The March, 1978 flood on the Hawkesbury and Nepean River between Penrith and Pitt Town

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Introduction

As a result of three days of heavy rainfall over the Hawkesbury catchment in March, 1978 floods occurred on all the streams in the Hawkesbury system. These floods caused considerable property damage and resulted in morphological changes to the channels and floodplains of the Hawkesbury system. This paper describes the flood in the Hawkesbury-Nepean system in the reach extending from Penrith to Pitt Town.

Storm Pattern

An intense low pressure cell developed over the Coral Sea on the 16th March, 1978. This low pressure system travelled southeast towards the Queensland coast and gained in intensity (Fig.1). On the 18th March it appeared that the cell would move eastwards away from Australia. However, the system reversed its direction of travel and moved inland. Resultant wind systems brought warm moist air from the east onto the coast of New South Wales. Consequently, heavy rainfalls occurred from the 18th to 24th March over the whole of eastern New South Wales.

The low pressure system was intense in its initial stages (Fig.2). The system began to dissipate as soon as it crossed the coast although it persisted until it moved out to sea in a southeasterly direction. An intense pressure gradient to the east of the cell during its early stages resulted in a high rate of landward movement of maritime air.

Rainfall Pattern

Rainfall less than 25 mm occurred over most of the Hawkesbury catchment during the 24 hr period to 9am, 18th March (Table 1). On the three following days the volume of daily rainfall increased
considerably (Figs. 3A-B). Several recording stations reported daily rainfall totals in excess of 250 mm. From the 21st March onwards daily rainfall declined rapidly as the low pressure system moved out to sea. Only light showers were recorded on the 24th March.

For the 6 day period to 9am, 24th March more than 500 mm of rain fell over 742 km$^2$ of the catchment, that is 3.4% of the Hawkesbury catchment (Fig. 3E, Table 2). The 24 hr period to 9am, 20th March was the one in which the highest 24 hr rainfalls for the catchment were recorded (Fig. 3B, Table 1).

The orographic nature of the rainfall is evident from the distribution of rainfall over the catchment (Fig. 3E). High rainfall volumes were recorded along the Illawarra escarpment, Lapstone Monocline and the high area around Mount Victoria. The distinct westwards declining rainfall gradient is also a result of the orographic nature of the rainfall (Figs. 3D & 3E). The absence of serious flooding in the western rivers was a result of the rapid decline in rainfall westwards of the coast.

The highest 6 day rainfall registration was at Robertson, on the boundary of the Hawkesbury and Shoalhaven catchments. The station recorded 940 mm of rain in the 6 day period to 9am on 24th March. While this may be a large volume of rain it is nowhere near the world record for a 6 day rain of 3,111 mm, recorded at Silver Hill Plantation, Jamaica (Jennings, 1950). However, the rainfall had a recurrence interval of greater than 100 yrs on the basis of data available for Sydney (Pierrehumbert, 1974). Even the 3 day rainfall to the 20th March of 640 mm has a recurrence interval greater than 100 yrs relative to Sydney. A 24 hr summer rainfall of 250 mm or greater for Sydney has a recurrence interval of approximately 50 years (Table 3).
Floods

Although rain fell in the Hawkesbury catchment prior to the storm of the 18th the catchment was relatively dry. A long dry period over summer had depleted soil moisture stores. Dams on the catchment had low levels. Consequently, the initial period of rain did not produce much runoff and it was not until Sunday the 19th that significant rises in stage occurred in the Hawkesbury system (Figures 4, 5 & 6).

Flood peaks occurred on the 20th for the headwater reaches of the main streams and on the 21st for the lower reaches (Table 4). The delay in the flood peak at Windsor, which occurred 13 hours after that at North Richmond, was probably a result of backwater effects from flooding in the Colo and MacDonald Rivers. The only alternative explanation to backwater effects for the lag between the two peaks is that the flood wave moved at the low velocity of 0.28 m/sec.

Analysis of the flood frequency records for the Nepean at Penrith and for the Hawkesbury at Windsor suggest that flooding in the lower reaches of the Hawkesbury was considerably influenced by flooding in the Colo and MacDonald Rivers.

The volume of rain which passed through the Penrith gauge (Fig. 4) was equivalent to a depth of 136 mm over the catchment. That is, approximately 40% of the catchment rainfall was converted into runoff.

Flood Frequency

A recurrence interval of between 6 and 13 years (Fig. 7, Table 5) is obtained from various flood frequency curves for the Nepean River at Penrith. However, the estimate of the recurrence interval of the flood at Windsor ranges between 21 and 44 years (Fig. 8, Tables 5 & 6).
The various estimates for the frequency of the March flood at Windsor arise from the poor fit between the data and the assumed frequency distribution. Although flood records are available for Windsor from 1790 they are incomplete with gaps of at least 20 years in them. The period of record from 1900 to 1978 is well documented and the selected cut off level of 8 m has reduced the possibility that small floods have been omitted. The series was split at 1940 because it is after this time that dams became important in the catchment hydrologic cycle. Also, Pickup (1974) suggests a distinct change in the hydrologic regime for sections of the Hawkesbury catchment sometime in the period 1940 to 1950.

The inability to accurately define the flood frequency for Windsor has some implications for land use planning in the area.

**Morphological effect of the flood**

Large sections of river bank along the Hawkesbury slumped immediately after the flood peak (Fig. 9). Bank collapse along Terrace Rd at Windsor was restricted to fluvial deposits overlying shale bedrock which outcrops at 1 metre (approximately) above low flow level.

Initial reports suggest that considerable volumes of sand were deposited in the Argyle, Windsor and Wilberforce Reaches of the Hawkesbury River. Some of this sand came from sand mining areas near North Richmond, some from bank collapse, and some may have come from erosion of the floodplain.

The floodplain between Bakers Lagoon and Pitt Town Bottoms was scoured in several areas. Scour holes up to 1 metre deep formed, particularly along depressions that drained the floodplain back into the river. Sinuous large scale ripples (Allen, 1968) with avalanche
faces up to 30 cm deep developed on the floodplain on the convex side of meander bends.

Along South Creek and the Hawkesbury River upstream of North Richmond there appeared to be only minor alteration of the floodplain surface. Deposits in these two areas are of silt-clay texture, which probably settled out during the long period of still water that occurred during the 22nd. Thickness of silt-clay deposits on grass, fence posts, cans, bottles, and other artifacts were less than 1 mm and generally less than 0.5 mm.

Sand and silt texture deposits up to 0.5 m thick were noted by the author at several localities along the Hawkesbury. However, as the deposits appeared to be thickest where the floodplain had been eroded floodplain deposits of sand and silt derived from the River were probably negligible. The area inundated between Agnes Banks and York reach is estimated to have had an average depth of river derived deposits less than 0.5 mm, and more likely less than 0.1 mm.

Unfortunately, because of rain in the week following the flood, initial observations of flood deposits could not be extended to obtain an accurate figure of average depth of deposits. The problem of sorting out locally derived and river derived deposits was also too complex to be solved in the time available.

Area of inundation

The area inundated between Agnes Banks and York Reach (Fig. 10) was km². The actual area of flooding is slightly more extensive than that indicated as several creeks to the south of Windsor and Richmond also flooded. However, these local floods were short, generally less than 12 hours duration.
Economic effects of flooding

In Windsor a large number of houses were inundated (Fig. 11) although not all of the houses indicated as being under water were actually underwater. In some cases floor levels are above flood level. Still, these houses did have water frontages for several days. Windsor Council building regulations now prohibit floor levels below 15 m.

Many houses on the levee along Freemans Reach and Argyle Reach were inundated. Again, in the case of double storey houses, the second floor was above flood level.

Shane Park on South Creek and Riverstone on Eastern Creek were affected by flooding. Approximately 40 houses were flood damaged.

Orchard and market gardens were destroyed or severely damaged. Orange orchards just on the point of being harvested were flood damaged. In one instance, a farmer on South Creek who had planted the week before the flood lost $2,500 (approximately) worth of seed.

Sand deposition on paddocks along the Hawkesbury and scour of soil from the paddocks will cause loss of productivity for some time.

Many roads were damaged, tarmac being ripped off in many cases and culverts undermined and approaches washed away. The approach to Yarrumundi Bridge was washed away (Fig. 12).

Bank collapse imperilled several riverside homes at Penrith and severely damaged a main sewer line at Windsor. The estimated cost of repair of the latter is in excess of $150,000. New bank stabilization works upstream of Windsor Pump station held. However, older works on the upstream area of Argyle Reach suffered minor slump failure.

The flood blocked roads and rail links over the area. The sewage treatment works at McGraths Hill was inundated.
Conclusion

The flooding was far more extensive than this report has indicated. The Colo and MacDonald Valleys and Hawkesbury Valley downstream of York Reach were all seriously affected by the flooding. However, the situation for the Hawkesbury as described herein is fairly typical for the remainder of the catchment.

Economic losses have not been assessed in monetary terms. Although, when one considers the losses that accrued from diversion of man power to flood relief, loss of productivity, transport delay, etc. as well as actual physical losses, the March flood in the area of discussion probably cost the local people and tax payers well over $2 million.

References


Figure Captions

Figure 1  Path of the low pressure cell of March 1978 that was responsible for floods in Eastern Australia. Crosses indicate the position of the cell centre at the time and date indicated.

Figure 2  Temporal isobaric trend map of the low pressure system of March, 1978. Isobars define the width of the cell normal to its direction of movement.

Figure 3A  24 hr rainfall to 9am, 19th March.
Figure 3B  24 hr rainfall to 9am, 20th March.
Figure 3C  24 hr rainfall to 9am, 21st March.
Figure 3D  72 hr rainfall to 9am, 20th March.
Figure 3E  Total rainfall for the 7 day period 18th to 9am, 24th March.

Figure 4  Hydrograph for Nepean River at Penrith.

Figure 5  Stage hydrographs for Hawkesbury River at North Richmond and Windsor.

Figure 6  Stage hydrographs for Grose River at Burralow and Nepean River at Penrith.

Figure 7  Flood frequency curve for the Nepean River at Penrith. Frequency curve is of the annual series for the period 1900 to 1968.

Figure 8A  Flood frequency curve for Hawkesbury River at Windsor, 1900 to 1977.
Figure 8B  Flood frequency curve for Hawkesbury River at Windsor, 1900 to 1940.
Figure 8C  Flood frequency curve for Hawkesbury River at Windsor, 1941 to 1977.
Figure 8D  Flood frequency curve for Hawkesbury River at Windsor, 1900 to 1977. Base level of series 10m.

Figure 9A  Bank collapse along River Road, Penrith. March, 1978.
Figure 9B  Bank collapse along Nepean River at Penrith. March, 1978.

Figure 10  Area of inundation by the March, 1978 flood. Map composed from flood heights field mapped onto 1:4,000 orthophotomaps.

Figure 11  Extent of flooding at Windsor by the March, 1978 flood.

Figure 12  Washed out approach to Yarramundi Bridge, March, 1978.
Fig. 1.
Low pressure system track

Areas with pressure < 1000 mb
Areas with pressure < 1004 mb
Areas with pressure < 1008 mb

March 1978

SCALE 0 100 1000 km

Fig. 2.
Fig. 4.

Nepean River at Penrith
Flood of March 1978

Flood peak
10,160 m$^3$/sec at 0530 hrs 21/4/78

Volume of flood
$1.44 \times 10^9$ m$^3$

Time
19th 20th 21st 22nd 23rd
Fig. 5.

Flood of March 1978
Stage hydrograph for
--- North Richmond
--- Windsor

Peak North Richmond, 1700 hrs, 15.25m
Peak Windsor, 0900 hrs, 14.31m

Deck level Windsor Bridge
STAGE HYDROGRAPHS FOR
FLOOD OF MARCH, 1978

Grose River at Burralow
Nepean River at Penrith

N.B. Stage not tied to Standard Datum

TIME

STAGE (metres)
Nepean River at Penrith
Annual maximum series
for period 1900-1968
Only floods >1200 m$^3$/sec plotted

Fig. 7.
Windsor flood frequency
Partial duration series for period 1900-1977
Floods >8m

Fig. 8A.
Windsor flood frequency
Partial duration series
for period 1900–1940
Floods > 8m

Fig. 8B.
Windsor flood frequency
Partial duration series for period 1941-1977
Floods >8m

Fig. 8c.
Windsor flood frequency
Partial duration series for period 1900 - 1977
Floods > 10m

Fig. 8D
TABLE 1

Average rainfalls (1) for Hawkesbury catchment and catchment at Penrith

<table>
<thead>
<tr>
<th>Period</th>
<th>Average rainfall (mm) for Catchment (2)</th>
<th>Nepean at Penrith</th>
<th>Hawkesbury</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 hrs to 19th March</td>
<td>91</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>24 hrs to 20th March</td>
<td>143</td>
<td>139</td>
<td></td>
</tr>
<tr>
<td>24 hrs to 21st March</td>
<td>80</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td>18th to 24th March</td>
<td>327</td>
<td>294</td>
<td></td>
</tr>
<tr>
<td>72 hrs to 20th March</td>
<td>238</td>
<td>207</td>
<td></td>
</tr>
</tbody>
</table>

(1) Derived from planimetric measurement and averaging of isohyetal maps.

(2) Areas of catchments are

Nepean at Penrith: 10, 609 km²
Hawkesbury at Broken Bay: 21,700 km²
### TABLE 2

Percentage area of Hawkesbury catchment receiving more than a given volume of rainfall.

<table>
<thead>
<tr>
<th>Rainfall (mm)</th>
<th>Percentage of catchment receiving more than given volume of rainfall for period</th>
<th>72 hrs to 9am 21st March</th>
<th>6 days to 9am 24th March</th>
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</thead>
<tbody>
<tr>
<td>600</td>
<td></td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>500</td>
<td></td>
<td>0.5</td>
<td>3.4</td>
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<td>400</td>
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<td>2.5</td>
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<td>5.5</td>
<td>44.0</td>
</tr>
<tr>
<td>200</td>
<td></td>
<td>49.9</td>
<td>86.5</td>
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<tr>
<td>100</td>
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<td>91.5</td>
<td>99.1</td>
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Table 3
Summer Rainfall recurrence intervals for 24, 72 and 144 hour periods (1)

<table>
<thead>
<tr>
<th>Recurrence Interval (years)</th>
<th>Rainfall (mm) for period of</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24 hrs</td>
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<tr>
<td>100</td>
<td>288 (331)</td>
</tr>
<tr>
<td>50</td>
<td>252 (293)</td>
</tr>
<tr>
<td>10</td>
<td>173 (216)</td>
</tr>
<tr>
<td>5</td>
<td>149 (204)</td>
</tr>
<tr>
<td>2</td>
<td>108 (180)</td>
</tr>
<tr>
<td>1</td>
<td>82 (141)</td>
</tr>
</tbody>
</table>

(1) Data extracted from Pierrehumbert (1974), Fig.4(e). Note, the data are derived for Sydney and cannot be easily transferred to other localities. They should be used as a guide. The average rainfall at Robertson is 35% greater than that at Sydney and an estimate of the Robertson rainfall for specific recurrence intervals and durations can be gained by multiply the given depths by 1.35. Estimates for the 24 hrs and 72 hrs depths for Robertson have also been calculated by the procedure outlined in Institution of Engineers, Australia, 1977. These calculated rainfalls are shown in brackets.
Table 4

Time and magnitude of flood peaks on the Hawkesbury River system for March, 1978

<table>
<thead>
<tr>
<th>Site</th>
<th>Time of peak</th>
<th>Peak stage (m) or discharge (m³/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avon Dam</td>
<td>20th, 0300 hrs</td>
<td>7.77 m³/sec</td>
</tr>
<tr>
<td>Nepean Dam</td>
<td>20th, 1400 hrs</td>
<td>1,027 m³/sec</td>
</tr>
<tr>
<td>Warragamba Dam</td>
<td>21st, 0200 hrs</td>
<td>6.134 m³/sec</td>
</tr>
<tr>
<td>Nepean at Penrith</td>
<td>21st, 0530 hrs</td>
<td>10.162 m³/sec</td>
</tr>
<tr>
<td>Grose River at Burralow</td>
<td>20th, 0930 hrs</td>
<td>9.90 m</td>
</tr>
<tr>
<td>Nepean at Menangle</td>
<td>20th, 1500 hrs</td>
<td>13.45 m</td>
</tr>
<tr>
<td>Hawkesbury at North Richmond</td>
<td>21st, 1700 hrs</td>
<td>15.25 m</td>
</tr>
<tr>
<td>Hawkesbury at Windsor</td>
<td>22nd, 0600 hrs</td>
<td>14.31 m</td>
</tr>
</tbody>
</table>
Table 5

Estimates of the recurrence interval of March, 1978 flood
on the Hawkesbury River at Windsor and Nepean River at Penrith

<table>
<thead>
<tr>
<th>Method of frequency analysis</th>
<th>Estimated recurrence interval (years)</th>
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<tbody>
<tr>
<td>Partial duration series,</td>
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</tr>
<tr>
<td>period 1900-1977,</td>
<td>44</td>
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<tr>
<td>base level 8m</td>
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<tr>
<td>Partial duration series,</td>
<td></td>
</tr>
<tr>
<td>period 1900-1940,</td>
<td>41</td>
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<tr>
<td>base level 8m</td>
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<tr>
<td>Partial duration series,</td>
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<tr>
<td>period 1941-1977,</td>
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<td>base level 8m</td>
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<td>Partial duration series,</td>
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<tr>
<td>period 1900-1977,</td>
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<td>base level 10m</td>
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<table>
<thead>
<tr>
<th>Method of frequency analysis</th>
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<tr>
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<tr>
<td>Annual maximum flood series,</td>
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<td>period 1900-1940</td>
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<tr>
<td>Annual maximum flood series,</td>
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<tr>
<td>Rank of Windsor floods</td>
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<td>------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>3</td>
<td>1900 July</td>
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<tr>
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<td>1904 July</td>
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<tr>
<td>32</td>
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? Possible error in North Richmond gauge
NR No records available

Source: Bureau of Meteorology