Risk Profile – El Salvador 2001 earthquake

1. **The 2001 El Salvador earthquake was a major disaster for the country with the reconstruction costs reaching around 2% of the country's capital stock and 10.4% of its GDP**
2. **A reanalysis of the event today, suggests a $527 million pricetag for the residential and non-residential stock; but also the chance for risk mitigation if targeted strengthening programs for the most vulnerable buildings were implemented.**

Why are we looking at El Salvador

- The country has one of the highest relative natural hazard AALs across the globe, and accurate characterisation of the stock is needed for future analyses.
- The El Salvador building stock lends itself to improvement of the "Concreto o Mixto" classes, and it is desirable to know what percentage of these have been built in which time period, and the relationship to the earthquake losses seen in 2001.

Why is this useful to the TTL?

The El Salvador scenario is useful to inform the GFDRR and TTLs of the potential reoccurrence of such an event as well as giving some background as to the potential losses in the residential and non-residential sector. It also provides lessons as to the collection within a PDNA in a future disaster as well as a new background to the El Salvador event of 2001.

Why are we doing the disaster scenario?

The "Disaster Scenarios" El Salvador 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 sector. By reviewing the loss differences today vs. at the time of the event, a full gambit of scientific studies, knowledge and expertise has been able to be used, which benefits the production of exposure, hazard and vulnerability models for earthquake anywhere around the world.

Background and historic losses

The 2001 El Salvador Earthquake affected most of the country, but principally the municipalities on softer soils and closer to the ocean.

Disaster Type	Earthquake		**Deaths**	944
Magnitude and Location	Mw7.7 (SLV)		**Homeless**	1,329,000*
Date	13/01/2001		**Houses existing at time**	1,562,366
Country Population at Time	5,812,000		**People in dam./destr. houses**	1,036,545
Capital Stock at Time (Res.) - $USDmn	14,567		**Houses destroyed**	108,949
Capital Stock at Time (Non-Res.) - $USDmn	6,457		**Houses damaged**	169,692

The economic loss of the event from the PDNA suggests a value of around $250 million in losses from the event.

How did we remodel the scenario?

Historic damage data, intensity maps and ground motion ordinate maps were examined in order to gain the best possible reanalysis of the scenario. Given a modelled scenario had been done in previous CDRP analyses, an analysis of the felt intensity in each municipality was undertaken to give a better indication of macroseismic intensity across municipalities. This was subsequently converted to PGA and other spectral ordinates.

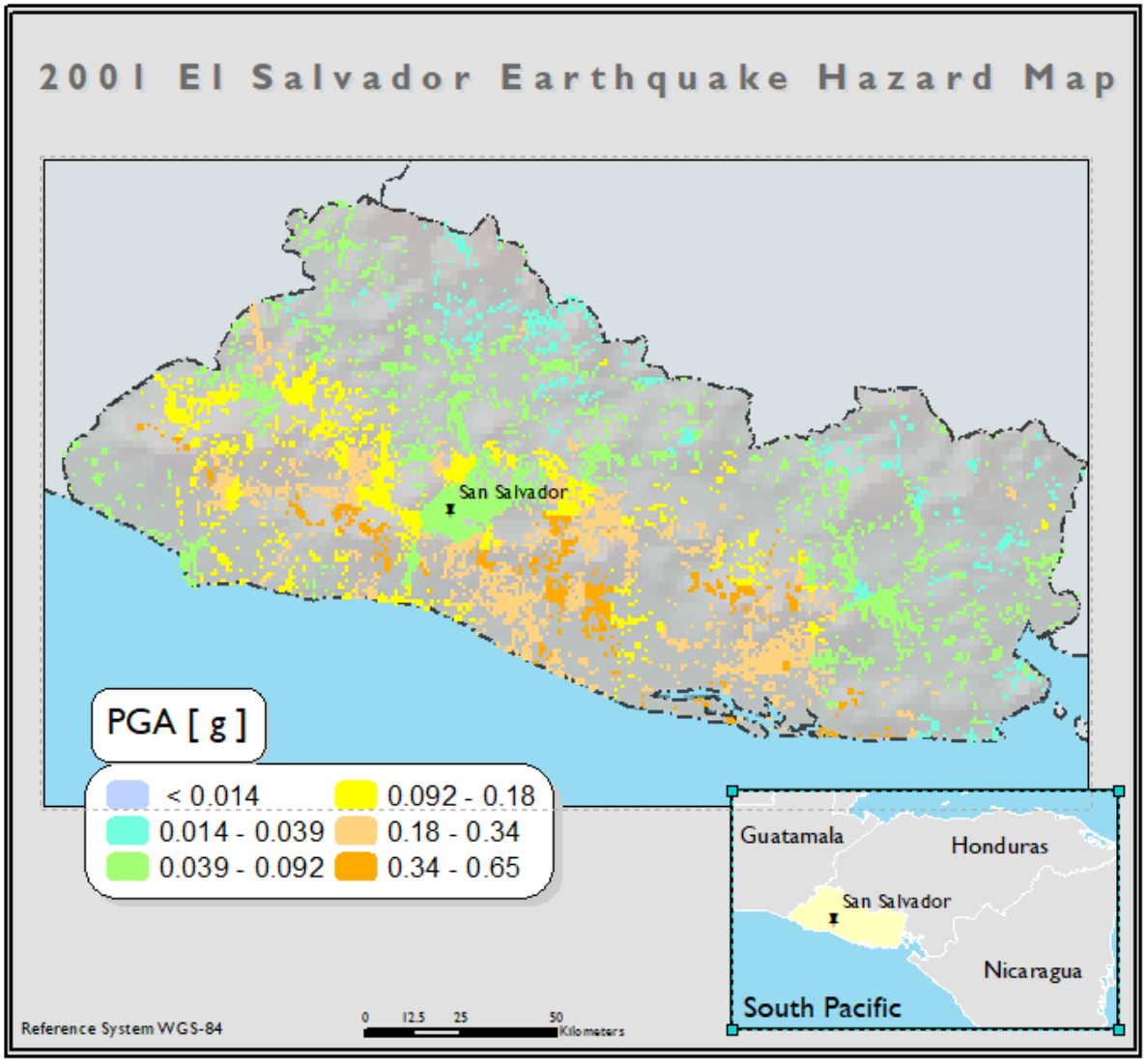

Figure 1: 2001 El Salvador earthquake hazard map measured in PGA (peak ground acceleration) in g

The assessment of the El Salvador residential buildings exposure was developed for the analysis of a repeat in present times of the destructive January 13, 2001 earthquake. The exposure includes the period of construction according to earthquake code developments (in 1966 introduction of the first code, 1986 second-improved code and 1994 modern earthquake design code) of the numerous houses with concrete block outer walls (category "*concreto o mixto*", in the 2007 Population and Housing Census). It has also taken into account the reconstruction that followed the January 13 and February 13, 2001 earthquakes that destroyed 10.5% of the country's housing stock (nearly 154,000 predominantly adobe and *bahareque* housing units). It is also developed separately for single-family houses and

houses found in apartment buildings. This exposure model therefore allows for various scenarios to be examined related to possible rate of adherence to the code by time period and region for cost-benefit analysis. Spatially the exposure was developed using the iURBAN tool which defines three homogeneous inventory regions (metropolitan, remaining urban and rural areas).The 2016 residential exposure was estimated at 27370 million USD and is split into eight structural typologies. It is noted that the exposure is roughly equal in the San Salvador and remaining urban areas (scattered around the country), with newer houses (post-1993) being more predominant in the remaining urban areas as these have grown more recently. Exposure in adobe and bahareque houses is very limited in the urban areas and significantly reduced in the rural areas compared to the equivalent distributions in 2001. The next map shows the housing stock in terms of roof cover type. At the time of the 2007 census occurrence of reinforced concrete slabs was quite limited while there is prevalence of tiled roofs in the north and east and laminated metal sheets in the rest of the country incl. San Salvador.

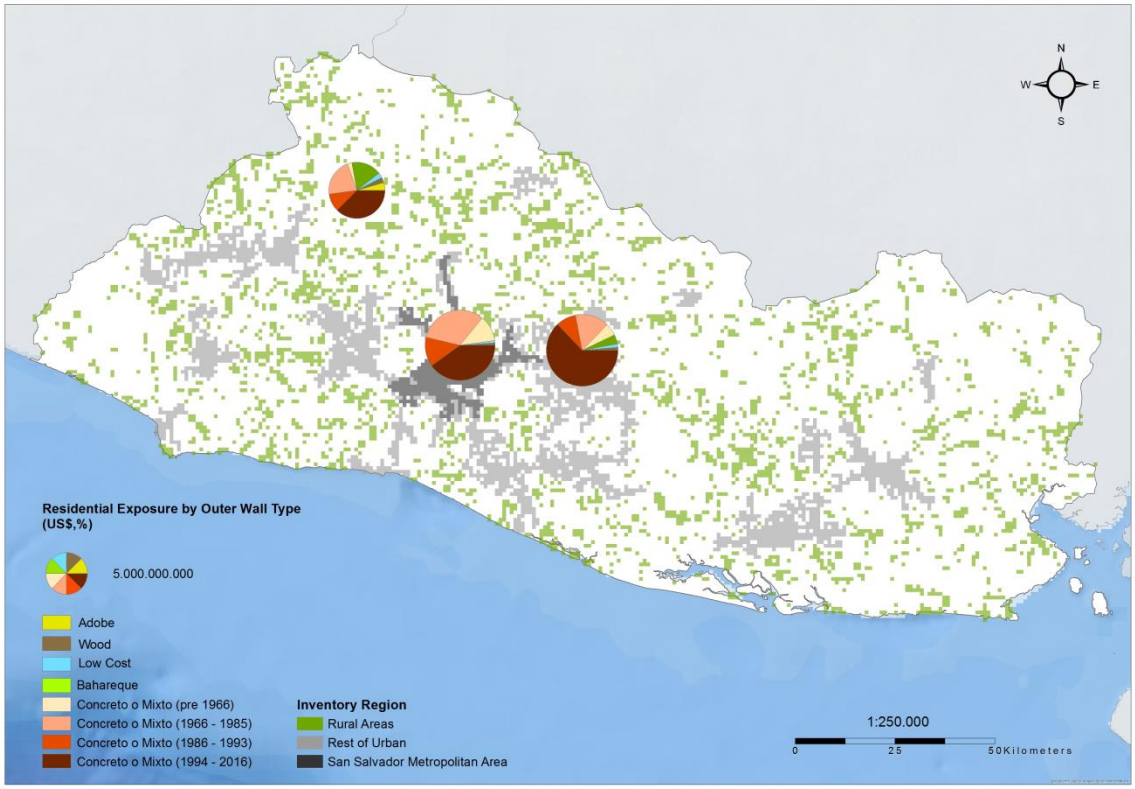

Figure 2: Residential exposure in the Dominican Republic (2016). The map shows the populated patches grouped into three homogeneous inventory regions (metropolitan, rest of urban and rural areas), the size of the exposure in USD (scaled pie charts) and its breakdown into eight vulnerability classes.

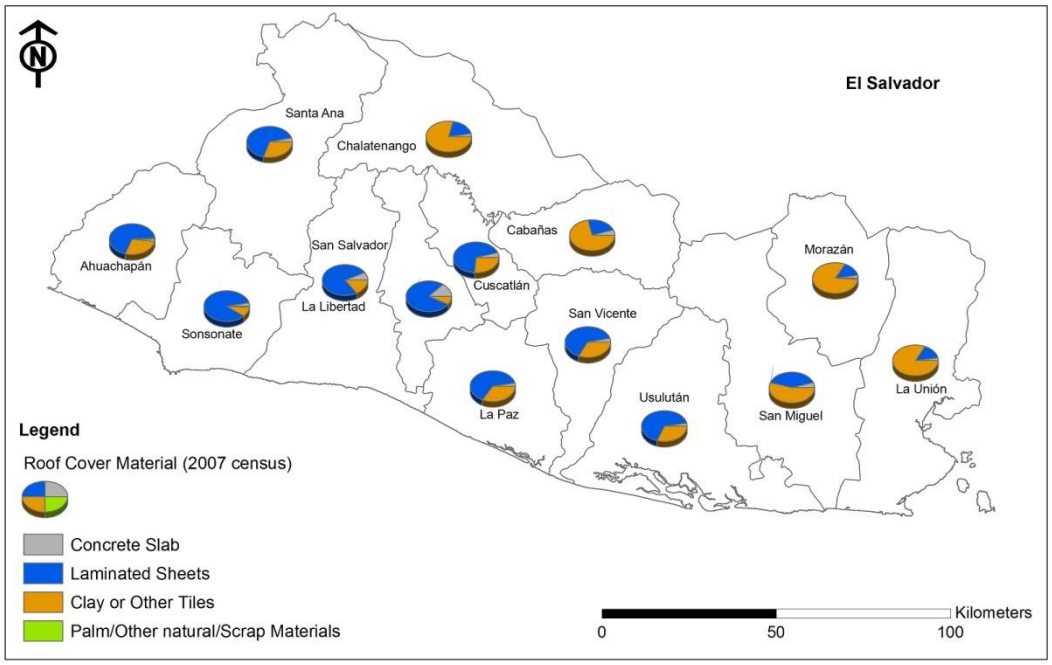

Figure 3: Department-level distribution of housing units by roof cover type in El Salvador (2007).

The vulnerability functions were based on work done within the CDRP risk profiles and reassessment project for building codes. In this assessment the concreto-mixto buildings were split into 4 code levels based on the historical age of the buildings, as the code level was assumed to only be partially implemented compared to CMX LC, MC, HC. This is further discussed in the Building Codes project report for El Salvador (Pomonis et al., 2016).

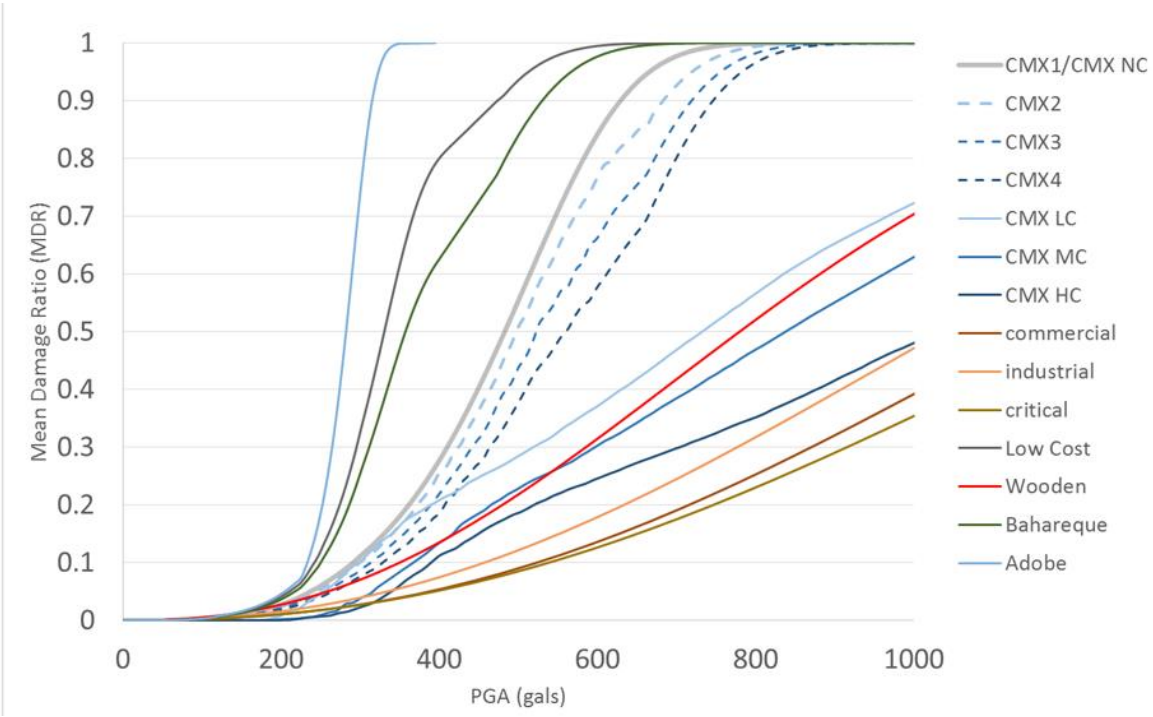

Figure 4: Vulnerability functions for El Salvador

What are the potential losses in El Salvador?

	Historic	Modelled
Residential Damage (mn USD)	250	461
Residential Stock (mn USD)	14567	27370
Residential Stock exposed MMI>6 (mn USD)		12901
Residential Loss Ratio	1.72%	1.69%
Non-Residential Damage (mn USD)	100	65
Non-Residential Stock (mn USD)	6457	12131
Non-Residential Stock exposed MMI>6 (mn USD)		5384
Non-Residential Loss Ratio	1.55%	0.54%

When comparing the losses versus the historical event losses, it can be seen that the absolute values today are higher than that of 2001, with $461 million loss expected. However, in relative terms this is a reduction compared to the event losses historically.

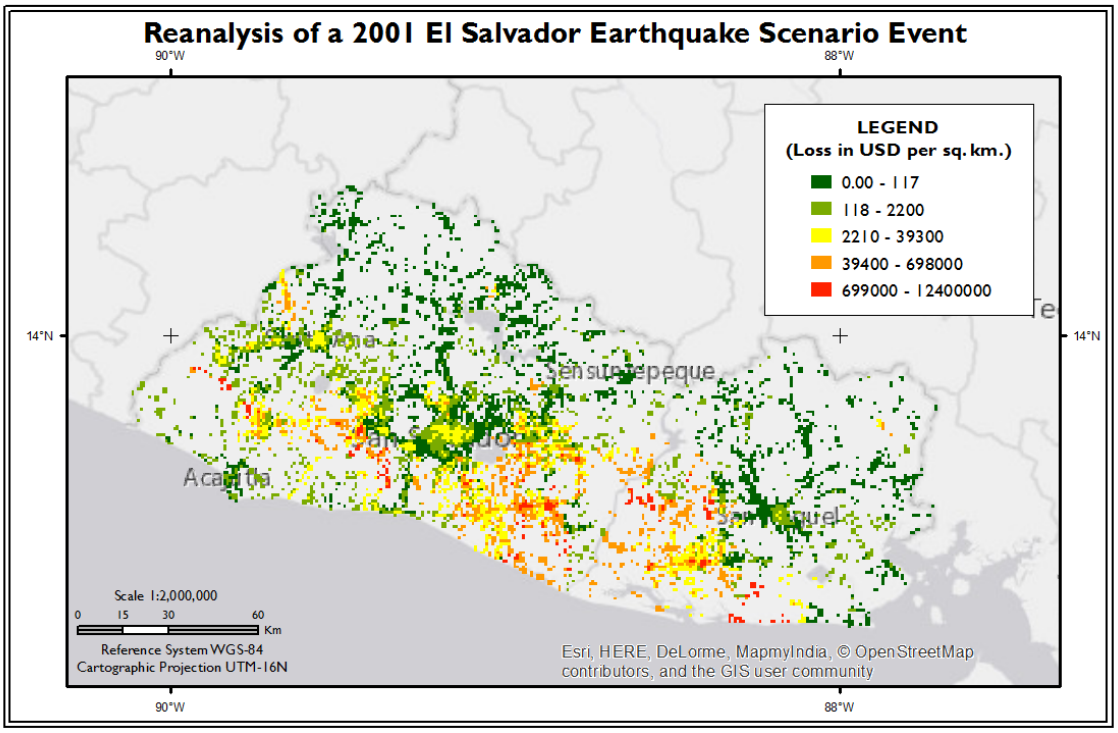

Figure 5: Absolute Economic Losses per square kilometer from the January 2001 earthquake reassessment

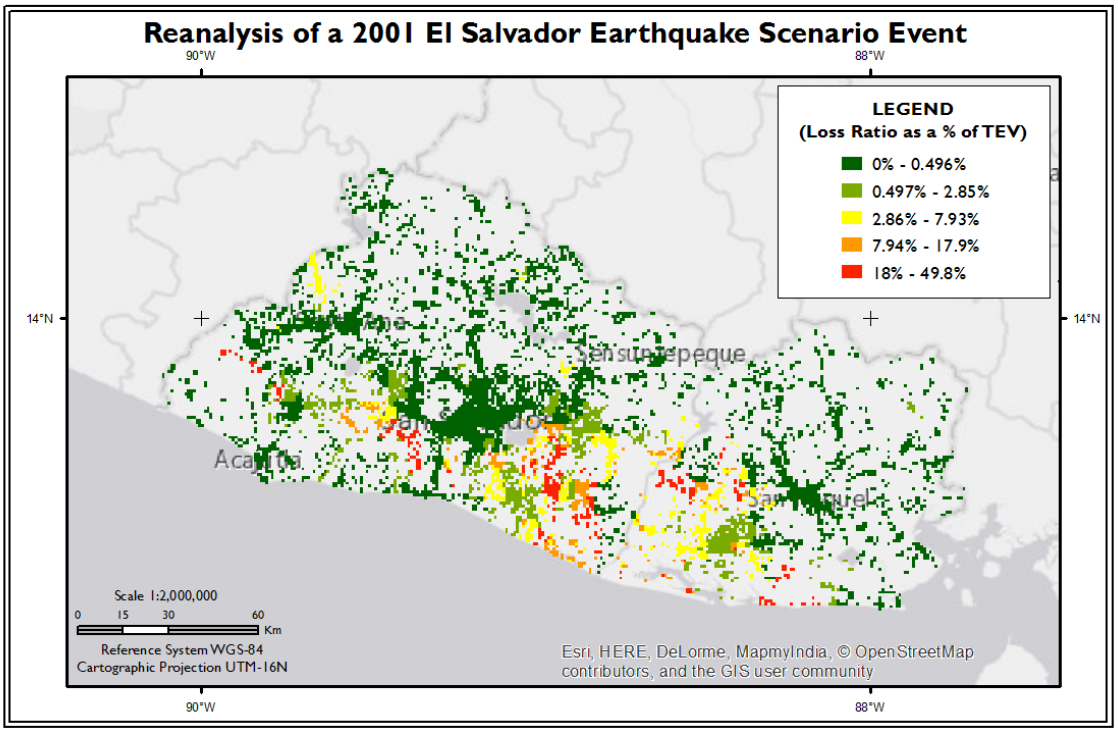

Figure 6: Relative Economic Losses per square kilometer from the January 2001 earthquake reassessment

It can be seen that the 2001 El Salvador earthquake scenario event mimics the results of the administrative level damage reasonably well (Figure 6 and Figure 8 vs. the real damage in Figure 9). It can be seen that closest to the epicentre, there was significant damage.

Table: Administrative Level 1 Losses and Exposure

Province	Mean MMI	Exposure ($USDm)	Loss ($USDm)	Relative Loss (%)
La Paz	8.13	1869.3	213.71	11.43%
Usulutan	7.83	2047.8	148.6	7.26%
La Libertad	6.79	5005.7	64.13	1.28%
San Vicente	7.43	1127.7	31.64	2.81%
Sonsonate	6.97	2539	29.26	1.15%
Ahuachapan	6.72	1495	13.92	0.93%
Cuscatlan	6.52	1413.1	10.12	0.72%
Santa Ana	5.97	3770.6	5.6	0.15%
San Salvador	5.95	14004.2	4.12	0.03%
San Miguel	5.86	2818.4	3.49	0.12%
Cabanas	5.6	885.9	0.99	0.11%
Chalatenango	5.02	1224.2	0.65	0.05%
La Union	5.31	798.7	0.36	0.05%
Morazan	4.99	501.8	0.001	0.00%

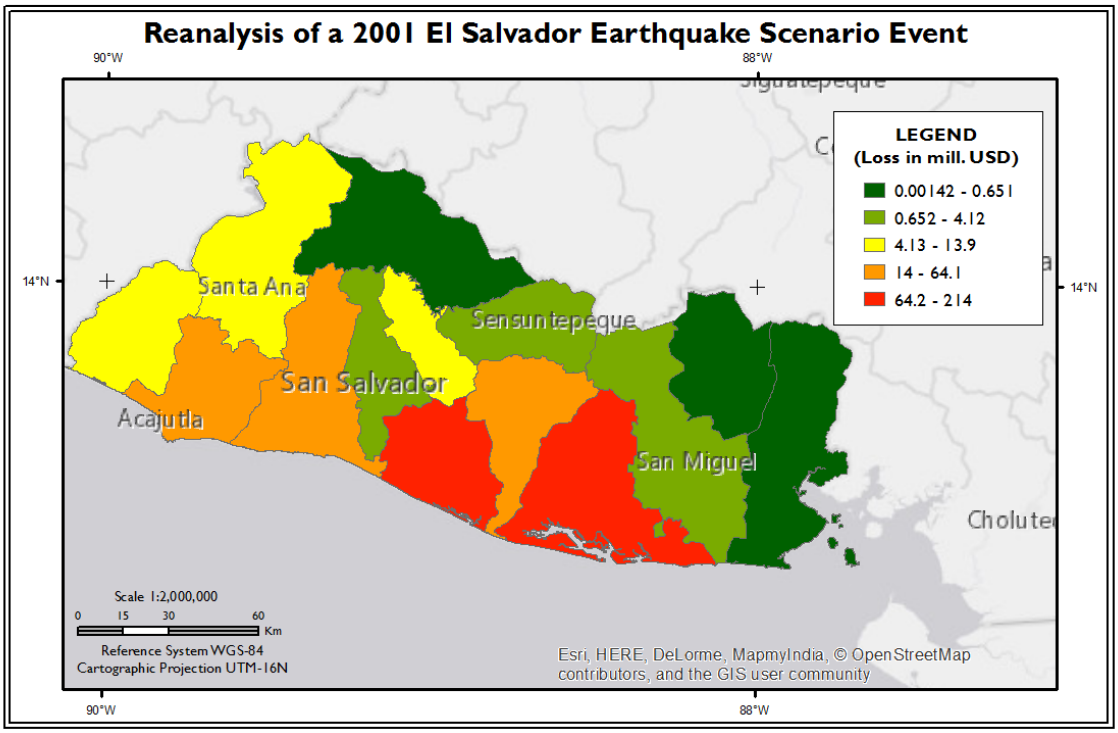

Figure 7: Absolute Economic Losses per administrative level 1 from the January 2001 earthquake reassessment

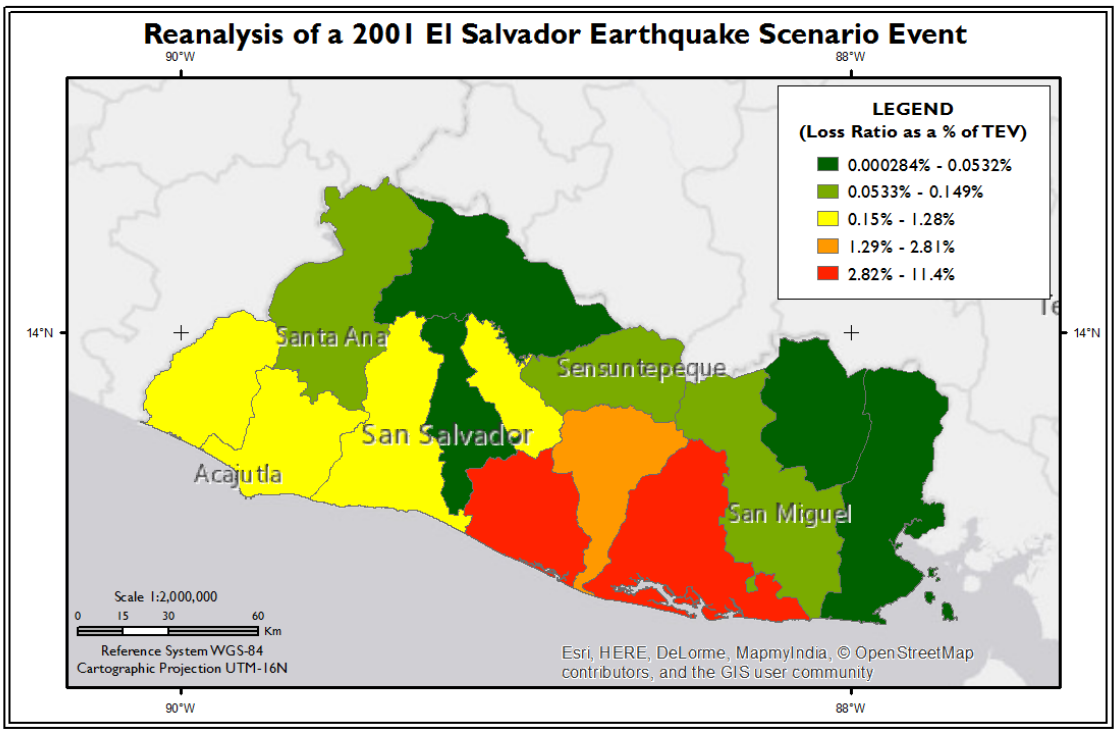

Figure 8: Relative Economic Losses per administrative level 1 from the January 2001 earthquake reassessment

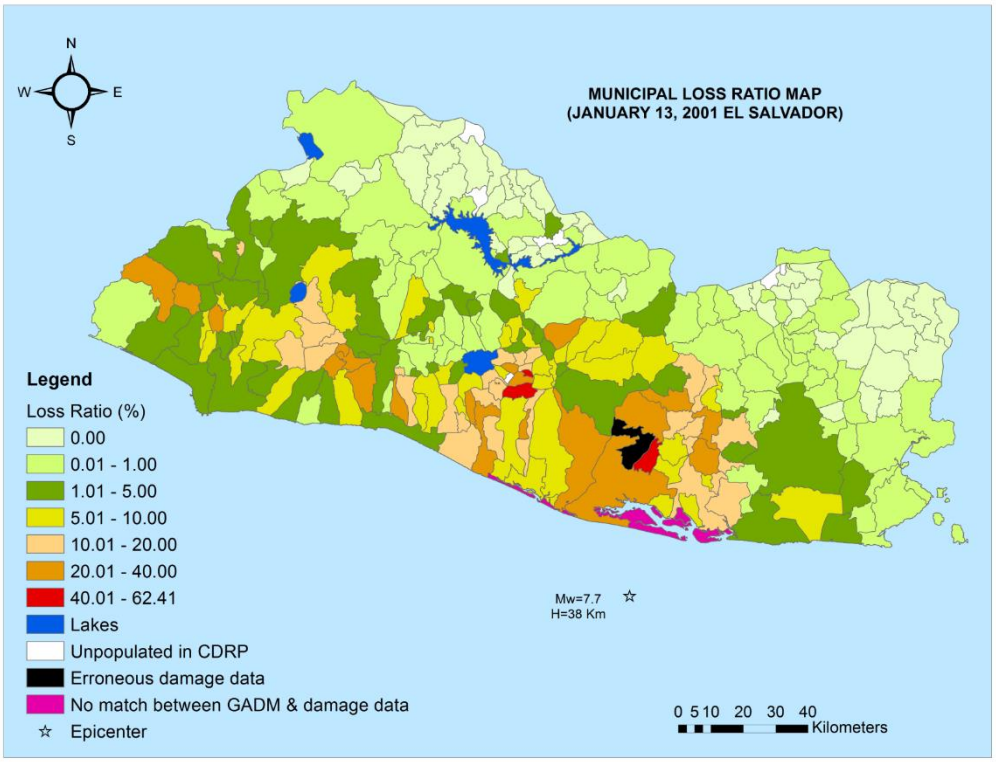

Figure 9: Relative Economic Losses per administrative level 1 from the January 2001 earthquake reassessment (Pomonis et al., 2016)

What is the return period of such an event?

The return period of an event such as this creating residential and non-residential losses as from the 2001 event differs depending on the EP curve study used. From GAR2015, this event loss is in the order of 35 years. From the CDRP risk profile, this is in the order of a 20-25 year event.

Why was it important to collate the data?

The 2001 El Salvador 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. The additional damage from the 13th February 2001 earthquake, meant that in many cases a disaggregated view of the first event was not clear.