

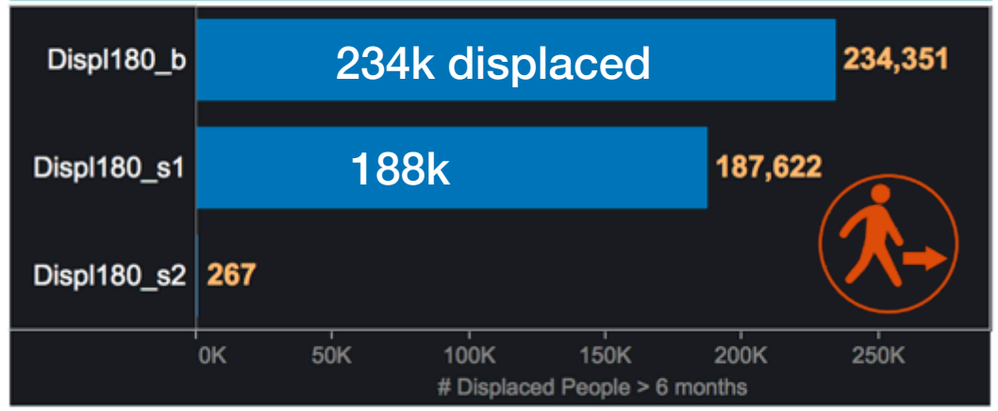
Building Performance



Public Safety



DIsaster Recovery



Economic Security

Performance indicators as a bridge to disaster resilience planning

Financial Risk Management

PHYSICAL SEISMIC RISK

Probability of damage and loss to people and structures due to earthquakes

SOCIO-ECONOMIC VULNERABILITY AND RESILIENCE

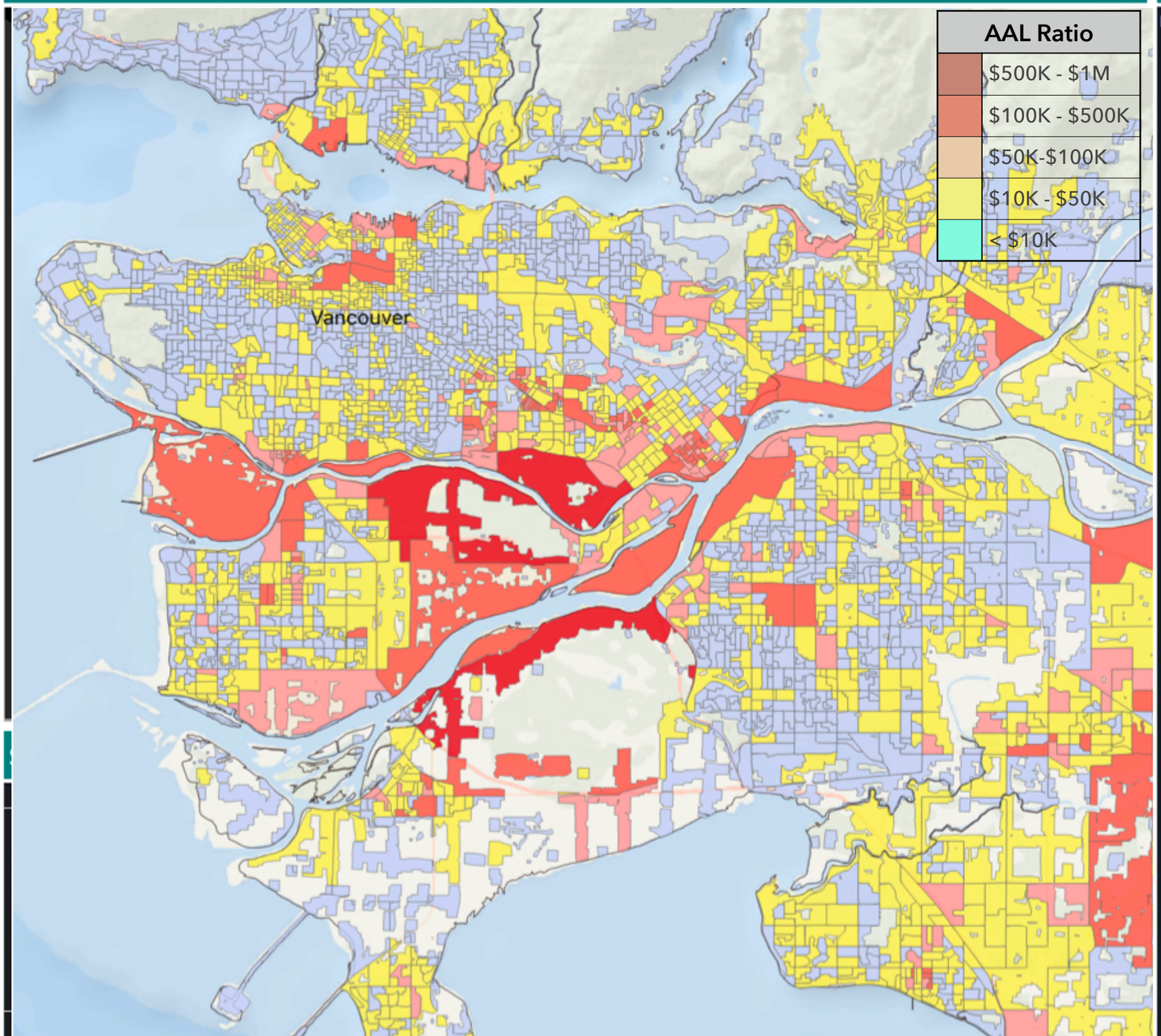
Vulnerability of society and economy and their capacity to cope with earthquake events

OPENQUAKE-CA

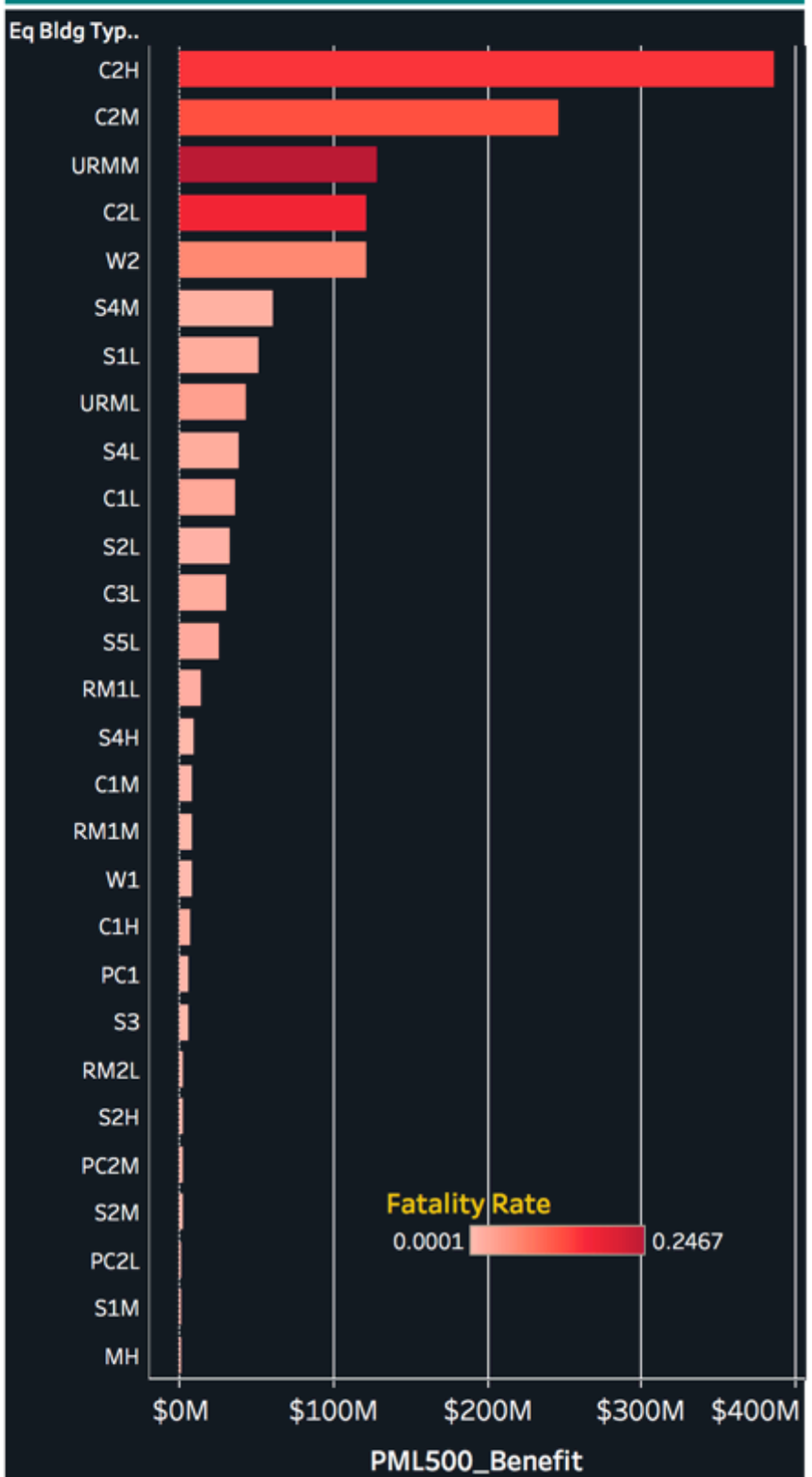
Financial Risk Management

ground-up loss profiles to inform mitigation and risk transfer

Losses Avoided Through Seismic Retrofit Investments



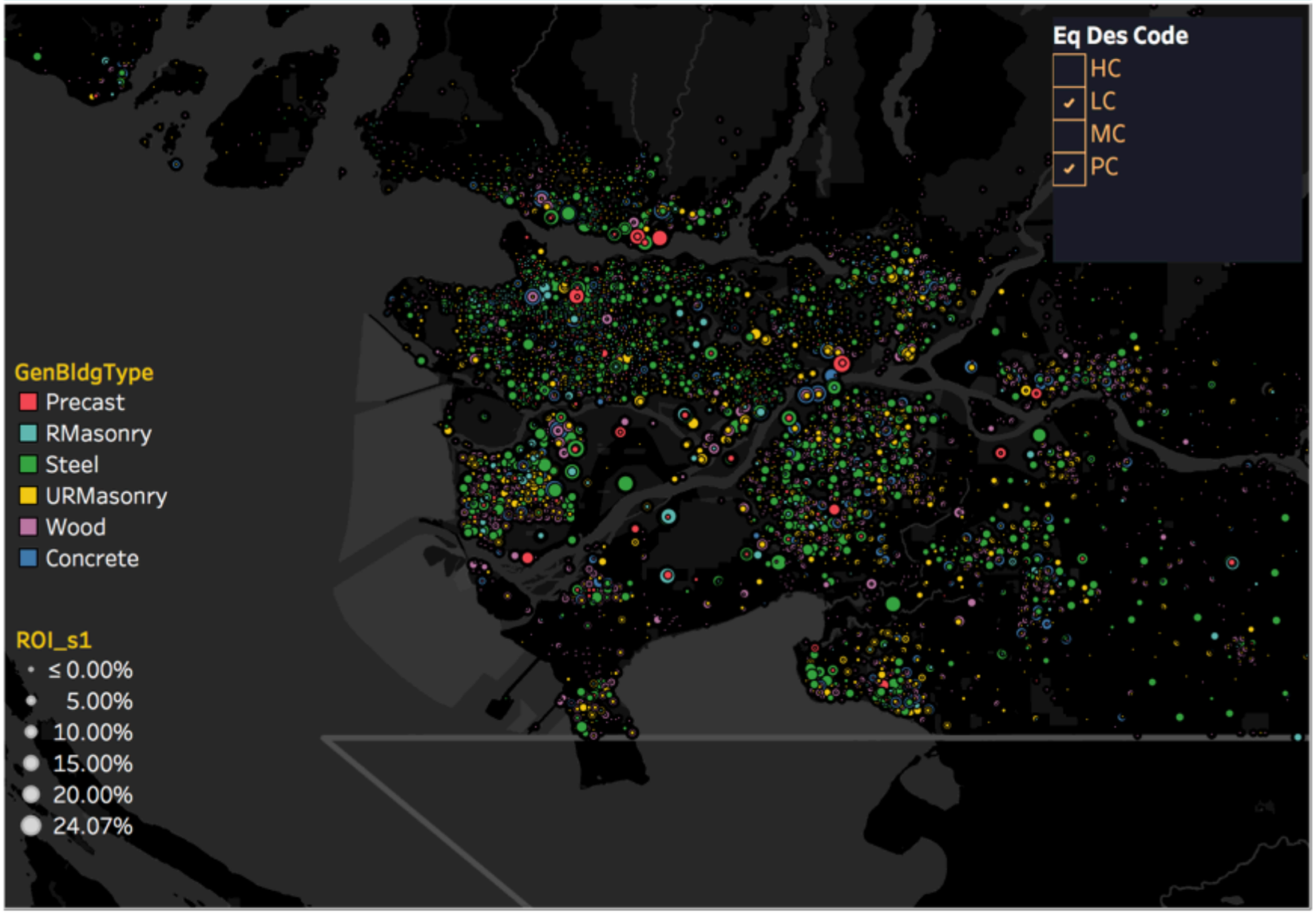
DRR Opportunities



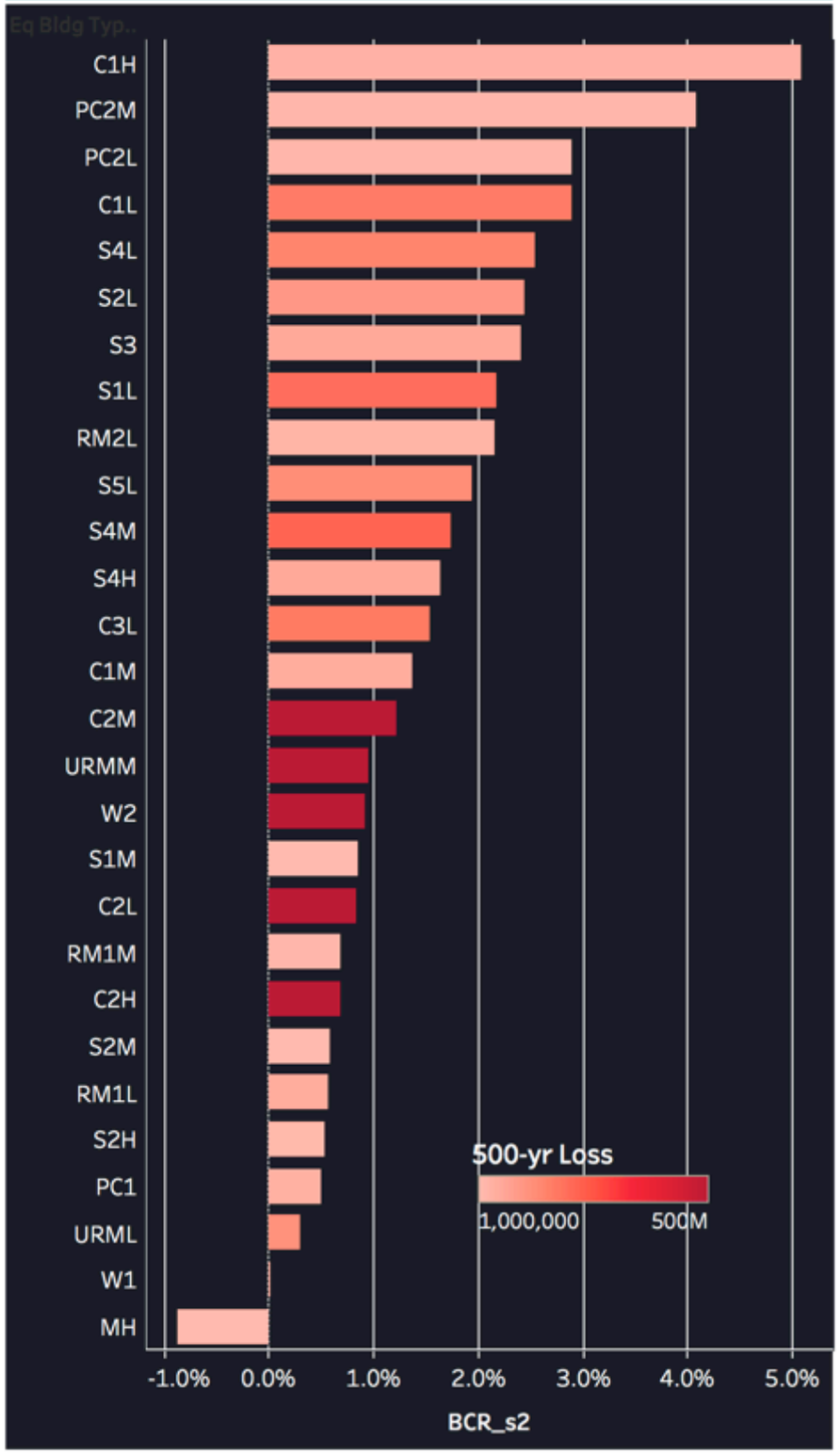
Financial Risk Management

ground-up loss profiles to inform mitigation and risk transfer

Expected Return on Mitigation Investment



Benefit/Cost Ratio



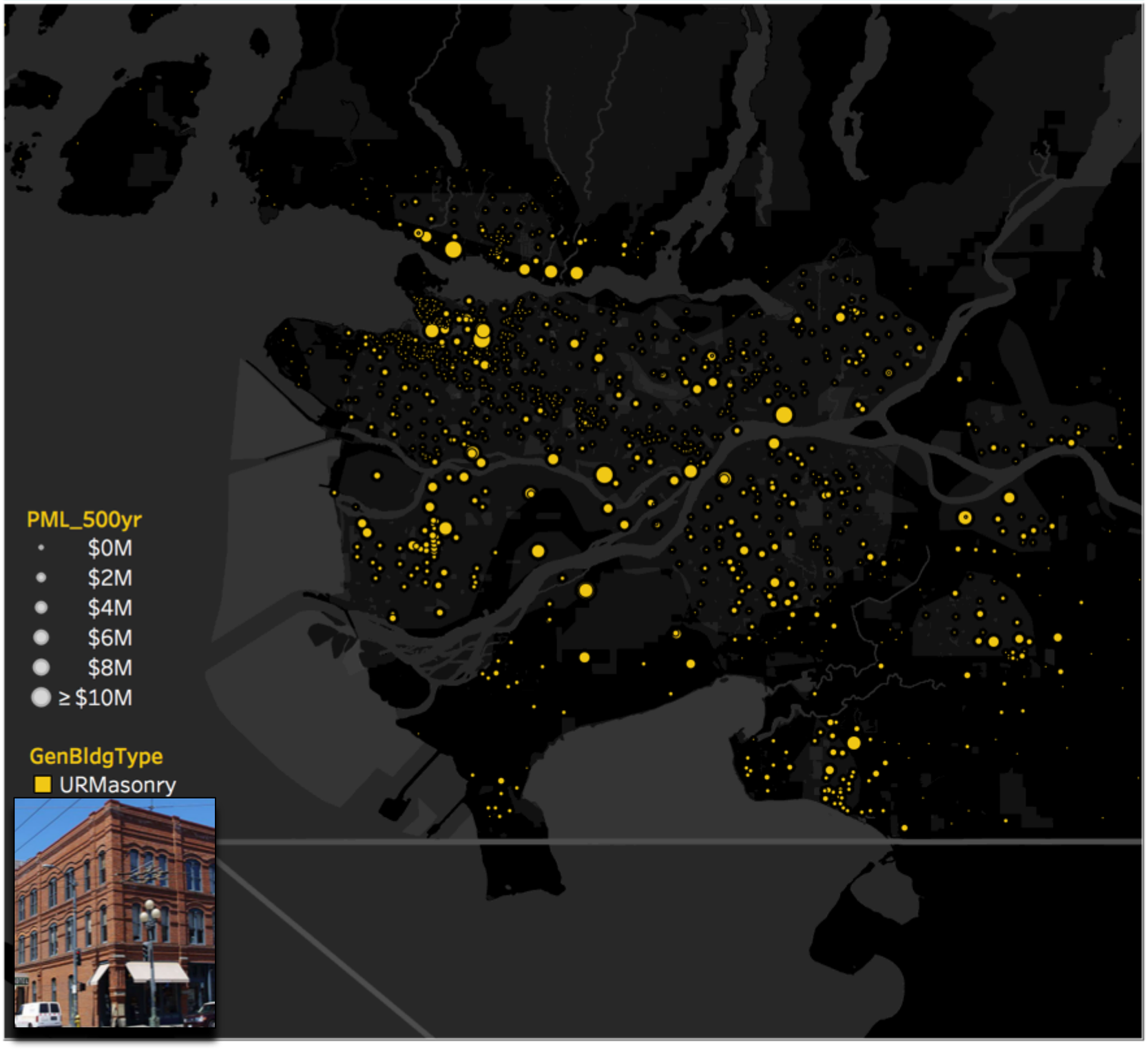
Seismic Retrofit Strategies

BldgGen (Low..	#Bldgs	DayPop	AALBldg b	AALBldg s1	AALBldg s2	BCR_ave	ROI_ave
Concrete	7,638	444,038	$30,780K	$18,697K	$6,431K	1.7%	3.68%
Masonry	12,254	504,395	$11,121K	$5,941K	$3,093K	0.8%	1.79%
Wood	321,042	580,950	$9,358K	$6,498K	$4,218K	0.5%	1.14%
Steel	2,266	47,376	$7,333K	$4,405K	$1,394K	5.1%	7.16%
Precast	385	10,027	$529K	$341K	$125K	2.1%	2.81%
Manufactured	1,915	9,575	$63K	$98K	$154K	-1.0%	-2.76%
Grand Total	345,500	1,596,361	$59,185K	$35,980K	$15,415K	1.0%	1.92%

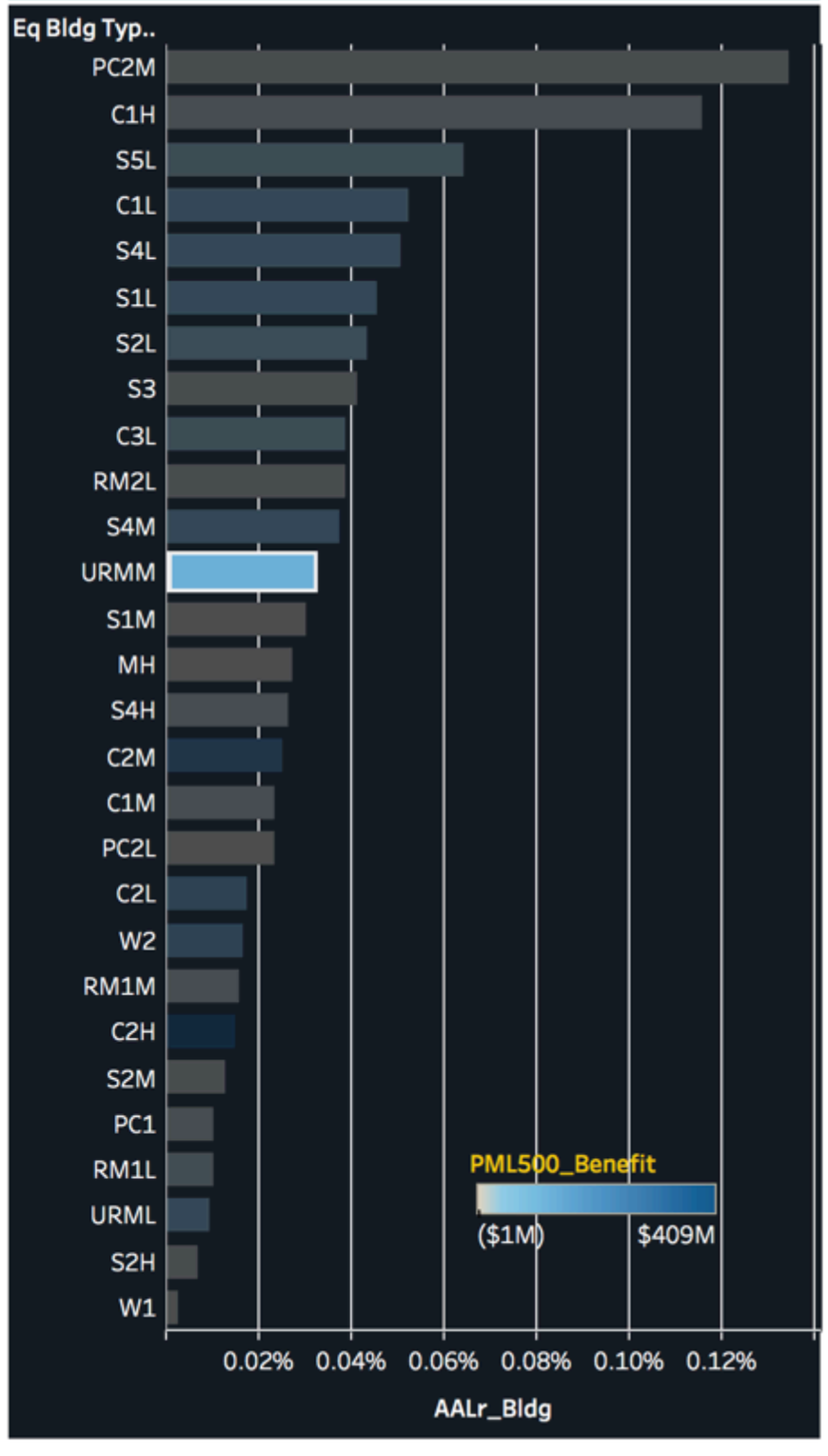
Financial Risk Management

ground-up loss profiles to inform mitigation and risk transfer

Probable Maximum Loss - 500yr



Average Annual Loss Ratio

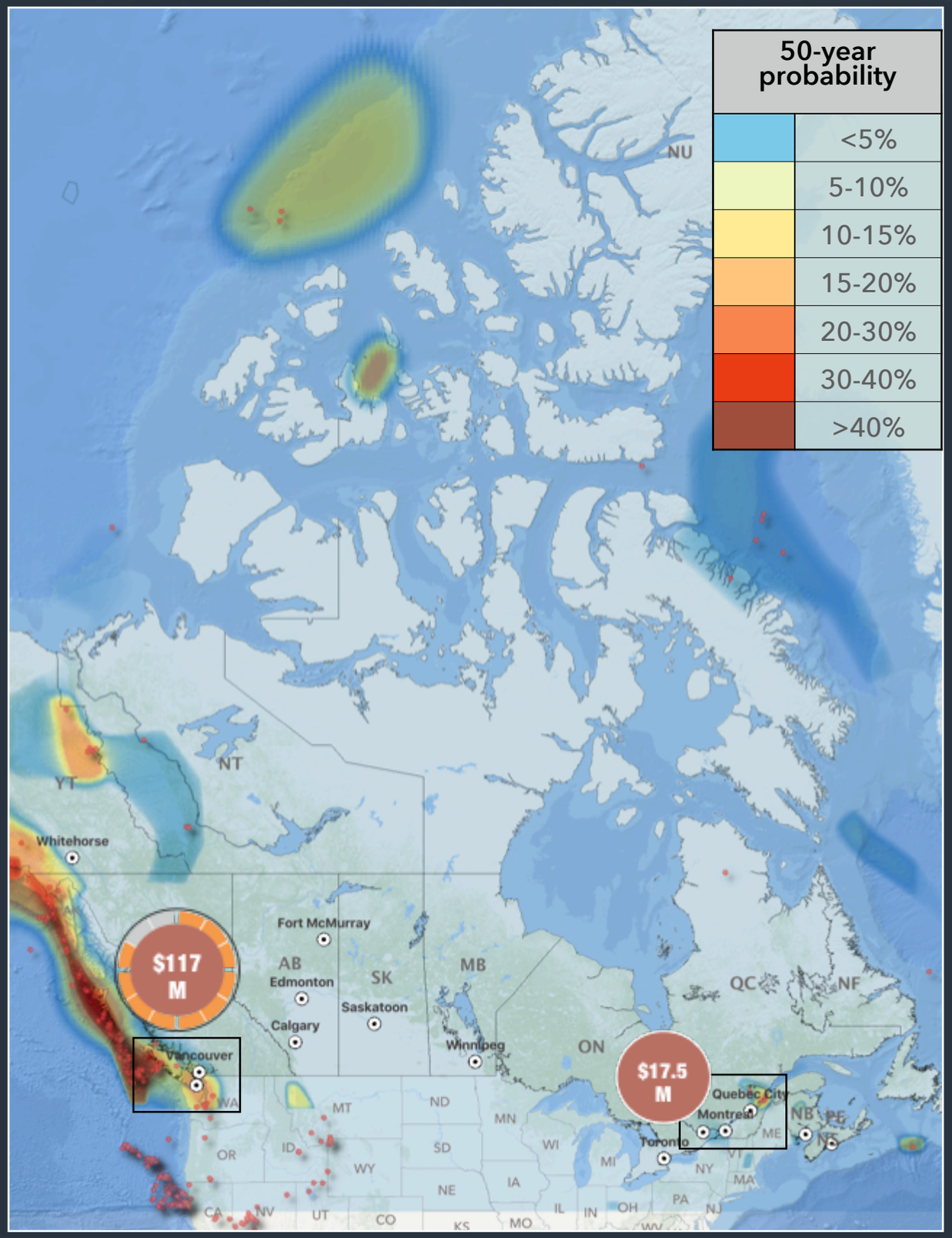


Financial Risk Management

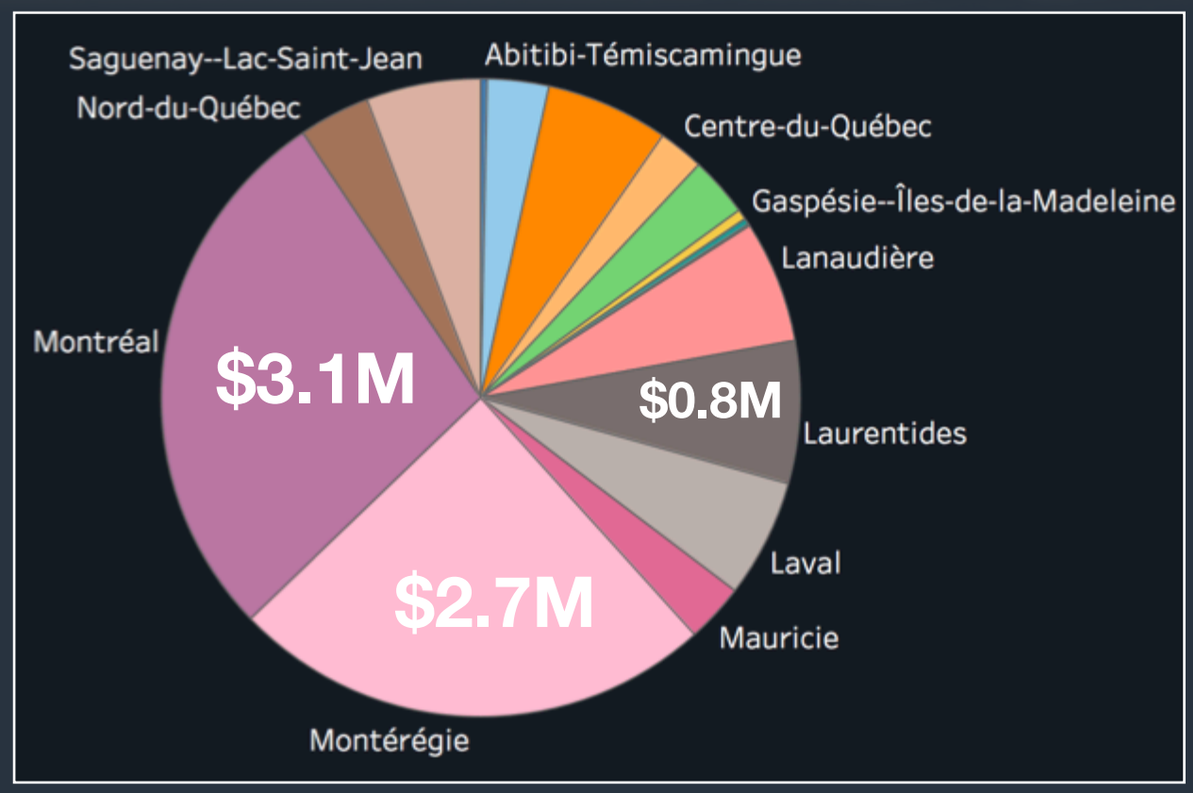
ground-up loss profiles to inform mitigation and risk transfer

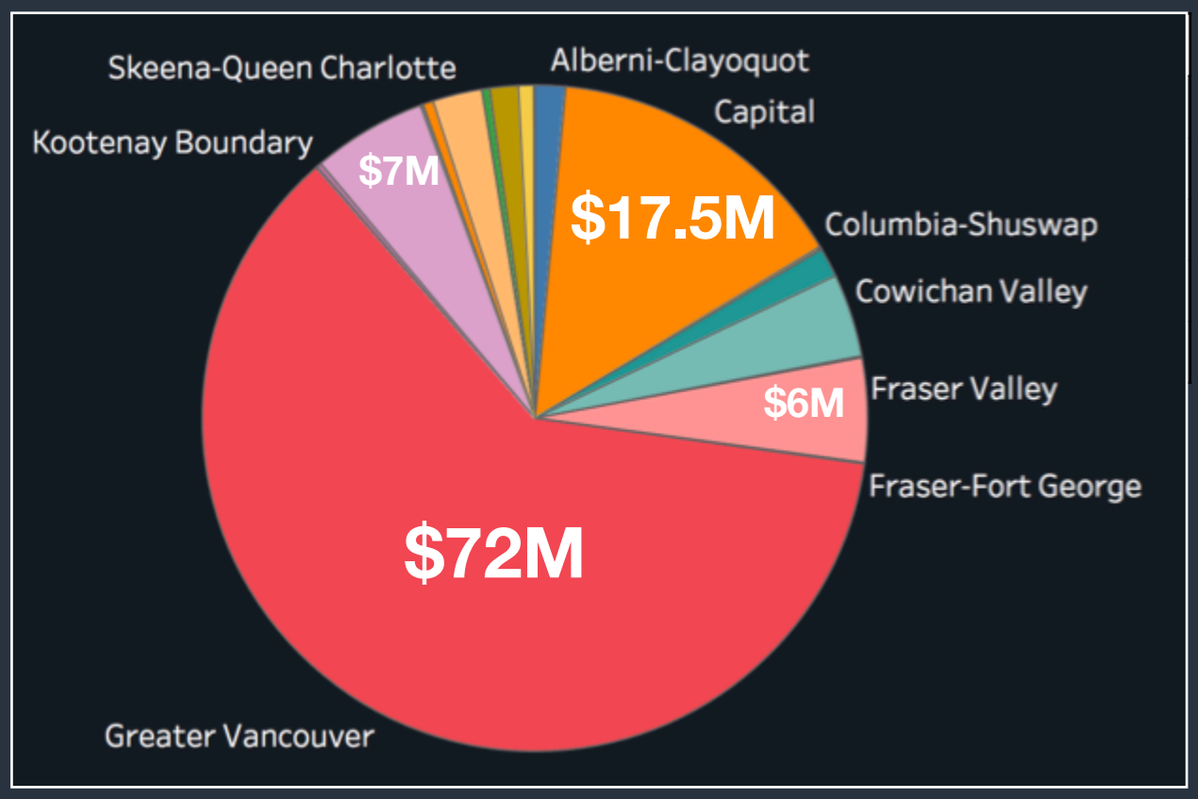
OPENQUAKE-CA

Expected Average Annual Losses



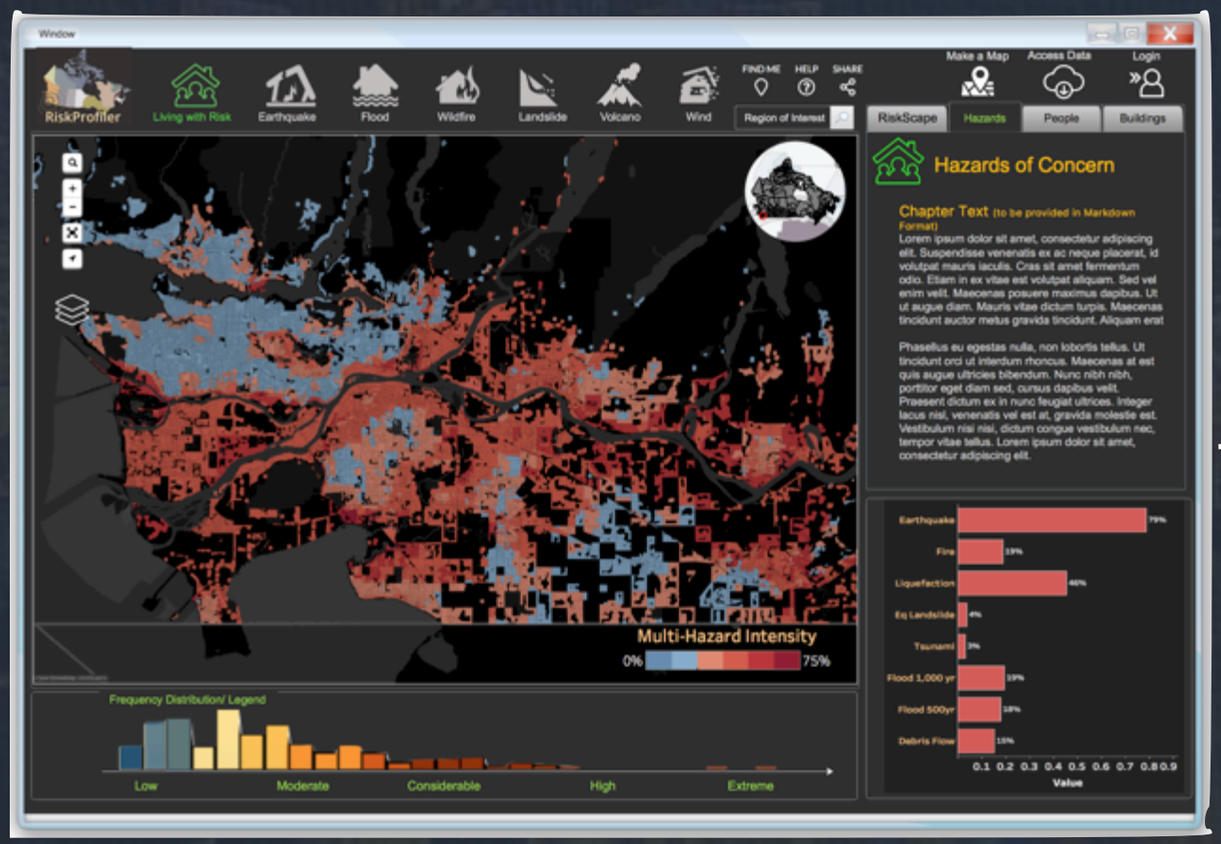
High Risk Regions





A User-Driven Risk Communication Strategy

NRCan RiskProfiler (Spring 2019)

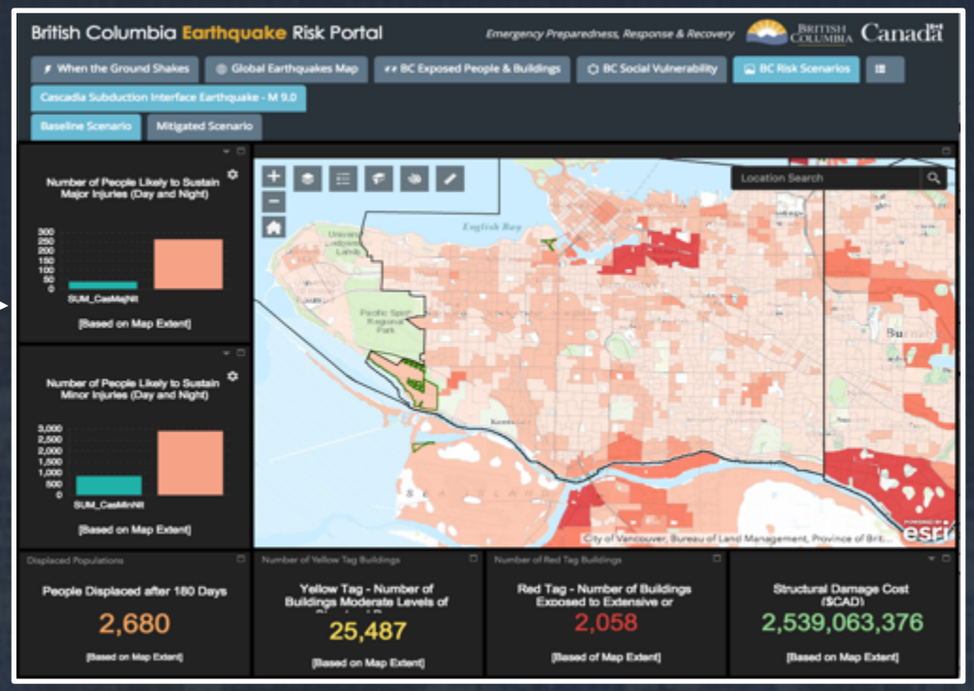


Engineer/ Analyst

Financial Sector

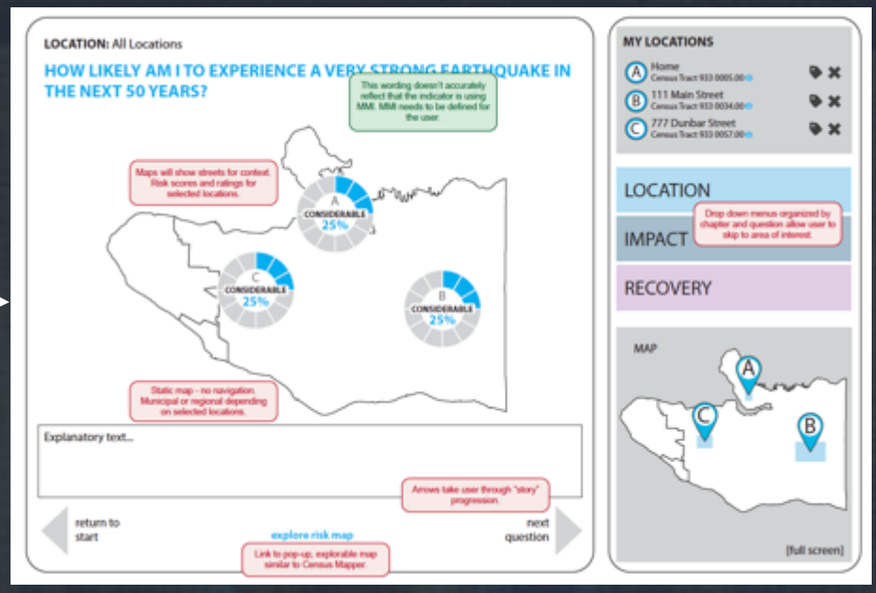
Community Planner

EMBC Web Portal



Emergency Manager

CoV RiskProfiler



Individual/ Business

Questions ?

murray.journeay@canada.ca
phone: 604-666-1130