The April 1999 Sydney hailstorm

Insured losses from the hailstorm that struck Sydney on Wednesday 14 April 1999 are projected to reach A$1.5 billion, making it the most damaging event in Australian insurance history. On Saturday 17 April, the Natural Hazards Research Centre (NHRC) placed a carefully prepared advertisement in The Sydney Morning Herald, encouraging readers to share their hailstorm experiences. A letterbox-drop was undertaken in suburbs where the response to the newspaper advertisement was low, and surveys were sent to three secondary schools. Including information derived from actual house inspections, over 350 responses were received—detailing hailstone sizes and the nature of any damage. Preliminary results from the survey are presented in this article. The context in which the event is placed is the product of several years' research on the hail hazard in Sydney.

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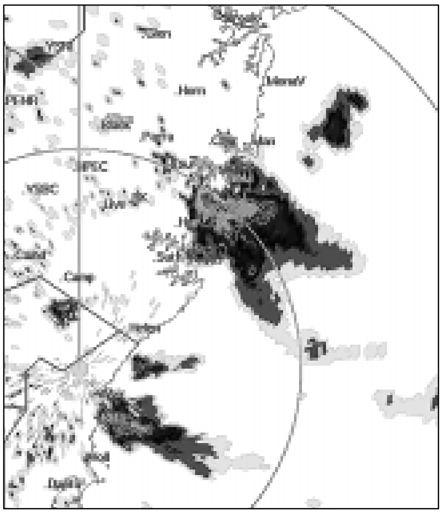

Figure 1: Radar image showing the hailstorm cell over the southeastern suburbs of Sydney and a second storm developing about 80km further south. *(Source: Bureau of Meteorology)*

The event

The 14 April 1999 Sydney hailstorm was, in every respect, a rather unusual phenomenon. The maximum hailstone size, the resultant damage, the season and timing of the storm occurrence, as well as other circumstances associated with the storm development made this event exceptional. Following its development about 150 kilometres south of Sydney, the initial storm cell moved northward parallel to the coastline (and mostly over the sea), only to change its track slightly inland south of the metropolitan area and to strike the coastal suburbs of Sydney at about 8pm. The major storm cell located over the southeastern suburbs of Sydney, followed by a second storm, which passed over the city two hours later (but produced only 2cm hail) can be seen in the radar imagery shown in *Figure 1*.

The Bureau of Meteorology reported the largest hailstones on 14 April 1999 to be 9cm in diameter. The NHRC survey invited respondents to nominate the largest size from a qualitative list (including $1 coin, golf ball, tennis ball, and larger than tennis ball), which were converted into quantitative data. The most commonly reported largest stone (37%) was of 'tennis ball' size (6.3cm), but many respondents (19%) reported 'larger' sizes. These included several 'cricket ball' (7cm) or 'orange' (8cm) sized hailstones, six reports of hail as large as 'grapefruits' (10cm), four reports of 'half-bricks' (about 11.5cm) and two reports of 'rockmelons' (about 13 cm).

Occurrences of 9cm hailstones, or even larger sizes reported by some residents in the affected areas, are rare but not unprecedented events in the Sydney area. The latest two hailstorms producing such hailstones hit Sydney in March 1990 and in January 1947. However, as shown in Figure 2, these are extreme events. The majority (or about 90%) of all hailstorms are marked by maximum hailstone sizes smaller than 5cm, while 2cm is most common.

The April storm occurred at a time of year characterised by low hailstorm activity. As shown in *Figure 2*, most hailstorms in the Sydney area can be expected during the late spring and summer months, while the maximum monthly hailstorm frequency is usually reached during the month of November. Moreover, the storm developed very late in a season which was marked by a substantially below-normal number of hailstorms (though west of the Dividing Range the hailstorm activity was normal or above-normal) and very late during a day that was not marked by any extremely unstable atmospheric conditions. Normally, the area of greater Sydney can expect about 8 hail-days per year and the majority of storms tend to develop in the afternoon between 2pm and 6pm.

Hailstones

Hailstones begin life as frozen raindrops or particles of ice. They grow mainly by accreting supercooled (substantially cooler than 0^0C) liquid from the surrounding cloud as they are held aloft by strong updraughts generated by severe thunderstorms. In their end form they can have different shapes ranging from spheroid to cones or irregular shapes. Depending on the environment they were created in, hailstones can also have different densities and come as soft and wet hail or graupel, or as harder and drier ice pieces. Most hailstones retrieved after the Sydney hailstorm were hard and had density comparable to that of gum tree wood.

The hailstone shown in *Figures 3 and 4*, which was collected at Newtown, was roughly spherical with a maximum diameter of 8.4cm and weighed 132 grams. This hailstone would have been travelling at between 140 and 200 kilometres per hour when it hit the ground. The growth time for a hailstone this size is likely to be

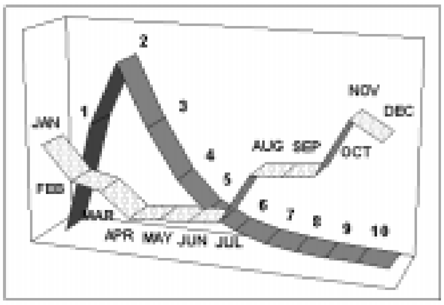

Figure 2: mean monthly hailstorm frequency (dotted pattern) and maximum hailstone size (cm) distributions (dark pattern) for hailstorms occurring in the Sydney area during the last sixty years.

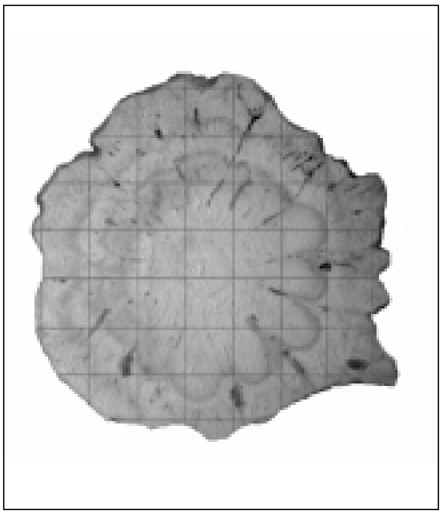

Figure 3: Photograph of a 2mm thin section of a hailstone that fell in Newtown illuminated by plain light (1cm background grid).

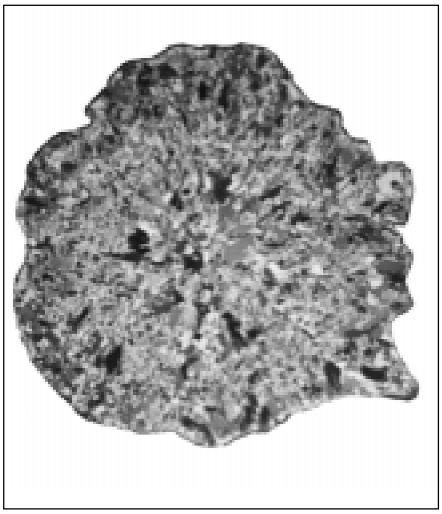

Figure 4: Photograph of a 0.7mm thin section of the same hailstone illuminated by cross-polarised light.

between 40 and 60 minutes. It would have grown at heights ranging from about 3 to 10 kilometres at temperatures varying from about 0^0C to -35^0C. The concentric opaque and transparent rings evident in *Figure 3* indicate the different growth modes the hailstone has undergone and thus, the different water concentration in the cloud. Opaque layers contain many small air bubbles and generally indicate 'dry growth' (low water content) at low temperatures. Clear layers contain fewer air bubbles and indicate 'wet growth' (high water content) at higher temperatures. Growth mode may change as the hailstone moves to different altitudes in the cloud or as the local temperature and water content of the cloud changes.

The knobbly surface of large hailstones is a consequence of a lobe structure. The lobe structure of the inner layers of the sectioned hailstone is clear in *Figure 3*. The lobes increase the surface area and cause the airflow around the hailstone to become more turbulent. These factors enhance the rate of heat transfer from the hailstones, allowing them to grow large but remain hard and dry rather than soft and wet.

The crystalline structure of hailstones also provides clues to their growth history (*Figure 4*). In general, long radially oriented crystals indicate growth at relatively high ambient temperatures (not far below zero) while smaller, more uniformly shaped crystals indicate growth at lower temperatures (less than –20°C for dimensions less than 0.5mm).

Low ambient temperatures occur high in the cloud, while higher temperatures occur nearer the ground. The crystalline structure shown in *Figure 4* (large crystals in the centre, medium sized crystals near the circumference, small crystals between) suggests the hailstone underwent periods of growth at a minimum of three different altitudes.

Distribution of hail falls

Figure 5 shows the spatial distribution of the largest reported hailstone sizes. Reports of hail were received from as far south as Kiama (about 100km from central Sydney) and as far north as McMasters Beach (about 50km from central Sydney). Large hailstones (greater than 5cm) fell in a SSW-NNE swathe from the Royal National Park to Sydney Harbour, with the exception of an area in the far north where the storm regained intensity. The map also shows a distinctive gradation in size across the swathe—from less than 3cm at South Coogee to greater than 7cm at Kensington to less than 3cm at Annandale.

Roof damage

Some form of damage to roofs was reported by 62% of respondents. *Figure 6* shows the distribution of three classes of roof damage—none, few broken tiles, and many broken tiles—according to the size of the largest hailstone. No tiles were broken by hailstones smaller than 3cm. No houses were without roof damage for hail sizes of 7cm or more.

The most common type of roof damage for hailstone sizes less than 5cm was a few broken tiles. Hailstones larger than 5cm often caused substantial damage. Inspections of damaged houses suggested that terracotta tiles were probably more susceptible to hail damage than concrete tiles, though all tiles were seen to have sustained severe damage.

Window damage

Window damage was reported by 34% of

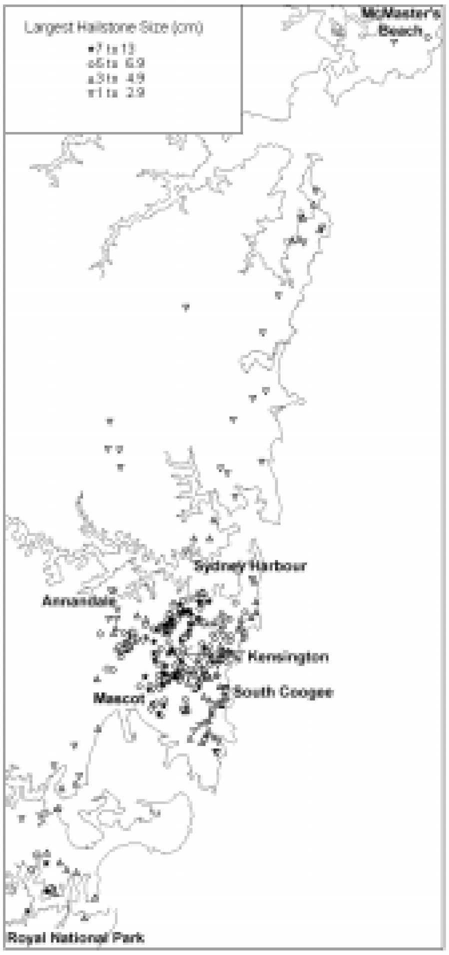

Figure 5: Largest reported hailstones, 14 April, 1999

respondents—notably less than roof damage.

Figure 7 shows that even for the largest hail size category, 40% of residents indicated no damage. This is probably a reflection of the vulnerability of different dwelling types. Many terrace houses, for example, do not have side windows. An interesting feature of the hail damage to roofs and windows and water damage to house interiors is a tendency for the most severe damage to be situated on the southern side of buildings. This corresponds to the predominant direction of the wind.

Vehicle damage

Damage to cars was reported by 53% of respondents. A significant proportion of the cars that did not sustain damage, even for hailstone sizes greater than 7cm, would have been garaged. Some respondents reduced the degree of damage by putting their cars under-cover at the outset of the storm, or by covering their cars with doonas. Figure 8 shows that hailstones smaller than 3cm caused little damage. Damage was more common for hailstones between 3 and 5cm in diameter, but most damage was slight. Severe damage was common for hailstones larger than 5cm.

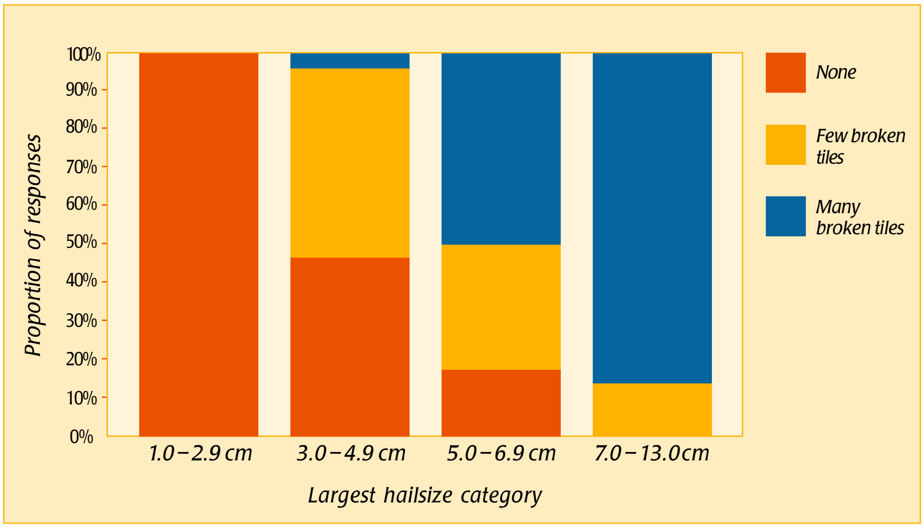

Figure 6: Largest hail size and roof damage

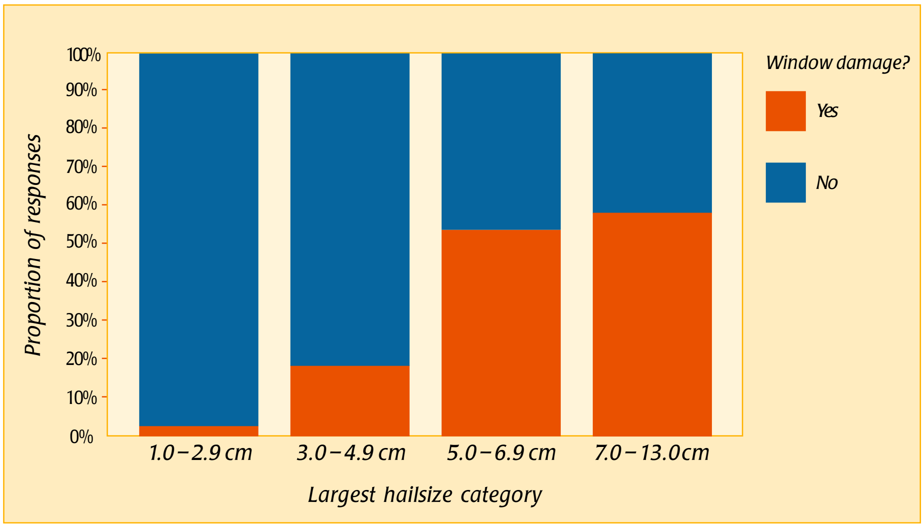

Figure 7: Largest hail size and window damage

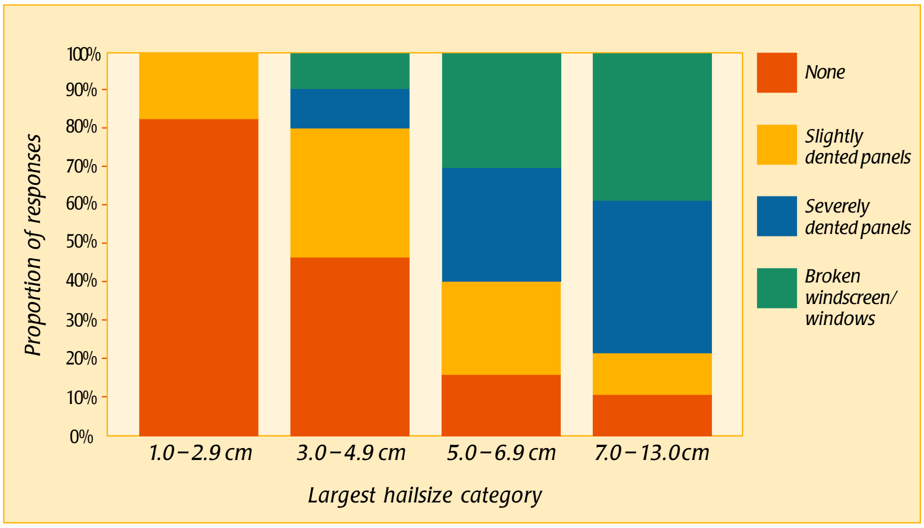

Figure 8: Largest hail size and car damage

Other damage

Rain entered over half of the respondents' houses, often through damaged roofs or skylights. Ceilings and walls needed repainting, and in the most severe cases, ceilings collapsed under the weight of broken tiles and saturated insulation bats. Water was often reported to have flowed down light fittings. Carpets were damaged in several houses. There were a few reports of dented external walls. Garages and sheds often sustained roof and gutter damage. Solar panels and television antennas were badly affected. Air-conditioners were dented. Pergolas and outdoors plastic furniture were holed. Other damaged items include fencing, hose fittings, letterboxes and pool covers. Very many people reported damaged, if not shredded, gardens. Terracotta and plastic pots were often broken. One or two people were bruised or cut when they tried to protect their cars. A number of respondents conveyed their distress.

Conclusion

The April 1999 Sydney hailstorm will not quickly be forgotten by the thousands of residents whose homes and cars were damaged. The survey initiated by the Natural Hazards Research Centre increases our understanding of the characteristics of Sydney storms and the patterns of damage they cause. Better understanding of the hailstorm hazard should lead to improved risk management, disaster mitigation and response strategies. The knowledge gained should provide impetus for the development of measures to reduce losses from hailstorms in the future; they are, after all, not unusual events in Sydney.

The NHRC is currently developing a hail risk model for Sydney with the support of Benfield Greig Australia, Partner Re, Hannover Re and Royal Sun Alliance. The numerical simulation model incorporates climatological data and exposure and vulnerability information for houses and cars. It is designed to estimate the magnitude of potential hail losses in Sydney. Improved understanding of the association between hailstone size and degrees of damage to roofs, windows and cars derived from the recent storm will be vital for the fine-tuning of the model.

Acknowledgments

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