# GIS and Natural  Hazard Loss Assessment

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## Abstract

The Natural Hazards Research Centre makes extensive use of GIS in determining the relationship between a hazard event and the damage caused by the event.  With the assistance of the Australian Insurance Industry we have compiled extensive databases detailing the type, extent and location of damage claims for damage to domestic buildings.

Some of the research to date is based on overseas experience and may not truly represent the Australian experience.  One of our research aims is to produce loss curves for building damage relevant to the Australian experience.  This requires intensive analysis of damage data, which would not be possible without GIS to provide the spatial framework for damage assessment.

***Keywords and phrases***: Probable Maximum Loss; earthquake, hail storm, loss curves.

## 1. Introduction

There are many lessons we can learn from hazard events such as the 1989 Newcastle earthquake and the 1990 Sydney hailstorm, the two examples presented in this paper.  GIS has proven to be a valuable tool in assessing the spatial patterns of damage caused by such events.

The insurance industry is interested in estimating Probable Maximum Losses (PML) for given natural hazards. The Natural Hazards Research Centre (NHRC) has been involved in the development of PML models for the insurance industry, particularly for losses that relate to domestic housing.  In order to produce loss curves it is necessary to analyse the damage data from past events as well as information regarding properties that were not damaged by a hazard event.  Both of the events analysed here resulted in damage over a wide area, but the extent of damage varied with distance from the centre of impact.  The amount of data available for each event is in the order of tens of thousands of items.  Without the aid of GIS, analysis would not have been possible.

## 2. Earthquake  Analysis

Australia lies in a low seismic zone. However, the Magnitude 5.6 Newcastle earthquake of 1989 caused 12 fatalities, around 160 injuries and A$1,124 million insured damage [1997$].  Copious amounts of data relating to this event exist, providing insights into the damage such events can cause in Australia.

Prior to this event, any estimate of the PML caused by an earthquake event relied on the use of loss curves created using data from overseas events.  Since these events include earthquakes that occur on plate margins as well as intraplate events and for buildings of different construction, their relevancy to the Australian situation is questionable. Research undertaken by the NHRC has developed loss curves for Australia, using the experience of the Newcastle earthquake.

The main source of information has been insurance claims for domestic dwellings resulting from this earthquake.  These data consisted of claim details for approximately 40,000 domestic dwellings.  Claim details for domestic dwellings included the full address, claim amount and sum insured and building construction type (brick, brick veneer, timber, fibro or other). Statistical analysis of the data enables a relationship between the ratio of claim to sum insured and the earthquake intensity to be established for each construction type. In order to identify a relationship, the earthquake intensity for each dwelling must be assigned.

Earthquake intensity is measured by the Modified Mercalli Scale (MM), where MM8 (the maximum experienced in Newcastle) is described as:

> "Buildings of average to good workmanship and materials damaged, some seriously, buildings designed and built to resist earthquakes to normal use standards damaged in some cases; … some infill masonry panels damaged; weak piles damaged; houses not secure on foundations may move …" (Bulletin NZ National Society for Earthquake Engineering, 25(4),345-357,1992)

The MM values for the Newcastle earthquake used, are those produced by the Australian Seismological Centre (McCue and Gregson, 1992), and are included in Figure 1. Since the amount of damage varied spatially throughout the region, with the MM decreasing with distance from the epicentre, the location of each claim had to be linked to the MM map. Even though the database contained the complete address, the spatial location of the building in relation to the length of the street was unknown and, as streets crossed MM boundaries, this location was an important factor. Without GIS, damage intensities could only be assigned on a postcode basis. GIS, and in particular MapInfo products, allowed damage intensities to be allocated on a much finer spatial scale.

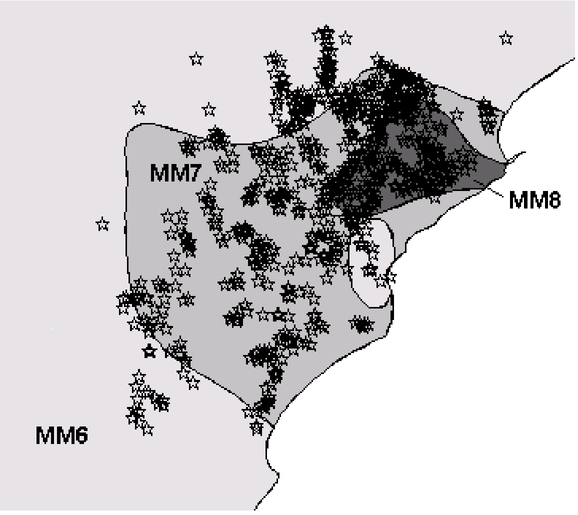

*Figure 1: Map of claim locations and MM values*

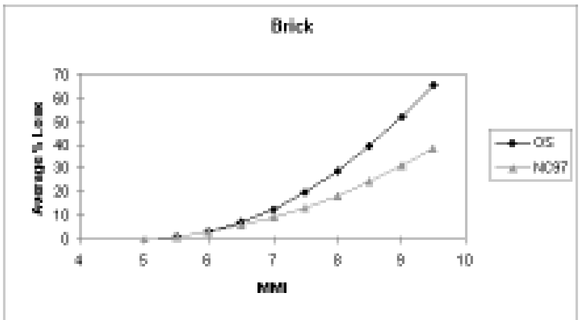

*Figure 2: Comparison of Overseas and Newcastle loss curves for Brick Dwellings*

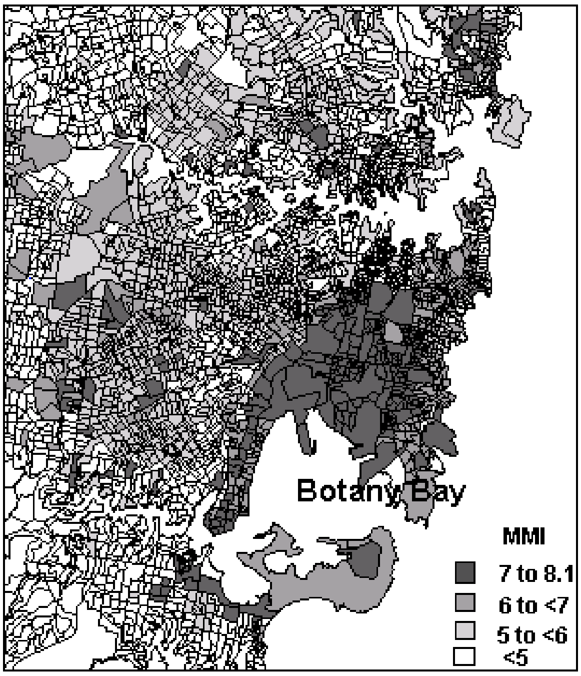

*Figure 3: Estimated MM values for an Magnitude 5.6 earthquake originating at a depth of 12km in postcode 2108*

Both the MM map and claim locations had to be exported into MapInfo. The MM map was digitised from published hard copy and the claims were geocoded (located as a point on the street block using linear interpolation in the Mapinfo product "GeoLoc"). Facilities within MapInfo then enabled the relevant MM value to be assigned to all claims. Figure 1 shows the relative position of the claims with respect to the MM areas.

Intensive statistical analysis was undertaken to establish the relationship between MM Intensity, construction type and percentage loss. The percentage ratio of the claims to sum insured for the data were found to be lognormally distributed. Numerical analysis of the lognormal distribution was undertaken to calculate the mean ratio ($\overline{R}$) and then average loss was calculated using:

Average % loss =$\overline{R}$ * Total Sum Insured for Claims/ Total Sum Insured for all policies

In order to produce curves that are relevant to all MM values from 5 to 9.5, curve fitting techniques were used to produce a set of quadratic curves, an example of which is shown in Figure 2. Figure 2 shows a comparison of the average of several overseas loss curves and the new loss curve produced from the Newcastle data for domestic buildings of brick construction. There is a significant reduction in average percentage losses for earthquakes with MM of 7.5 or greater.

These relationships were then used in an earthquake Probable Maximum Loss model. This model has been used to produce several earthquake PML reports for Benfield Greig Australia, assessing PMLs for Australian capital cities. GIS has also been invaluable in providing the necessary input data and to display results.

Model input required include:

- housing data - obtained from the insurance industry and from census data, giving details of construction types, average sums insured for each construction type and the total number of households in the census area,
- a spatial basis - on which to relate the housing data. The finest resolution the insurance industry could provide was postcode. The postcode boundary maps were obtained from the 1991 Census data. The average area for a Sydney postcode is 17 km$^2$. Census data provides details at Collection District (CD) level which have an average area of 0.7km$^2$, and allowing a much finer resolution for modelling. Insurance data was interpolated to CD level, and
- geological data - to provide information on soil vulnerability to earthquake ground shaking. Soil maps were used for this purpose. More recently (in the Sydney and Adelaide studies) these have been available in a digitised form from the relevant State Government Departments. Since geology can change dramatically over a small area, using postcodes as the area for modelling was clearly inadequate. Instead, soil characteristics were assigned a ground shaking vulnerability. This vulnerability was assigned to each CD at the centroid, using GIS.

Probable Maximum losses were then estimated by

- Assigning an earthquake epicentre, hypocentre and magnitude (the postcode centriods are used as centroid, with depths of 7, 12 or 17km and magnitudes of ML 4.6, 5.6 or 6.6). For Sydney, with 208 postcodes, a total of 1872 earthquakes),
- Calculate an estimated MM value for each CD using the ground shaking vulnerability and the Gaull et al. attenuation function,
- Estimate average percentage loss for each each postcode and each construction type using the loss curves produced,
- The PML% is then calculated by summing the losses for all postcodes and expressing result as percentage of the total sum insured and
- This process is repeated for all 1872 earthquakes. The losses for each earthquake scenario can then be compared.

Figure 3 is a typical map used to display model output in the Sydney PML study and shows an example of the anticipated ground shaking associated with a Magnitude 5.6 earthquake located beneath the centroid of postcode 2108 (Rosebery) at a depth of 12km. Rosebery is a suburb located a few kilometres north east of the International Airport which juts out into Botany Bay, an area with potentially high ground shaking. Areas around the epicentre have high MM values, and generally decrease with distance, except in areas where the soil is particularly vulnerable to ground shaking, for example areas consisting of soft coastal sediments.

Without this type of presentation, interpretation of the results would be very difficult as adjoining postcode numbers are not always concurrent. Maps such as that produced in Figure 3 provide an insight into the areas most at risk from earthquakes', by using this as base map, clients may overlay building construction details or population details to ascertain the risk associated with areas of interest.

In these earthquake studies it has not been the GIS which has limited our analysis, but the quality of the data, the spatial boundaries available and the cost of additional data. At present the insurance data are amalgamated on a postcode basis. In the future we hope to be able to obtain more detailed location data and hence improve the spatial analysis.

## 3. Hail Storm Analysis

On the 18th March 1990 Sydney experienced a severe hail storm which caused $384 million (1997$) worth of damage from some 84,354 claims. About 35% of the claims were for damage to domestic housing. Data from this storm have formed a basis for the development of a hail PML model. An initial analysis of damage undertaken by this Centre (Andrews and Blong, 1997) revealed that claims for damage to buildings were spread across 130 postcodes (the Sydney area comprising approximately 208 postcodes), with two postcodes holding approximately 20% of the claims. Figure 4 shows the maximum hail size recorded in each postcode in the Sydney area, showing a very clear storm path across Sydney from the South West to the North East. The largest hailstones (up to 8cm in diameter) were reported in and around the south-western suburbs of Liverpool and nearby Bass Hill. Hail 5 cm in diameter or greater was reported in the Roseville and adjacent suburbs in Sydney's north. A detailed analysis of hail falls in Sydney since 1791 indicates that, in terms of maximum hailstone size, this event has an average recurrence interval of about once in 20 years; in terms of the area affected the mean return period is about once in 25 years. The strong winds accompanying the storm unroofed houses and brought down trees and power lines, with seventy suburbs blacked out. In some areas it took two days to restore power .

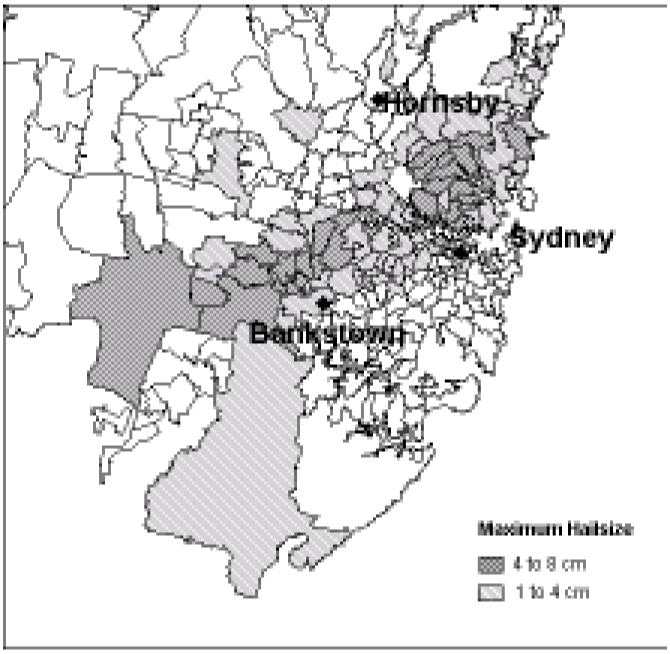

*Figure 4: Storm path defined by maximum hail size*

The aim of the hail storm research is to:

- determine the distribution of damage caused by this storm in terms of percentage of Total Sum Insured (TSI) and percentage of policies affected,
- identify the domestic building and contents items most vulnerable to damage,
- establish relationships between the item damage, the cost of the damage and the cause of the damage, and
- develop relationships between losses and hailstone sizes in order to establish percent loss curves for the March 1990 hailstorm.

The development of the loss curves is presently underway, with initial data analysis completed. Data were obtained

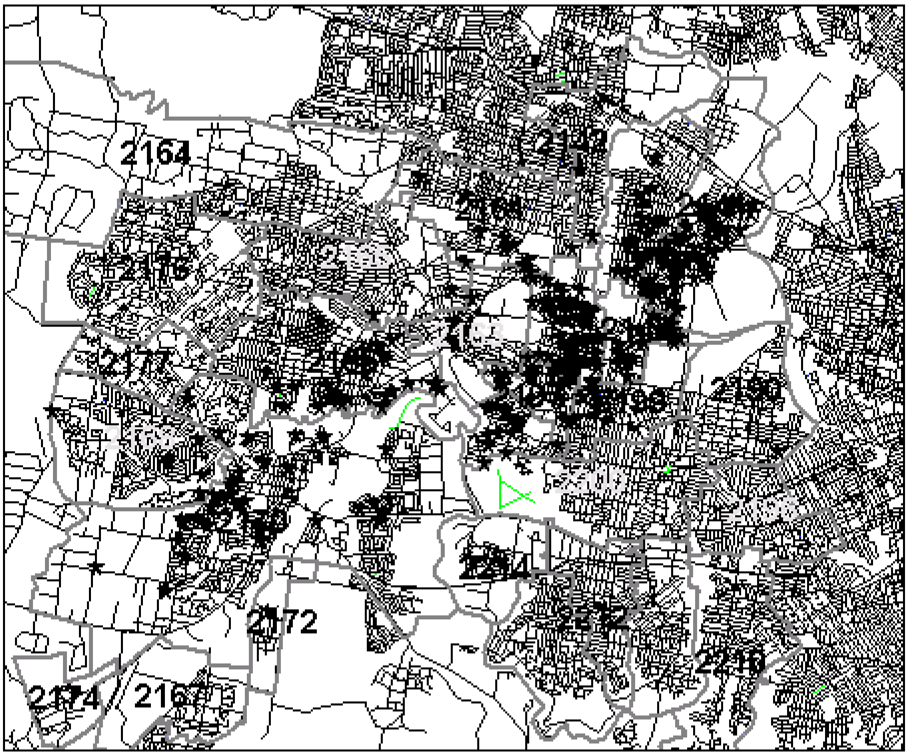

*Figure 5: Claims distribution in storm path*

from several Australian insurers, who provided information on claims made in relation to this storm. Some companies provided information on their complete portfolio so that percentages of claims to non-claims could also be calculated. The analysis includes a total of 105,000 policies with a TSI of A$12 billion.

Our initial analysis (Andrews and Blong, 1997) was based on postcodes. This enabled an analysis of average claim or number of claims per postcode. Statistics such as ratio of the number of claims to total policies (used in the formation of loss curves) are meaningless on a postcode basis - if only a small area of the postcode was affected, however severely, the ratio of claims to total sum insured for that PC would be quite low. There was a need to look at this data on a reduced spatial scale to get a clear insight into storm damage. A similar process to that used in the earthquake study was undertaken, where claims were geocoded to enable a detailed analysis of their location. Figure 5 shows the area of Sydney, around Bass Hill, where the largest hailstone sizes were reported. As a result the path of the intense centre of the storm is more clearly visible than in Figure 4.

The concentration of claims within a narrow spatial area has meant that the choice of spatial unit for modelling has to be carefully considered. Insurance data is usually provided on a summary by postcode basis, clearly inadequate, but supply of full address details also poses its own problems - companies may not wish to provide this level of detail or that the amount of data becomes too much to incorporate into a model that can run in a reasonable time. This problems are currently being addressed.

As analysis of claims along the storm path progressed, GIS highlighted features in the data that had not previously been considered. An interesting feature of Figure 5 is those areas with few claims that exist in areas with a high density of claims. GIS was then used to investigate the areas of low claim density. A map was produced showing the housing density on a CD basis (the smallest spatial unit available). When the claims and density maps were combined it was clear that low claims coincided with

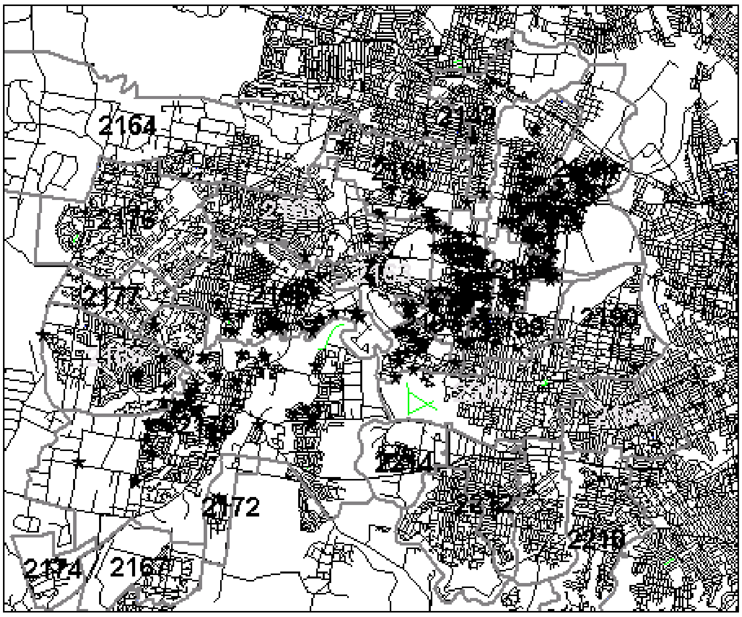

*Figure 6: Claims distribution and housing density*

low housing densities, these probably indicating industrial or parkland areas (Figure 6). The ability to show various map layers (spatial characteristics) is an invaluable tool in our analysis.

## 4. Conclusions

Changes in basic GIS programs over the years have allowed us to improve our modelling techniques significantly. The models developed are numercially intensive, and as a result are run externally to the GIS program. As with any numerical technique, interpretation of results becomes cumbersome when it involves page after page of numbers. Again, GIS becomes invaluable for the interpretation of modelled results.

The earthquake PML model has used GIS to join spatial data, provide numerical model input and display the model results meaningfully. As the Centre undertakes modelling of other hazards, such as the development of the hail model, GIS remains an integral part of the modelling process.

## Acknowledgements

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