Risk Profile – Armenia 1988 earthquake

1. **The 1988 Armenia earthquake caused between $150-200 million (in 1988 US dollars) of damage to the residential sector; and ca. $900 million capital and $500 million productive sector damage and losses.**
2. **A reanalysis of the 1988 Armenia earthquake for today's residential exposure using the changed building stock and updated vulnerability functions suggests around $420 million in damage. The reconstruction costs are expected to be higher with improved construction standards needed for new buildings.**

Why are we looking at Armenia

- The losses resulting from the 1988 Armenia earthquake are among the least understood earthquakes in the last 30 years, mainly because of the uncertainty on its economic impact, and the historical changes in the USSR at the time of the event.
- The Armenian building stock consists mainly of pre-1988 Soviet stock, making an interesting case for reconstruction, replacement and depreciated stock.
- With high future earthquake risk, the characterisation of an accurate buildings vulnerability schema and country exposure is needed.

Why is this useful to the TTL?

The Armenia scenario is useful to inform the GFDRR and TTLs of the effects from a potential reoccurrence of such an event as well as giving some background as to the potential losses in the residential sector. It also provides lessons as to the collection within a PDNA in a future disaster as well as a new yardstick as to the economic impact at the time of the event.

Why are we doing the disaster scenario?

The "Disaster Scenarios" Armenia model can be applied to a country-level 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 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 earthquake anywhere around the world.

Background and historic losses

The December 7, 1988 Spitak (Northern Armenia) earthquake was one of the largest earthquakes to strike Armenia. With a magnitude Mw6.8, very shallow hypocentre and vulnerable building stock, it caused huge damage in the cities of Gyumri, Spitak and Vanadzor and surrounding rural areas. There was no damage in the capital Yerevan. Around 25,000 people were reported to have lost their lives, but due to mass exodus of population etc., this number has some uncertainties.

Disaster Type	Earthquake	**Deaths**	25,000
Magnitude and Location	Ms6.8 (Spitak)	**Homeless**	517,000
Date	07/12/1988	**Houses existing at time**	868,391
Country Population at Time	3,777,500	**People in dam./destr. houses**	561,150
Capital Stock at Time (Res.) - $USDmn	2,123	**Houses destroyed**	61,000
Capital Stock at Time (Non-Res.) - $USDmn	n/a	**Houses damaged**	68,000

The economic loss of the event has even more uncertainties with estimates such as $14 billion (Munich Re) being commonplace. As part of the reanalysis, a new value for the event of $1.1-1.7 billion is estimated; with only around $150 million of damage to the housing sector based on much reanalysis of capital stock and productive sector GDP. Around 8% of the residential capital stock of the country was affected as part of this earthquake at the time.

At the time it was reported that the earthquake would cost 13.3 billion rubles. Although the official rate of the USSR ruble to USD at the time was 0.9; the black market and real exchange rate in terms of construction value was 8.8. This is also related to the estimated GDP of Armenian SSR in 1988 at around $1.5-2.1 billion. Using Gillula (1984), Alexashenko (1992) splits of capital stock across the Armenian SSR were able to be produced for the housing sector as well as other capital markets. This correlated well with the quoted loss results in readjusted USD.

Estimated value of 1988 earthquake losses

Capital stock losses = $850-900 million; Built reconstruction cost = $1360 million (due to "build-back-better" costs)

Housing	**$150 million**
Other Buildings (ca. 60% of housing)	**$100 million**
Productive Capital	**$450 million**
Roads/Bridge/Railways	**$120-200 million**

Productive Sector losses = $525 million; Cross-Sector losses = $140 million in relief, temporary housing etc.

How did we remodel the scenario?

The buildings exposure of Armenia was built up from a number of studies but mostly from the National Statistical Service of the Armenian government. There are significant building typology differences across the country, and these were taken into account when producing the analysed scenario.

Historic damage data, intensity maps and ground motion ordinate maps were examined in order to gain the best possible reanalysis of the scenario.

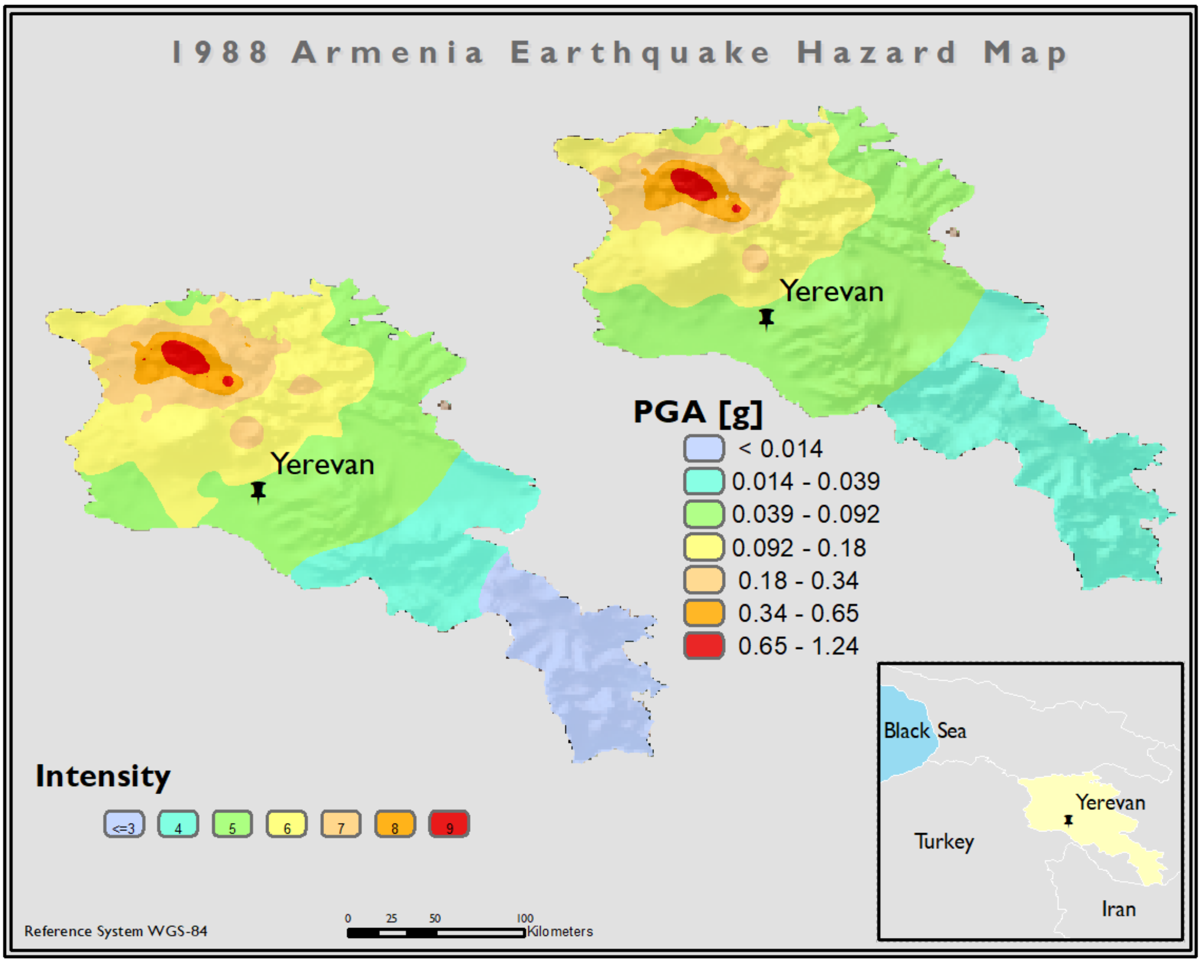

Figure 1: Hazard map showing Modified Mercalli intensity and PGA of the Armenia 1988 Scenario

During the 1988 earthquake around 350 multi-story apartment buildings of various structural systems with 4 to 16 floors containing around 10000 housing units collapsed causing the death of about 20500 people, while buildings of other structural systems stood undamaged or moderately damaged nearby. In addition several thousand low-rise unreinforced stone masonry single family houses also collapsed across urban and rural areas killing another 4500 people. Ground motion amplification was also thought to contribute to the demise of many 9 story buildings that collapsed in Gyumri as their counterparts in Vanadzor had suffered moderate damage. In Armenia the last Population and Housing Census was carried out in 2011 and includes information about the period of construction of the housing units. Following the 1988 disaster and independence in 1991, a new earthquake code was introduced. Furthermore with the end of the centralized economic system and privatization of housing, production of housing using new, more modern structural typologies emerged. However due to various reasons, including a state of war with neighbouring Azerbaijan, meant that economic recovery in Armenia has been rather slow and the post-1990 housing stock is estimated to amount to only about 13% of the total built floor area in 2016. As a result in the earthquake affected region in Northern Armenia, as well as in the rest of the country people still live in Soviet-era buildings that provide no safety during strong seismic ground motion and are now mostly dilapidated or in a poor state of maintenance. A vulnerability schema therefore has been developed taking into account these factors in order to convert the 2011 housing census data into an as much as possible adequate portrayal of the distribution of population and residential built floor area and associated replacement value by structural vulnerability class (Fig. 2).

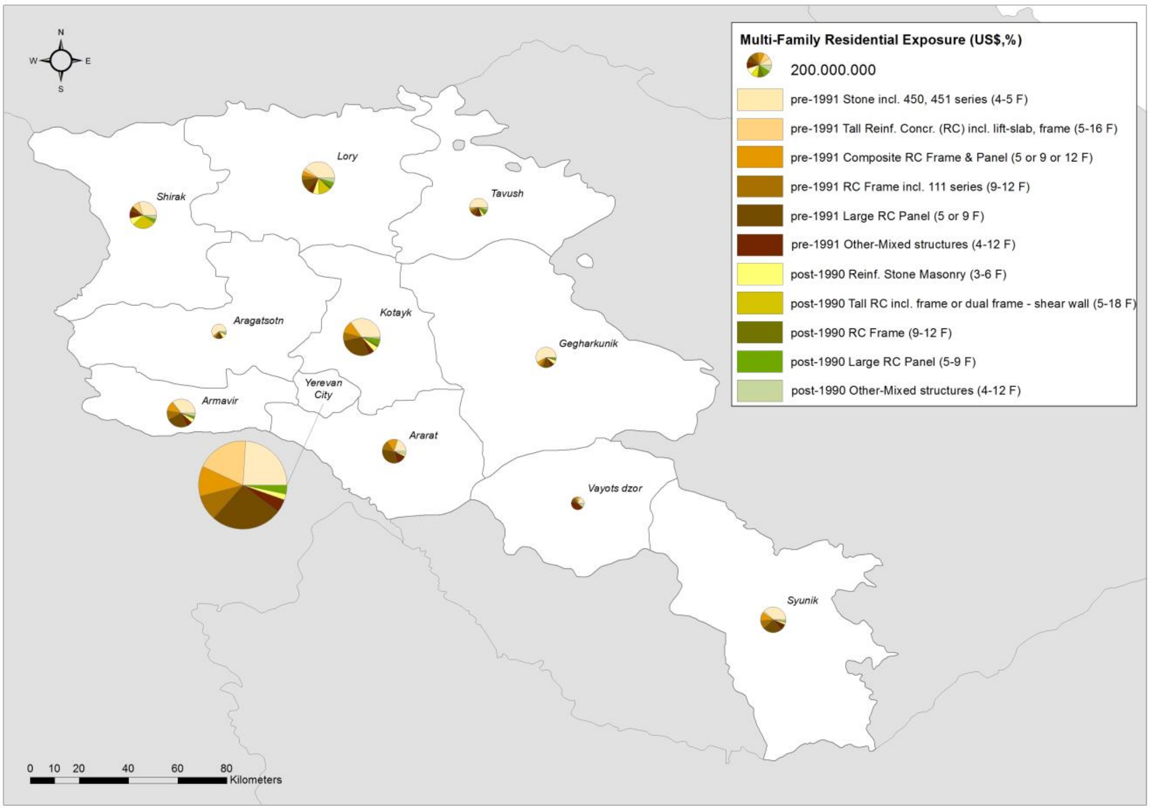

Figure 2: Multi-family residential exposure in Armenia (2016). The map shows the size of the exposure in USD (scaled pie charts) and its breakdown into vulnerability classes including construction before and after independence (1991) in the 11 provinces.

Studies of Pomonis (1989) as well as JICA (2012) for Yerevan City and GeoRisk (2011) for Gyumri City have been taken into account. The Armenia vulnerability schema splits the Armenian dwelling stock into single and multi-family occupancy, in the urban and rural areas of each of the 11 provinces, for houses built prior or since independence in 1991. The single-family houses that account for around 56% of the total built floor area of 92 million square meters (in 890,000 housing units), are subdivided into 3 vulnerability classes (stone masonry, wooden and other-mixed). Houses in multi-family buildings account for around 44% of the existing in 2016 built floor area and are split into seven structural classes, two of which (the most vulnerable) are no longer practiced after independence. The exposure sums to 5635 million USD in apartment buildings (Fig. 2) and 4155 million USD in single-family houses. Around one sixth of the exposure is in the two provinces affected by the 1988 earthquake (Lori and Shirak). At the province level there is relatively uniform distribution of the per capita residential exposure ranging between 2784 and 3648 USD, with bigger differences between urban and rural parts of each province (Fig. 3).

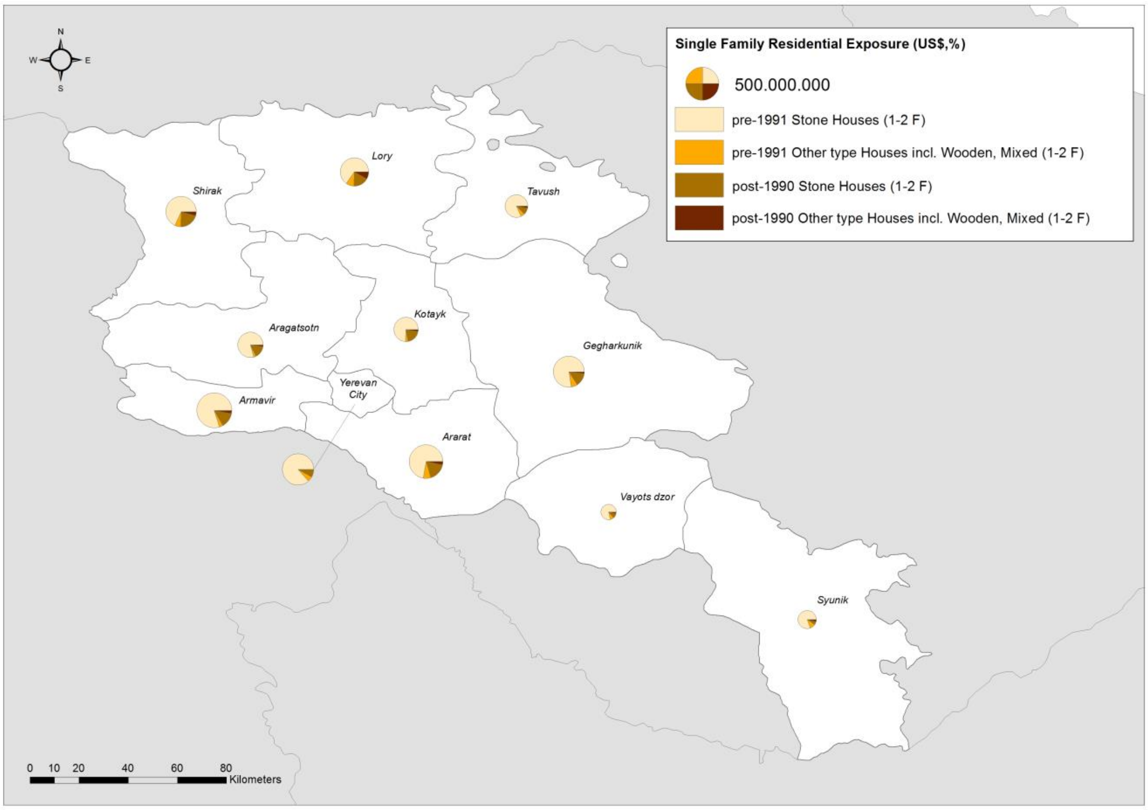

Figure 3: Single-family residential exposure in Armenia (2016). The map shows the size of the exposure in USD (scaled pie charts) and its breakdown into vulnerability classes including construction before and after independence (1991) in the 11 provinces.

Given the large number of high-rise buildings and Soviet style building typologies, accurate characterisation of the spectra as well as the exposure was required in order to resolve the losses when derived back into PGA-based functions.

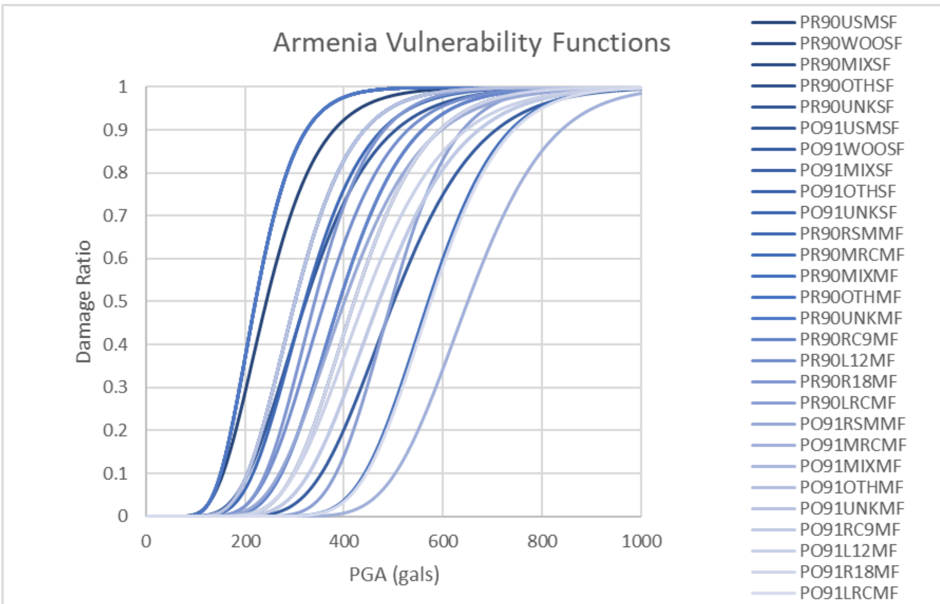

Figure 4: Vulnerability functions as developed for single-family and multi-family residential buildings, for pre-1990 and post-1991 stock.

The **vulnerability** of the built structures was characterised within various projects including those mentioned above via JICA and studies for Gyumri City, as well as from observed damage data from the 1988 earthquake.

What are the potential losses in Armenia from a repeat of the 1988 earthquake?

	Historic	Modelled
Residential Damage (mn USD)	150	419
Residential Stock (mn USD)	2123	9791
Exposed Stock over MMI6		3816
Residential Loss Ratio	7.06%	4.28%

When comparing the present-time losses versus the historical ones, it can be seen that the absolute values today are higher than that of 1988, with $419 million loss expected. However, in relative terms this is a reduction. The $150 million estimate of 1988 has many uncertainties associated with it (similar to the estimate of residential capital stock value being $2.12 billion in 1988).

Our analysis shows that the main reasons for the reduction in the residential loss ratio are a) significant outmigration from Northern Armenia to other parts of the country and abroad and b) the fact that at present the mix of buildings in the affected area is less vulnerable as the Soviet apartment blocks that collapsed or were damaged beyond repair were slowly but surely replaced with new less vulnerable construction. The population in the cities of Gyumri and Vanadzor (Armenia's second and third biggest cities) is now around half of what it used to be in 1988 as recovery has not yet fully taken place. At the same time other cities and regions in Armenia and especially Yerevan (threatened by the Garni fault) have large parts of their population occupying pre-1988 buildings that provide little safety during strong ground motion and this is a big concern for Armenia's future.

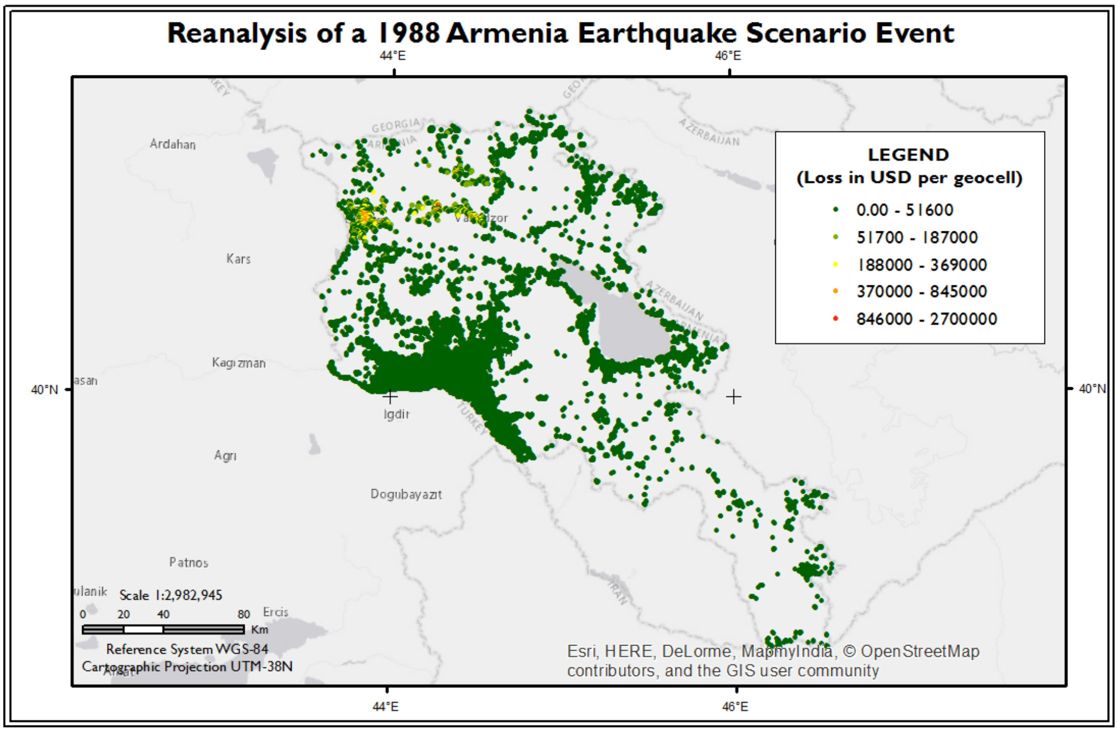

Figure 5: Absolute loss on a 1km resolution for the reanalysis

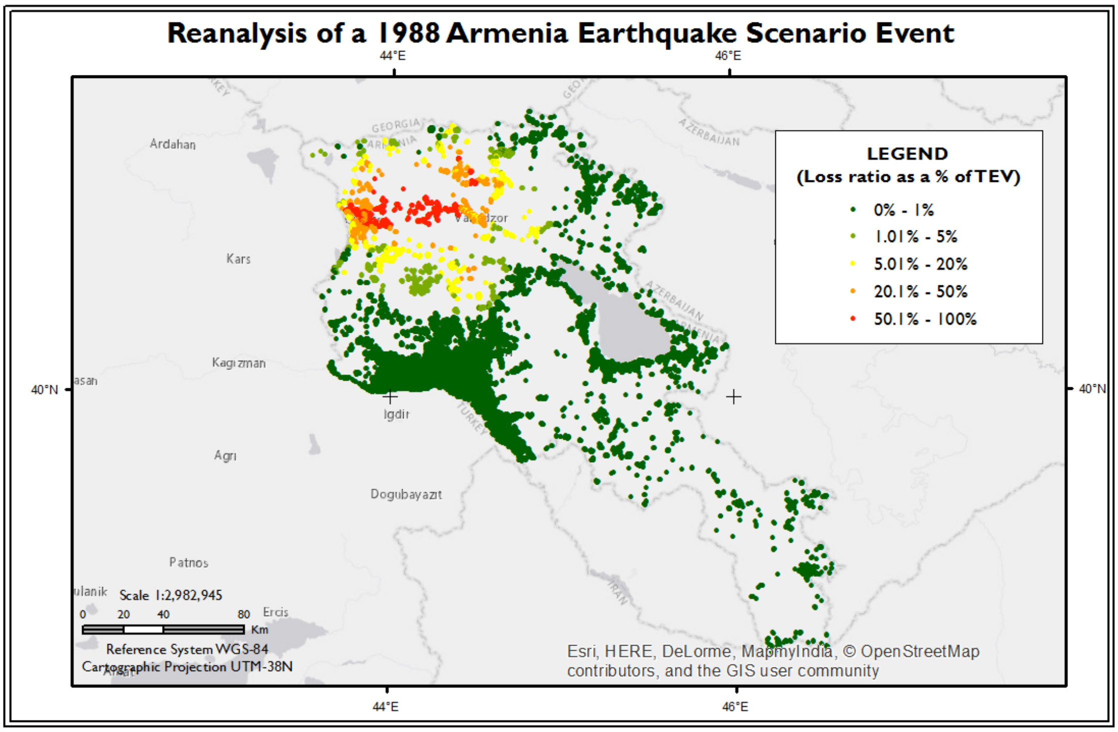

Figure 6: Relative loss on a 1km resolution for the reanalysis as a % of total exposed value

In terms of the administrative level losses, damage was primarily to Shirak and Lori provinces with over 20% of stock damaged.

Table 1: Administrative Level 1 Losses as a percentage of exposure

Province	Exposure ($USDm)	Loss ($USDm)	Loss Ratio (%)
Shirak	752.7	247	32.8%
Lori	820.7	165.4	20.1%
Aragatsotn	410.5	3.5	0.8%
Kotayk	847.9	1.4	0.2%
Tavush	391.8	0.9	0.2%
Armavir	927.1	0.8	0.1%

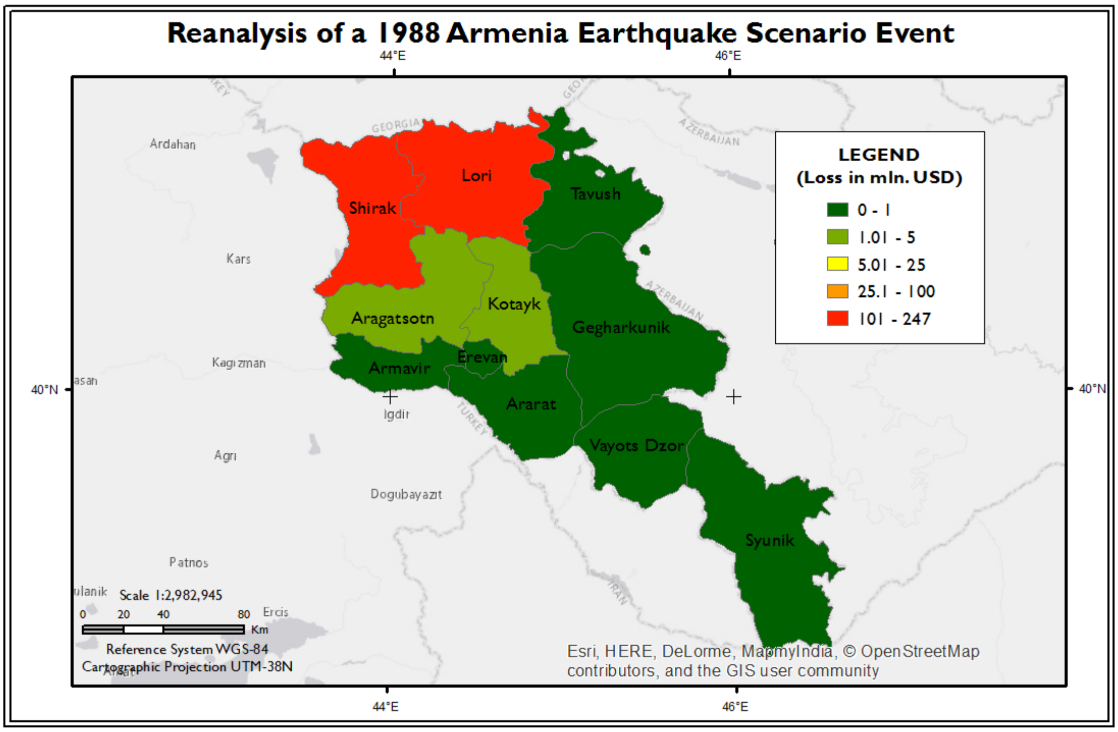

Figure 7: Absolute loss on an administrative level 1 for the reanalysis

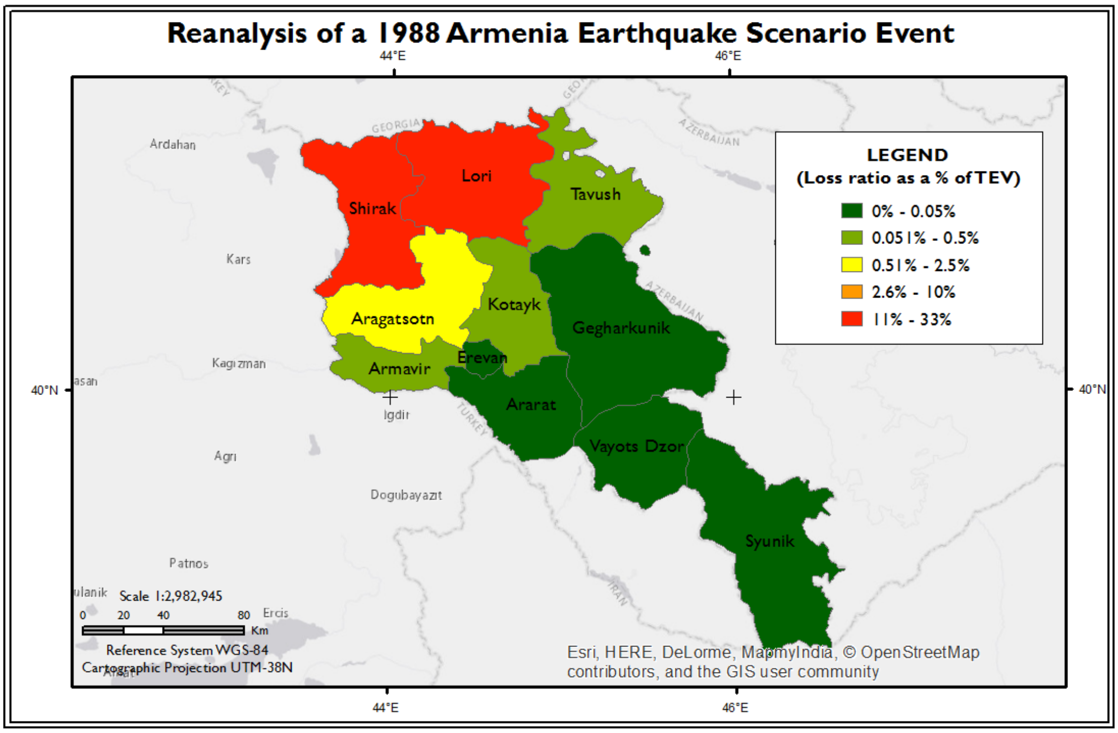

Figure 8: Relative loss on an administrative level 1 for the reanalysis as a % of total exposed value

What is the return period of such an earthquake loss in Armenia?

Given that most historical loss curves have been calibrated on a much higher loss attributed to the 1988 Spitak event, not a lot of trust can be given to existing PML curves outside of the Daniell and Schaefer (2014) study, which used a much lower value of loss for the Armenia 1988 earthquake of $1.8-4.3 billion USD. The 1931 Zangezur earthquake caused around 2.9% of capital stock to be lost and is the only other major event with a reasonable loss estimate since 1900 in Armenia.

Using the PML curve of Daniell and Schaefer (2014), the loss can be associated with a return period of ca. 160 years. Using the GAR2015 loss curve (another study which seems to have used lower losses associated with the 1988 event), a 225 year event is determined.

Why was it important to collate the data?

The 1988 Armenia event was an event where there was a significant amount of information and many studies undertaken post-disaster. However, this also meant that there were many conflicting numbers post-disaster including huge overestimations on the economic losses. For the first time, a definitive estimate of losses from the event have been produced, significantly reducing the literature values associated with this event.

Daniell, J., and A. Schaefer (2014), Eastern Europe and Central Asia Region earthquake risk assessment country and province profiling, GFDRR/World Bank. [Available at https://wbg.app.box.com/files/0/f/11669366416/1/f_148268286296].

GAR (2015)

Pomonis (1989)

JICA (2012)

GeoRisk (2011)

GAR2015

Gillula, J. W. (1984). Components of gross investment in 1966 and 1972 Soviet input-output tables: report. [Washington, D.C.]: The Center.

Alexashenko (1992)

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