Risk Profile – Pakistan 2005 Earthquake Reanalysis

1. **Significant changes in building typologies have occurred in the affected region and Pakistan at large since the 2005 Kashmir earthquake, yet also a greatly increased capital stock.**
2. **The residential damage expected would be about 10% less relatively to the capital stock from a 2005 Kashmir event occurring again today, but in absolute terms it would be greater at around $1,889mn USD.**
3. **A nationwide exposure model has been produced for Pakistan's residential stock for use in future risk analyses.**

Why are we looking at Pakistan

- The country has had very few risk studies done on the entire country, with largely differing estimates of built capital available via existing natural hazards scenarios and PDNAs.
- Building typologies differ greatly across the country meaning that relative vulnerability changes significantly and needs to be explored.
- A comparison with the flood impact of 2010 can be gleaned for the same country.

Why is this useful to the TTL?

The 2005 Kashmir earthquake scenario is useful to inform the GFDRR and TTLs of a model check of the original PDNA result as well as giving some background as to the potential losses in the residential sector in Pakistan and the change in vulnerability within the area of losses back in 2005.

Why are we doing the disaster scenario?

The "Disaster Scenarios" Pakistan earthquake model can be applied to a probabilistic or deterministic modelling effort in the future. The building of this model allows for future events to be quickly analysed and losses to be determined more easily in the residential and non-residential sector. By reviewing the loss differences today vs. at the time of the event, a full suite of scientific studies, knowledge and expertise has been used, which benefits the production of exposure, hazard and vulnerability models for earthquakes anywhere around the world.

Background and historic losses

The Mw 7.6 October 8, 2005 Pakistan earthquake was the greatest since independence in 1947 and the most lethal killing 73,800 in Pakistan, 1200 in India, thus surpassing the 1935 Quetta earthquake's death toll (38,500). The earthquake severely affected eight districts in Azad Jammu and Kashmir and in Khyber Pakhtunkhwa destroying close to 450,000 houses where nearly 3 million people lived.

Disaster Type	Earthquake		**Deaths**	73,786
Magnitude and Location	Mw7.6 (Kashmir)		**Homeless**	1,250,000-3,500,000
Date	08/10/2005		**Houses existing at time**	23,113,493
Country Population at Time	154,167,000		**People in dam./destr. houses**	4,017,860
Capital Stock at Time (Res.) - $USDmn	84,061		**Houses destroyed**	437,536
Capital Stock at Time (Non-Res.) - $USDmn			**Houses damaged**	136,444

How did we remodel the scenario?

Historic damage data, intensity maps and ground motion recording stations were examined in order to gain the best possible reanalysis of the scenario. USGS Shakemaps were examined however, the intensity data from the survey of Martin and Szeliga (2010) were used and kriged as part of the analysis. This was then correlated to ground motion estimates from the event.

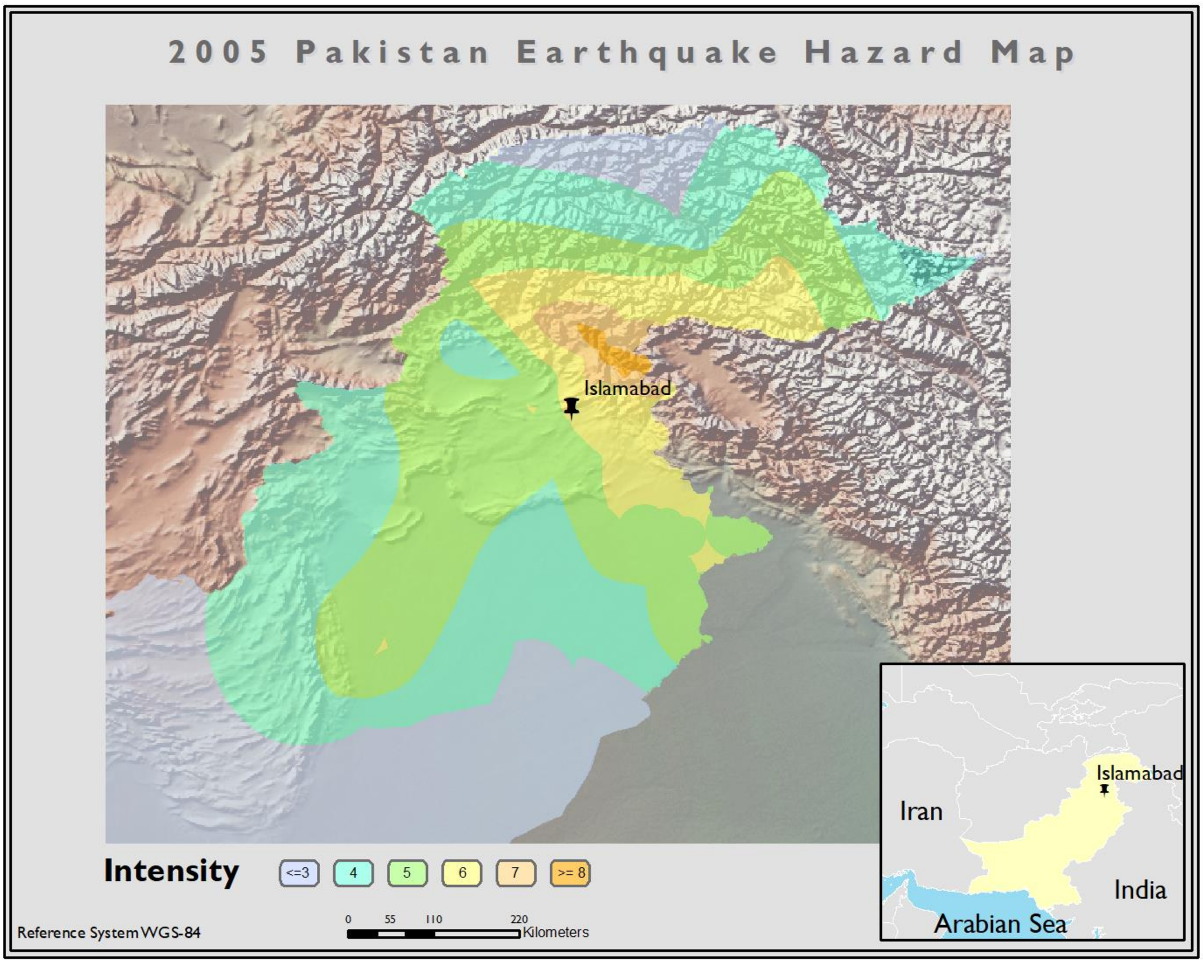

Figure 1: Intensity and ground motion (PGA) map for the 2005 Kashmir earthquake

The assessment of the Pakistan residential buildings exposure was developed for the analysis of the October 2005 Kashmir earthquake. The exposure was estimated using the 2012 LandScan population layer. The residential exposure is at the district level. The last Population and Housing Census in Pakistan took place in March 1998 (a new census was carried out in 2017). A custom shape file of 123 Pakistan districts was developed as many districts were either split or merged in the last 20 years. The data of the 2014-15 Pakistan Social & Living Standards Measurement Survey (PSLM) were used to characterize the housing stock by its outer wall type (PSLM is a 1 per 300 household living conditions survey). This survey covers 100 districts i.e. it includes most of the districts in the 5 non-autonomous provinces (ca 93% of the Pakistan population). Appropriate queries were developed in order to extract the necessary data. For the remaining districts the 1998 census data as shown in Appendix I of the University of Karachi report entitled “WP4-Seismic Vulnerability Assessment of Existing Buildings of Pakistan” were used with appropriate projections both in terms of numbers and typologies. For the districts affected by the 2005 earthquake in Azad Jammu and Kashmir (Bagh, Muzaffarabad and Poonch) that were not included in the PSLM survey, the replacement of nearly 237,000 destroyed dwelling units with new types of construction has been taken into account by reference to the literature and the ERRA district reports. The key indicator of people per dwelling unit (irrespective of wall type) was derived from the PSLM survey for each district as well as our own analysis for the 20 districts not included in the PSLM survey. The number of dwellings in 2012 was estimated at 31 million units, with average occupancy being 6.12 persons as opposed to 6.71 in 1998. This includes owner occupied as well as rented, vacant dwelling units. For dwelling size we used the PSLM survey (we obtained number of rooms and outer wall type cross tables) allowing for 25 square meters per room. The average dwelling size in Pakistan was thus considered to be 59.6 square meters. For the unit cost of construction we referred to the numerous Pakistan specific reports in World Housing Encyclopedia and well as to the Earthquake Reconstruction and Rehabilitation Authority reports. We have allowed higher unit costs in the 8 major cities of Pakistan (7 cities with 1998 population greater than 1 million and Islamabad). The exposure is adjusted to the Gross Capital Stock of Pakistan allowing for devaluation of older buildings. The Pakistan residential exposure sums to 169039 million USD (Fig. 2). In Fig. 3 the district-level per capita residential exposure is shown. It ranges between 133 and 2005 USD as it is influenced by the house typologies, dwelling sizes and the mean size of the households in each district.

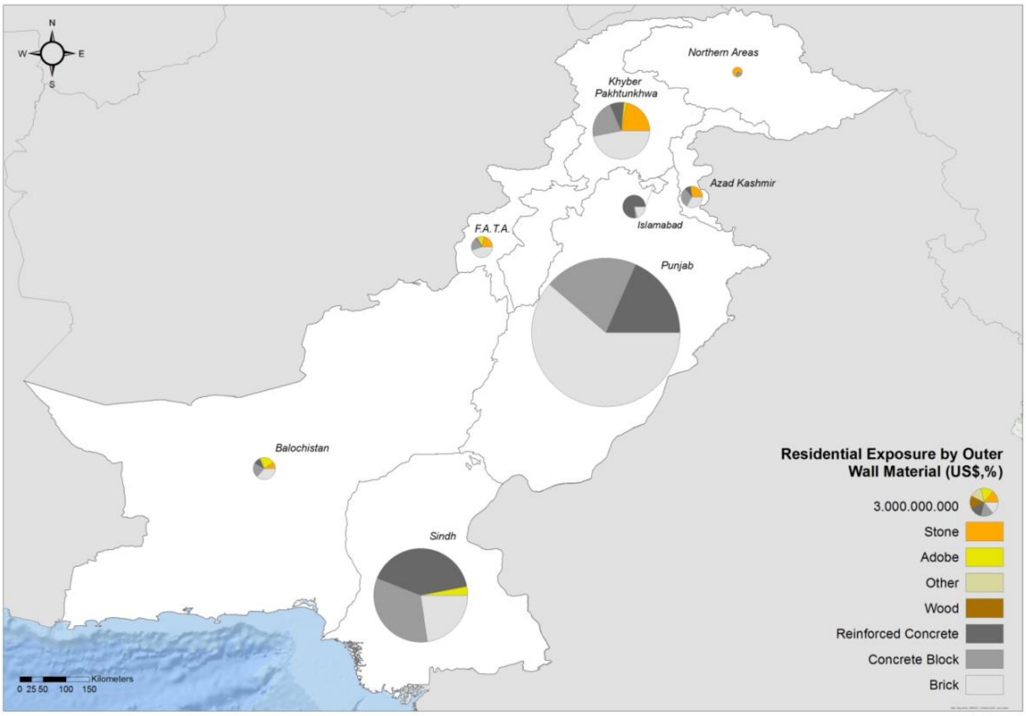

Figure 2: Residential exposure in Pakistan. The map shows the size of the exposure in USD (scaled pie charts) and its breakdown into outer wall typologies for each of the 8 provinces.

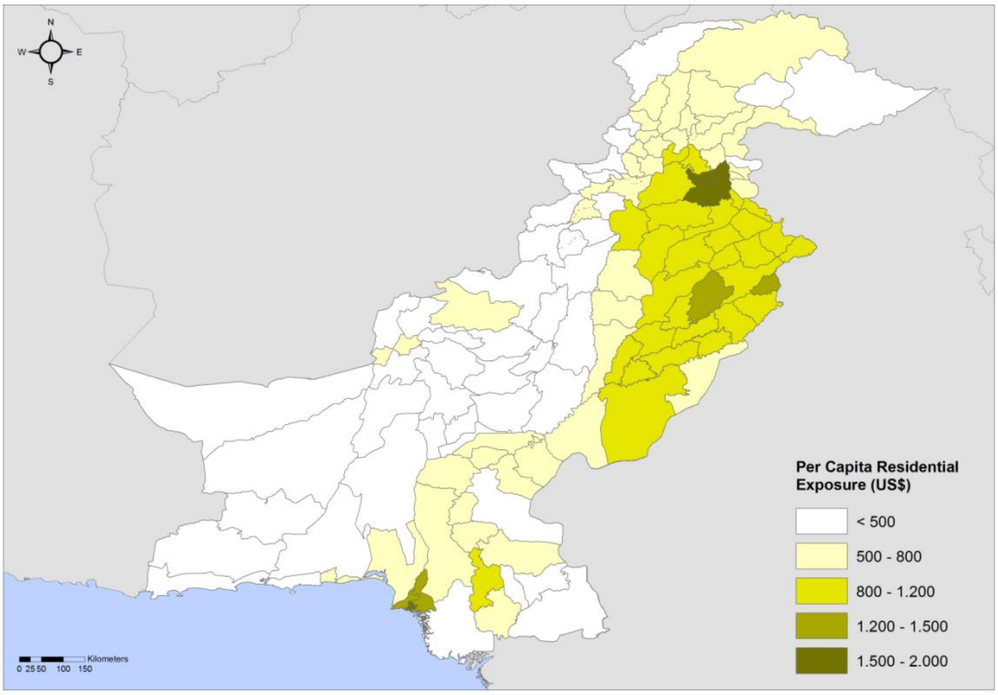

Figure 3: Per capita residential exposure in Pakistan (in USD) at district level.

Vulnerability of structures was examined on the basis of many post-earthquake surveys undertaken in Pakistan including Maqsood and Schwarz (2008) which gave indications as to the vulnerability. Vulnerability functions were also informed by the work of Haldar et al. (2013).

What are the potential losses due to the reanalysis?

	Historic	Modelled
Residential Damage (mn USD)	1031	1889
Residential Stock (mn USD)	84061	169039
Exposed Residential Stock over MMI6		23975
Residential Loss Ratio	1.23%	1.12%

Losses were comparatively lower in the region for the reanalysis, given the significant exposure change which had occurred post-2005. The replacement of stock has caused a vulnerability reduction and thus lower losses resulted than the 2005 event. The stock reduction can be seen in the work of Maqsood and Schwarz (2010) where a significant reduction was seen in the adobe typology post-Kashmir, with this replaced by mostly stone masonry and other forms of brick and block masonry, thus improving the vulnerability significantly.

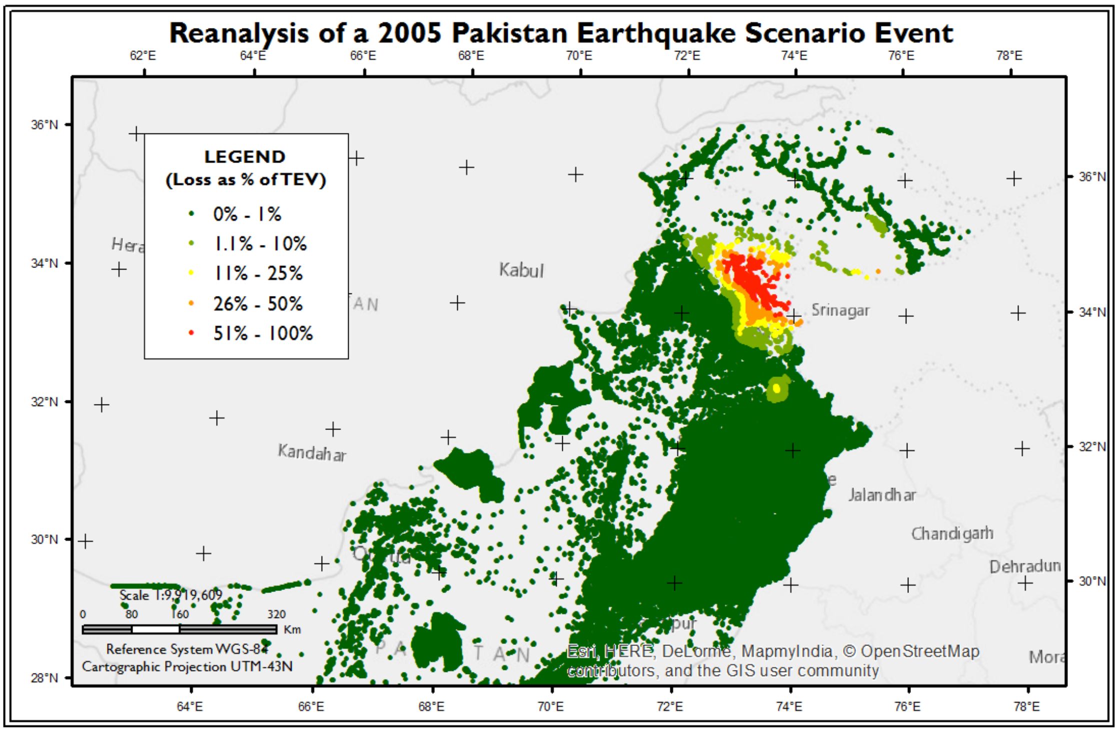

Figure 4: Relative losses at a 250m geocell resolution.

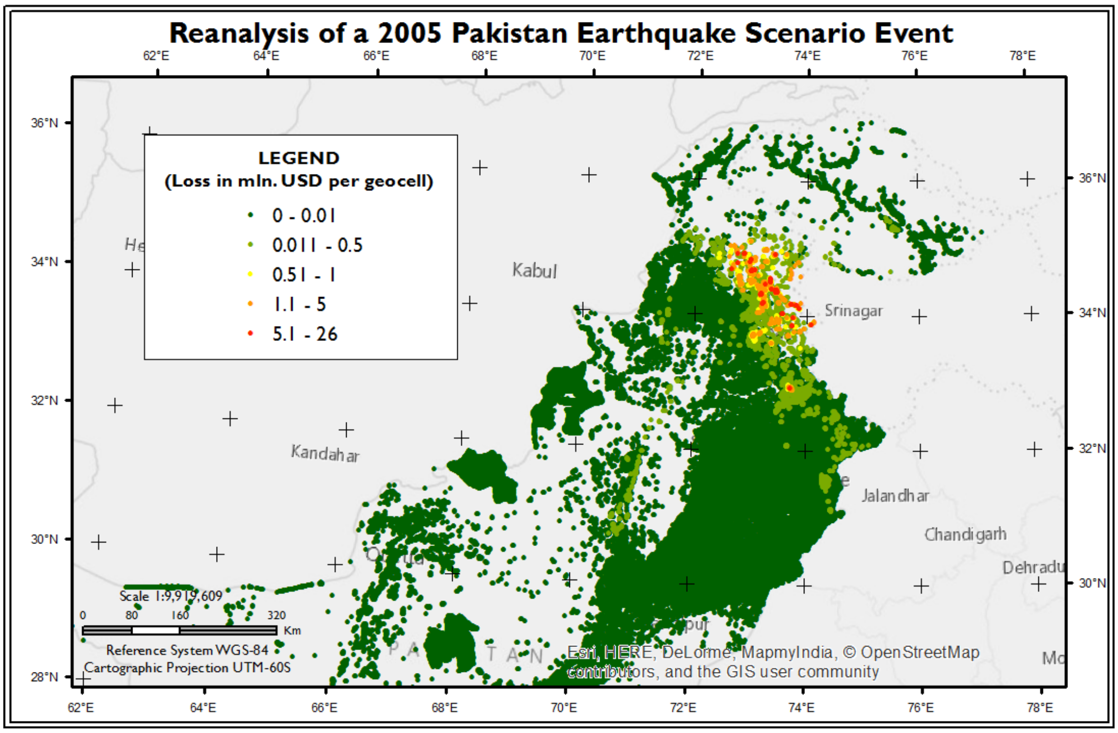

Figure 5: Absolute losses in million USD at a 250m geocell resolution.

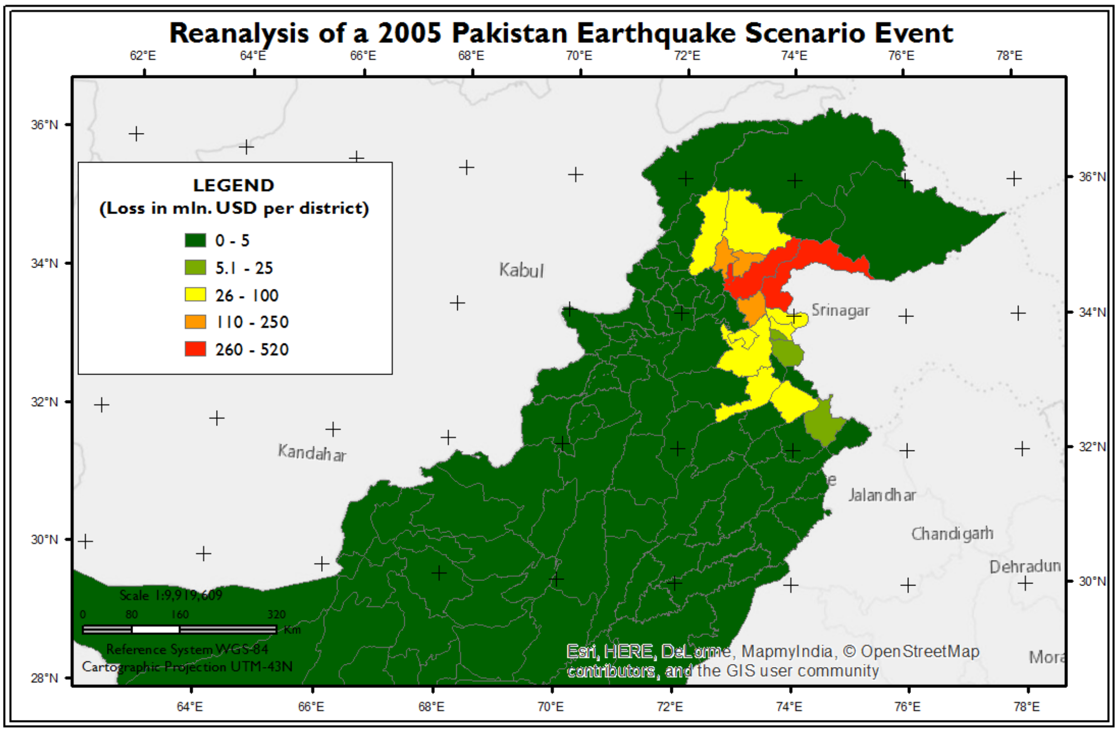

Figure 6: Absolute losses on an administrative level 2 unit (districts) (Loss as a % of Total Exposed Value)

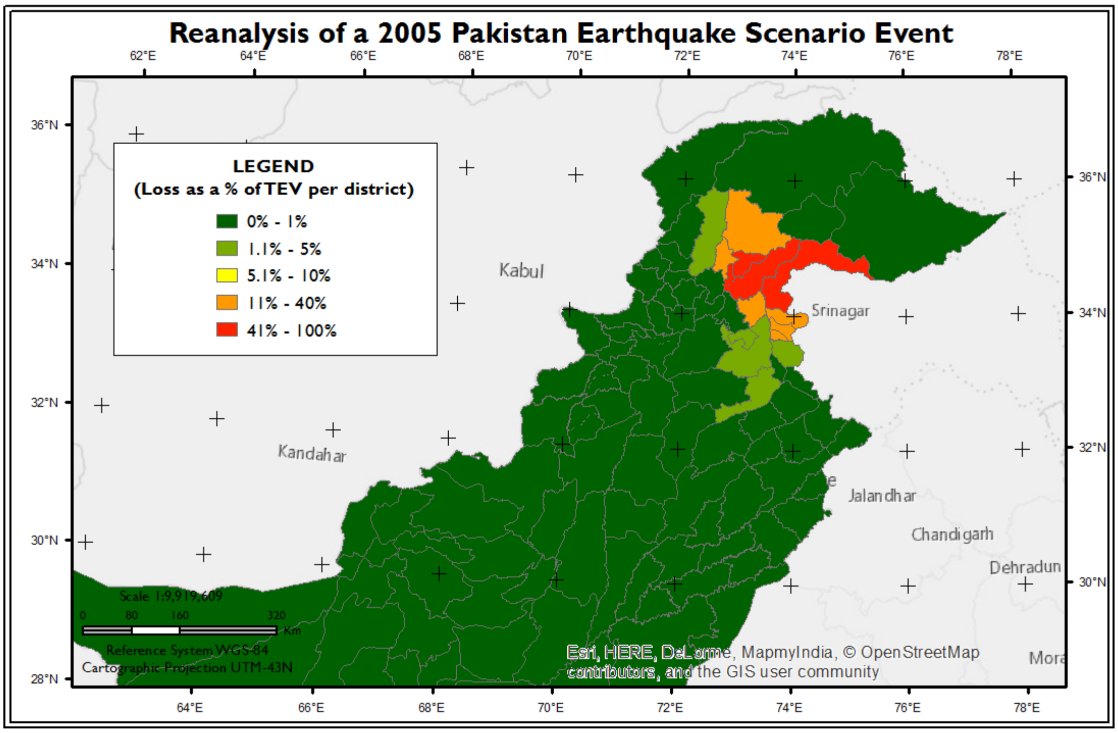

Figure 7: Relative losses on an administrative level 2 unit (districts) (Loss as a % of Total Exposure Value)

The losses were concentrated around the MMI7+ region, with significant losses affecting many of these districts with at least 50% of residential capital stock destroyed. In the regions with softer soils to the south of the epicentre, damage still occurs but not in the same order as the weak masonry areas close to the epicentre. Vulnerability functions have been applied using lognormal functions which allow for 100% destroyed at a certain level of ground motion. In reality, different building typologies have much variation, and the ground motions will also differ greatly in close proximity leading to lower losses than 100%. Thus for the worst districts, this modelling technique yield conservative results.

Table: Largest losses by administrative level 2 (districts)

District	Province	Population (ppl)	Exposed Stock ($USDm)	Loss ($USDm)	Loss Ratio (%)
Mansehra	Khyber Pakhtunkhwa	2577333	1188.1	517.2	43.53%
Muzaffarabad	Azad Kashmir	1057608	399.9	331.8	82.98%
Abbottabad	Khyber Pakhtunkhwa	1818695	800.4	203.5	25.43%
Batagram	Khyber Pakhtunkhwa	626052	272.7	197.9	72.55%
Shangla	Khyber Pakhtunkhwa	753985	388.4	130.5	33.60%
Rawalpindi	Punjab	6567231	7524	99.4	1.32%
Islamabad	Federal Capital Territory	2119866	2443.1	80.6	3.30%
Bagh	Azad Kashmir	654017	228.1	78.6	34.48%
Jhelum	Punjab	1776309	1430.9	47.6	3.33%
Poonch	Azad Kashmir	579713	344.6	46.1	13.39%
Kohistan	Khyber Pakhtunkhwa	956706	365.1	44.7	12.24%
Swat	Khyber Pakhtunkhwa	2641928	1174.8	27.8	2.37%
Gujrat	Punjab	4223041	2900.1	26.3	0.91%
Sudhnati	Azad Kashmir	372239	104.3	11.5	11.06%

What is the return period of such an event?

Using GAR2015, the return period of an event loss is in the order of 150-175 years, after refactoring residential portions of loss, for the EP curve. Using the 2015 risk profile of GFDRR/World Bank, this loss estimate would be around a 40-45 year event according to their PML curve (Report 94474-PK, World Bank Group).

On the basis of historical events, the 1935 Quetta, and 1945 Makran earthquake are the only events to also be around 1% of capital stock impacted. The 1935 event were it to occur today, could also impact in the order of 1% of capital, and thus be close to that of the 2005 event. This would suggest that a return period of under 100 years would be reasonable.

Why was it important to collate the data?

The 2005 Kashmir earthquake was one of the most deadly events since 1900 yet very few reanalyses of the event have been undertaken using a full country exposure. The estimation of capital stock and building typologies allows for future events to be analysed.