Stakeholder Awareness Workshop on Increasing Building Resilience to Earthquake Damage

Impact and Lessons from Great Earthquakes and Overview of Earthquake Building Losses Results

Examples around the world

July 26, 2022

Thimphu, Bhutan

GeoHazards International

- Experience in over 20 countries
- Currently have offices in 6 countries, incl. HQ
- **Earthquakes, landslides, tsunamis,** climate-induced hazards
- Mostly international staff

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Past Projects in Bhutan

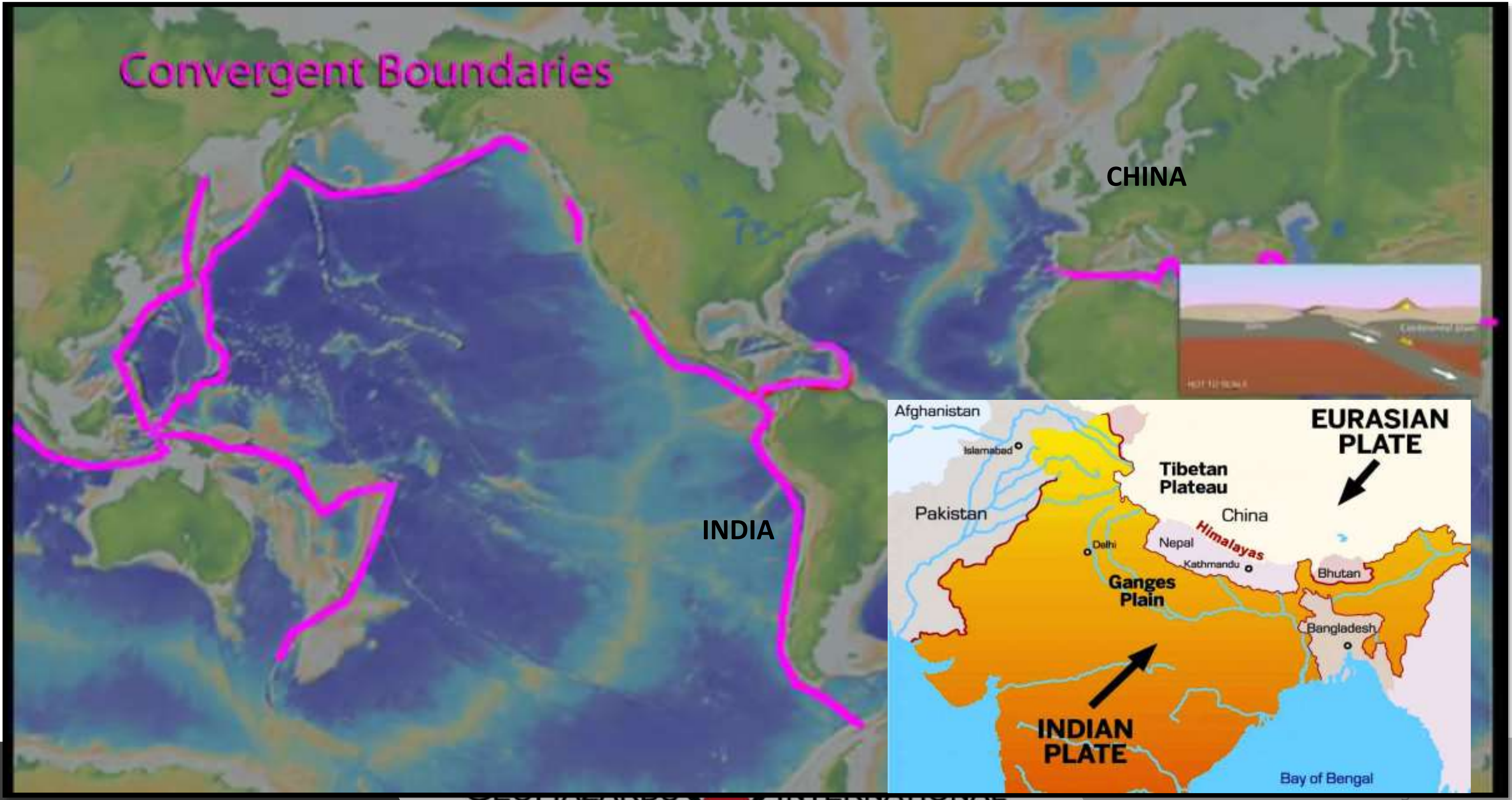
- Formulation of **National Action Plan for School Earthquake Safety**
- Formulation of **National Action Plan for Earthquake Safety of Health Facilities**
- GeoHazards International (GHI) in-collaboration with the Ministry of Education carried our the **Earthquake Desk Project in Bhutan**
- GHI in-collaboration with DDM and DES developed the ***Field Manual: Postearthquake Safety Evaluation of Buildings,* ATC 20-1**
- Conducted **Seismic Vulnerability Assessment** for JDWNRH and Mongar Regional hospital
- JDWNRH **Emergency Evacuation** mock Drill

Current Projects in Bhutan

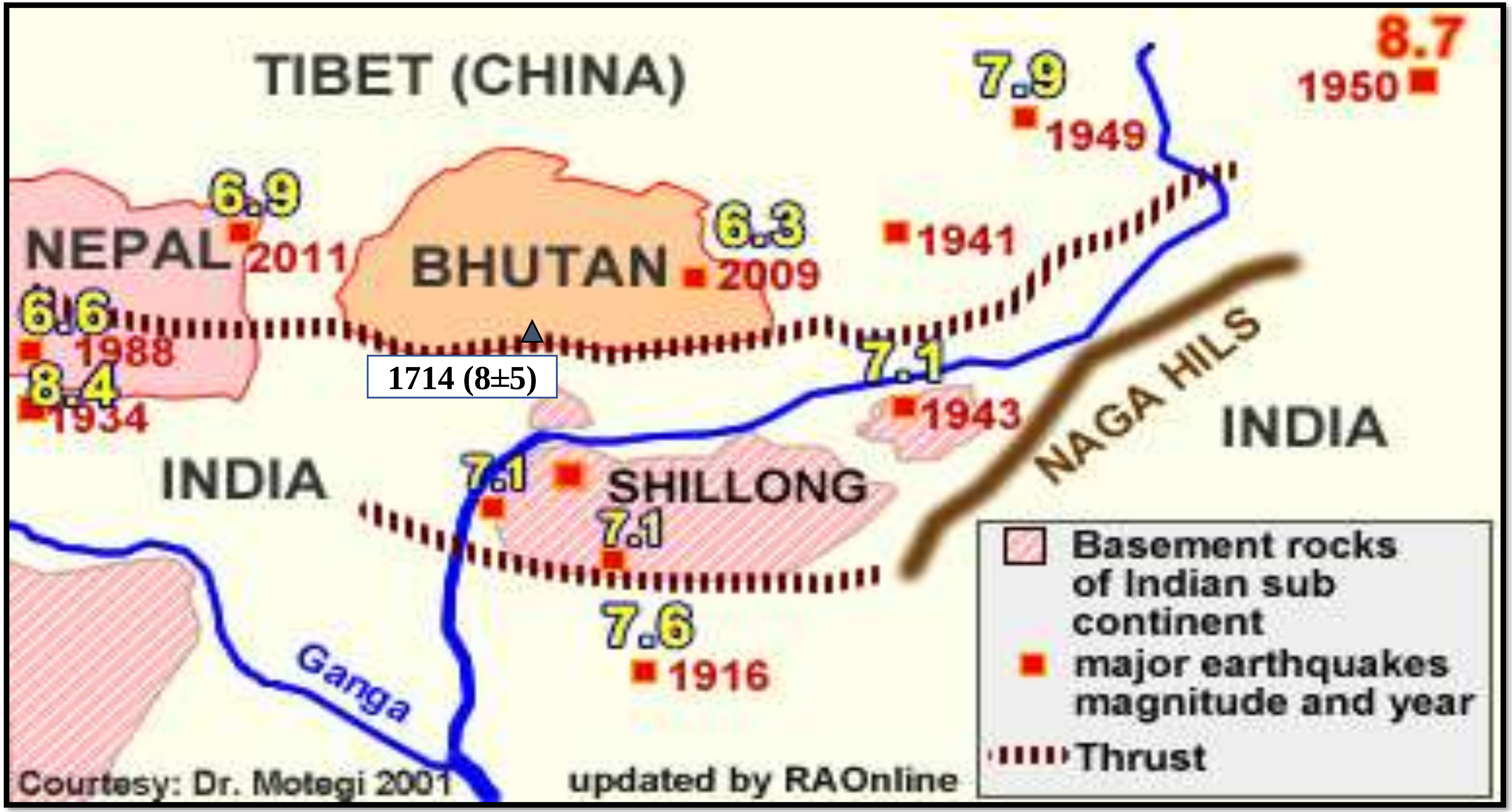
- Strengthening Policy Frameworks for Disaster Risk Management and Climate Change Adaptation for Bhutan – with DDM

- Quantifying Thimphu Earthquake Risk from Buildings Project

HISTORICAL EARTHQUAKES IN HIMALAYAN REGION



HISTORICAL EARTHQUAKE IN HIMALAYAN REGION



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1714 Earthquake

According to the study, Bhutan experienced a major earthquake on May 4, 1714 (20th of the 3rd Bhutanese month) of between 7.5 and 8.5 magnitudes in central and western Bhutan. The findings were based on Bhutanese biographies, Assamese records and geologic studies.

The earthquake took place when the ninth Je Khenpo Shakya Rinchen was four years old. The earthquake killed his mother but young Shakya Rinchen, who lay cuddled on his mother's lap, was dug out of the debris. He went on to become one of Bhutan's most illustrious writers and religious figures and wrote about the earthquake in his books. His successor, the 10th Je Khenpo Tenzin Chogyal also records how the new Gangteng temple built by Tenzin Lekpai Dhondup was reduced to rubble in the spring of 1714.

"The earth shook about thirty times that day alone and the aftershocks continued for about a month," Karma Phuntsho said, citing the historical sources. "People across the country were struck with fear and the young ruler of Bhutan, Chogley Namgyal, had to sleep in a tent outside the dzongs in Thimphu and Punakha. It is thanks to such biographical and historical writings in Bhutanese archives that scientists, who have some geological evidence for the earthquake, are today able to narrow down the location, time and the magnitude of the earthquake."

Great Hanshin-Awaji (Kobe) Earthquake, 1995

- **January 17, 1995**, 5:46 A.M.
- Near Kobe city, Japan
- M 6.9
- Level 7 intensity
- Extensive damage to coastal cities – Osaka, Kyoto, Shiga
- **6,434 deaths; 94,900 injuries**; 317,000 evacuated
- 68 children under the age of 18 orphaned; 332 lost one parent
- **More than 400,000 buildings**

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- Regular Building Code Improvement effect – buildings built after 1981 code suffered minimal damage.
- Traditional houses – the light wood frames supporting the heavy tiled roofs built to resist typhoons, gave way, crushing the unreinforced walls and floors in pancake collapse
- Transportation - Hanshin expressway failed over 20 Km length; 3 main railway lines failed; Elevated viaduct for bullet train failed
- Major effects in Port of Kobe – impeded business shipments and impacted electronics, apparel and auto manufacturing companies

- Essential Services – water supply, water treatment and gas systems failed
- Secondary hazards effect –300 fires started within minutes of the earthquake – fires destroyed more than one million square meters of residential area in Kobe

Source: Japan Times

Sichuan Earthquake, China, 2008

- May 12, 2008; 14:48
- M 8 / 7.9
- Maximum intensity of XI
- 46, 200,000 people affected
- 15, 000,000 evacuated
- 5 million homeless
- 374,159 injured
- 69,225 dead
- 7000 schools destroyed (19065 children dead) – “Tofu Schools”
- 2000 orphans

Many school infrastructure failed

WHY?

- Quality compromization, corruption and standard implementation failure

(Source: Weebly.com)

-Many death due to building collapse

Engineering Mistakes can be costly!

2015 Nepal Earthquake

- 25 April, 2015; 11:56
- M 7.8
- Intensity IX
- Death – 8964
- Injured – 21,952
- Mount Everest Avalanche – 21 killed
- Langthang Valley landslide – 250 people missing
- 3.5 million homeless

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- Saturday – schools not in session; and almost noon time – people were working out in the fields
- Destruction of heritage sites in Kathmandu Valley - Kathmandu, Patan and Bhaktapur Durbar Square, Boudhanath and Swayambunath stupas
- Tourism – 20,000 foreign nationals visiting at the time



Source: Conde Nast Traveler

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Secondary Hazard effect - landslides

Source: The Indian Express and NDTV

- Social effects – increase in human trafficking; violence against women and girls; malnutrition in children worsened; children could not go back to schools

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- Imaging technologies – satellite, smart phones – instrumental by providing rapid and systematic mapping of damaged areas
- Mountainous terrain – communication and transportation challenges – use of helicopter for medical evacuation, relief distribution

- Managing international rescue and relief teams and materials – receipt and distribution channel; aid mismatch, sub-standard relief materials, inedible food; distribution delays; custom delays

2009 Eastern Bhutan Earthquake

21 September, 2009; 02:53pm

M 6.1

Death – 12

Damaged properties worth of US$ 52 million

Approximately 7290 people were left without adequate shelter

2009 Eastern Bhutan Earthquake

- No Disaster Management Polices/ACT
- Most of the failure are non-engineered buildings – such stone masonry buildings

- **TURNING POINT**

For Bhutan in the

Disaster Management

Remarks

- Every great earthquake has a lesson to learn – which helps in the change of polices
- We should not wait for great to happen rather we plan and prepare before it happen
- Lets build safe infrastructure

Overview of Results of Earthquake Building Losses

Hazard – Event Definition

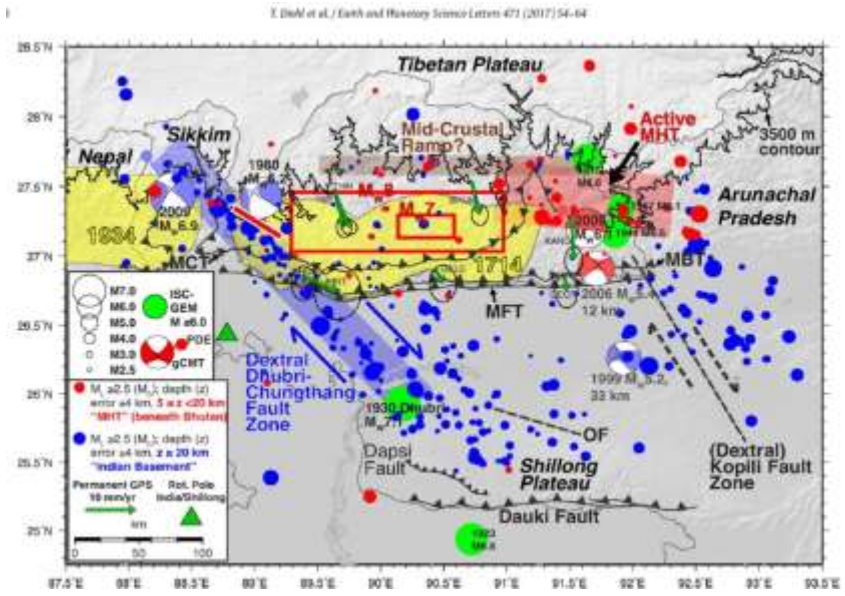
1. **M_w8 event** on the Main Himalayan Thrust (MHT), similar to the 1714 earthquake
   - Rupture geometry inferred from GEM Global Active Faults Database, as well as specific information on the MHT
   - A single planar dip similar to the 2015 Gorkha, Nepal earthquake
   - The epicentre is chosen to be similar to that of the 1714 earthquake in Bhutan
   - The lower depth is estimated based on the temperature distribution in the geologic crust, as well as MMI from similar earthquakes in the region

	Event 1
Fault name	Main Himalayan Thrust
Fault dip	10.0
Mw	8.0
Epicentre Lon	90.467
Epicentre Lat	27.362
Depth	9.985
Rake	90.0
Upper fault depth	0.0
Lower fault depth	20.0

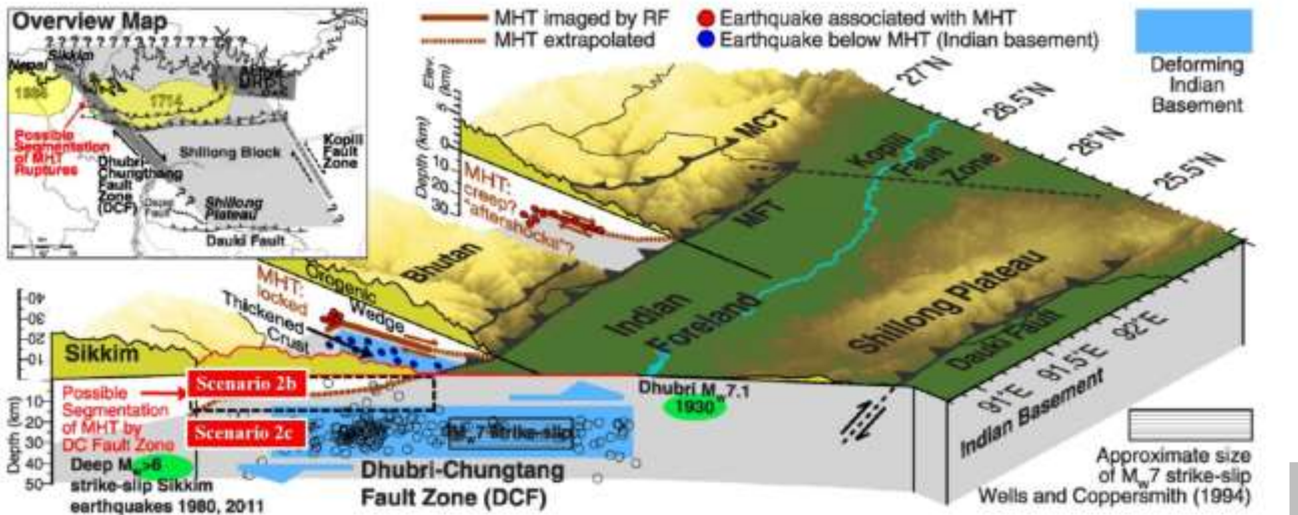
Hazard – Event Definition

2. M_w7 along the Dhubri-Chungthang Fault Zone (DCF):
   - Based on 1980 Mw 6.3 event– same epicentre, strike (301), dip, and rake (rupture proceeds southeast from epicentre):
   - Located below the MHT but with shallower depth than occurred in 1980 (to estimate the shaking Thimphu could expect from a shallower rupture (still below the MHT), we placed the rupture at the highest depth range that still seems reasonable)

	Event 2. c)
Fault name	Dhubri-Chungthang dextral fault – Below MHT
Fault dip	89.0
Mw	7.0
Epicentre Lon	88.817
Epicentre Lat	27.368
Depth	32.0
Rake	-141
Upper fault depth	20.0
Lower fault depth	32.0

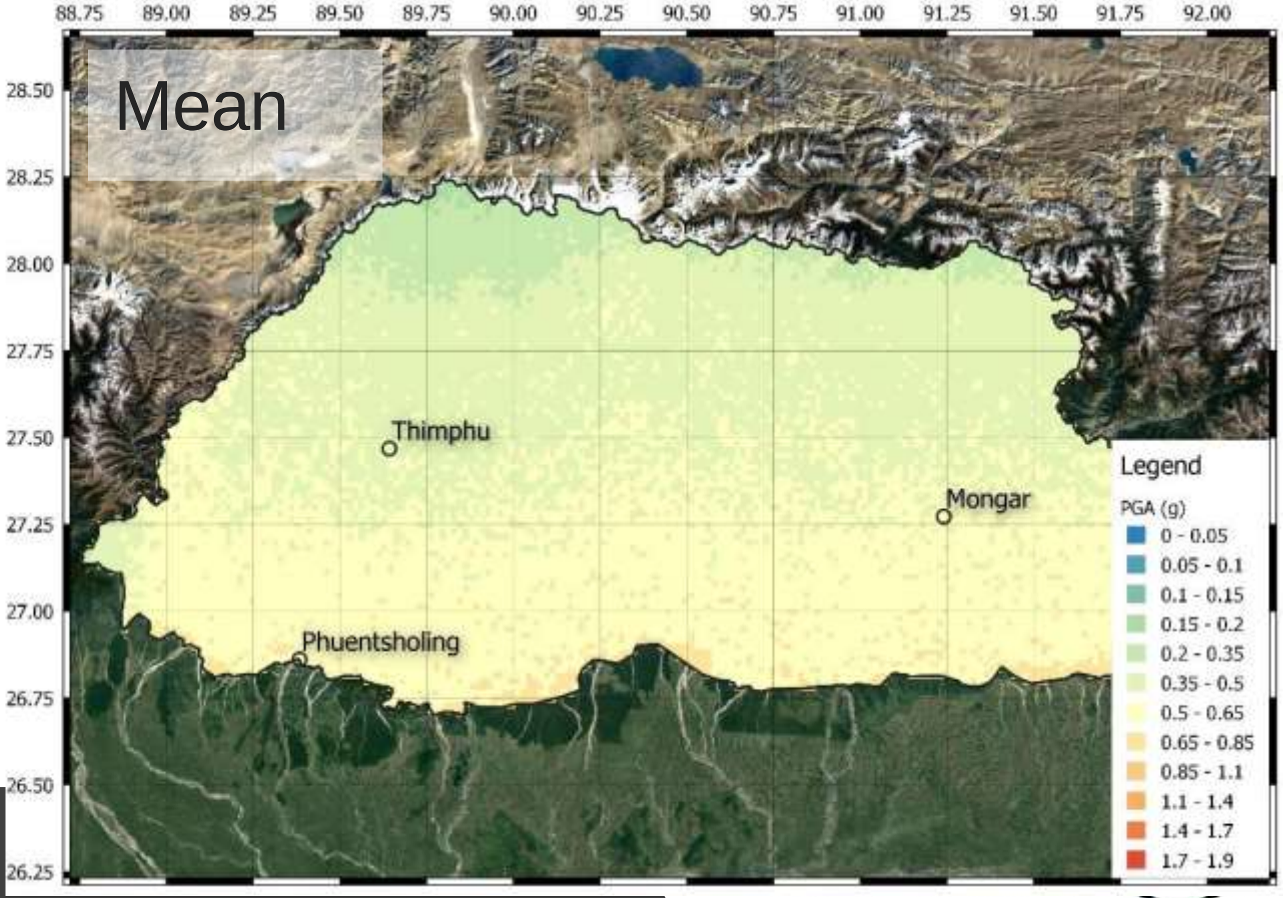


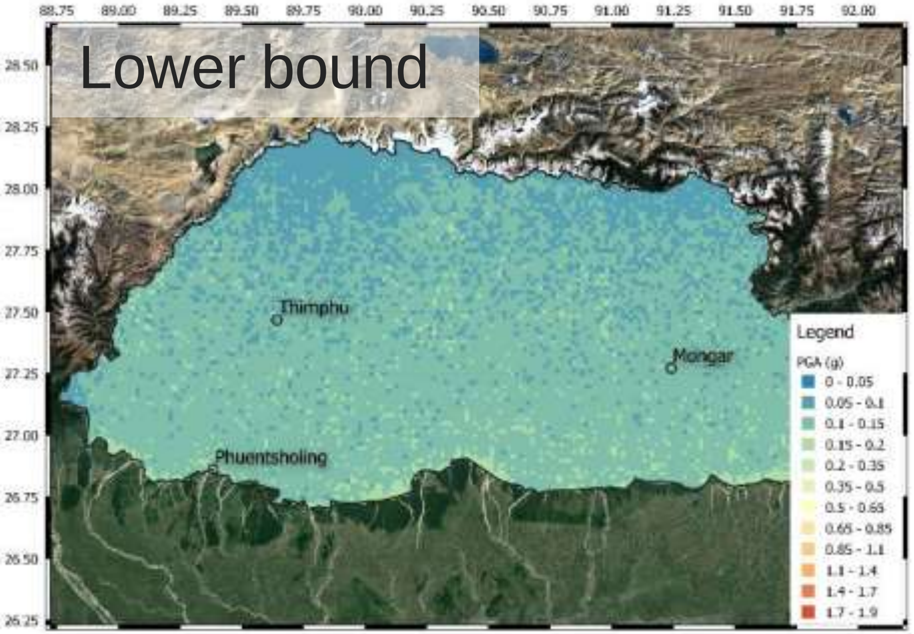
T. Diehl et al. / Earth and Planetary Science Letters 471 (2017) 54–64 61

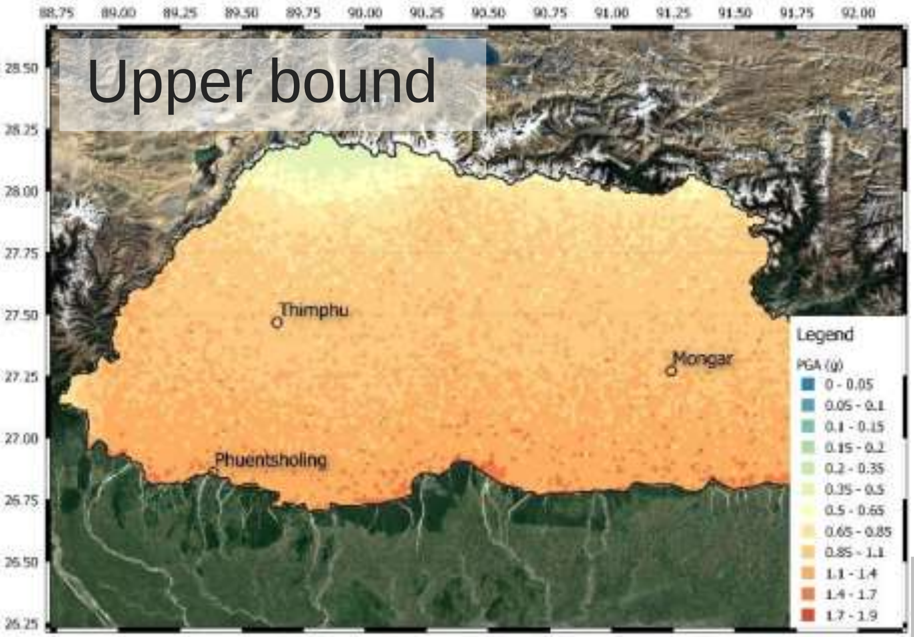


Hazard – Ground Shaking (PGA) Footprints (ShakeMaps)

Event 1 – Mw8 event on the MHT (200 possible ground shaking footprints were produced for each GMPE)

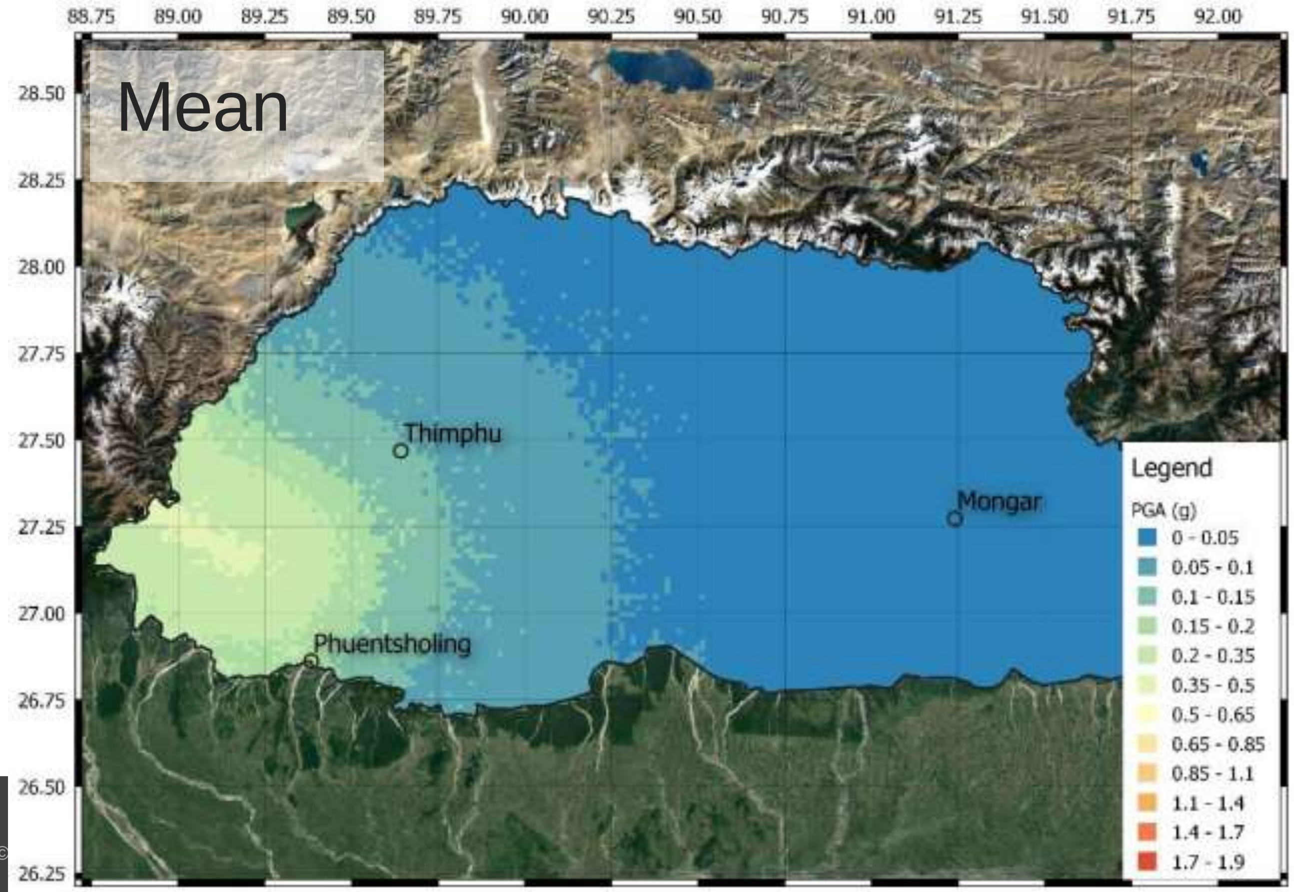


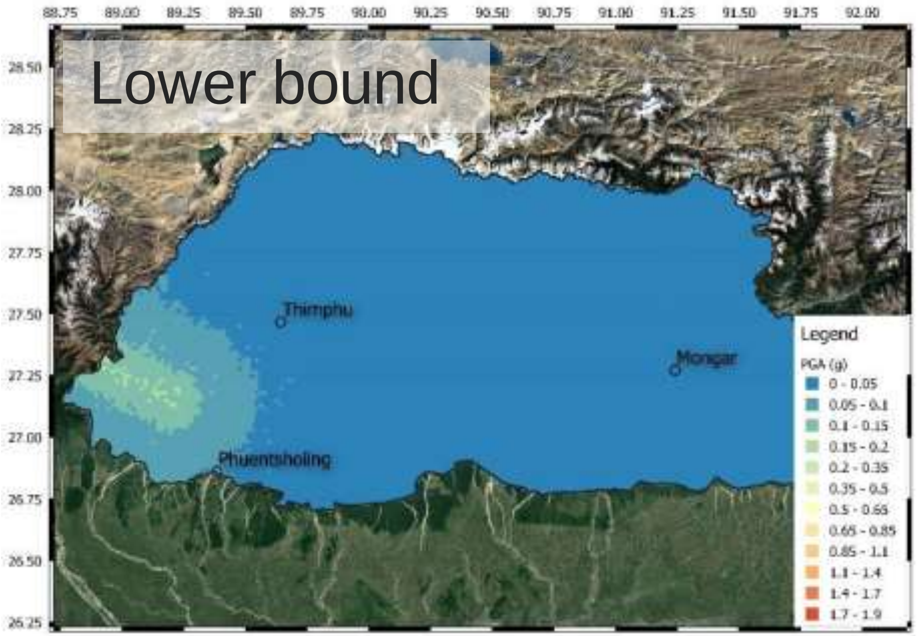


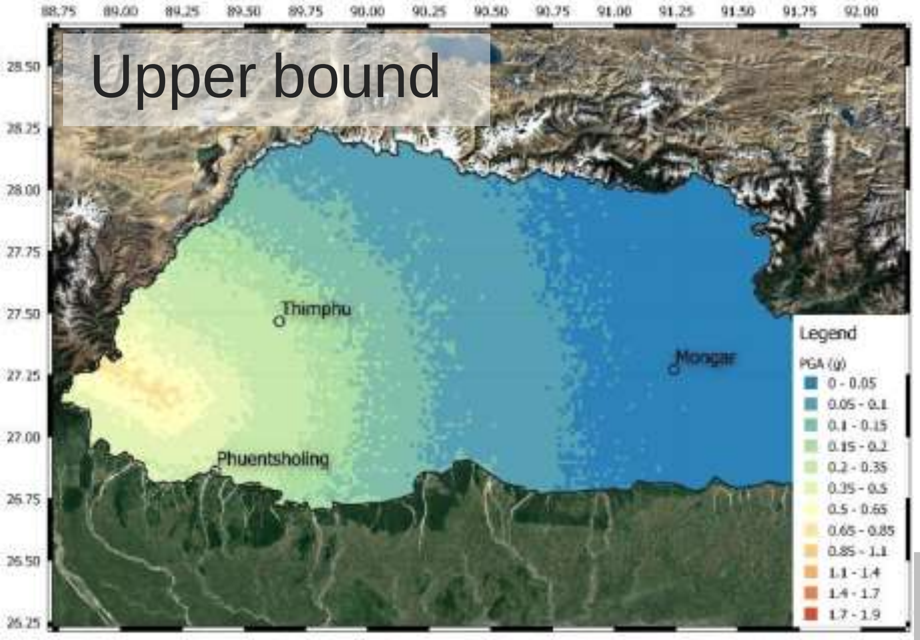


Hazard – Ground Shaking (PGA) Footprints (ShakeMaps)

Event 2 – Mw7 event on the DCF (below MHT) (200 possible ground shaking footprints were produced for each GMPE)







Project working group members

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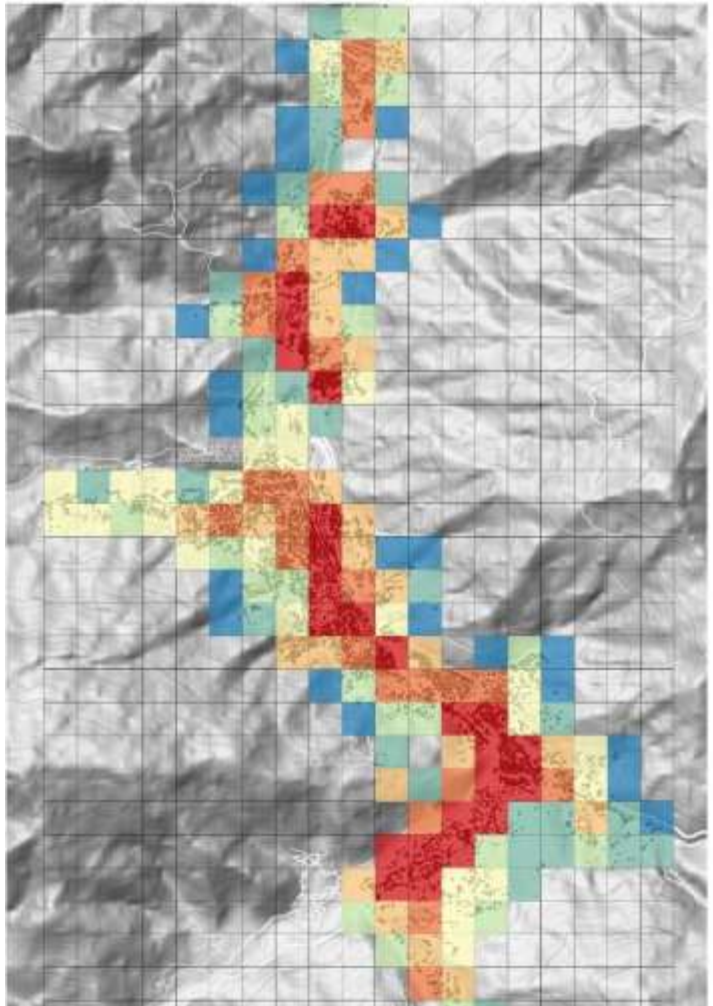
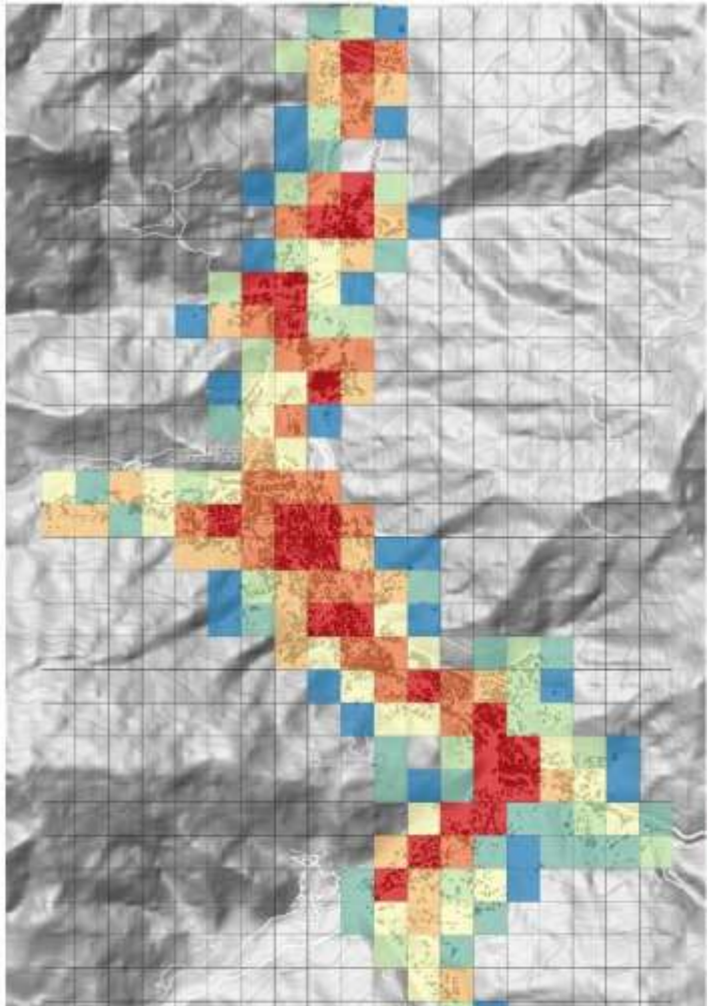
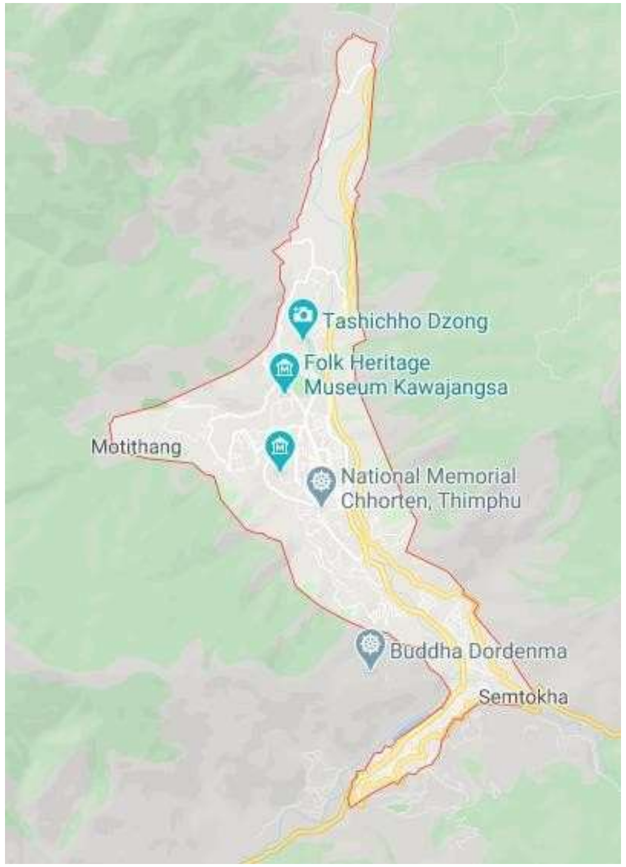
Summary Results

Summary Loss Results – Mw7 and Mw8 Event – Spatial Distribution


Median Loss Map – **Mw7 Event**


Median Loss Map – **Mw8 Event**



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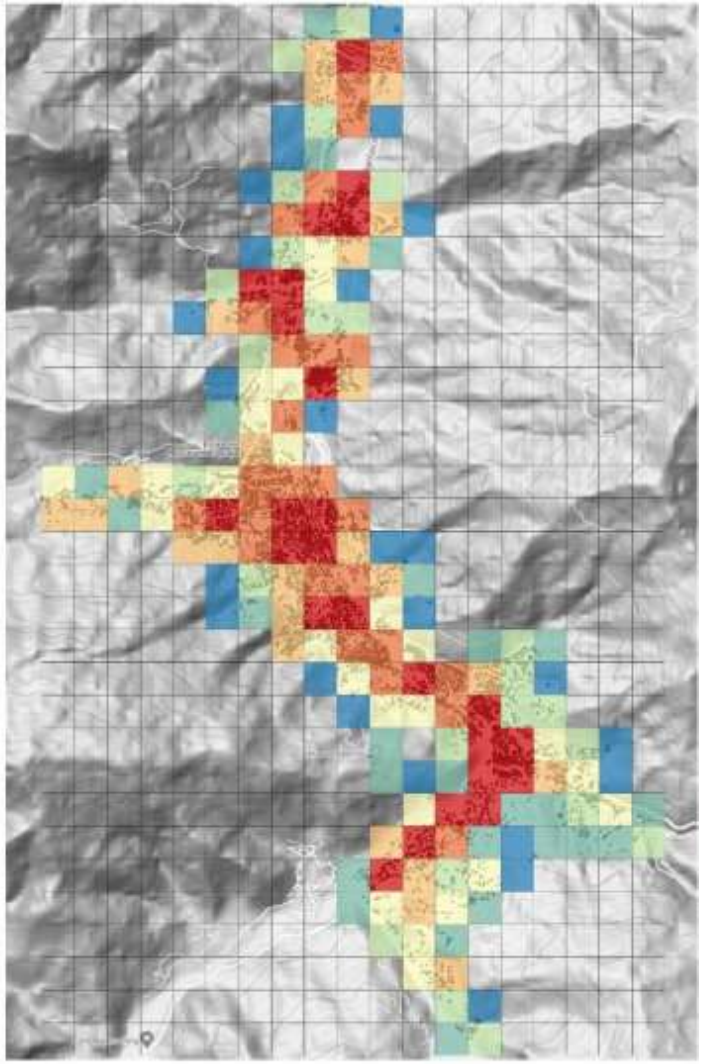
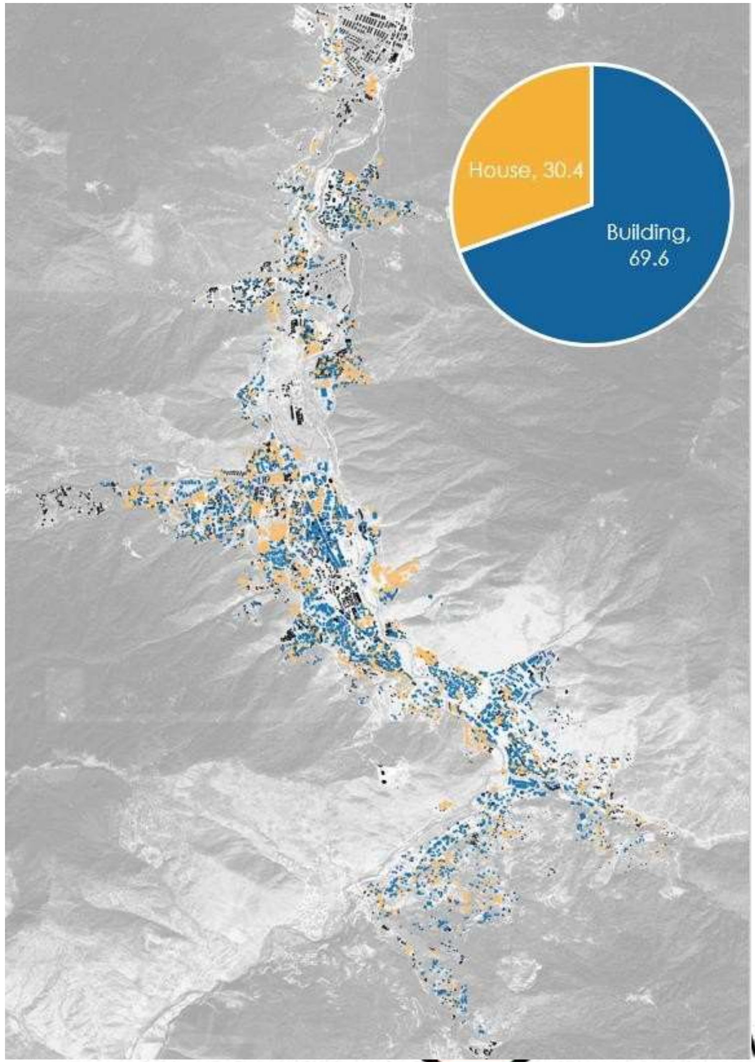
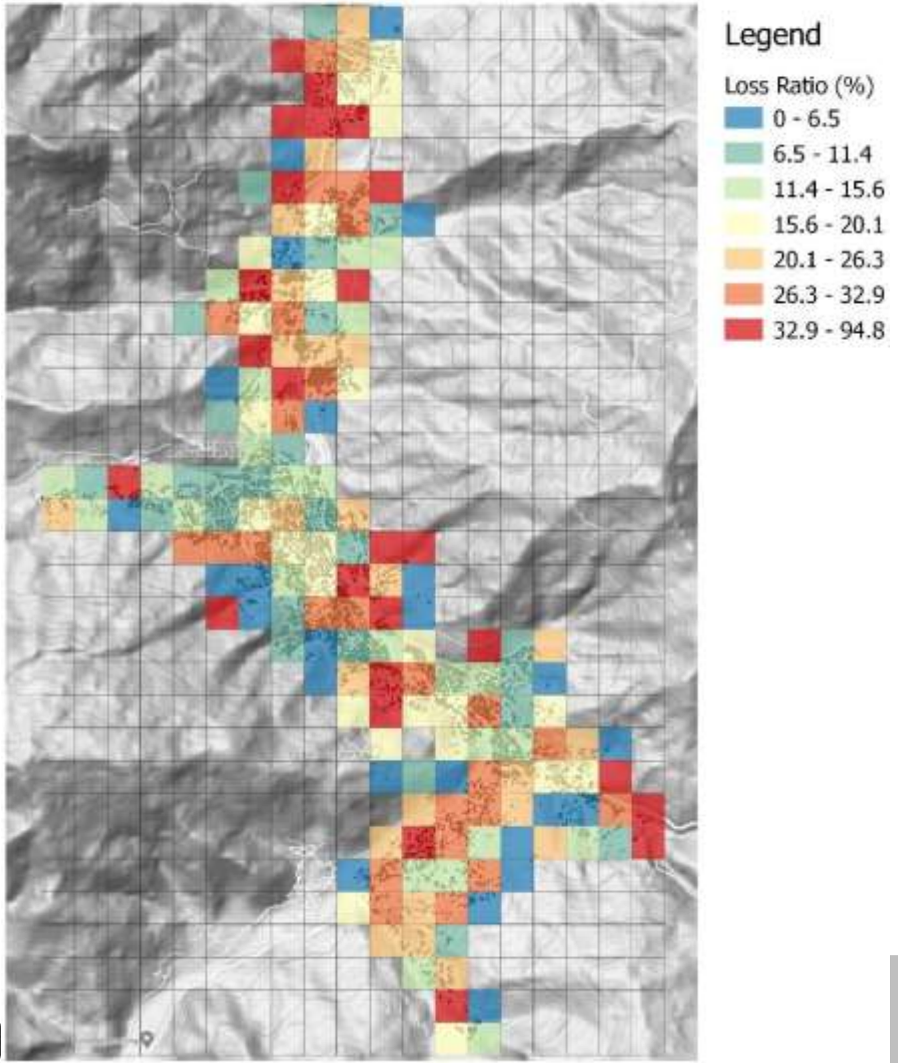
Summary Loss Results – Mw8 Event – Spatial Distribution

Median Event **Loss – Mw8**





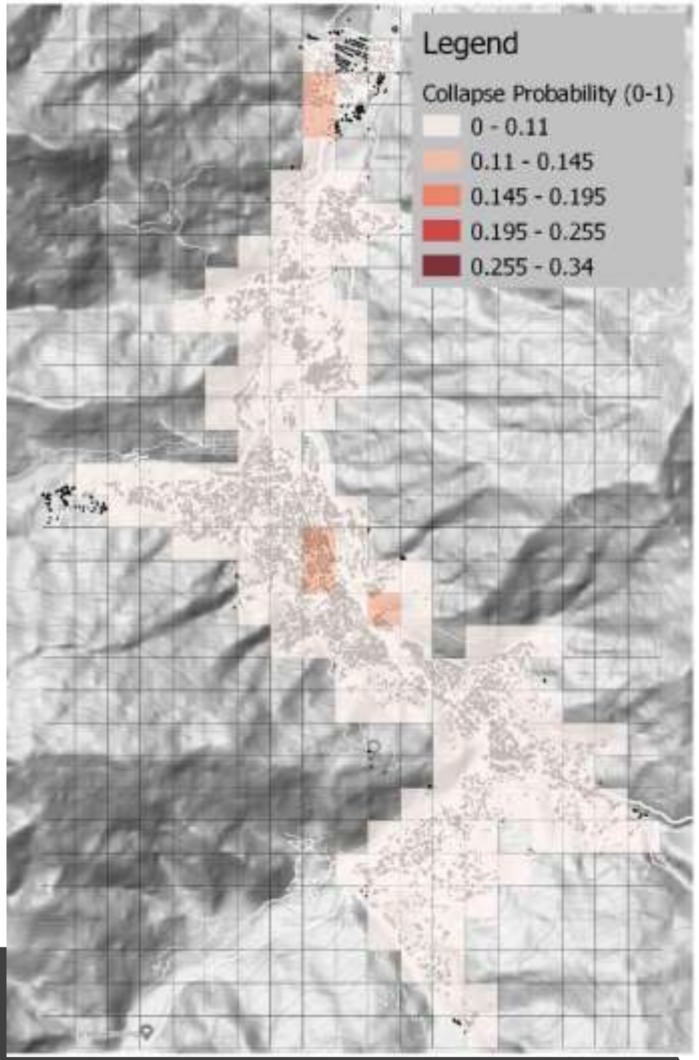
Median Event **Loss Ratio* – Mw8**



***Loss ratio = Loss / Building Value**

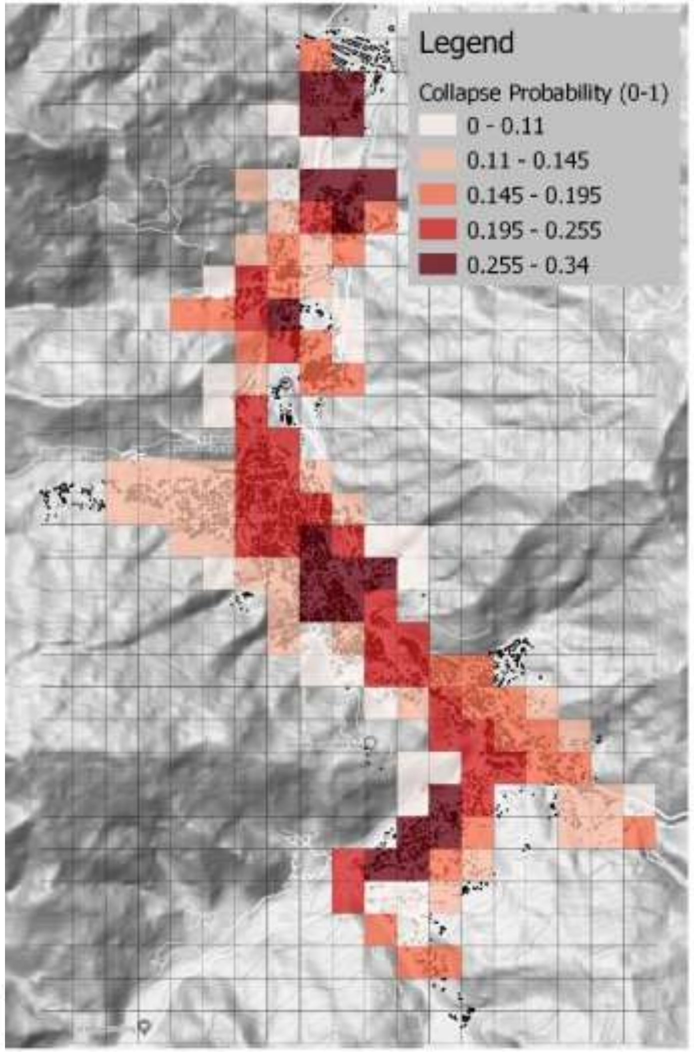
Summary Loss Results – Mw8 Event – Collapse Probability

M8 Scenario – Reinforced Concrete



Expected Collapses = 100

M8 Scenario – Masonry



Expected Collapses = 300

Take-away Results and Conclusions

Best Estimate Results and Conclusions

Mw7

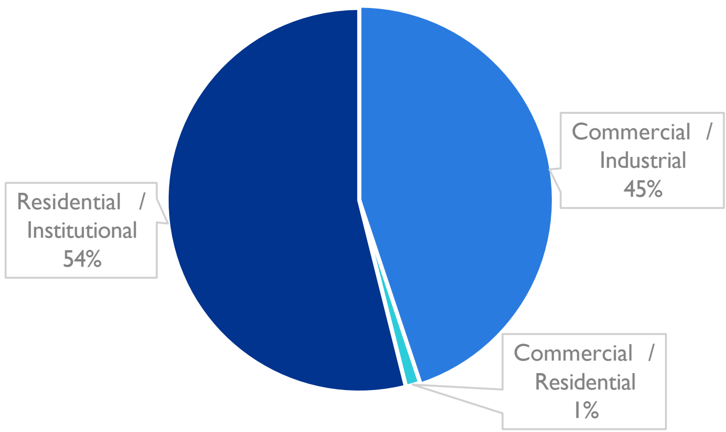
Monetary Losses

- Best Estimate = 50 USD Million
- Upper Bound = 150 USD Million

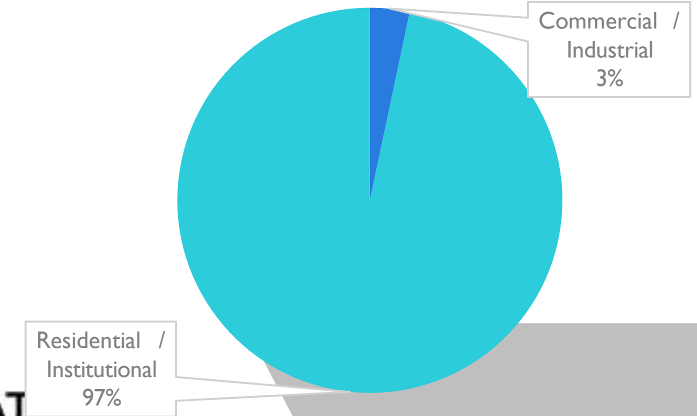
Best Estimate Building Collapses = 10

- RC = N/A
- Masonry = 10

Mw7 Loss per Building Use



Mw7 Collapses per Building Use



Best Estimate Results and Conclusions

Mw8

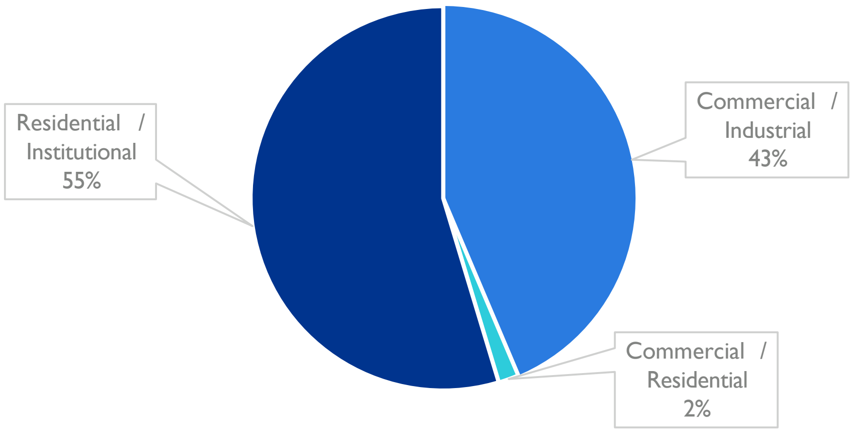
Monetary Losses

- Best Estimate = 400 USD Million
- Upper Bound = 600 USD Million

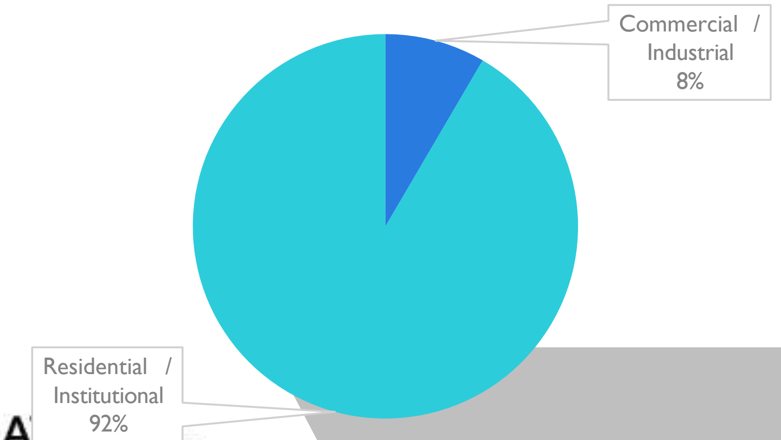
Best Estimate Building Collapses = 400

- RC = 100
- Masonry = 300

Mw8 Loss per Building Use



Mw8 Collapses per Building Use



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Let Build Safe Infrastructure for All!

Thank You!

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