October 21, 2014

Global Earthquake Risk Reduction: Cascadia, the Next Frontier

Kit Miyamoto & Amir Gilani

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Outline

- Lessons from recent Large Earthquakes
- Damage Assessment and Evaluation
- Risk Management and Preparedness
- Application to Cascadia Region

2011 East Japan Earthquake and Tsunami

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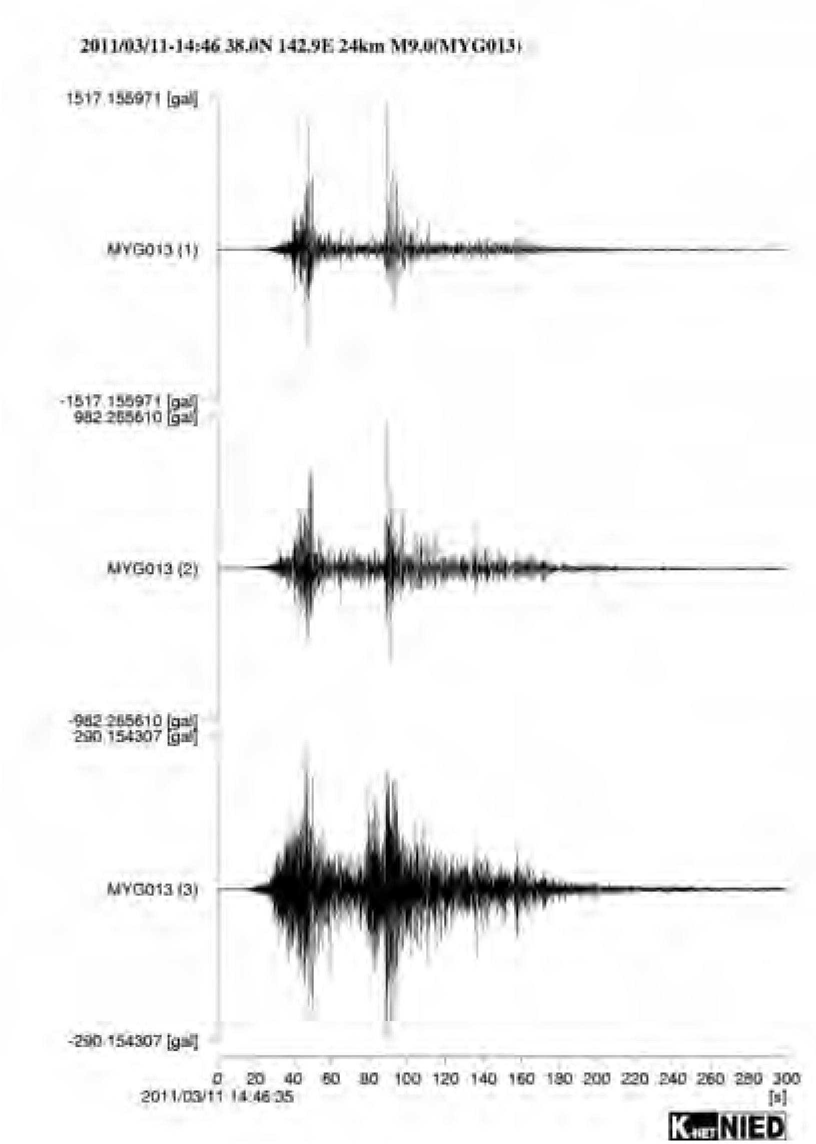
Earthquake

- MW 9.0 March 2011
- Western Pacific Ocean; epicenter ~130 km from Sendai, Honshu, Japan
- In the subduction zone between the Pacific Plate and Northern Honshu Plate
- Rupture length 100s of km
- Depth of 25 km
- MMI VIII-IX in major cities



- Large PGA (>1g)
- Long strong motion duration (>90 sec)

Tsunami

- Waves of up to 29.6 m (average 10 m)
- Traveled 10 km inland
- Tsunami inundated an area of ~ 470 km^2
- Tsunami damage far greater than that of the quake
- Smaller waves reached North America and caused damage

Consequences

Description	Comment
Death/missing	>10000’s
Building collapse, damage	120,000+
Transportation (road bridges)	Many damaged
Critical facility	Fukushima Nuclear reactors (I to VI)
Total damage	$300B

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Wood frame Buildings

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Foundations

Reinforced Concrete Buildings

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RC and Steel Buildings

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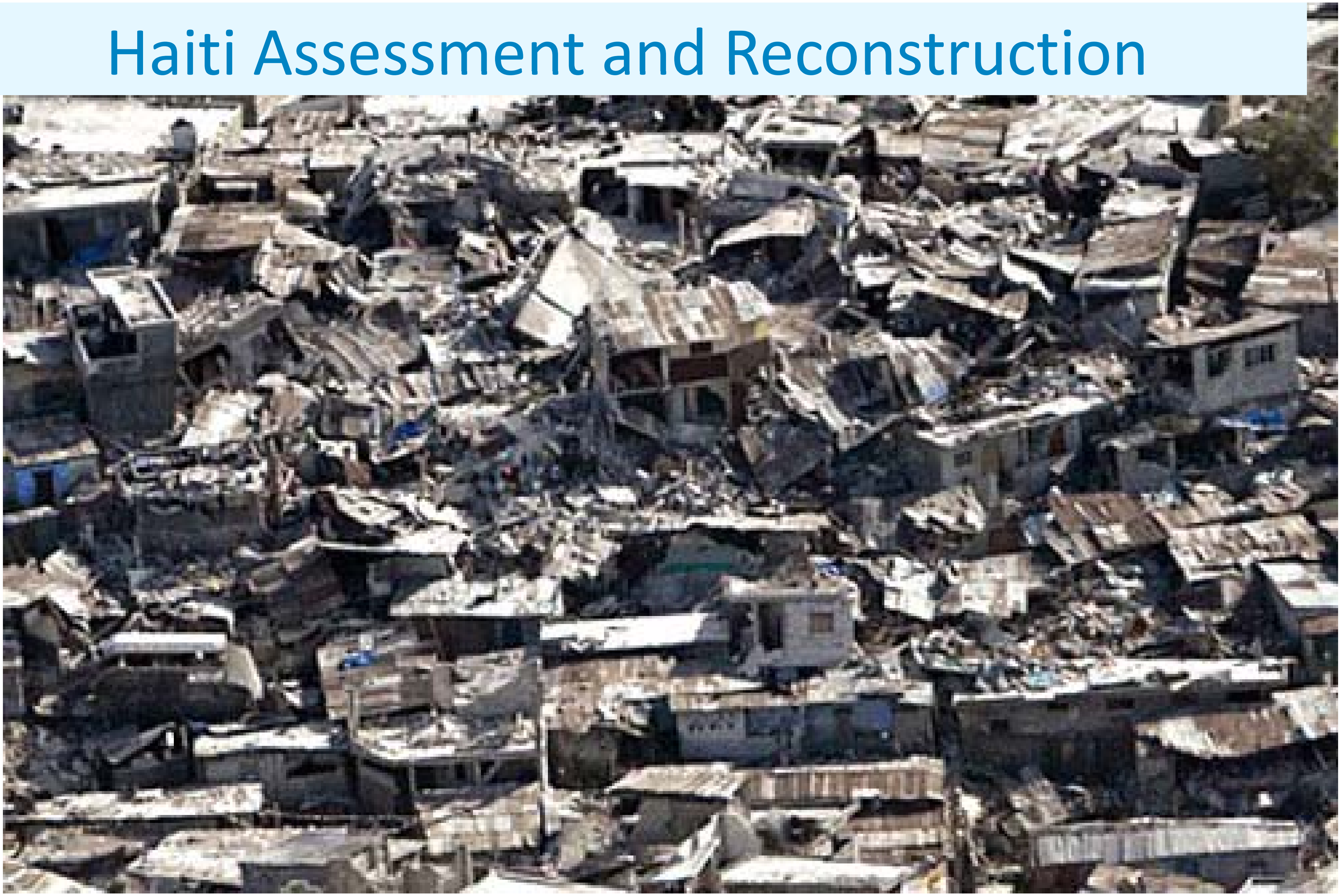
Bridges

Seawalls

Haiti Assessment and Reconstruction



2010 Earthquake

- Mw7.0, 2010 January
- Epicenter 25 km W-SW of PAP
- Main event MMI VIII
- Past large (but not recent) earthquakes.
  - 1770 event leveled the city
  - 1842, event destroyed the city of Cap-Haïtien
  - 1860 event resulted in a tsunami

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Consequences

Human and financial	Estimated cost
People affected	3,000,000
Fatalities/Injuries	200,000 +/300,000+
Made homeless	1,000,000 to 1,800,000
Collapsed & damaged Res/Commercial	250,000/30,000
Economic cost/% GDP	US $14B/ 15%

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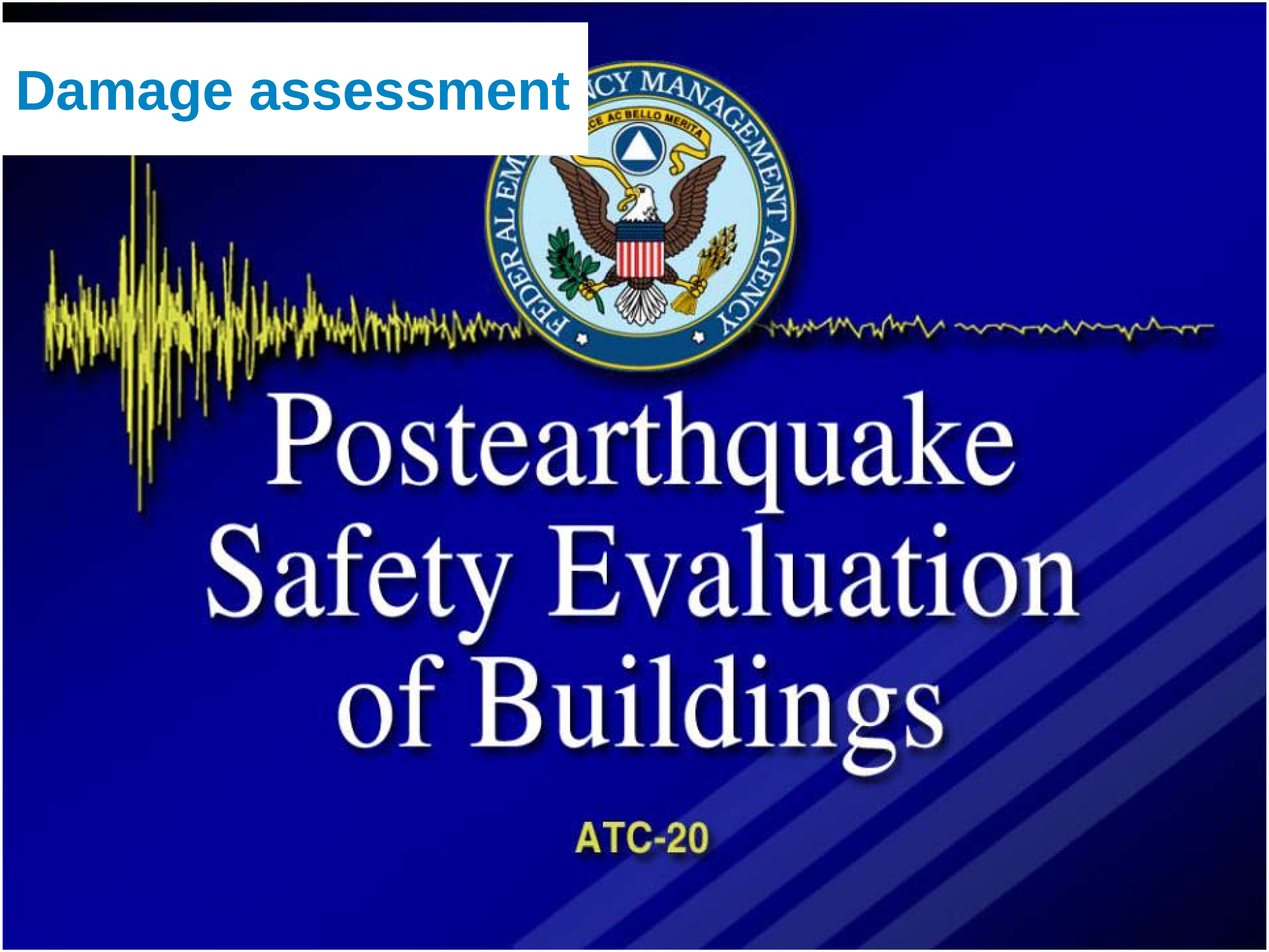
Causes of Damage

- Not a large event
- Lack of proper design & Poor construction
- Many non-engineered
- Vulnerable type of buildings
- No recent EQ
- No Seismic training or code

Examples

Damage assessment



- Following EQ, 100,000s of people displaced and resided in temporary shelters
- Cause of concern because of disease, living condition, hurricanes
- Quickly assess (and repair) buildings so people can return

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Program Components

- 600 Haitian engineers trained
- 17 teams to perform inspection
- 3000 buildings a day
- 400,000 buildings inspected
- ATC20 modified for Haiti construction
- PDA-based and reviewed
- Develop database

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Damage Assessment Program Coding

- Inspected (green-tagged”), building is structurally undamaged OK for occupancy
- Restricted Entry (“yellow-tagged”), building should not be occupied for extended periods and that parts of the building might be considered off-limits.
- Unsafe”(“red-tagged”), meaning that the building cannot be safely inhabited.

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Sample Building

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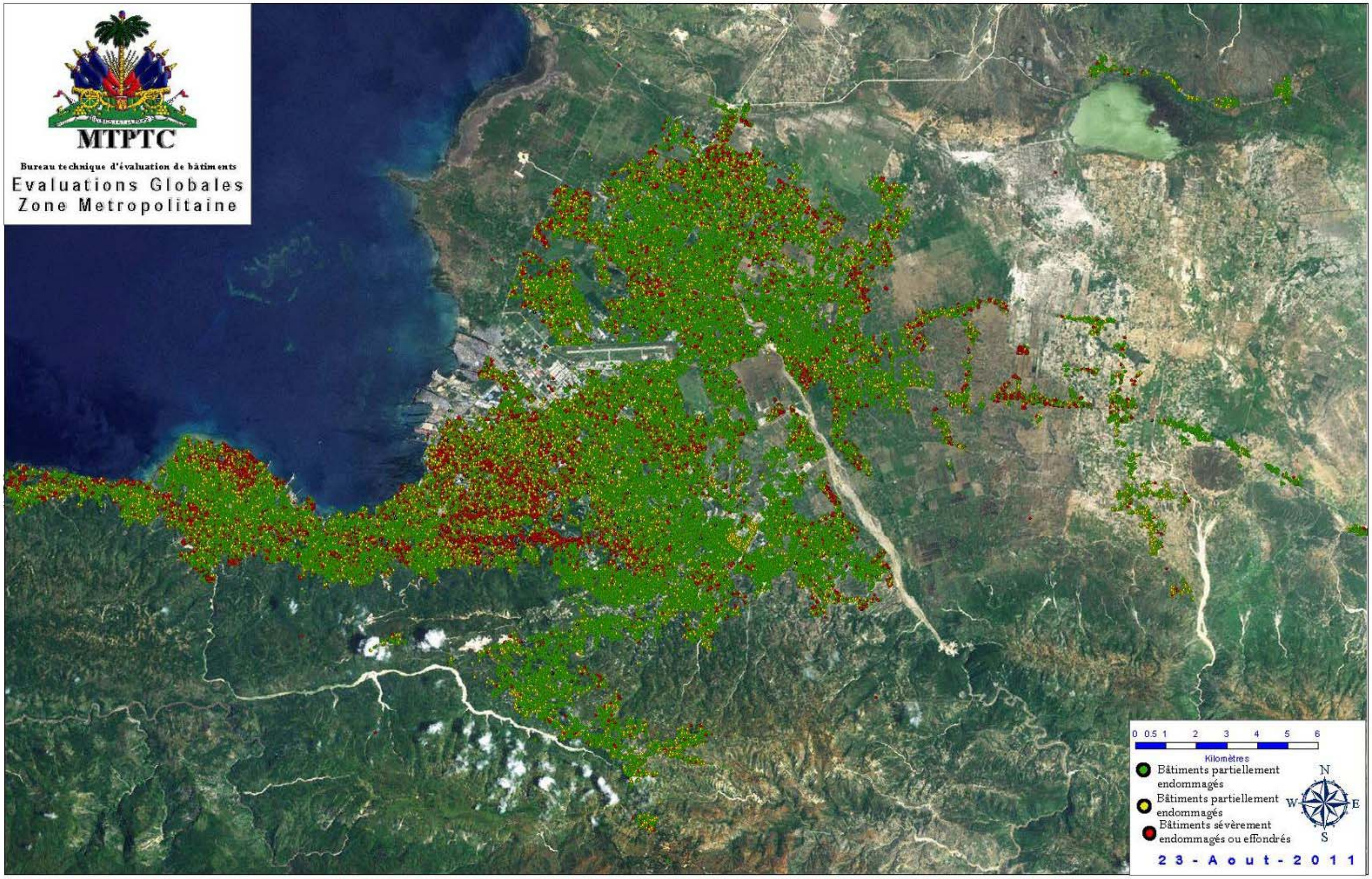
Findings

Category	Green	Yellow	Red	Overall
No. of buildings	213,100	102,100	79,500	398,800
Percentage	53%	26%	20%	100%
Median damage	0 –1%	10-30%	60-100%	-

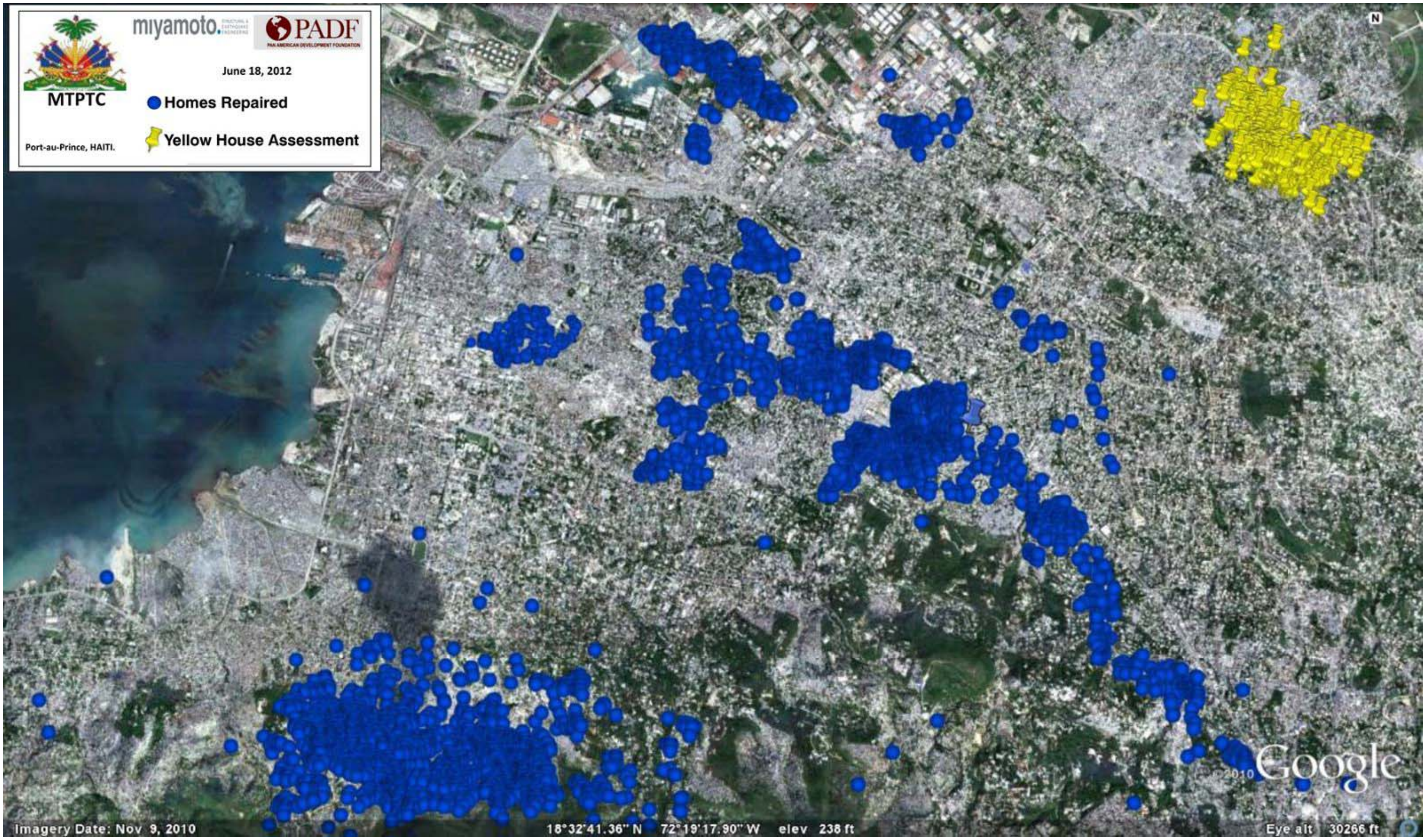

MTPTC
Bureau technique d'évaluation de bâtiments
Evaluations Globales
Zone Metropolitaine
0 0.5 1 2 3 4 5 6
Kilomètres
Bâtiments partiellement endommagés
Bâtiments partiellement endommagés
Bâtiments sévèrement endommagés ou effondrés
N
W
E
S
23-Aout-2011

School Buildings

Occupancy	Y+R
Residential	46%
Schools	51%
Healthcare	36%
Civic	44%
Commercial	36%

Reconstruction Program

- Based on database from assessment
- Cost-effective and simple repair for typical residential buildings
- Programs to communicate and train contractors and communities to repair and reconstruct
- Repair assessment method and construction inspection plan
- Implement project communications program


MTPTC
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PADF
June 18, 2012
Homes Repaired
Yellow House Assessment
Port-au-Prince, HAITI.
Imagery Date: Nov 9, 2010
18°32'41.36" N 72°19'17.90" W elev 238 ft
Eye alt 30266 ft
Google


PROGRESS IN HAITI CONTINUES
AFTER
BEFORE
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STRUCTURAL
ENGINEERS

Metro Manila Risk Management Program

Scope

- Multi-hazard prioritization methodology
- Building construction and code cycles
- Cost-benefit analysis
- Strengthening guidelines

Methodology

Identify Credible Natural Hazards Affecting Metro Manila

- Earthquake
- Typhoon
- Flood
- Volcanic eruption
- Tsunami

Evaluate Multihazard Impacts to Determine Dominant Risk

- Loss history
- Hazard maps
- Intensity
- Frequency/return period
- Annualized loss and casualties

Identify Predominant Hazard—Earthquake

Develop Earthquake Evaluation and Prioritization (Cost-Benefit) Methodology to Select Candidates for Upgrade

- Structural vulnerability and risk
- Occupant casualties and injuries
- Upgrade feasibility and cost

Develop Earthquake Upgrade Guidelines

Apply Methodology to Determine Top 100 Candidates for Retrofit

Multi-Hazard Prioritization

- Natural Hazards Global Hotspot
  - Ranked 8th in most exposed countries in the world
  - 85% of GDP activity in at-risk areas
  - Exposed to earthquakes, typhoons, floods, volcanoes and tsunamis

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Impact on Schools/Hospitals

	Earthquake	Tsunami	Typhoon Flood	Volcanic
Damage	High	Mod.	Mod.	High
BI	High	Mod.	Mod.	High
Percent Affected	>50%	≈30%	5–20%	0%
Injuries	High	Mod.	Low	Mod.
Deaths	High	Mod.	Low	Mod.

Findings: Annual ized Fatalities

- Earthquake
  - 200 deaths per year
- Flood, hurricane and volcanic hazard
  - Approximately 10 per year
- Earthquake hazard is the main risk that needs to be investigated for MM schools and hospitals

Earthquake

- The two recent major earthquakes:
  - 1990, M7.7 Luzon – 1,620 deaths
  - 1976, M7.9 Mindanao – 8,000 deaths
- Schools
  - Damage observed, but few student deaths because both struck in evenings when schools were unoccupied

Prior Studies in Earthquake Risk Reduction

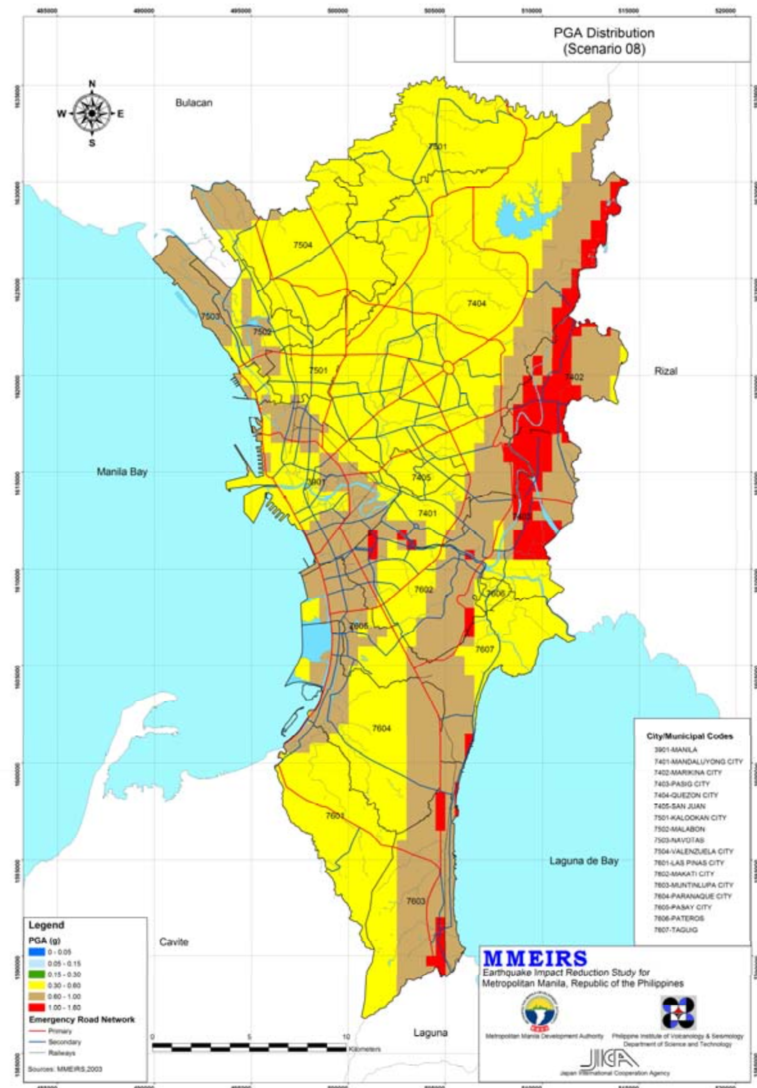
Japan International Cooperation Agency (JICA)
Metropolitan Manila Development Authority (MMDA)
Philippine Institute of Volcanology and Seismology (PHIVOLCS)

Earthquake Impact Reduction Study for Metropolitan Manila, Republic of the Philippines

Final Report
Volume 1
Executive Summary

March 2004

Pacific Consultants International
OYO International Corporation
PASCO Corporation



M7.2 West Valley Fault

- Metro area (2013 population: 11.5M - 20M)
  - 200-400 year event; last EQ > 300 years ago
  - 2004 estimate: 33,500 deaths (9M population)
- Schools
  - 2.1M students, 24,000 fatalities
  - 10% of schools to have heavy damage and/or collapse; 210,000 students endangered
  - School risk is similar to Sichuan, China

Findings

- Earthquake can produce highest fatalities
- A M7.2 event with 24,000 student deaths
- Unlike typhoons, floods and volcanic eruptions, earthquakes provide no warning
- Multi-story RC (typical construction type)
  - Proven safe in floods and typhoons
  - Dangerous in earthquakes, if nonductile

Typical School

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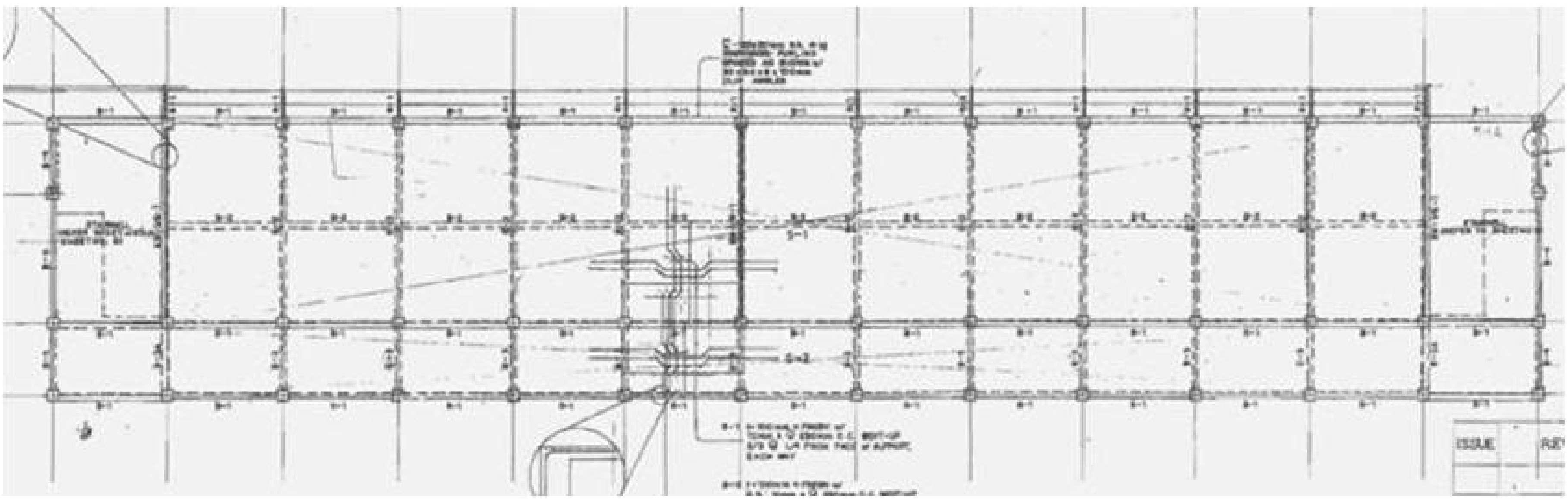
Lateral Framing

- RC frame building with infill
- 3m-tall stories
- 8m x 8m classrooms



Code Cycles

Edition	Issued	Title	Code basis
1	1972	NBCP	UBC 1970
1	1977		
2	1982	NBCP	UBC 1979
3	1987	NSCP	UBC 1985
4	1992	NSCP Vol. 1	SEAOC 1988 UBC 1988
4	1996		
5	2001	NSCP	UBC 1997

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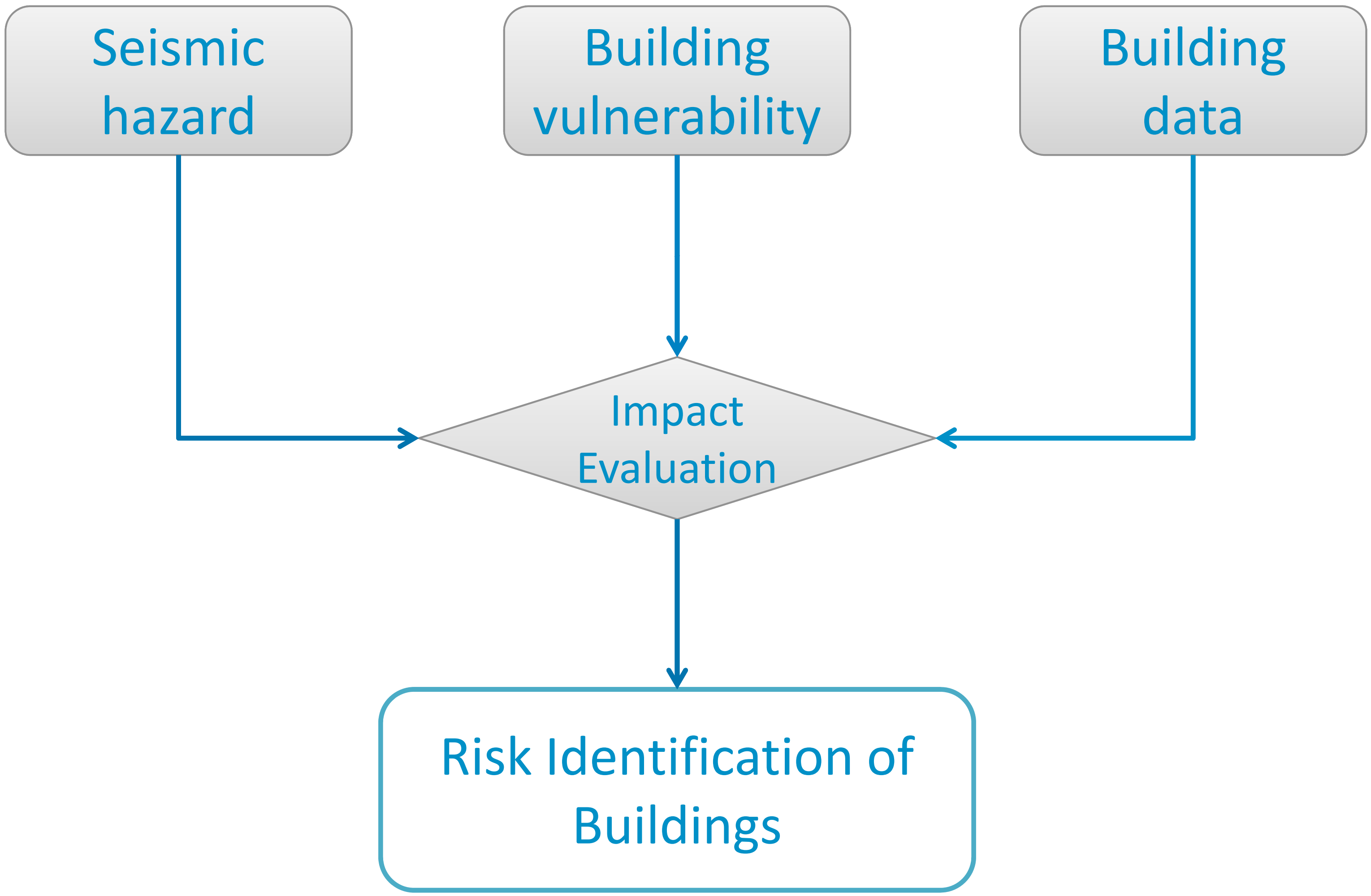
Risk Assessment Process



Data Collection

- Number of levels
- Date of construction
- Type of construction
- Soil type
- Site earthquake intensity
- Occupancy level

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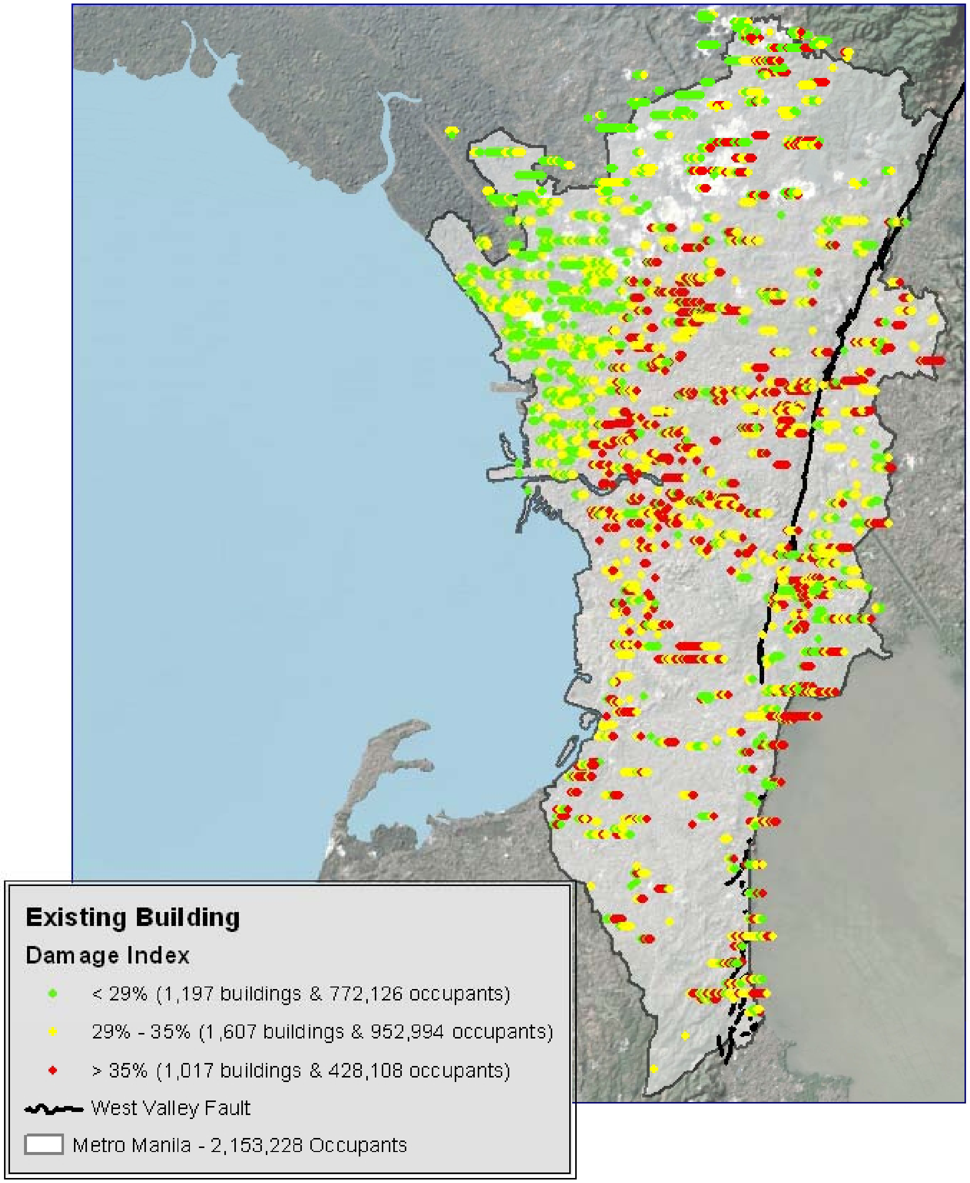
School Damage Index



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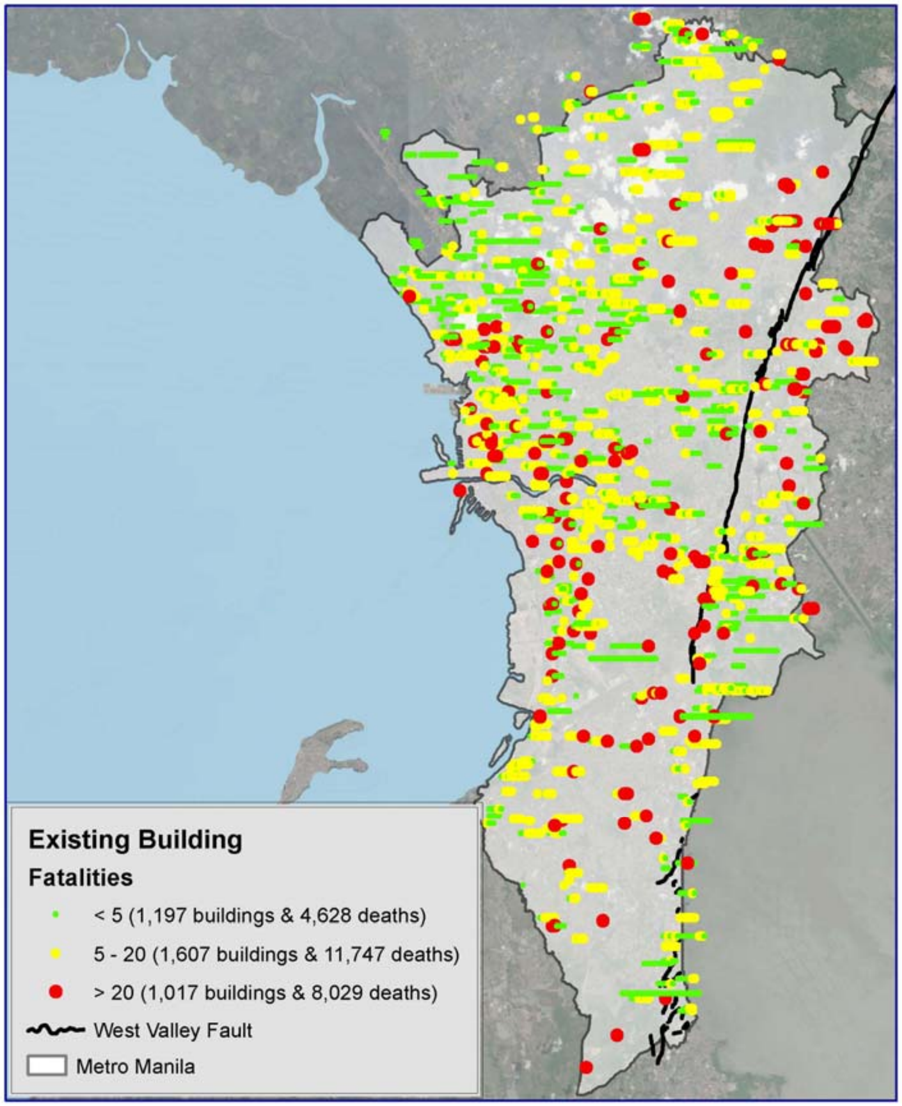
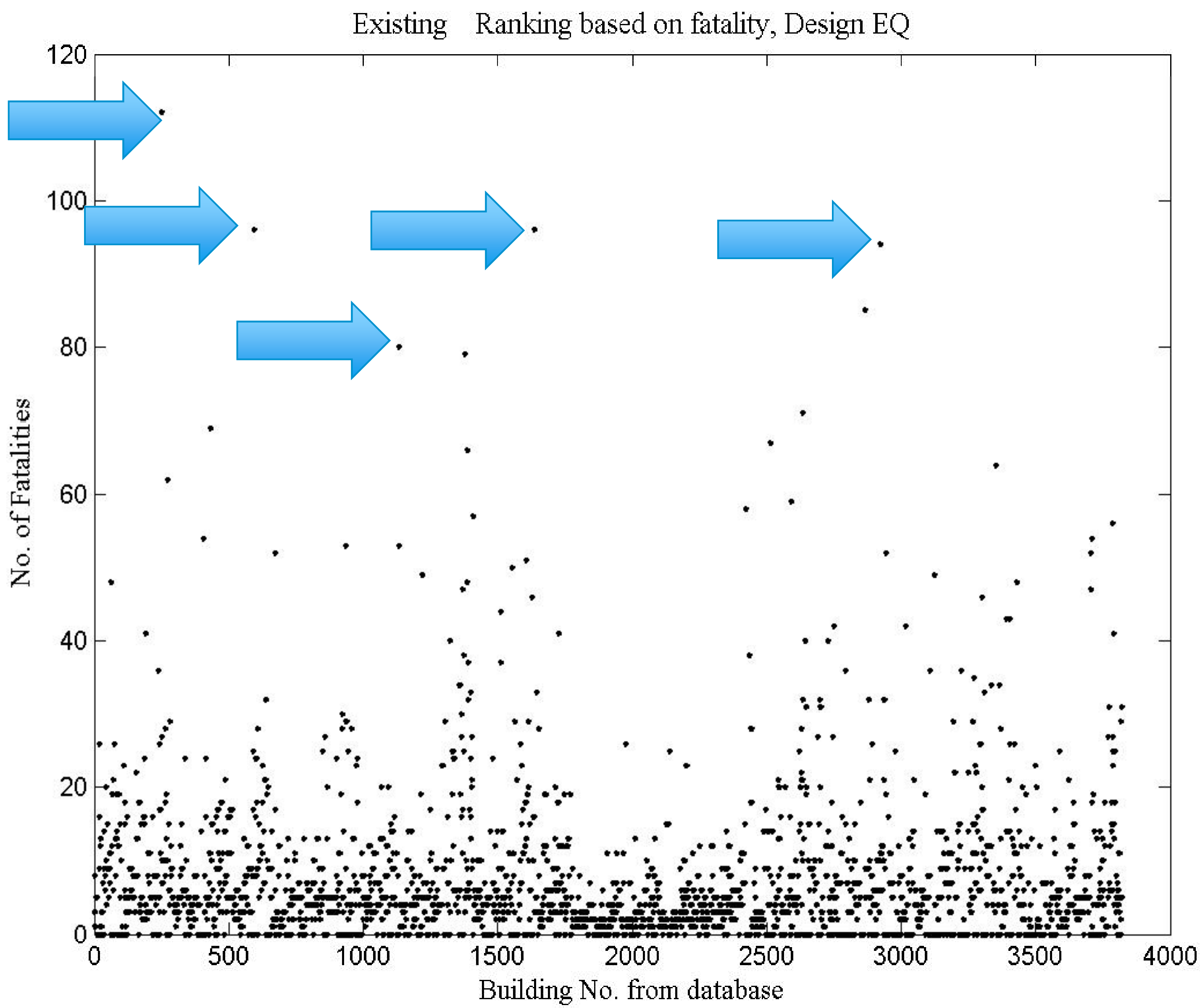
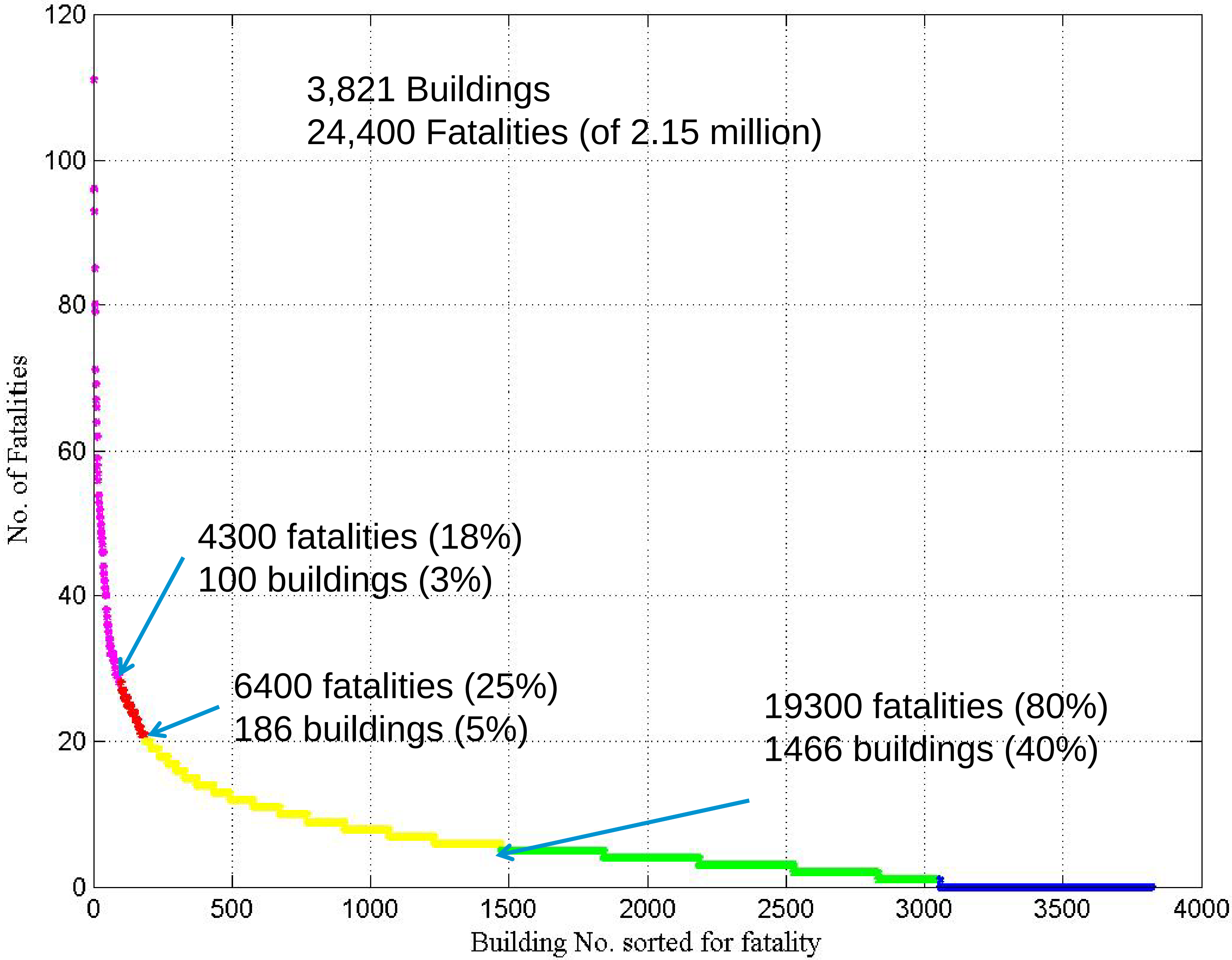
School Building Fatalities



Total Fatalities: 24,404



Existing Ranking based on fatality, Design EQ
No. of Fatalities
Building No. from database
0
20
40
60
80
100
120
0
500
1000
1500
2000
2500
3000
3500
4000


3,821 Buildings
24,400 Fatalities (of 2.15 million)
4300 fatalities (18%)
100 buildings (3%)
6400 fatalities (25%)
186 buildings (5%)
19300 fatalities (80%)
1466 buildings (40%)
No. of Fatalities
Building No. sorted for fatality
0
20
40
60
80
100
120
0
500
1000
1500
2000
2500
3000
3500
4000

Cost Analysis

- Cost data (from local contractor survey)
  - New or Replacement
    - *$580 /m^2*
  - Strengthening and functional upgrade
    - *$120 -$260 /m^2*
    - *(20 -40% of replacement cost)*
  - Strengthen and renovate up to 5 buildings for the cost of 1 new building

Key Findings

- One can systematically retrofit certain structures and greatly reduce the number of fatalities
- The cost of retrofitting such structures is significantly less than new construction

Cost Analysis

Buildings	Strengthening Cost	Student Lives
Worst 5% (190)	$40 - 80M	25% (6,380)
Worst 40% (1500)	$180-360M	80% (19,330)

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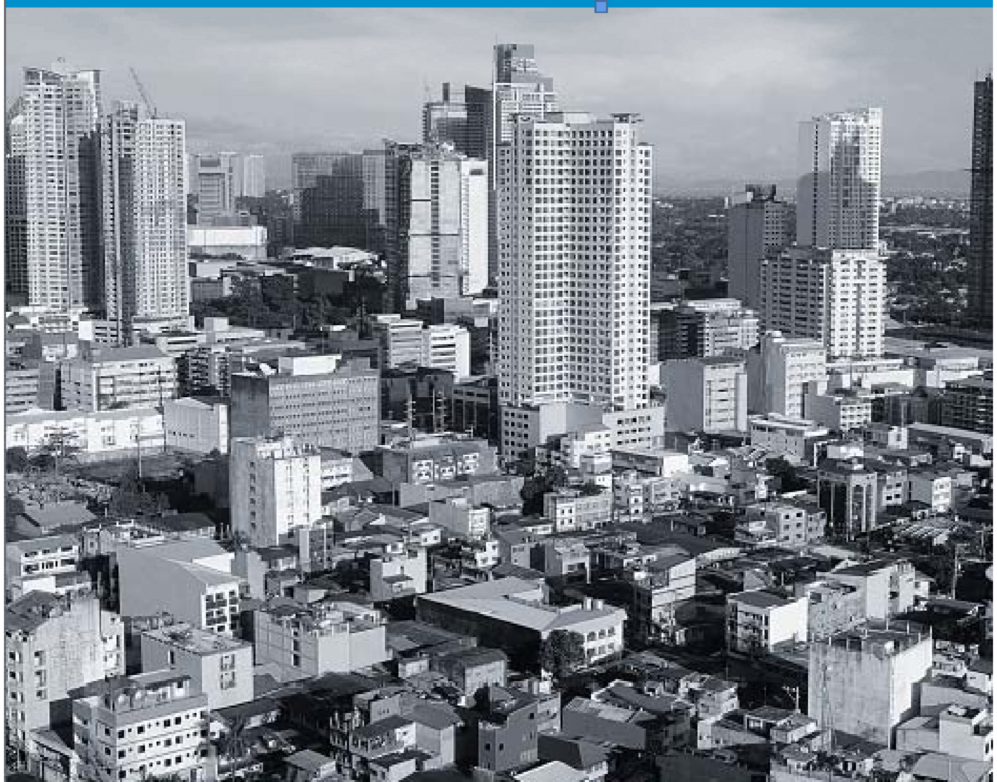
Seismic Strengthening Guidelines

- Volume I
  - Simplified methodology for evaluation and strengthening: Based on the National Code & US practice
- Volume II
  - Advanced
- Volume III
  - Design examples

Note: Guidelines are only the foundation for a comprehensive national program.

Guidelines for

EARTHQUAKE STRENGTHENING AND UPGRADING OF PUBLIC SCHOOLS AND HOSPITALS IN METRO MANILA



Volume III: Design Examples of Seismic Upgrade for Typical Reinforced Concrete Buildings

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Retrofit Objectives

- New system to carry 100% EQ load
- Limit drift ratio
- Investigate NSC
- Investigate non-building structures, such as canopies, Gym areas

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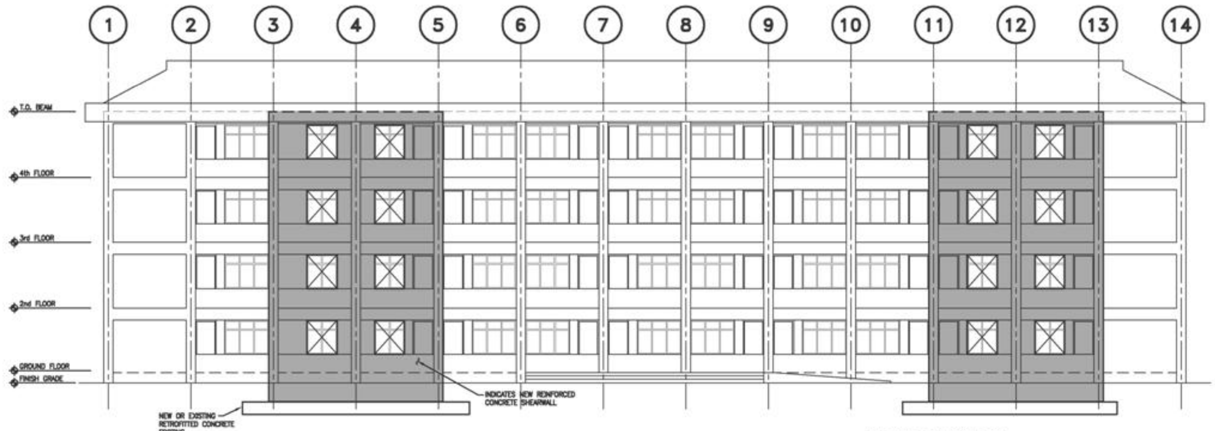
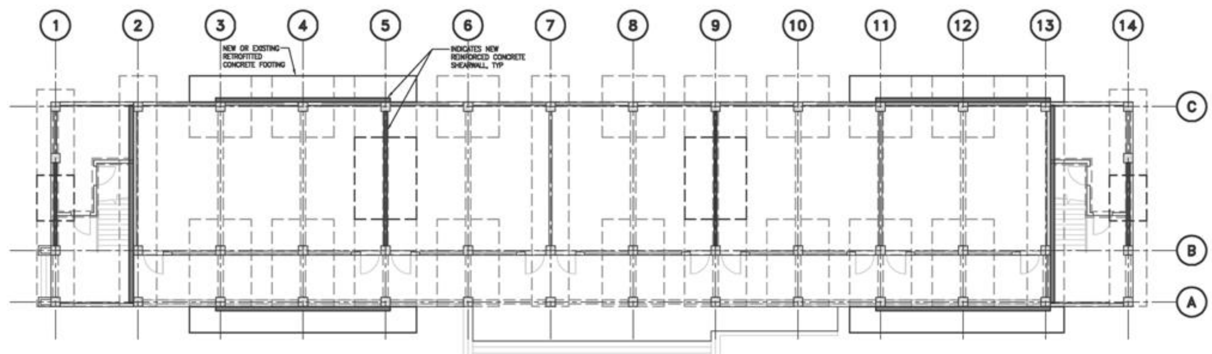
RCSW retrofit

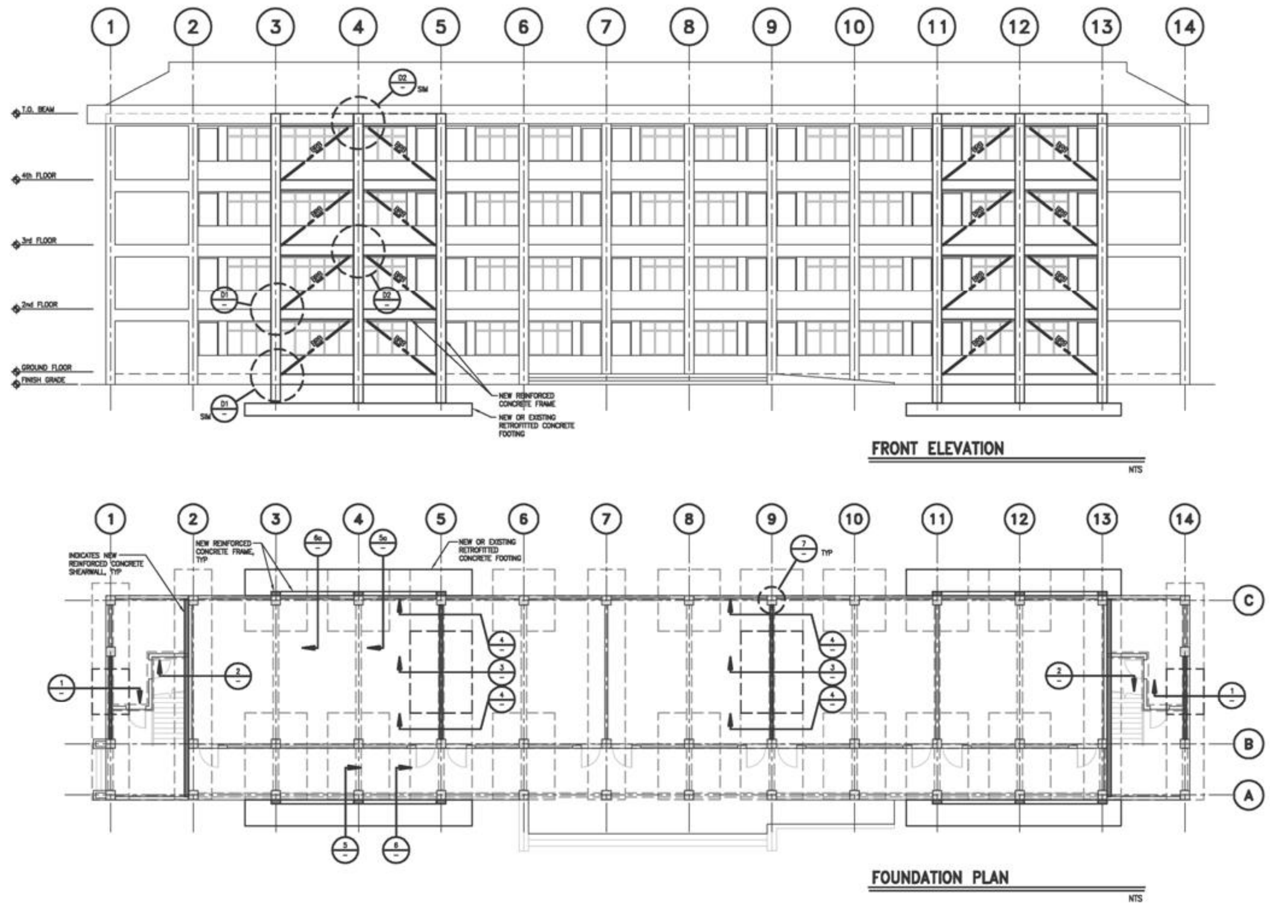


FRONT ELEVATION
NTS



FOUNDATION PLAN
NTS

BRBF retrofit



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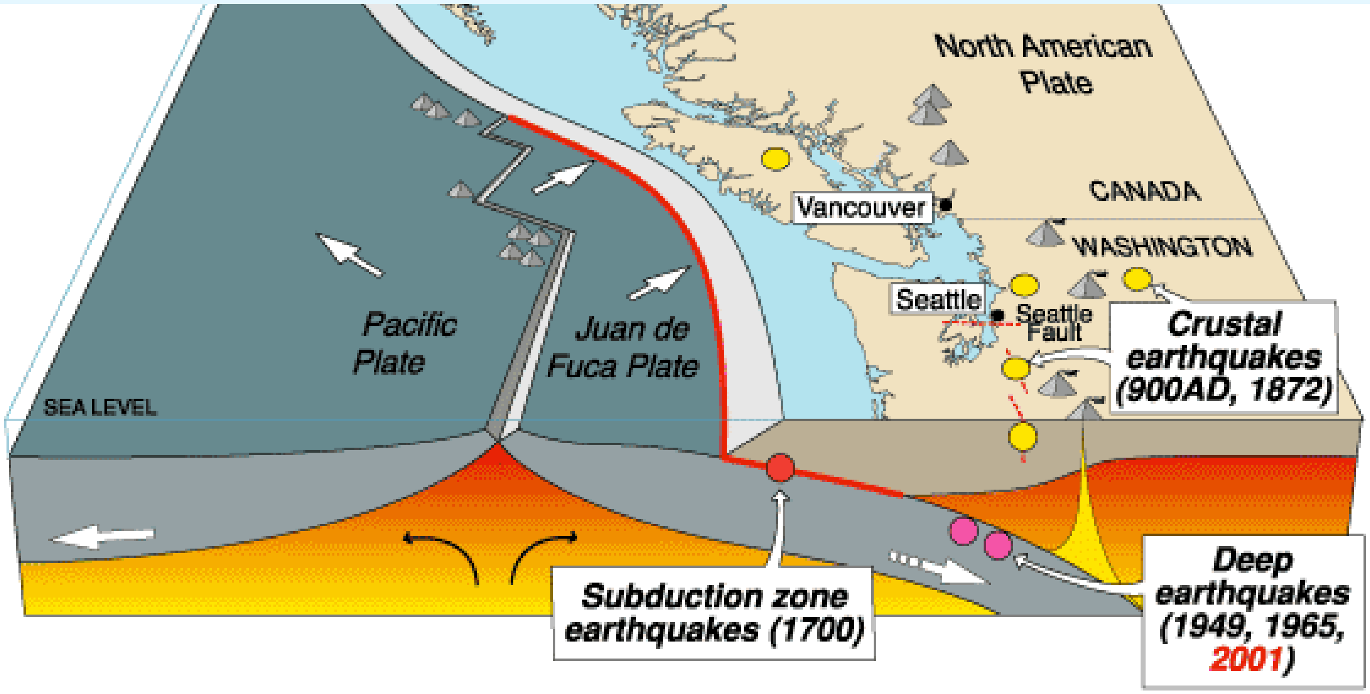
Concrete Shear Walls

Cascadia Subduction Zone



	Source	Affected area	Max. Size	Recurrence
🔴	Subduction Zone	W.WA, OR, CA	M 9	500-600 yr
🟣	Deep Juan de Fuca plate	W.WA, OR,	M 7+	30-50 yr
🟡	Crustal faults	WA, OR, CA	M 7+	Hundreds of yr?

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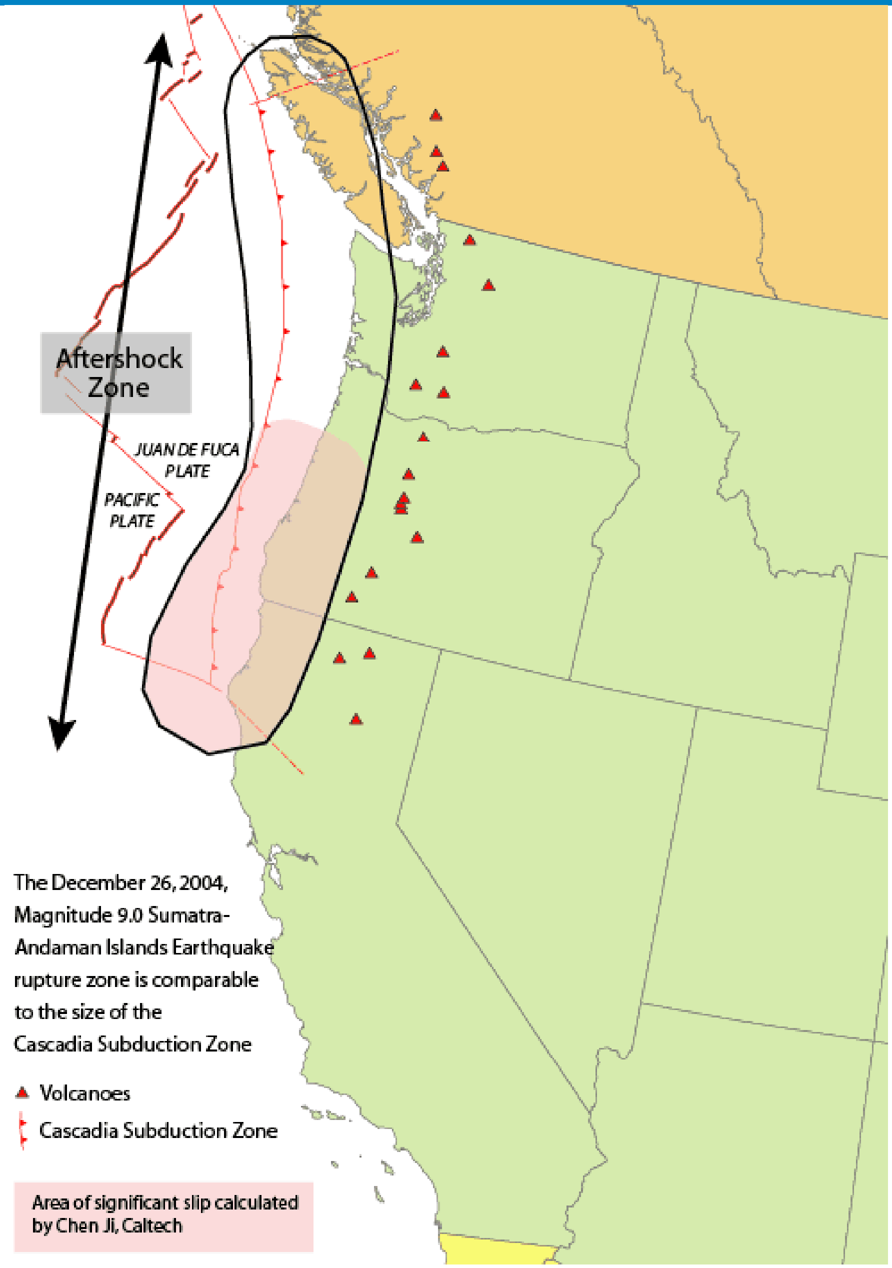

- Potential for very large earthquakes affecting west coast of N. America
- Last earthquake 1700
  - 1000 km rupture
- Return period 100s of year

Discussion (Preparedness)

- Design tsunami safe vertical evacuation structures for debris impact forces
- Critical & essential buildings should located on high ground or be tsunami safe
- Consider designing seawalls for wave heights larger than design level tsunami

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Discussion (Damage Assessment)

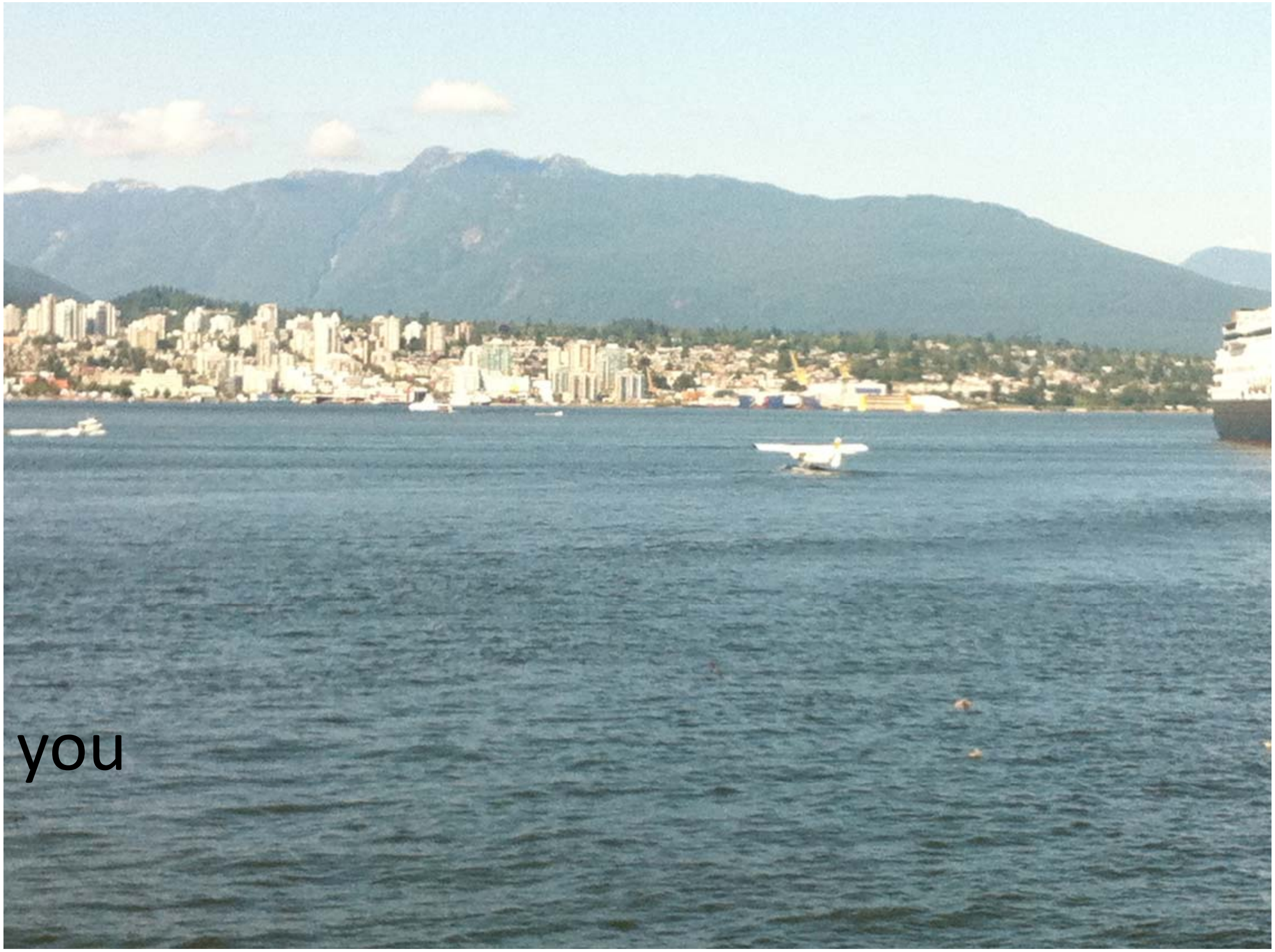
- Communities need to plan and train individuals for post-earthquake inspection (SAP)
- Rapid response teams to develop database and identify type and extent of damage
- Retrofit existing vulnerable buildings (cheaper than replacement)
- New code provides LS and prevents collapse…but not damage free

Discussion (Risk Management)

- Earthquakes have the potential to produce the high casualties for schools
- Critical structures can be systematically retrofitted and greatly reduce the number of fatalities
- Earthquake strengthening is cost effective
- A successful program should rely on input from all stakeholders

Discussion (Cascadia)

- A repeat of large earthquake expected
- Adverse effect on Northwest
- Many areas not prepared for such event
- Many older and non-ductile buildings will likely not perform well
  - Schools
    - Private schools
- Other successful programs (Istanbul, Philippines) can be used as reference



Thank you