Hawkesbury Floodplain Risk Management Study & Plan

Drawing of night-time rescues during the 1867 Hawkesbury River flood (Source: Illustrated Sydney News, June 1867)

Volume 1 − Main Report

December 2012

Report of Hawkesbury City Council's Floodplain Risk Management Advisory Committee
Adopted by Hawkesbury City Council at its meeting on 11 December 2012

Bewsher

HAWKESBURY CITY COUNCIL

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Volume 1 − Main Report

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Adopted by Hawkesbury City Council at its meeting on 11 December 2012

Bewsher

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FOREWORD

In New South Wales the prime responsibility for local planning and the management of flood liable land rests with local government. To assist local government with floodplain management, the NSW Government has adopted a Flood Prone Land Policy in conjunction with the *Floodplain Development Manual*.

The Policy is directed at providing solutions to existing flood problems and to ensure that new development is compatible with the flood hazard and does not create additional flood problems. The Policy sets out four sequential stages in the process of floodplain management:

1. Flood Study	Assessment to define the nature and extent of the flood problem.
2. Floodplain Risk Management Study	Evaluation of management options for the floodplain with respect to both existing and proposed development.
3. Floodplain Risk Management Plan	Formal adoption by Council of a management plan for floodplain risks.
4. Implementation of the Plan	Measures undertaken to reduce the impact of flooding on existing development, and implementing controls to ensure that new development is compatible with the flood hazard.

Flooding problems in the Hawkesbury-Nepean Valley have been extensively investigated over recent years under the auspices of the *Hawkesbury-Nepean Floodplain Management Strategy*, the achievements of which are summarised in the Implementation Report (HNFMSC, 2004). One outcome of the Strategy was a *Regional Floodplain Management Study*. An important component of the Regional Study was a *Flood Hazard Definition Tool* used to define flood behaviour in the valley. This represents the baseline Flood Study used by the current study. Another component of the Regional Study was a series of Guidelines for land use planning, subdivision and building on flood prone land. These best practice Guidelines are important references for the current study.

This *Hawkesbury Floodplain Risk Management Study & Plan* builds on the previous work, with a focus on the Hawkesbury River floodplain within the Hawkesbury Local Government Area.

Hawkesbury City Council commissioned Bewsher Consulting to prepare this report. It has been prepared with financial assistance from the NSW Government through the Office of Environment and Heritage (OEH). This document does not necessarily represent the opinions of OEH.

The assistance of Council's Floodplain Risk Management Advisory Committee and officers from Council and OEH in preparing this document is gratefully acknowledged. The assistance of Grech Planners in providing town planning input, Molino Stewart for preparing an evacuation working paper, and Halcrow for traffic engineering advice is also acknowledged. Risk Frontiers provided some input (gratis) on the issue of flood insurance.

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EXECUTIVE SUMMARY

Introduction

This is a Floodplain Risk Management Study and Plan for the Hawkesbury River floodplain within the Hawkesbury LGA.

The study has been commissioned by Hawkesbury City Council with financial assistance from the Office of Environment and Heritage (OEH). The study has been prepared by Council's Floodplain Risk Management Advisory Committee with the assistance of specialist floodplain risk management consultants.

The study's documentation comprises three volumes:

- **Volume 1** — Main Report
- **Volume 2** — Town Planning Issues; and
- **Volume 3** — Flood Maps and Annotated Bibliography of Reviewed Reports

Reasons for the Study

The Hawkesbury-Nepean Valley has one of the most significant flood risk exposures within Australia. The risks to both property and people resulting from flooding in the Valley have been recognised for some time. Following the establishment of the *Hawkesbury-Nepean Flood Management Advisory Committee* in 1997, the *Hawkesbury-Nepean Floodplain Management Strategy* (HNFMS) was prepared under the guidance of the State Government. The *Strategy* was developed to enable all levels of government and the wider community to recognise more fully and respond more appropriately to the flood risks in the Valley.

An important outcome of the HNFMS was a Regional Floodplain Management Study which provided tools to assist each council in the Valley develop its own local floodplain risk management plans. This included preparation of a flood hazard definition tool and a set of best practice guidelines covering land use planning, subdivision and building on flood prone land.

The Hawkesbury Floodplain Risk Management Study and Plan builds on the significant work done at the regional level. It advances local floodplain management initiatives including the revision of local planning policies and the provision of advice to Hawkesbury City Council and the State Government concerning the evacuation risk exposure of future development proposals.

Data Review

As part of the current study a vast amount of literature including over 60 reports relating to flood risks in the study area have been reviewed. This information is summarised in the detailed annotated bibliography within Appendix B of **Volume 3**.

Flood Mapping

All of the flood behaviour information used in the current study has been based on previous investigations and reports. Revised mapping of the areal extent of the 5 year, 20 year, 50 year, 100 year, 200 year, 500 year and 1000 year ARI floods, and the probable maximum flood (PMF) has been undertaken for this study utilising the latest airborne laser scanning (ALS) topographic data. Detailed information concerning flood levels, flood extents and flood hazards has been provided separately to Council in GIS format and are published in **Volume 3**.

Following on from the *Land Use Guidelines* prepared for the Hawkesbury-Nepean Floodplain Management Steering Committee, the floodplain has been classified according to its flood risk. Five flood risk bands comprising very low, low, medium, high and extreme flood risks have been adopted (see **Figure 1**).

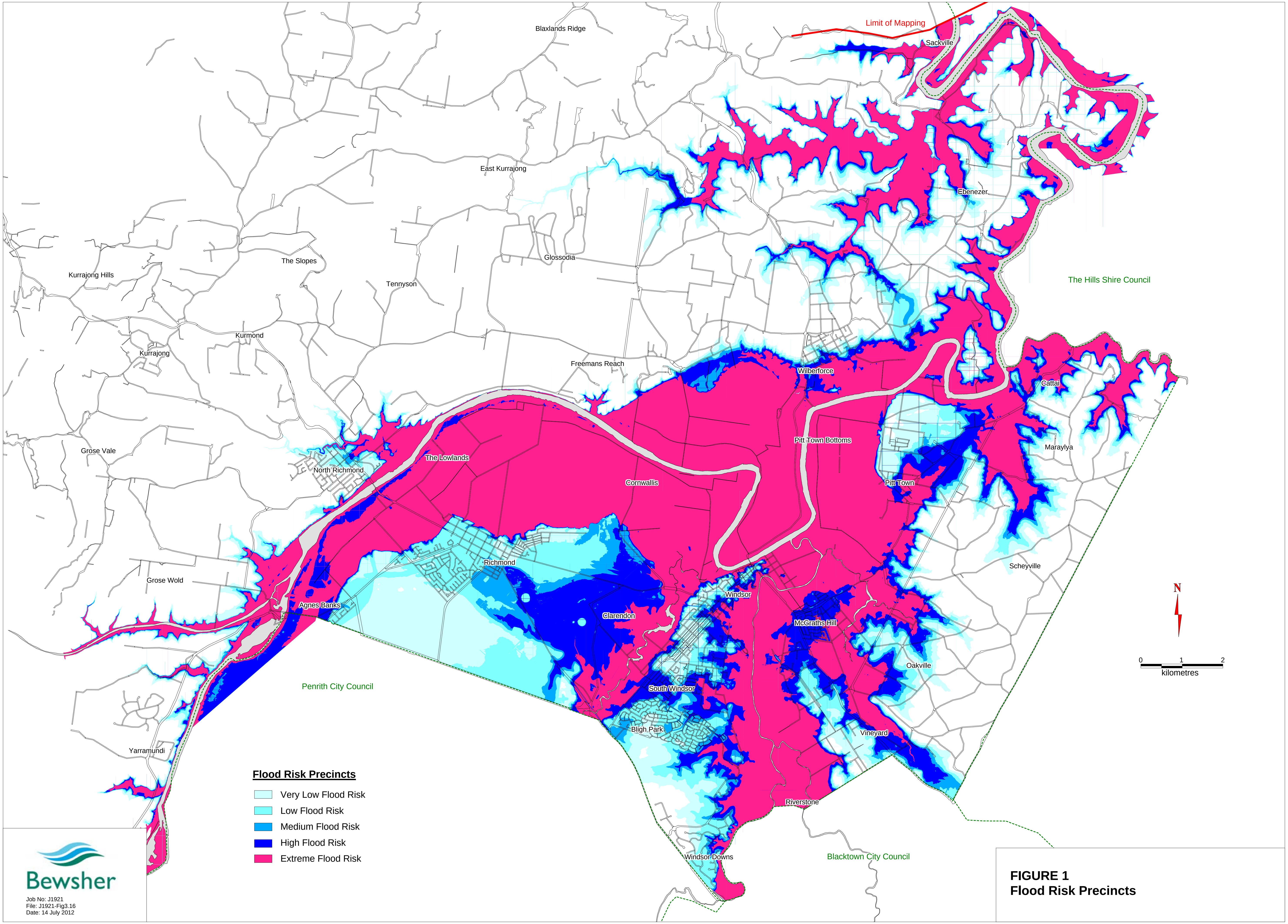

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FIGURE 1
Flood Risk Precincts

Flood Risks to Property

An assessment was made of the number of buildings potentially flooded. Assuming all floor levels are approximately 0.3m over the ground (at the building), **Table 1** shows that about 350 houses would be inundated in the 20 year flood, rising to 1,600 in the 50 year flood, 3,200 in the 100 year flood and over 13,000 in the PMF. In the 100 year flood, almost 1,400 dwellings would be inundated to depths exceeding 2 metres. The distribution of houses flooded is summarised in **Figure 2**.

TABLE 1 – Estimated Number of Buildings Flooded by Design Event, Depth and Land Use, Hawkesbury River within Hawkesbury LGA

	5 year*	20 year*	50 year*	100 year	200 year	500 year	1000 year	PMF
Ground level at building								
Residential	40	466	1,840	3,387	4,898	7,480	10,316	13,418
Commercial/Industrial	14	86	297	609	778	1,093	1,571	1,754
Over floor *(assumed 0.3m)*								
Residential	33	348	1,591	3,165	4,538	6,958	9,974	13,344
Commercial/Industrial	11	60	219	527	731	925	1,520	1,753
1m over floor								
Residential	12	139	933	2,240	3,453	5,178	8,014	13,012
Commercial/Industrial	6	36	128	358	627	792	1,250	1,740
2m over floor								
Residential	1	67	360	1,380	2,699	3,874	6,081	12,395
Commercial/Industrial	2	21	79	173	453	705	859	1,679

* Excludes areas downstream of Sackville

McGraths Hill is severely affected in a 50 year flood and virtually entirely inundated in a 100 year flood. South Windsor also presents a serious flood risk exposure in the 50 year and 100 year floods, and is progressively more affected up to the PMF. A large number of houses are affected in Windsor, Pitt Town and Wilberforce in the 50 year and 100 year events. Houses in Bligh Park, Richmond, Hobartville and North Richmond are little affected in events up to and including the 100 year flood, but are very much exposed at Bligh Park and Richmond in the 200 year and rarer events.

An assessment of the potential costs of flooding to the residential sector was made using the standardised methodology provided by OEH. The results are presented in **Table 2**. The annual average cost of flood damage to houses is calculated as about $18 million, whilst the present value of damages over a 50 year period is calculated as about $261 million. These estimates do not include for actual building failure (which is expected to be significant where depths are large) or for damages to the commercial/industrial sector, to infrastructure, to motor vehicles or to special uses including caravan parks, the RAAF base or the UWS Hawkesbury campus.

Flood Risks to Life

Flooding presents very serious risks to life within the study area. Guided by the principles and processes espoused in the *Floodplain Development Manual* (NSW Government, 2005), careful consideration has been given to these risks during the current study.

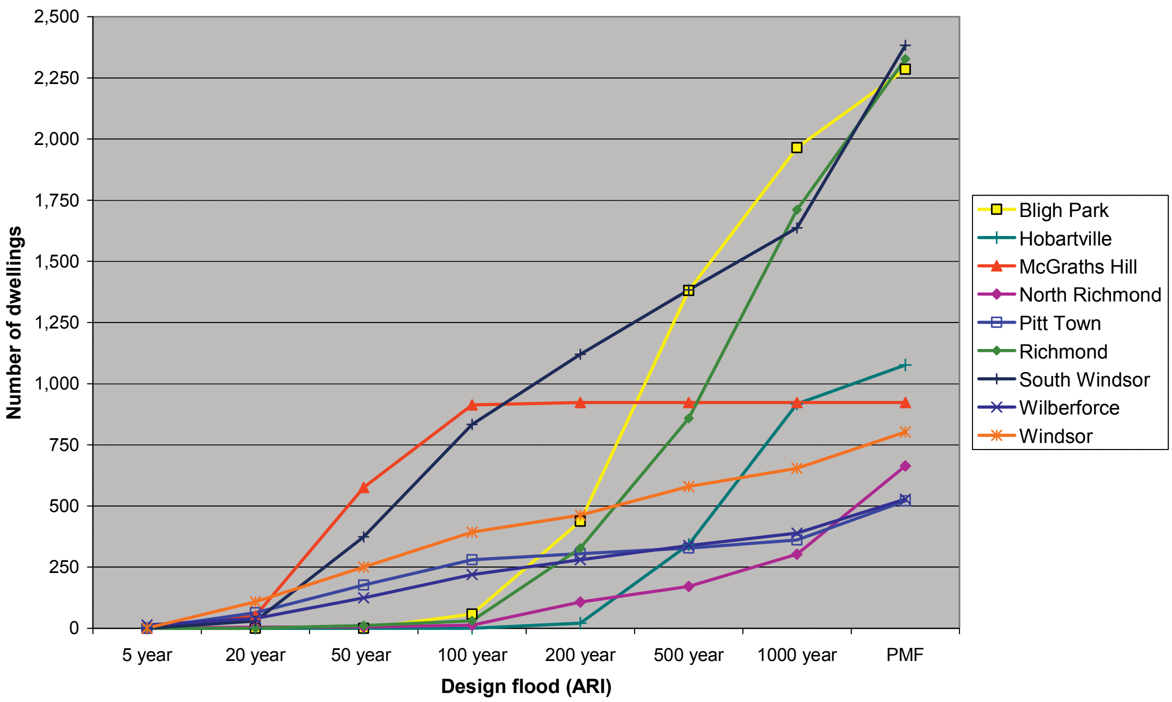


FIGURE 2 – Estimated No. of Dwellings Flooded to Ground Level by Design Event and Suburb

Note: only suburbs with >500 dwellings affected in PMF shown

TABLE 2 – Summary of Residential Flood Damages by Event

Flood Event	Predicted Actual Damage in Flood Event ($2010)	Contribution to Average Annual Damage (AAD) ($2010)		Present Value of Damage over 50 Years ($2010)
5 year	$3M	$0.5M	3%	
20 year	$38M	$3.1M	18%	
50 year	$184M	$3.3M	19%	
100 year	$403M	$2.9M	16%	
200 year	$613M	$2.5M	14%	
500 year	$947M	$2.3M	13%	
1000 year	$1,408M	$1.2M	7%	
PMF	$2,214M	$1.8M	10%	
TOTAL	–	**$17.7M**	100%	$397M (4% discount rate) **$261M** (7% discount rate) $177M (11% discount rate)

In most rivers in NSW, the differences between the 100 year flood level and the probable maximum flood (PMF) are relatively small (i.e. nearly always less than 2m). However within the study area, the water levels in the Hawkesbury River during an extreme flood can rise up to three building storeys above the 100 year flood level. During these major flood events, significant areas of land are inundated. Most importantly in regard to risks to life, 'islands' of higher land can form as flood waters rise, isolating the communities on the island who, for whatever reason, may have failed to evacuate prior to the onset of the flood. As waters continue to rise during extreme floods, there is the potential for these low flood islands to be overwhelmed with disastrous loss of life.

Consequently the flood evacuation constraints of existing and future developments have been a principal focus of this study.

An overview of the low flood islands within the study area and their flood risks are provided in **Figure 3**. Further details of the flood risk considerations within ten key urban centres in the study area are provided in **Figures 5.4** to **5.13** which can be found in **Section 5**.

The Floodplain Risk Management Plan

The principal outcome the current study is the preparation of the Floodplain Risk Management Plan which is provided in **Table 3**. This Plan presents the Committee's views of the most appropriate manner in which to manage the existing and future flood risks within the study area.

The remainder of this Executive Summary details the principal considerations and components of the Plan.

Community Flood Education and Resilience

Ongoing community flood education is vital in the Hawkesbury floodplain because of the infrequency with which severe floods have been experienced, the significant depths of inundation associated with severe floods which pose very serious threats to life and property, and the essential importance of community flood readiness for the timely evacuation of the floodplain prior to inundation of low flood islands. In addition, building and maintaining the community's resilience to the flood threat is a paramount risk management objective.

A good deal of work was done under the *Hawkesbury-Nepean Floodplain Management Strategy* to assess community attitudes towards flood risk and to inform a Regional Public Awareness Program. An important component of an education campaign is periodic review and evaluation to ensure continued reach, relevance and effectiveness. Accordingly, a review and evaluation of the Regional Public Awareness Program is recommended, which will also set the basis for coordinated flood education and resilience building measures for the next 5-10 years.

From a review of the previous research and education measures in the Hawkesbury, and drawing upon experience elsewhere in the State, the following are a number of recommendations which should be considered in the proposed review.

First, there appears to be a need for more geographically targeted approaches, since the flood risks and response strategies are not equal across the Hawkesbury floodplain.

Second, a greater use of the record 1867 flood is desirable to overcome barriers to preparedness such as the myth that only properties below the 100 year level are flood-prone, and to persuade people that floods can be very dangerous, requiring early evacuation.

A number of messages need to be conveyed in a suite of flood education measures, including:

- why flooding is such a significant risk in this area?
- how flood levels are calculated and what a 100 year flood means?
- what role if any Warragamba Dam has in alleviating flooding?
- how I will be warned about a rising flood?
- why I need to evacuate so early when I can’t see the flood?
- where my evacuation route is?
- why I need to evacuate when the previous warning proved to be a false alarm?
- what could happen if I decide not to evacuate?

Several modes for communicating these messages to the community are proposed. Perhaps the key measure for raising a community’s awareness of flooding and building resilience are via the issuing of certificates to all occupiers of the floodplain, indicating design flood levels at individual properties. There is a need for suburb-specific FloodSafe guides including maps of the local and regional evacuation route. Certificates and the appropriate FloodSafe guide could be delivered with Council’s rate notice every two years.

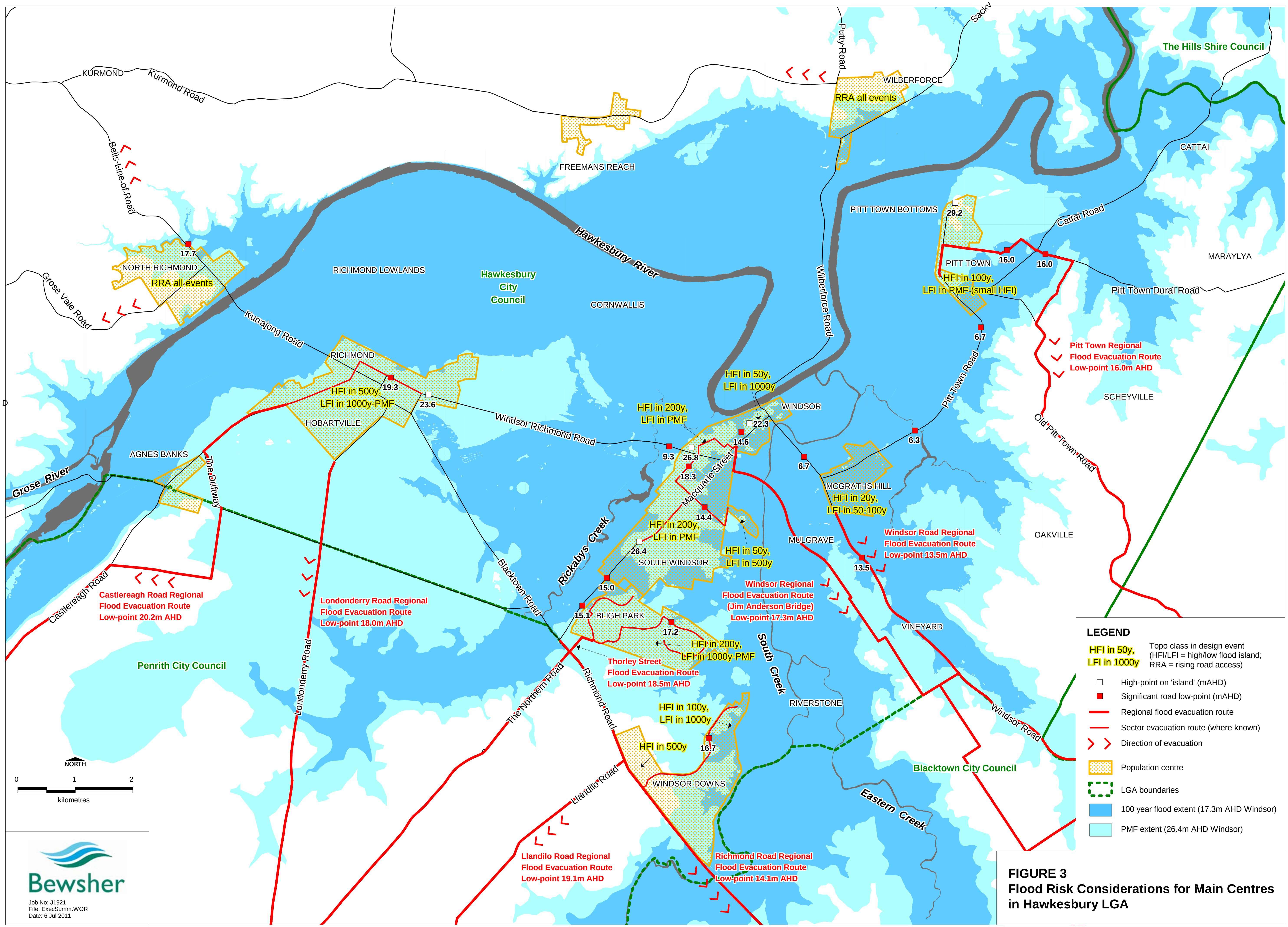


FIGURE 3
Flood Risk Considerations for Main Centres in Hawkesbury LGA

TABLE 3 – Floodplain Risk Management Plan

ITEM	CAPITAL COST	AGENCY	PRIORITY
1. **Community Flood Education and Resilience** (a) Review and evaluate Regional Public Awareness Program. (b) Issue flood certificates on regular basis. (c) Prepare suburb-specific FloodSafe guides. (d) Prepare flood tolerant housing poster and brochure. (e) Enhance flood information on Council's web-site. (f) Commission book and video production on Hawkesbury flooding and vital community responses. (g) 150 year commemoration of 1867 flood. (h) Install flood icons/markers at key locations. (i) Continue to host Business FloodSafe breakfasts.	$300K	HCC, SES	High
2. **Emergency Management** (a) Implement dual outbound lanes on Jim Anderson Bridge during flood emergencies.	$100K	SES, RTA	High
(b) Enhance emergency management assessment tools. Develop best practice traffic modelling to better assess implications of various evacuation scenarios. Integrate with flood modelling.	$200K	SES	Medium
(c) Promote construction of community refuges within major new buildings on flood islands to service the existing communities.	−	HCC, State	High
(d) Continue to prepare and maintain flood emergency management plans for special uses and utilities. (e) Use caravan park emergency management plan template to raise awareness and increase preparedness.	−	Private Sector, HCC, SES, State	High
(f) Review and update Hawkesbury-Nepean Flood Emergency Sub Plan and NSW State Flood Sub Plan (Annex C).	−	SES, BoM, State	High
(g) Provide additional evacuation capacity possibly through a new crossing of South Creek at Eighth Ave, Llandilo.	(not costed)*	HCC, RTA, State	Low-Medium
(h) Identify local evacuation route upgrades and revise FRMP.	$100K*	HCC, SES	Medium
(i) Investigate lane duplication options, east of Jim Anderson Bridge.	$150K*	HCC, SES	High
3. **Future Development − Flood Risk Advice to Consent Authorities** (a) Provide advice to Council and State Government concerning severity of flood evacuation risks as per **Tables 4** and **5**.	−	HCC, State	High
4. **Town Planning** (a) Advise DPI of principal planning recommendations of this Plan. (b) Amend flood risk provisions of Council's existing DCP. (c) Amend LEP in accordance with Volume 3. (d) Prepare maps to guide application of Codes SEPP. (e) Revise S149 notifications in accordance with **Volume 3**. (f) Lodge application for 'exceptional circumstances' with DPI & OEH.	−	HCC, State	High
5. **VHR and Redevelopment** (a) Survey all houses inundated in 20 year ARI events. (b) Assess eligibility for voluntary house raising (VHR)/ redevelopment and possibly for voluntary house purchase (VP). (c) Report back to Council. Revise FRMP if required.	$100K*	HCC	Medium
6. **McGraths Hill** (a) Feasibility study of 50 year levee including consultation. (b) Assess community attitudes to levee and refuge mound. (c)Report back to Council. Revise FRMP if required.	$60K*	HCC	Medium
7. **Updating Flood Behaviour Data in Valley** (a) Utilise latest 2D flood modelling and latest topographical data. (b) Extend along main tributaries. (c) Include revised IFD rainfall. (d) Include for revised climate change influences. (e) Update data for smaller more frequent flood events.	$500K	HCC, other Councils, State	Low
TOTAL (rounded)	**$1.5M***		

*Note: Construction costs are not included. Plan to be revised to include these costs once investigations are completed.

There is also a need to make the *Building Guidelines* prepared for the Hawkesbury-Nepean Floodplain Management Steering Committee more accessible, and to this end the preparation of a Flood Tolerant Housing poster and brochure is recommended.

Some suggestions are made to enhance Council's website to create a 'one-shop stop' for flood information in the Hawkesbury LGA.

There would also be merit in commissioning a comprehensive, quality book on Hawkesbury flooding, both to document the rich history of flooding in the Hawkesbury and also to form an instrument of persuasion promoting appropriate community responses during flooding.

June 2017 marks the 150^{th} anniversary of the devastating 1867 flood, and would be an excellent opportunity for an intensive campaign to raise the profile of flood risks in the Valley. Other initiatives could be planned to build momentum in the lead-up to 2017, such as the launch of the proposed book and the development of an 1867 flood heritage tour.

It is also recommended to install several permanent flood icons or markers at key locations on the flood 'islands'. Various styles of design are available, including 1867 flood level markers on a totem pole and direct message signage installed at busy traffic interchanges (e.g. "The Hawkesbury floods – are you prepared?").

Initiatives such as the SES Business FloodSafe breakfasts are encouraged to help businesses plan for flooding.

Community Refuges

There are a number of low flood islands scattered throughout the study area that present significant safety risks in the event of major or extreme flooding. The largest urban flood island exposed to frequent flooding is McGraths Hill with its population of about 2,500 people which becomes isolated in a 20 year ARI event and is overwhelmed in a 100 year ARI event.

There is a much greater population at risk on the other urban flood islands within the study area however most of these become inundated in much rarer flood events. These include Windsor which becomes isolated at the 100 year ARI flood level (when the Jim Anderson bridge access is cut) and overwhelmed in PMF.

The SES has confirmed that they will take every possible action to ensure the populations of all flood islands are evacuated. Nevertheless despite the diligent efforts of the SES, there is a very real possibility that significant numbers of people will remain on flood islands as a result of their unwillingness to leave, their inability to evacuate before egress routes become cut by floodwater, meteorological uncertainty in forecasting the flood or for other reasons. The provision of elevated building floor levels located above the reach of floodwaters on the higher portions of flood islands, would provide locations where trapped people could take refuge. While such facilities might not necessarily provide comfortable conditions for the occupants until such time as they were rescued, they could serve as an option of last resort to avert many deaths by drowning.

It needs to be recognised that the frequency of the flood events when such refuges might be used, is rare or very rare. Whilst a refuge within McGraths Hill might be used every 50 years on average, the refuges on the higher parts of Richmond and Windsor would be vital less often than once every 1000 years on average. Consequently buildings purpose-built solely to service this refuge requirement, may be an unnecessary impost on the community. Rather refuges could be provided within public or private buildings such as schools, government offices, gymnasiums, etc, as an ancillary use to the main function of the building.

It is the recommendation of this study that Council and the State Government condition future development approvals to ensure that safe refuges be constructed on the higher points of the major flood islands within Windsor, Bligh Park, Richmond and McGraths Hill.

If evacuation south along Llandilo Road becomes excessively congested, there is also opportunity for evacuees to take temporary refuge within a new facility on higher ground in the Windsor Downs area until the road congestion clears.

Diversion to Currency Creek – Flood Mitigation Option

This option involves the diversion of floodwaters from the York reach of the Hawkesbury River about 3km downstream of Wilberforce through a low point in the adjacent saddle and into the Chain-of-Ponds Creek and thence into Currency Creek, before allowing floodwaters to return to the Hawkesbury River downstream of Sackville. Although this option has previously been investigated as part of the HNFMS, further reconsideration was requested by the Committee. The option was found to have moderate benefits and would typically reduce 100 year flood levels across much of the urban areas within the LGA by about 0.9m. Nevertheless the proposed 160m wide channel would likely need to be about 4–6km long and based on past estimates, may include rock excavation with a volume in excess of one million cubic metres and a much larger quantity of earth.

The channel would be constructed through a rural area and require bridging to facilitate existing road access at a number of locations. The approximate construction cost of the channel and bridges is estimated to be $250-$350 million. The saving in flood damage costs is estimated to be $45 million (net-present value) and consequently the option has a low benefit-cost ratio of only 0.1−0.2.

In view of the likely poor economic performance and the potential for there to be significant adverse environmental, social and geomorphological impacts, the option has not been recommended at this stage.

McGraths Hill Levee and Refuge Mound

The most favourable levee option investigated as part of the HNFMS was at McGraths Hill. Accordingly this option has been reviewed as part of the current study. This proposal involves the construction of a levee to prevent inundation of McGraths Hill in floods up to a 50 year ARI. Approximately 3.5km of earth levee about 2m high is envisaged.

Assuming an earthen levee could be constructed on rural land immediately adjacent to the existing urban area, the total construction costs would be $7.2 million. The resultant reduction in flood damages is estimated to be about $17 million, yielding a benefit-cost ratio of 2.4.

The economic benefits are attractive however it is anticipated that a levee might not be favoured by the local community because of aesthetic impacts, and the severance caused to landholders. Consistent with the recommendations of the HNFMS, it is proposed that Council consult closely with the McGraths Hill community before proceeding further with this option. It is recommended that a levee feasibility study be undertaken which identifies a preliminary alignment and height of the levee around McGraths Hill and then used as a basis for consultation.

In addition, there had been previous proposals to construct an earthen mound some 9m to 10m high on the outskirts of McGraths Hill to provide a refuge for local residents who for whatever reason were unable to evacuate from McGraths Hill during a significant flood event. (The mound has been proposed as it may be impractical to construct a building of sufficient height to serve as a refuge). The mound would likely have a significant visual impact and it may be advantageous to conduct consultation concerning the mound concurrently with the levee proposal.

Evacuation Capability Assessments (ECAs)

Various evacuation capability assessments (ECAs) for parts of the study area have been prepared. These are reported in **Appendices E** and **F** and in a working paper prepared by Molino Stewart (2011a,c). An ECA is essentially a calculation of the time necessary to evacuate the population (in motor vehicles) from key areas of the floodplain using the regional flood evacuation routes in accordance with the *Hawkesbury Nepean Flood Emergency Sub Plan* (SEMC, 2005). During the course of the study, the SES advised that they will conduct their operations to ensure that evacuations commence in sufficient time to allow all flood affected communities to leave before egress routes become cut by floodwaters. The ECA methodology was revised to reflect this. The ECA makes an assessment of the time required for evacuations from each SES sector using assumptions about the number of vehicles, the capacity of evacuation routes and the time required for residents to pack and leave (including the time taken to warn them).

A key issue is whether such evacuations must commence earlier than the time at which the need for the evacuation can be confidently predicted given the available meteorological information (i.e. earlier than the limit of confident flood prediction or LCFP). Evacuations which require more time than the LCFP may result in calling unnecessary evacuations which are likely to have huge social and economic impacts upon floodplain communities due to the disruption, loss of employment and costs to emergency services.

The tasks of calculating the time required for evacuation and the meteorological assessment necessary to determine the LCFP are particularly complex and subject to a number of uncertainties. Accordingly the sensitivity of varying some of the key assumptions in the ECA has been undertaken which produce alternative ECA outcomes based on a more-conservative and a less-conservative approach. The more conservative approach assumes a shorter LCFP whereas the less conservative approach uses a longer LCFP.

Limit of Confident Flood Prediction (LCFP)

As discussed in the previous section a key assumption in preparing an ECA is determination of the longest time prior to critical flood levels being reached, at which confident flood predictions can be made. The approach preferred by the SES has been to adopt an LCFP of 9 hours when considering new developments. That implies that when considering the evacuation of a flood island that may have its egress route cut at a certain time, the prediction of that loss of egress cannot be made confidently more than 9 hours ahead. Consequently there will be sufficient time to carry out the evacuation only if all warning and evacuation movements can be carried out within a 9 hour period. If longer than 9 hours is required there will be less confidence in calling the evacuation and on some occasions, an evacuation may be called unnecessarily (and thus incur significant unnecessary social and economic costs).

During the course of the study, discussions have been held with the Bureau of Meteorology, which is responsible for flood prediction in the Hawkesbury-Nepean Valley. The Bureau has indicated that predictions can be made with some confidence over periods longer than 9 hours, possibly 15−18 hours. Clearly confidence in flood predictions decreases the further ahead that such predictions are made. Further, as noted in Molino Stewart (2011c), use of an LCFP of 9 hours has a 95% confidence and therefore a longer LCFP will have lower confidence.

The Committee considered the selection of an appropriate LCFP during a number of their meetings. The Bureau of Meteorology was invited to address the Committee on one occasion and also provided written advice. As a result of these deliberations the Committee decided to utilise a LCFP of 15 hours for the purposes of the current study.

Advice on Evacuation Capacity of Jim Anderson Bridge

Consistent with the advice of the SES, all previous ECAs carried out in the Valley have assumed that the Jim Anderson Bridge provides only a single outbound lane for evacuation traffic. During the progress of the study, the consultants became aware of previous proposals to reconfigure the bridge to allow two outbound lanes for evacuation traffic. Given that this change would almost double the evacuation capacity and have a significant bearing on the ECA, Halcrow (traffic engineers) were engaged to provide advice on its practicality. Halcrow confirmed that in their opinion, the bridge could be reconfigured to provide two outbound lanes (and one inbound lane) during flood emergencies and that this would significantly increase the evacuation capacity. In addition, research undertaken during the current study indicates that use of dual outbound lanes during flood emergencies was the original design intent of the Bridge. NSW Roads and Maritime Services also confirmed that the bridge was wide enough to provide for two outbound lanes and one inbound lane during flood emergencies. Nevertheless the implementation of dual outbound lanes would involve changes to the existing SES operational arrangements and other practical considerations and therefore the proposal to utilise dual outbound lanes is ultimately a matter for the SES.

Planning Controls

One of the most important activities undertaken during the current study has been to review Council's existing planning controls for the management of flood risks. This review has been undertaken in the light of the *Land Use Guidelines* which were prepared for the Valley as an outcome of the HNFMS. This allowed a risk based approach to be applied which considers the probability and consequences to future developments from all possible flood events, big and small, rather than relying on a singular flood standard. A range of flood planning levels (FPLs) have been proposed consistent with the regional guidelines and current best practice. The most significant decision for residential development has been to continue to allow application of a zero freeboard and 100 year ARI FPL for double storey dwellings, but require a 200 year ARI FPL for single storey dwellings, provided flood tolerant building materials are used throughout. This will result in an increase in floor levels of single-storey dwellings. It could be argued that higher increases in floor levels are appropriate when compared with other floodplains in NSW, given the very significant flood risks in the Hawkesbury. Nevertheless as there was pressure from some sectors to keep the existing FPLs, it was considered that the resultant FPL recommendations provide an appropriate balance.

A comprehensive assessment of Council's existing planning framework has been prepared and documented within **Volume 2**. The relevant flood risk management controls within Council's consolidated DCP have been reviewed and revised. The floodplains of the LGA have been classified into different flood risk precincts (FRPs) and mapping prepared for incorporation within the DCP.

A range of other planning related recommendations have been made in **Volume 2** including preparation of mapping to ensure that complying development only occurs in areas of the floodplain with 'very low', 'low' and 'medium' flood risks. Recommendations to improve Council's system of Section 149 notations have also been prepared.

It is noted that the draft DCP included in **Volume 2** and recommended in the Plan will be subject to separate assessment and public exhibition under the EPA Act, before it can be adopted and implemented.

It is also recommended that an 'exceptional circumstances' application should be made to the relevant State Government departments to confirm application of residential controls above the 100 year flood level. Such an application would merely confirm the existing practice noting that Council has already been applying such controls for many years.

Providing Advice on Evacuation Risks of Future Developments

Arguably the most important outcomes of this study address the implications of flood risk management on future development within the LGA. In recent years, Council has had a number of requests to rezone flood prone land to allow additional development. Council has also prepared a Residential Land Strategy that identifies potential development areas. In addition there is potential for infill and other development on existing zoned land within the major urban centres of the LGA. As many of the locations where future developments are proposed were identified during the HNFMS as being evacuation constrained, Council must seriously assess the potential flood risks before allowing further development either on existing zoned land or as part of future rezonings.

When considering the appropriateness of future development, flood risk constraints are but one of many constraints and other considerations that Council (or other consent authorities) must take account of. In this context therefore it is not appropriate for a floodplain risk management study to recommend specific developments but rather the study should provide advice to the planning process so that flood risk can be properly considered in the development decision. A four tiered approach to such advice is provided in **Table 4**.

In determining which class of evacuation risk advice should be provided to the planning process, a number of factors have been considered including the results of the ECA, the availability of refuges (with or without support facilities), the topography of the land and the proposed land-use.

TABLE 4 – Evacuation Risk Categories (ERCs) to Inform the Planning Process

Class A	Risks are Minor – Limited Consideration is Required
Class B	Risks are Moderate – Detailed Consideration is Required
Class C	Risks are Serious – Very Detailed Consideration is Required
Class D	Risks are Intolerable/Unacceptable – Development Should Not Proceed

TABLE 5 – Evacuation Times (Hours) and ERCs based on LCFP = 15 Hours

INVESTIGATION AREAS	2010# One outbound lane on JAB	2010# Two outbound lanes on JAB	2031* Two outbound lanes on JAB plus other measures
Residential Land Strategy Areas			
Richmond	12.5	12.5	15.0
Windsor	15.0	8.7	11.5
N Richmond	6.1	6.1	6.9
Wilberforce	5.5	5.5	6.2
Glossodia	%	%	%
Windsor Downs/Bligh Pk	@	@	@
Metropolitan Development Program (MDP) Areas			
Bligh Park Stage 2	n.a.	n.a.	11.5
Pitt Town	5.2	5.2	8.4
Vineyard	n.a.	n.a.	n.a.

NOTES

- LCFP = Limit of Confident Flood Prediction. JAB = Jim Anderson Bridge
- Evacuation times for Richmond, Windsor, North Richmond, Windsor Downs and Bligh Park based assessments in **Appendices E** and **F**. Estimates for other areas derived from Table 7 of Molino Stewart (2011a). The time required for SES mobilisation is additional to the evacuation times quoted here.

@ ERCs for Windsor Downs and Bligh Park times have been inferred from the preliminary sub sector times in **Appendix F**.

% Inferred from Molino Stewart (2011a).

n.a. Not applicable as development not currently present.

The ERC assessment for the 2010 scenario is for infill only.

* The 2031 scenario includes for infill and additional dwellings under the Residential Land Strategy and the MDP (i.e. including for Bligh Park Stage 2). The 'other measures' for 2031 include the provision of community refuges as recommended in **Section 6.6.4**.

The resultant advice for the key future developments currently under consideration in the LGA is provided in **Table 5** based on the adopted LCFP of 15 hours. The most important implications of this would be that, compared with a LCFP of 9 hours:

- *for future development in Richmond* over the next two decades, the evacuation risk advice would be Class B (i.e. 'moderate') rather than Class C (i.e. 'serious');
- *for future development in Windsor*, assuming dual outbound lanes on the Jim Anderson Bridge could be utilised during flood evacuations, then the evacuation risk advice could be immediately lowered from Class D (i.e. 'intolerable/unacceptable') to Class C (i.e. 'serious'), and once community flood refuges were provided, the evacuation risk advice could be further lowered to Class B (i.e. 'moderate'); and
- *for future development of Bligh Park Stage 2,* a Class B (i.e. 'moderate') would apply rather than Class D (i.e. 'intolerable/unacceptable').

Voluntary House Raising (VHR) and Redevelopment

There are potentially over 300 dwellings within the study area that may have their floors inundated in a 20 year ARI flood event (refer **Table 1**). Whilst the location and vulnerability of these dwellings has been assessed based on the aerial photography and topographic information, there is a need for verification of the affected properties through field survey of floor levels and an assessment of the building type (and its vulnerability to damage and suitability for raising/redevelopment). Once the extent of this exposure has been quantified, the potential exists for the more severely affected dwellings to be raised or redeveloped as a means of reducing flood risks and flood damages.

As has been successfully implemented in other parts of the State (e.g. Fairfield), it is recommended that the owners of selected properties be offered a subsidy to either raise or redevelop their properties. Initially a scoping study should be carried out to identify the extent of properties that could participate in the scheme, followed by a feasibility study.

Updating Flood Behaviour Data in the Valley

There have been a number of detailed and complementary studies of flood behaviour and flood mapping which provide a solid basis for managing flood risk within the study area to the present time. Nevertheless in looking to the future, there is a need to provide improved and more extensive flood behaviour data. Consequently it is recommended that Council consider updating and extending the current database of flood information within five to ten years. This would provide an opportunity to use the latest two-dimensional hydrodynamic modelling techniques and parameters. Whilst this may not alter the overall flood levels throughout the valley to any great extent, it would allow a more reliable prediction of the spatial distribution of flood levels including extension into the middle reaches of major tributaries including the Colo River. The provision of this data to the SES, (including data for the smaller more frequent flood events), will also assist in improving emergency management in the Valley.

Engineering Study of Regional Flood Mitigation Options

It has not been within the terms of reference of this study to examine regional flood mitigation works and measures. Nevertheless the Committee has shown a keen interest in these options including changes to the operation of Warragamba Dam to increase flood attenuation, raising of the Dam to provide a flood mitigation compartment, dredging of the River to lower flood levels and various large scale river diversion works including a diversion into Currency Creek. It is noted that during the course of the current study the Committee separately recommended to Council that it consider funding a further study to examine these regional works and measures, although this recommendation was not carried through into the Floodplain Risk Management Plan.

1. INTRODUCTION

1.1 CONTEXT

The NSW State Government's Flood Prone Land Policy adopts a merit based approach for planning development in floodplains across the full range of flood risk. As detailed in the *Floodplain Development Manual* (NSW Government, 2005), this means that the potential risk of rarer floods to life and property must be taken into consideration when defining appropriate flood planning levels (FPLs). In most coastal rivers in NSW, the differences between the 100 year ARI flood level, the most commonly adopted FPL, and that of the Probable Maximum Flood (PMF), are often relatively small. However, in the case of the Hawkesbury-Nepean River system the differences in peak flood levels between a 100 year design flood and the rarer design floods are much greater. This makes the potential risk of flood damage and loss of life during such severe events much more pronounced. It also means that events not much more severe than the 1 in 100 year event can cause much more damage and pose more risk than in most other catchments. As a result, the merits based approach to floodplain management has been decidedly more difficult to apply in this river valley than in other areas, if the exposure to risk is not to remain many orders of magnitude higher than most other floodplains.

To address this issue the NSW Government established the *Hawkesbury-Nepean Flood Management Advisory Committee* in 1997 which was community based and included representatives from all of the councils located along the River from Penrith to the ocean. The aim of this committee was to prepare a comprehensive floodplain management strategy to address the serious flood problem in areas of the Hawkesbury-Nepean Valley, downstream of Warragamba Dam. The *Hawkesbury-Nepean Floodplain Management Strategy* was developed to enable all levels of government and the wider community to recognise more fully and respond more appropriately to the range of risks associated with flooding in the valley.

The structure of the Strategy is presented in **Figure 1.1**. The components were directed to existing development, future development and emergency response. One critical outcome of the Strategy was a *Regional Floodplain Management Study* which was aimed at providing appropriate tools to enable each local council to develop its own local floodplain risk management plans. Among these tools are a computer-based *Flood Hazard Definition Tool* and a set of best-practice Guidelines covering land use planning, subdivision and building on flood-prone land.

The Hawkesbury Floodplain Risk Management Study & Plan aims to build on the significant work done at a regional level, advancing local floodplain management initiatives including the provision of input to local planning instruments.

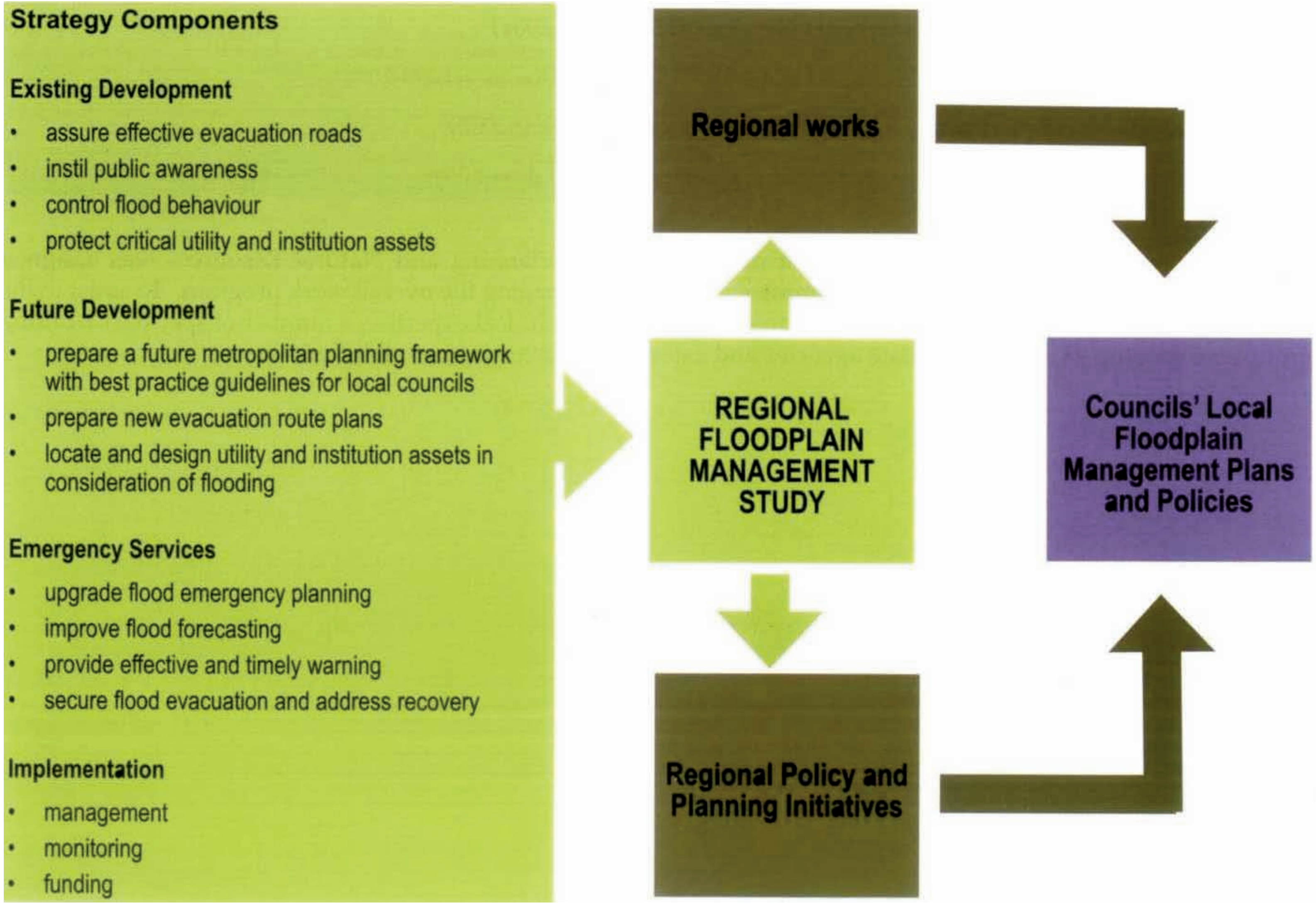


FIGURE 1.1 – Hawkesbury-Nepean Floodplain Management Strategy Components and Outcomes
Source: HNFMSC, 2004, Appendix IV

1.2 THE STUDY AREA

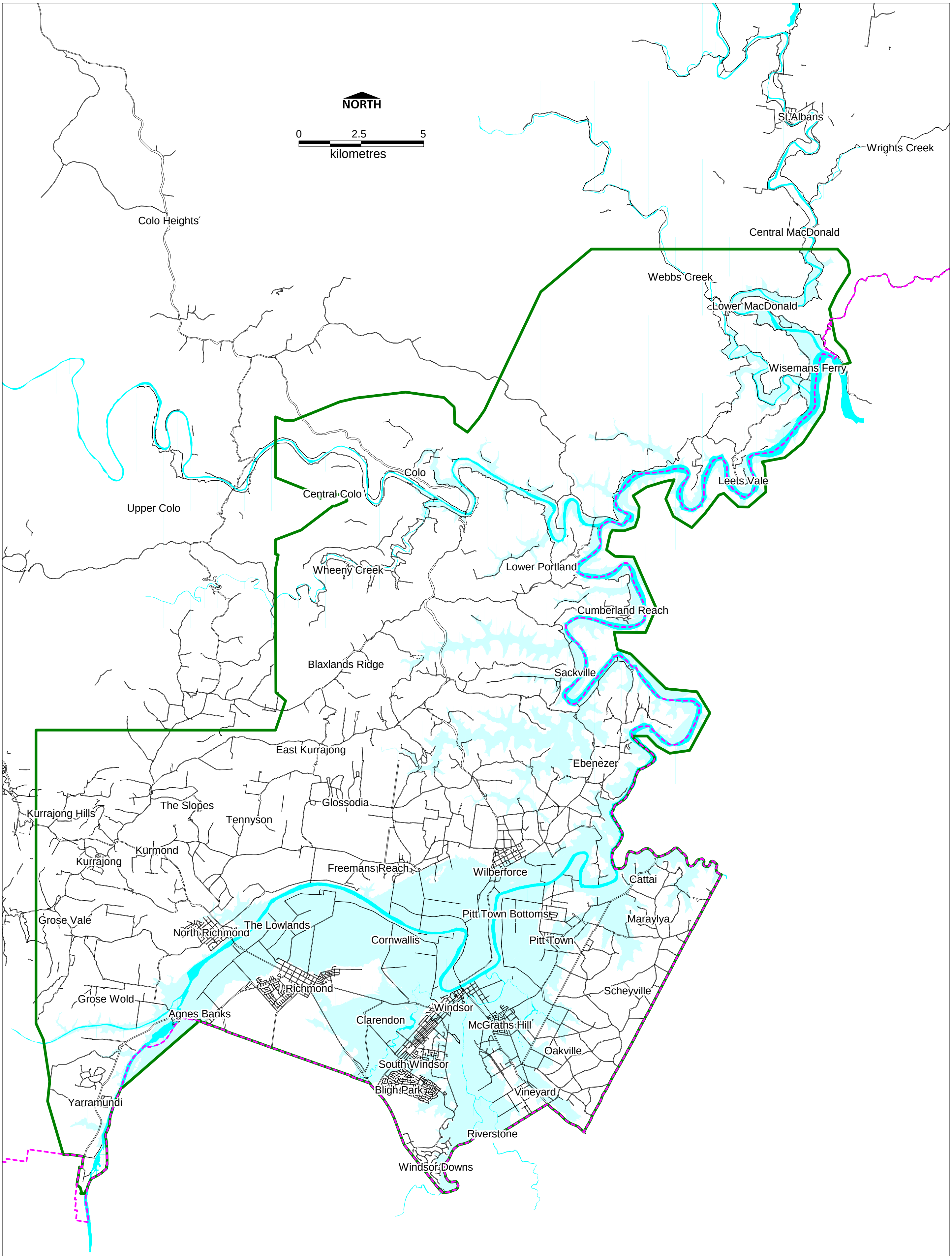
The study area of the Hawkesbury Floodplain Risk Management Study & Plan comprises all of the Hawkesbury River and its immediate surrounds that fall within the Hawkesbury Local Government Area. It extends from Agnes Banks/Yarramundi in the south to Wisemans Ferry in the north, representing a river distance of approximately 83 km and an area of some 220 km^2 subject to inundation in the Probable Maximum Flood (PMF). The main area of focus is for the area from Agnes Banks/Yarramundi to Wilberforce, including the flood-prone communities of Richmond and Windsor (see **Figure 1.2**).

The Hawkesbury-Nepean catchment covers about 22,500 km^2 and is one of the largest of all coastal rivers in New South Wales (see **Figure 1.3**). It includes extensive grazing areas in the south-west and large National Parks in the Blue Mountains to the north-west. Urban development in the catchment area includes towns such as Goulburn and Lithgow and outer suburbs of western Sydney including Camden and Penrith (ERM Mitchell McCotter, 1995).

More than 40% of the total Hawkesbury-Nepean catchment – about 9,000 km^2 – is upstream of Warragamba Dam. Half of this area comes from the Wollondilly River. The Warragamba River joins the Nepean River 3.5 km below the dam. The Grose River is a major tributary which joins the Nepean at Yarramundi, after which the Nepean is known as the Hawkesbury. Whilst the Grose has a catchment of only 650 km^2, it drains a high rainfall area and can have a significant effect on flooding at Windsor. In particular, it can cause flood levels to rise quickly in the early part of major storms (ERM Mitchell McCotter, 1995).

The catchment area at the Windsor gauge is about 12,800 km^2. South Creek joins just downstream of the Windsor gauge. Whilst its catchment area of 640 km^2 is virtually the same as the Grose, it receives less rainfall and thus has less impact on Hawkesbury River flooding. At Lower Portland the Hawkesbury is joined by the Colo River, which drains an area of 4,640 km^2 (ERM Mitchell McCotter, 1995). The Colo can influence flooding in the Hawkesbury River depending on the movement of flood producing rainfall over the Hawkesbury and Colo River catchments. The Colo has a shorter response time to rainfall and as shown in the 1978 flood, it can have a large impact on Hawkesbury River levels, particularly downstream of Sackville. A study of the joint probabilities of floods originating from the Hawkesbury and the Colo has been carried out (AWACS, 1997). AWACS found that the 100 year design flood levels in the Hawkesbury downstream of the Colo confluence were relatively insensitive to the assumed Colo contributions. Nevertheless in some events, flooding in the Hawkesbury River within the lower portions of the study area can be significantly influenced by the Colo subject to the spatial and temporal distribution of the rainfall.

When measured in 2000, the Hawkesbury River was subject to tidal influence up to Yarramundi Bridge (MHL, 2005). However, the limit of tidal influence is rarely constant. There are short-term cyclical changes in response to the ever-changing ocean tides, and changes over long time spans according to both natural processes and artificial disturbance. Sand extraction in the vicinity of the limit of tidal influence in the Hawkesbury River is reported to have caused the tidal limit to move a further 10 km upstream over the 20th century (Estuaries Branch, 2010).



Legend

- LGA boundary
- Limit of DEM and boundary of flood mapping
- Estimated extent of 100 year flood

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FIGURE 1.2
Hawkesbury Study Area

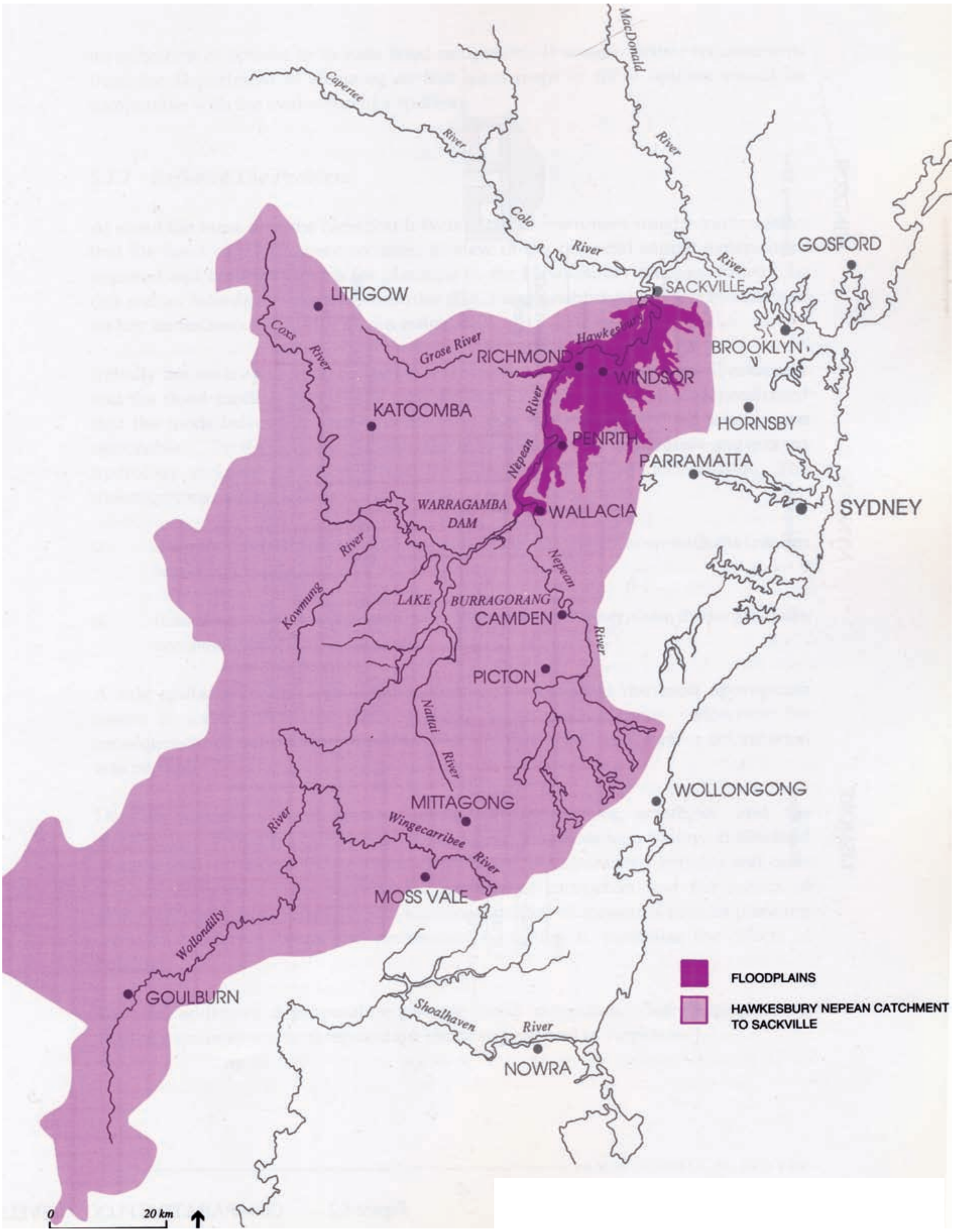

FIGURE 1.3 – Hawkesbury-Nepean Catchment and Floodplain to Sackville
Source: ERM Mitchell McCotter, 1995, Figure 5.1

1.3 THE GOVERNMENT'S FLOODPLAIN MANAGEMENT PROCESS

The NSW Government's Flood Prone Land Policy and a *Floodplain Development Manual* (NSW Government, 2005) form the basis of floodplain management in NSW. The main responsibility for managing flood prone lands in NSW rests with local government councils. The NSW Government's Floodplain Management Program is administered by the Office of Environment and Heritage (OEH) and provides councils with technical and financial assistance to undertake flood and floodplain risk management studies, and for the implementation of works identified in those studies. The Department of Planning and Infrastructure is responsible for assisting councils on land use planning matters consistent with the *Floodplain Development Manual*.

The primary objective of the Flood Prone Land Policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods.

For existing developed areas, the impacts of flooding are generally reduced by flood mitigation works and measures, including on-going emergency management measures, the raising of houses where appropriate and by development controls. For areas proposed for development or redevelopment, the potential for flood losses are generally contained by the application of ecologically sensitive planning and development controls.

The implementation of the Flood Prone Land Policy generally culminates in the preparation and implementation of a FRMP by Council, which is the ultimate objective of the current study. Community consultation is an important part of the process.

The steps in the floodplain management process are summarised in **Figure 1.4**.

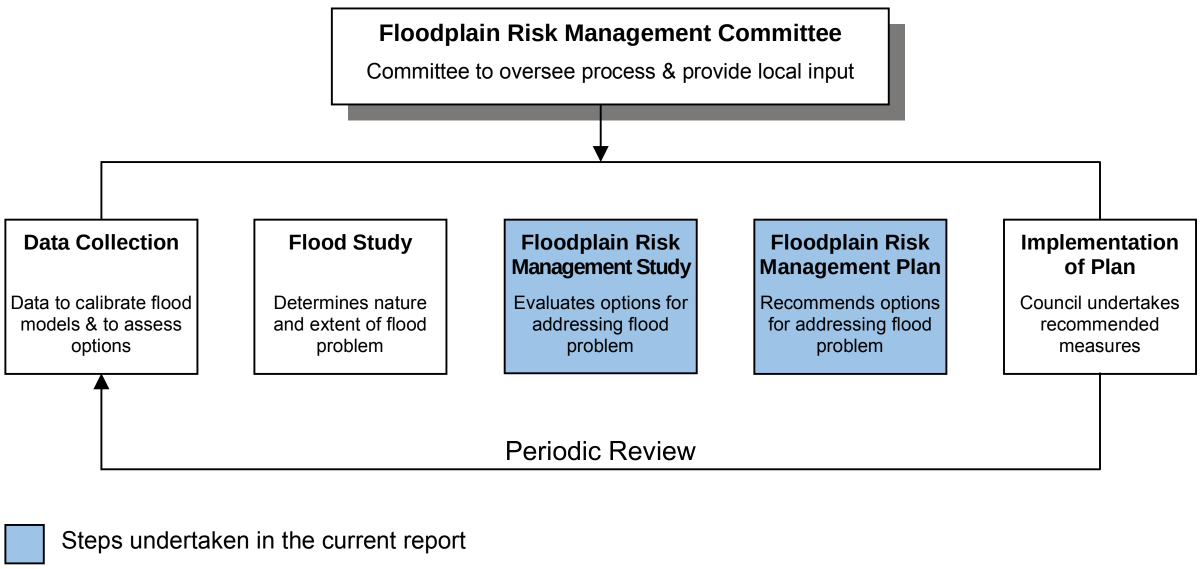

FIGURE 1.4 – The Floodplain Risk Management Process

2. DATA REVIEW

A vast amount of literature is available regarding flooding issues in the Hawkesbury-Nepean Valley. The project brief listed many publications which were to be reviewed as part of the current study, so as to avoid repeating work conducted in the past and to better understand the context. **Volume 3** provides an annotated bibliography of the reviewed literature, whilst the main points are summarised in this chapter, together with identification of any "gaps" which the current study can seek to fill.

2.1 FLOOD BEHAVIOUR

2.1.1 Historical Floods

The Hawkesbury River has a long history of flooding. **Table 2.1** lists observed peak flood levels exceeding 10m AHD at Windsor from 1799, together with calculations showing what flood levels would have been before (or after) the construction of Warragamba Dam in 1960, where known. The data indicates that Warragamba Dam *can* have an ameliorating effect on peak flood levels at Windsor, depending on the dam storage level at the commencement of the flood (it was 83% full in 1961 and 84% full in 1978), and the location of the rain-bearing storm. **Figure 2.1** shows inflow and outflow hydrographs for the March 1978 flood. The effect of Warragamba Dam was to reduce and delay the peak outflow.

The largest flood in the historical record peaked at Windsor at 5 a.m., Sunday 23rd June 1867. The peak level of 19.7m AHD is based on the observation of astronomer John Tebbutt (ERM Mitchell McCotter, 1995, p.5.9). Newspaper articles of the day provide an insight to the flood's causes and characteristics (see **Appendix A** and a summary in **Table 2.2**). The weather conditions suggest that an East Coast Low was the cause of the flood-generating rains, which were presumably higher in the catchment than the few gauge records indicate. Reported rates of rise at Windsor vary from about 0.8m/hour early in the event to about 0.2m/hour closer to peak. The flood was higher than 14.0m AHD for about four days. A hydrograph of the 1867 flood, derived from comparisons with the 1864 or 1867 flood peaks, further shows the observed rates-of-rise and duration (**Appendix A**). High flow velocities were described for the Sackville Reach where the valley floor is narrow. A number of reports describe the effect of the easterly gale creating waves on the surface of the water body, which was very extensive around Richmond and Windsor. (Damage attributed to waves generated from high winds was reported in the August 1990 flood – see **Figure 2.2**). Maps showing the maximum extent of flooding are presented in **Appendix A**. Reports from Windsor give a vivid description of the "shrinking island" to which most inhabitants fled:

> *Saturday 22nd, noon: The town is divided into islands, which are gradually and terribly diminishing. The greater portion of the town is now inundated… The people themselves are every hour being driven closer and closer together as the mighty flood encroaches on the land. Houses are giving way before the sweeping current… Unless a change takes place very soon… the whole town will be deluged. Hairbreadth escapes are heard of from all points, and at best nothing but utter ruin and desolation stares us in the face.*
>
> (Sydney Morning Herald, Tuesday 25th June 1867, p.2, 'The Floods – Windsor')

A flood of the magnitude of the 1867 flood has been estimated to have an average recurrence interval (ARI) of between 200 and 300 years (see **Table 2.2**).

Saynor and Erskine (1993) found geological evidence for substantially higher floods than the 1867 flood in the Nepean River.

TABLE 2.1 – Major Historic Floods at Windsor (> 10m AHD)

Sources: Hawkesbury-Nepean Valley Flood Awareness Committee, 1994; WMA, 1996 (Table D.A4); Feb 1992 level from DECCW. Council's website http://www.hawkesbury.nsw.gov.au/services/emergency-information/flood-information/?a=45515 also has a comprehensive list.

Note: WMA, 1996 provides a detailed analysis of the origin and reliability of the Windsor flood record. The levels reported below are considered the most reliable. Where two flood peaks occurred within a month, the lower reading is not reported here. Some differences are noted from historic levels reported in other sources including SEMC (2005), www.hawkesburyhistory.org.au/articles/floods.html, Council's website and Nichols (2001).

Flood	Observed level (m AHD)	Adjusted level (pre-dam) (m AHD)	Adjusted level (post-dam) (m AHD)	ARI for observed level
1799 Mar	10.5	N/a		
1806 Mar	12.9	N/a		
1809 Aug	14.7	N/a		
1816 Jun	14.1	N/a		
1817 Feb	14.4	N/a		
1819 Mar	12.9	N/a		
1857 Aug	11.9	N/a		
1860 Apr	11.8	N/a		
1860 Jul	11.1	N/a		
1860 Nov	11.4	N/a		
1864 Jun	15.1	N/a		
1864 Jul	11.4	N/a		
1867 Jun	19.7	N/a	19.3	
1869 May	11.6	N/a		
1870 Apr	14.1	N/a		
1871 May	11.7	N/a		
1873 Feb	13.1	N/a		
1875 Jun	12.3	N/a		
1879 Sep	13.6	N/a		
1889 May	12.2	N/a		
1890 Mar	12.3	N/a		
1891 Jun	11.2	N/a		
1894 Mar	10.1	N/a		
1898 Feb	10.1	N/a		
1900 Jul	14.5	N/a		
1904 Jul	12.7	N/a		
1916 Oct	11.0	N/a		
1925 Jun	11.5	N/a		
1943 May	10.3	N/a		
1949 Jun	12.1	N/a		
Warragamba Dam commenced				
1952 Jul	11.8	N/a		
1956 Feb	13.8	N/a		
Warragamba Dam completed				
1961 Nov	15.0	15.8	N/a	35 year
1964 Jun	14.6	14.8	N/a	30 year
1969 Nov	10.2		N/a	<5 year
1975 Jun	11.2	12.3	N/a	5 year
1978 Mar	14.5	15.2	N/a	30 year
1986 Aug	11.4	12.9	N/a	5-10 year
1988 May	12.8	13.1	N/a	10 year
1988 Jul	10.9	10.9	N/a	<5 year
1990 Aug	13.5	13.7	N/a	20 year
1992 Feb	11.1		N/a	<5 year

TABLE 2.2 – Characteristics of the 1867 Flood at Windsor

<table>
<tr><th>Characteristic</th><th colspan="6">Description</th><th>Source</th></tr>
<tr><td>Weather</td><td colspan="6">"The rain clouds came up steadily throughout from the E. and E.S.E … The greatest force of wind was experienced in the forenoon of the 21st from the S.E., but did not reach that of a gale" (J. Tebbutt, Windsor)

East Coast Low</td><td>SMH Fri 28th June 1867, p.5

SEMC, 2005</td></tr>
<tr><td rowspan="4">Rain
(for 24 hours ended 9 a.m. on recorded date)</td><td></td><td>19th</td><td>20th</td><td>21st</td><td>22nd</td><td>23rd</td><td></td></tr>
<tr><td>Windsor</td><td>23mm</td><td>107mm</td><td>75mm</td><td>N/a</td><td>N/a</td><td>SMH Fri 28th June 1867, p.5</td></tr>
<tr><td>Sydney</td><td>26mm</td><td>105mm</td><td>55mm</td><td>85mm</td><td>34mm</td><td>Bureau of Meteorology</td></tr>
<tr><td>Bringelly (Maryland)</td><td>0mm</td><td>102mm</td><td>108mm</td><td>103mm</td><td>29mm</td><td>Bureau of Meteorology</td></tr>
<tr><td>Source of inflows</td><td colspan="6">Warragamba River and possibly the Grose River</td><td>ERM Mitchell McCotter, 1995, p.5.11</td></tr>
<tr><td>Peak level at Windsor</td><td colspan="6">"The flood reached its greatest height about 5 a.m. on the 23rd, being then about 14½ feet above the flood-mark of June, 1864, or about 62 feet above the mean tidal level of the South Creek" (J. Tebbutt, Windsor)

19.7m AHD</td><td>SMH Fri 28th June 1867, p.5

Hawkesbury-Nepean Valley Flood Awareness Committee, 1994</td></tr>
<tr><td>Extent</td><td colspan="6">"The plain on which Windsor is partly situated unites with South Creek and Eastern Creek to form a vast inland sea … A boat may now be taken through deep water from Riverstone to the Blue Mountains - a distance of about 15 miles; and from Hall's at Pitt Town to the Kurrajong - some twenty miles"</td><td>SMH, Mon 24th Jun, 1867, p.5</td></tr>
<tr><td>Rate-of-rise</td><td colspan="6">2½ ft/hr = 0.75m/hr (Thurs 20th morning)

"On Friday afternoon [21st] the waters had risen, and continued to rise, very rapidly" (T. Eather, Cornwallis)

7 inches/hr = 0.18m/hr (Sat 22nd noon)</td><td>SMH, Tues 2nd Jul 1867, p.3

SMH, Mon 1st Jul 1867, p.3

SMH, Tues 25th Jun, 1867, p.2</td></tr>
<tr><td>Rate-of-fall</td><td colspan="6">9 inches/hr = 0.23m/hr (Mon 24th 2 p.m.)</td><td>SMH, Tues 25th Jun, 1867, p.2</td></tr>
<tr><td>Duration</td><td colspan="6">Higher than 14.0m AHD for almost four days</td><td>See hydrograph in Appendix B</td></tr>
<tr><td>Velocity</td><td colspan="6">Destruction of Sackville Church attributed to "very strong current"</td><td>SMH, Tues 2nd Jul 1867, p.3</td></tr>
<tr><td>Waves</td><td colspan="6">"… When the wind is high the broken crested billows roll with as much force and volume as they do during moderately squally weather in Sydney Harbour"

"The violence of the wind and waves" (T. Eather, Cornwallis)</td><td>SMH, Mon 24th Jun, 1867, p.5

SMH, Mon 1st Jul 1867, p.3</td></tr>
<tr><td>Frequency</td><td colspan="6">200 years

250 years

280 years

300 years</td><td>WMA, 1996, p.D58

SEMC, 2005, p.11

ERM Mitchell McCotter, 1995, p.10.34

WMA, 1997, p.4</td></tr>
</table>

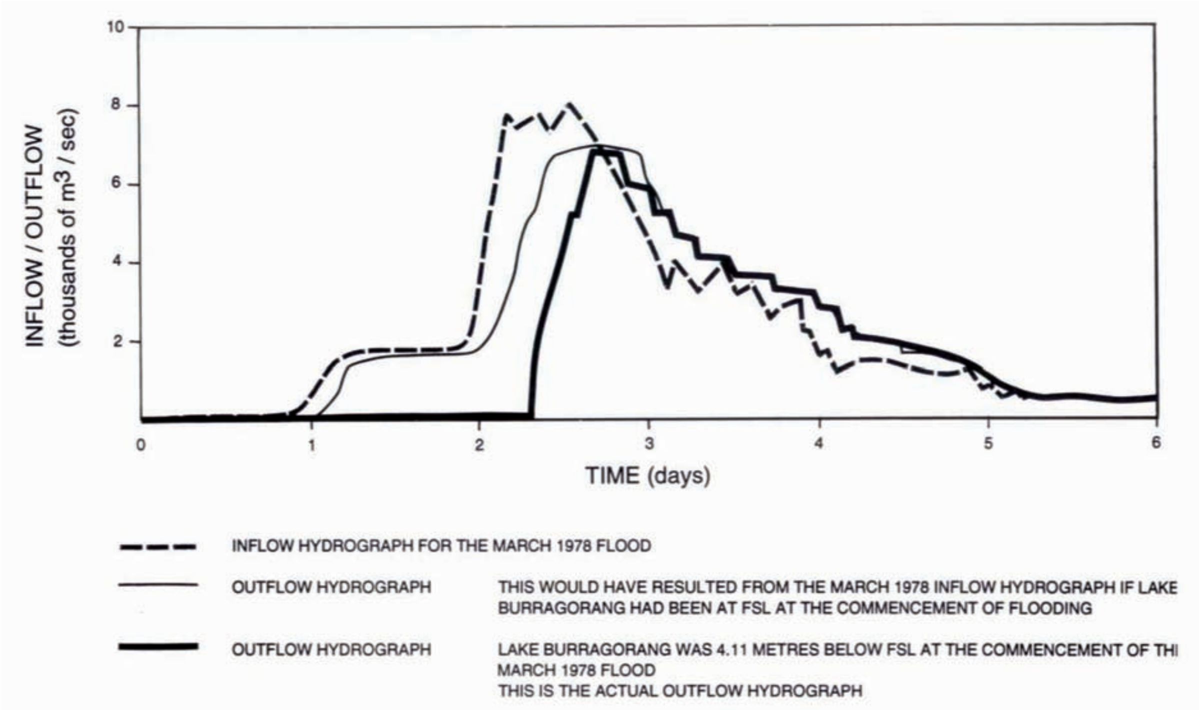

FIGURE 2.1 – Effect of Warragamba Dam of 1978 Flood Hydrograph

Source: ERM Mitchell McCotter, 1995, Figure 4.4

FIGURE 2.2 – Damage to Shed opposite Butterfly Farm, Wilberforce, August 1990 Flood, Attributed to Waves

Source: Council

It needs to be recognised that there is wide variability in flooding both spatially across the study area and temporally during a flood (e.g. prior to and during overtopping of the river banks). The spatial variation is most noticeable when comparing the wide floodplain flows that occur in the Richmond-Windsor area with those areas along the gorge, which extends from Ebenezer to downstream of Sackville, where velocities are relatively higher and the hazards are different.

2.1.2 Design Floods

Design flood behaviour in the study area was investigated in detail as part of the *Warragamba Dam Auxiliary Spillway Environmental Impact Study* (WMA, 1996). This investigation utilised RORB and RUBICON modelling software, which was subsequently converted to RMA-2 for inclusion in the *Flood Hazard Definition Tool*. From Sackville and downstream, the results of the *Lower Hawkesbury River Flood Study* using the RMA-2 model (AWACS, 1997) were used for the *Flood Hazard Definition Tool*. Useful summaries of the baseline flood studies (including their limitations) are contained in the *Flood Hazard Definition Tool* Manual (HNFMS, 2003).

Design flood levels are presented in **Table 2.3**. One feature is the relatively large increase in flood levels (and consequently, depths) for small decreases in frequency. The large flood height range at Windsor sets it apart from other locations in NSW (**Figure 2.3**). The reason for this is a long gorge which extends from Ebenezer to downstream of Sackville and which functions as a natural "choke point" such that inflows from the Hawkesbury River and its tributaries are larger than the outflow rate. As floodwater rises, "islands" are created (including at Windsor and Richmond), which results in isolation of communities as their evacuation routes are cut, and possibly results in a shrinking island and eventual submergence.

TABLE 2.3 – Design Flood Levels
Note: levels are post construction of the Warragamba Dam Auxiliary Spillway
Sources: WMA, 1997, Table 1 (North Richmond and Windsor)*; AWACS, 1997 (Lower Portland to Webbs Creek Ferry); WMA, 1999 (Sackville Ferry 5y to 50y); *Flood Hazard Definition Tool* (Sackville Ferry 100y to PMF)

Flood event	North Richmond Bridge	Windsor Bridge	Sackville Ferry	Lower Portland	Leets Vale	Webbs Creek Ferry
5 year	12.5	11.1	7.4	5.5	3.8	3.2
10 year	14.0	12.3				
20 year	15.3	13.7	10.2	7.5	5.2	4.4
50 year	16.4	15.7	11.7	9.1	6.5	5.6
100 year	17.5	17.3	12.9	10.3	7.6	6.7
200 year	18.9	18.7				
500 year	20.4	20.2				
1000 year	22.1	21.9				
PMF	26.5	26.4	23.0	22.3	17.9	16.3

* Levels reported in Table D16 of the Warragamba Dam Auxiliary Spillway EIS Flood Study (WMA, 1996) do not appear to include allowance for the construction of the auxiliary spillway.

Note that there are some isolated differences between the design flood levels presented here and the maximum values extracted from the raw RUBICON results and shown in **Figures 2.4a** and **2.4b**. When the differences exist they are typically 0.1m suggesting they may be due to 'rounding'. As the **Table 2.3** values are understood to be those formally used by Council, these should be used in preference to **Figures 2.4a** and **2.4b**.

Design flood hydrographs for the Hawkesbury River at North Richmond and Windsor are presented in **Figure 2.4**. This shows the floods peaking after about two days of the onset of flooding. Rates of rise are highest while the water is contained in the channel, reducing as the flood height increases and floodplain storage becomes available. Typical rates of rise on the Hawkesbury-Nepean floodplain are reported to be 0.5m/hour for several hours (HNFMAC, 1997, p.23). Because severe flooding in the Richmond/Windsor floodplain is associated with water backing up from the choke point, flow velocities are relatively low towards the peak, but are potentially higher on the rising limb of the hydrograph (see **Figure 2.5**). The hydraulic hazard, which takes account of combinations of depths and velocities, is mainly related to the depth of flooding for the study area.

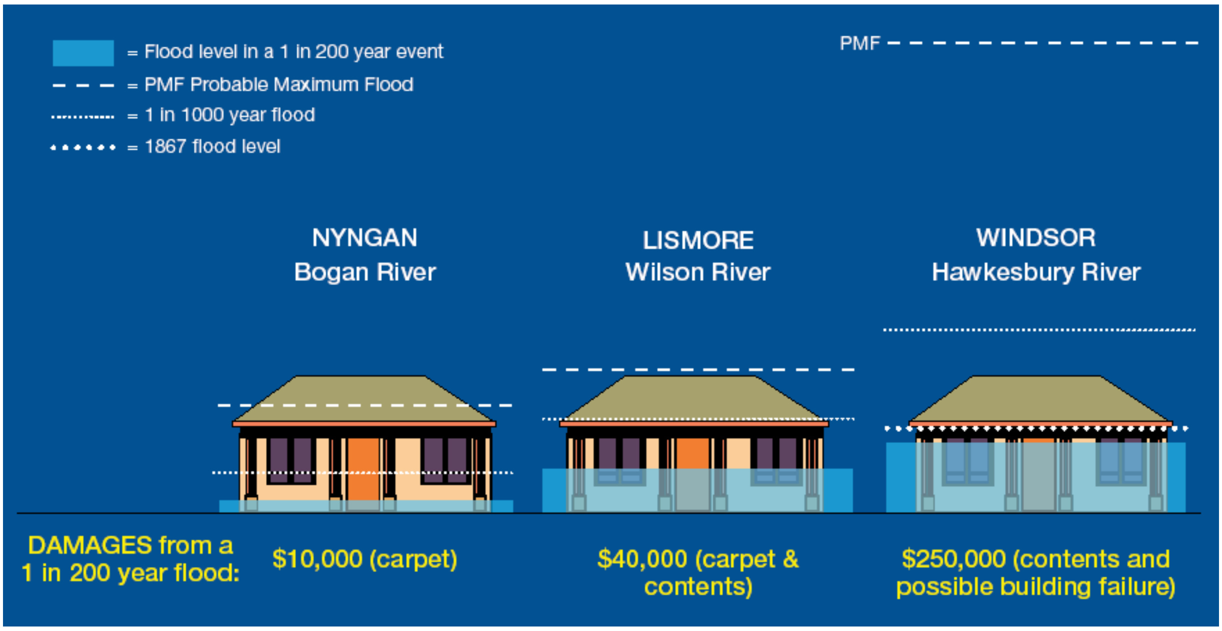

FIGURE 2.3 – Comparative Flood Risk in New South Wales
Source: Managing Flood Risk through Planning Opportunities, Figure 15

The brief for the current study requests considerable mapping of design floods using the Flood Hazard Definition Tool. This work is reported in **Chapter 3**.

2.1.3 Intermediate Regime Shifts

The history of flooding at Windsor lends some support to the debated existence of alternating flood-dominated regimes (FDRs) and drought-dominated regimes (DDRs) (see **Table 2.4**). These are defined as rainfall-driven, alternating periods of high and low flood activity of multi-decadal duration. The period since 1991 is believed to be part of a DDR.[1]

[1] The concept of alternating FDRs and DDRs was argued against by Kirkup et al. (1998), and defended by Erskine and Warner (1998).

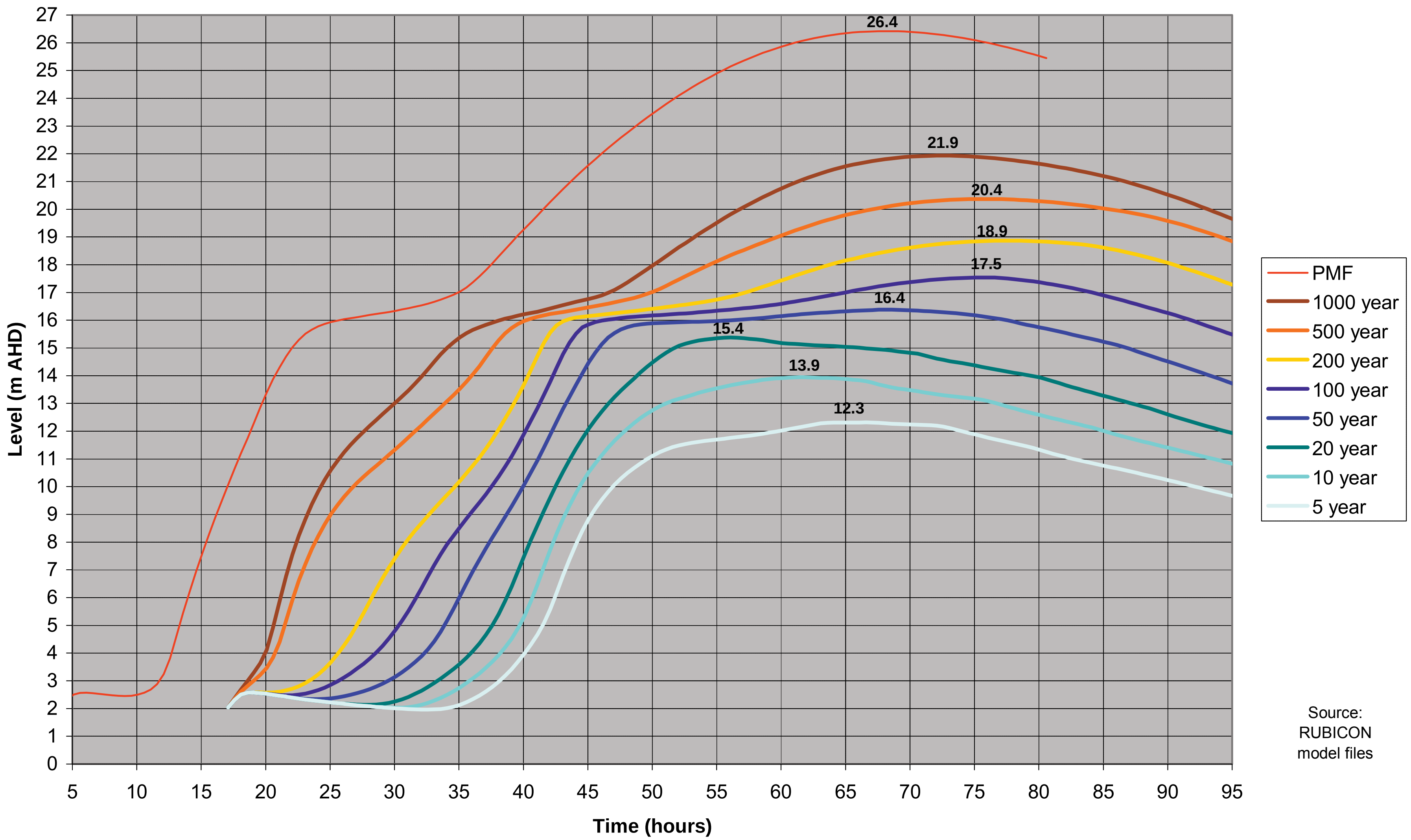

FIGURE 2.4a – Design Flood Hydrographs for the Hawkesbury River at North Richmond Bridge
Source: WMA, 1999, RUBICON model files

See note at bottom of **Table 2.3**

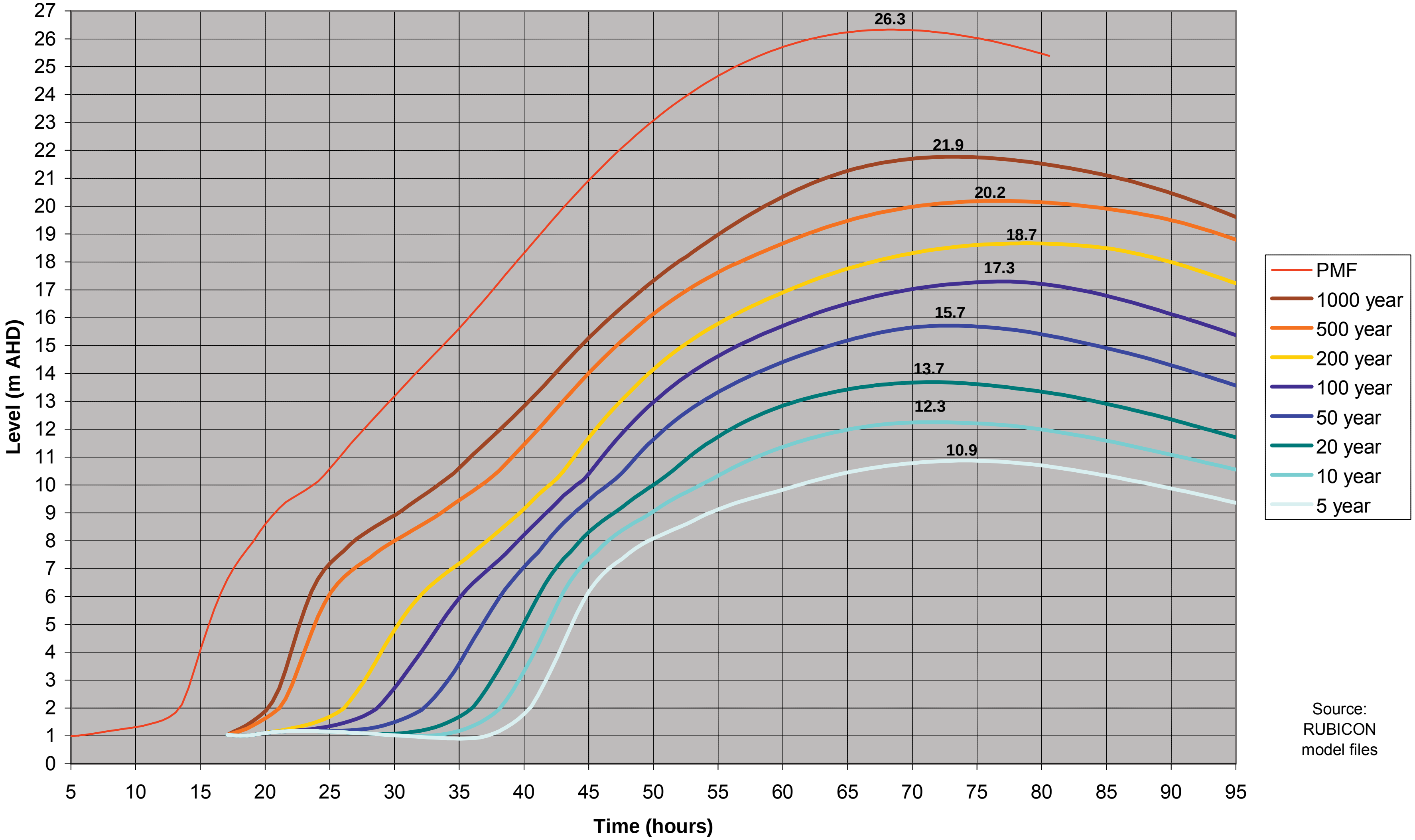

FIGURE 2.4b – Design Flood Hydrographs for the Hawkesbury River at Windsor
Source: WMA, 1999, RUBICON model files

See note at bottom of **Table 2.3**

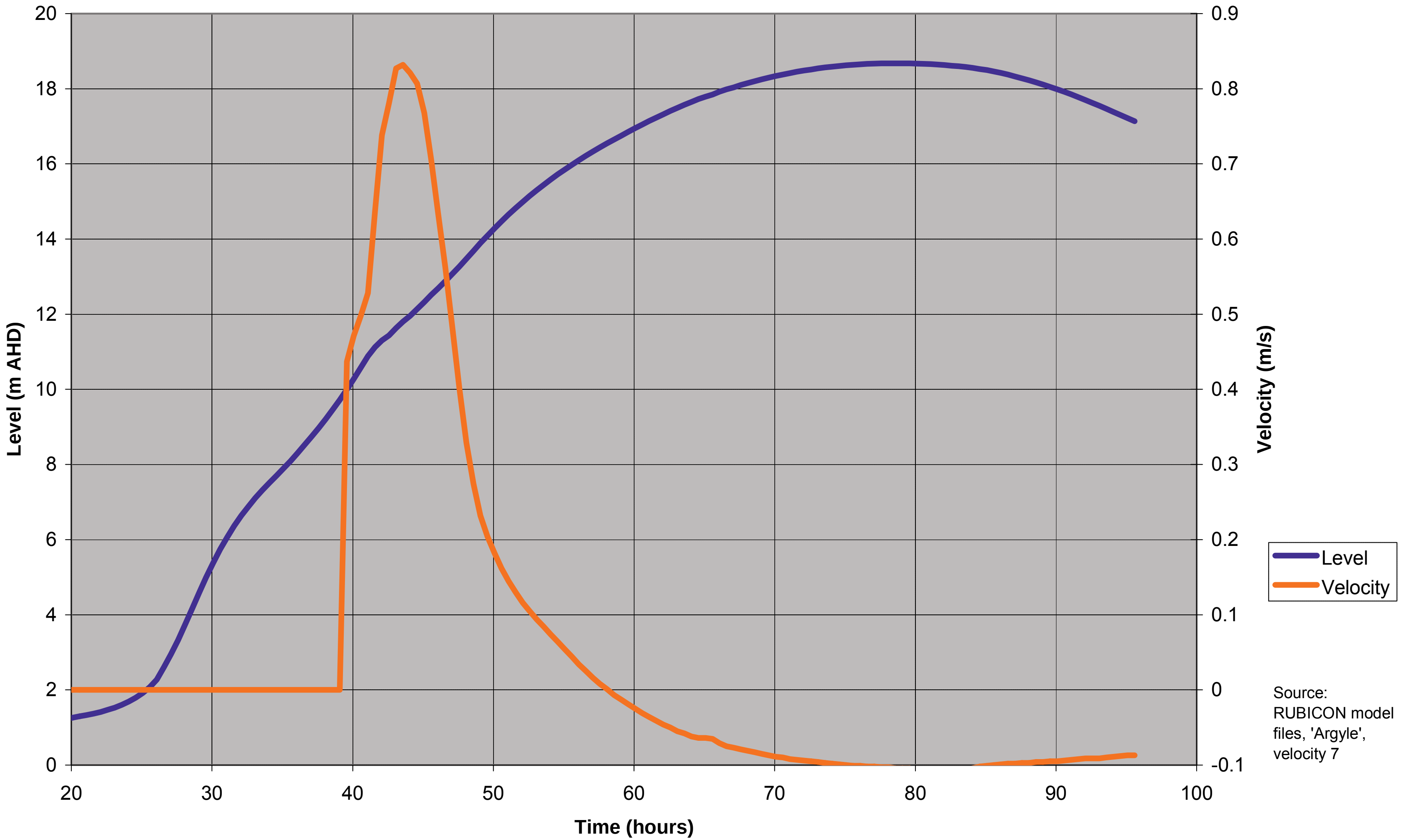

FIGURE 2.5 – 200 Year Flood Hydrograph, Hawkesbury River Floodplain at Cornwallis
Source: WMA, 1999, RUBICON model files

TABLE 2.4 – Floods exceeding 8m, 10m and 12m for Flood-Dominated Regimes and Drought-Dominated Regimes at Windsor Bridge
Source: Warner, 2009

Period	8–10 m	10–12 m	>12 m	Regime
1799–1820	0	0	5	FDR 22 y plus
1821–1856	0	0	0	DDR 26 y
1857–1900	13	10	7	FDR 44 y
1901–1948	3	3	0	DDR 48 y
1949–1990	23	6	7	FDR 42 y
1991–2006	0	1	0	DDR 16 y

The proponents of the concept of FDRs and DDRs did not set out to identify any climatic mechanisms that could account for the regime shifts. The recently documented Interdecadal Pacific Oscillation (IPO) could provide this mechanism, which is defined as low frequency anomalous warming and cooling of Pacific-wide sea surface temperatures. It is noted that the reported timing of FDRs and DDRs does not match precisely the timing of the positive and negative phases of the IPO. Nevertheless, Kiem et al. (2006) observe that flood-producing La Niña events are both enhanced and more frequent during the decadal/multi-decadal periods when the IPO is negative. They argue that the non-stationarity of flood probability in eastern Australia is not adequately taken into account in current flood risk management strategies. Westra et al. (2010) suggest that the main value of the IPO index in applied flood hydrology is to emphasise the need to use a precipitation record that is not biased to a single IPO phase, which can be achieved using long instrumental records.

2.1.4 Climate Change

There is increasing evidence that the temperature of the earth's atmosphere and oceans has increased over the last century, and that the accumulation of greenhouse gases in the earth's environment will accelerate this process in future years. Australian average temperatures are projected to rise by 0.6 to 1.5°C by 2030 and by between 2.2°C to 5.0°C by 2070, should global greenhouse gas emissions continue to grow at rates consistent with past trends (CSIRO/BOM, 2010).

Climate change could affect flood behaviour in the Hawkesbury study area through:

(i) increased sea levels; and/or
(ii) increased severity of flood producing storms or other weather systems.

From 1870 to 2007, the global average sea level rose by 20cm, with an increased rate from 1993 to 2009 (CSIRO/BOM, 2010). Sea levels are expected to continue rising throughout the 21st century and there is no scientific evidence to suggest that sea levels will stop rising beyond 2100. In October 2009, the NSW Government released the *NSW Sea Level Rise Policy Statement* (DECCW, 2009), which lists sea level rise planning benchmarks of increases above 1990 mean sea levels of 40cm by 2050 and 90cm by 2100. The *Flood Risk Management Guide* (DECCW, 2010) and the *NSW Coastal Planning Guideline* (DoP, 2010) require that these planning benchmarks be considered in relation to flooding.

The impact of climate change on rainfall is a topic of greater uncertainty. The *Practical Consideration of Climate Change* Floodplain Risk Management Guideline (DECC, 2007) reports that extreme rainfall (40 year 1 day rainfall total) could vary by -3 to +12% by 2030 and -7 to +10% by 2070 for the Hawkesbury-Nepean catchment.

An assessment of the potential impacts of climate change on flood behaviour in the Hawkesbury-Nepean behaviour was conducted by WMAwater (2009) following the protocol described in DECC's 2007 Guideline. Sea level rises of 0.18m, 0.55m and 0.91m, increases in peak rainfall and storm volume of 5%, 10% and 20%, and a combined high level ocean rise and high level rainfall increase were assessed for the modelled 20, 100 and 200 year ARI events.

Sea level rises produced no significant increases in peak flood levels for the majority of the floodplain. Small rises were recorded downstream of Lower Portland (0.19m at Wisemans Ferry for the 20 year ARI high sea level rise scenario.

However, peak flood levels are highly sensitive to increases in rainfall. **Table 2.5** and **Figure 2.6** show that for the 100 year ARI event, peak flood levels at Windsor Bridge would rise by 0.5m (for a 5% rainfall increase), 0.9m (for a 10% rainfall increase) and 1.7m (for a 20% rainfall increase) at Windsor Bridge.

TABLE 2.5 – Effect of Increased Rainfall Intensities on Peak Flood Levels
Source: WMAwater, 2009

Location	20y ARI			100y ARI			200y ARI		
	+5% rainfall	+10% rainfall	+20% rainfall	+5% rainfall	+10% rainfall	+20% rainfall	+5% rainfall	+10% rainfall	+20% rainfall
North Richmond Bridge	0.33	0.63	1.14	0.45	0.86	1.66	0.45	0.90	1.71
Windsor Bridge	0.50	0.98	1.90	0.47	0.90	1.71	0.46	0.91	1.73

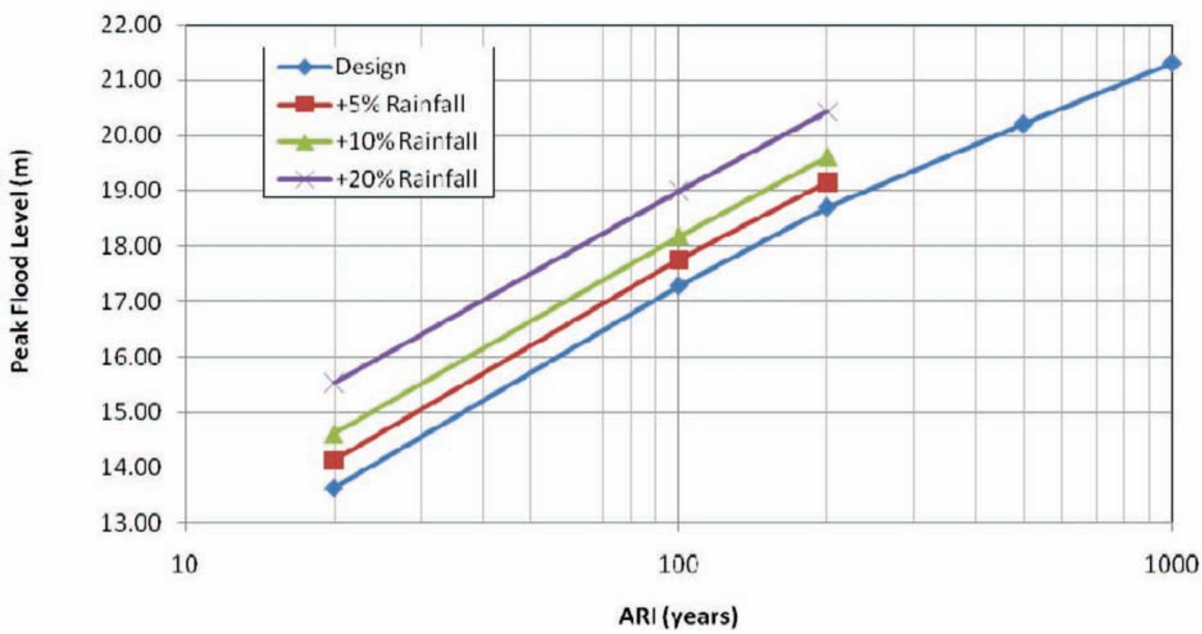

FIGURE 2.6 – Effects of Climate Change on Peak Flood Levels and ARI at Windsor
Source: WMAwater, 2009

There are two ways of looking at these preliminary figures:

(i) With climate change, the current 100 year ARI level at Windsor of 17.3mAHD will occur more frequently. It would become:
- 80 year ARI with a 5% rainfall increase;
- 60-70 year ARI with a 10% rainfall increase; and
- 40-50 year ARI with a 20% rainfall increase.

(ii) To maintain a 100 year ARI protection, the current minimum floor level of 17.3mAHD (without freeboard) would need to increase in the future to:
- 17.7mAHD with a 5% rainfall increase;
- 18.2mAHD with a 10% rainfall increase; and
- 19.0mAHD ARI with a 20% rainfall increase.

The potential for climate change to erode the protection provided by floor level controls is of major concern in the Valley. The recommendation in **Volume 2** to provide a second storey to new residential developments that have their lower storey at the existing 100 year ARI flood level, provides a good buffer against possible climate change risks.

2.2 FLOOD CONSEQUENCES/DAMAGE/IMPACTS

Flooding along the Hawkesbury River in the Windsor and Richmond districts has been problematic from the earliest settlement. The first flood fatality is reported in 1795 when a settler drowned as the river rose 25 ft above its usual level (Stubbs, n.d.). Five fatalities occurred in the March 1806 flood and eight in the August 1809 flood (Josephson, 1885). Severe losses to agriculture were reported for most of the early flood events. Ten children and the wives from the families of brothers Thomas and William Eather drowned at Cornwallis in the June 1867 flood when washed off the roof of the house to which they were clinging (Nichols, 2001). The memorial to this disaster is shown in **Figure 2.7**. The loss of life from this record event is much lower than it could have been, with reports of many "near misses" as boat rescues were accomplished just in time.

An assessment of the consequences of a repeat of the 1867 flood in modern times reveals the following (based on HNFMAC, 1997; Molino Stewart, 2000; SEMC, 2005):[2]
- 100% of McGraths Hill flooded, depths up to 7m over floor level;
- 50% of Windsor/South Windsor flooded, depths up to 9m over floor level;
- 50% of Bligh Park flooded, depths up to 3m over floor level;
- 30% of Richmond/Hobartville flooded, depths up to 5m over floor level;

[2] The degree of flood affectation for various Hawkesbury communities has been updated by reference to the flood mapping reported in this study. The percentages are sensitive to how each community is defined. Here, the main built-up area has been used.

FIGURE 2.7 – Eather Family 1867 Flood Disaster Memorial

- 25% of Pitt Town flooded, depths up to 7m over floor level;
- Large populations trapped on shrinking islands unless evacuated;
- A need for the evacuation of 40,000 people from the Hawkesbury-Nepean Valley;
- Considerable loss of life if evacuation were not completed;
- Up to 7,000 houses inundated throughout the Valley;
- Up to 2,000 houses destroyed throughout the Valley;
- Alternative accommodation for 6,000 persons in the Valley required for up to 12 months;
- Loss of electricity supply for up to 80,000 people for a period of 2-5 weeks;
- Loss of water supply for if pumps lose electricity supply;
- Flow of untreated sewage into the Hawkesbury River from several STPs;
- Severely disrupted telecommunications and no PSTN telephone in places;
- Emotional and medical trauma such that 4,500 residents may need medical treatment;
- Inundation of Hawkesbury District Hospital at Windsor; and
- Damages approaching $2 billion (Patterson Britton & Partners, 1993).

Molino Stewart (1997) investigated the impacts of flooding on communities and infrastructure in the Hawkesbury-Nepean Valley. The damages above the Flood Planning Level (FPL) become extremely high because of the large flood depths and the fact that few measures have been taken to minimise impacts for the rarer events. In Molino Stewart's opinion, planning has been based mainly on probabilities with minimal consideration of consequences. The report describes the consequences of floods of different levels for infrastructure assets including roads and bridges, railways, electricity, telecommunications, gas and oil, water, sewerage, defence, health facilities and emergency services. It was estimated that the average annual damages from flooding is $21–$68 million with an expected cost of about $38 million, with residential damages contributing about 28%, commercial/industrial 20%, agriculture 11%, electricity supply 10% and the RAAF base 10%. On average about 240 houses per year would flood.

Clarke & Tickle (2001) investigated the potential impacts of flooding on household finances. The loss of, or severe damage to, a dwelling and its contents could result in families dropping below the poverty line. The effects would be compounded for families under mortgage stress or without accumulated savings, and where flooding disrupts employment.

Much of the information about the potential consequences of flooding in the Hawkesbury-Nepean catchment presents consequences only at the macro (catchment-wide) level. The current study reports consequences in terms of number of houses and population liable to inundation for each suburb.

2.3 FLOOD MODIFICATION OPTIONS

One suite of measures to address the high flood risk in the study area are options which modify the behaviour of floods. These options were studied as part of the *Proposed Warragamba Flood Mitigation Dam EIS* (ERM Mitchell McCotter, 1995) and the *Hawkesbury-Nepean Floodplain Management Strategy* (WMA, 1997).

Options considered in the former study are summarised in **Table 2.6** (ERM Mitchell McCotter, 1995) Several new flood detention dams were considered but were not recommended due to their cost, environmental impacts and (excluding the sites on the Wollondilly and Coxs Rivers) limited mitigation benefits. A large-scale river straightening scheme was found to be extremely impractical, and large-scale dredging would have unacceptable impacts on the riverine ecology and stability. Depletion of the Warragamba Dam storage to provide for flood mitigation would require an alternative water supply. Levees to protect the main population centres were also considered but would have unacceptable impacts on unprotected property as well as unacceptable visual impacts. The EIS favoured a flood mitigation strategy of raising the existing Warragamba Dam wall by 23 metres to gain flood detention air space above Lake Burragorang. However, following consideration of the EIS, the State Government decided not to proceed with the scheme and resolved that Sydney Water should proceed with an EIS for an auxiliary spillway to address issues of dam safety only (see ERM Mitchell McCotter, 1996).

The merit of flood mitigation dams was also investigated in the second study (WMA, 1997, summarised in HNFMAC, 1997). Those located on the Wollondilly and Coxs Rivers and on the Nepean River could significantly reduce flood levels at Windsor but the high financial and environmental costs render them inappropriate. A bypass channel linking the Hawkesbury River near Wilberforce to Currency Creek would lower levels upstream but increase levels downstream and in addition to its high cost for excavation and land resumption, may have adverse environmental and social impacts. Dredging the main river channel was found to be economically unviable and would have a major environmental impact. An option to amend the existing H14 Operating Procedures in force at Warragamba Dam was viewed as worthy of some investigation, to allow for either some pre-release of water at the onset of a flood in order to reduce the later peak flow downstream, or to delay the rising limb of a flood in order to increase time available for evacuation.[3]

[3] An earlier investigation in 1995 found that whilst alternative gate arrangements could be beneficial in reducing downstream flood levels without compromising dam safety, however it would also result in higher water levels upstream of the dam, increase the duration of downstream flooding and reduce warning times due to early release of stored water (HNFMAC, 1997).

TABLE 2.6 – Comparison of Mitigation Strategies considered for the Hawkesbury-Nepean Valley in the *Proposed Warragamba Flood Mitigation Dam EIS*

Source: ERM Mitchell McCotter, 1995, Figure 1.3 and text

Option	1867 flood peak at Windsor with selected option (m AHD)*	Cost ($1992)	Comments
Nepean River detention dam	19.1	$290M+	Worse flooding at Camden.
15% storage depletion at Warragamba Dam	19.1	$390M	Alternative water supply required immediately.
Colo River Detention Dam	19.1	$290M+	Major structure affecting pristine bushland.
Grose River Detention Dam	19.1	$290M+	Major structure affecting pristine bushland.
River straightening between Sackville and Wisemans Ferry	18.1	$820M	Extremely impractical. 50 million m^3 of material to be disposed of. 23 km of riverine environment significantly modified.
River dredging between Sackville and Wisemans Ferry to increase river depth by 10m	16.9	$440M	Up to 50km of riverine environment permanently damaged. 20-30 million m^3 of material to be disposed of.
90% storage depletion at Warragamba Dam	16.0	$390M	70 km^2 of unvegetated areas exposed. Alternative water supply required immediately.
Raise Warragamba Dam wall by 15m	16.0	$245M	Temporary inundation impacts upstream.
Levees	16.0	$265M+	Houses demolished for levees. Adverse flood effects outside levees. High visual impacts. Limited effectiveness.
15% storage depletion and 12m raising of dam wall	14.8	$400M	Alternative water supply required immediately. Temporary inundation impacts upstream.
Wollondilly/Coxs Rivers flood detention dams	14.8	$500M	Two major structures affecting pristine bushland in national parks.
Raise Warragamba Dam wall by 23m	14.8	$250M	Minor impacts on disturbed bushland around dam wall and temporary inundation upstream during flooding.
Raise Warragamba Dam wall by 30m	14.0	$340M	Greater construction and operational impacts than other dam raising options.
New dam at Warragamba 35m higher than existing dam	14.0	$390M	

* The current level of the 1867 flood, with Warragamba Dam, is reported to be 19.3m AHD (see **Table 2.1**).

The second study also investigated several potential local levee schemes around Windsor and Richmond, with the results summarised in **Table 2.7**. Many schemes were considered not viable due to their costs and high environmental, social and visual impacts. The most viable option was considered to be a ring levee around McGraths Hill offering protection to the 50 year ARI level, though there is a danger that residents could be slow to evacuate if they (wrongly) perceived the levee offered complete protection. A PMF refuge mound at McGraths Hill was considered to be a "very desirable safety feature" and the visual impact might be managed by fashioning it as a lookout.

It is noted that the brief for the current study emphatically states that *regional* flood modification measures are *not* to be re-investigated in this study. Rather the focus is on *local* management measures which are within the means and the jurisdiction of Council to implement. This includes *local* flood modification measures, such as the levees considered in WMA (1997), which have been examined within the current study.

2.4 FLOOD FORECASTING AND WARNING

A second suite of measures to address the high flood risk in the study area are options which modify human response to flooding, including improved flood forecasting and warning, improved flood emergency response planning, the provision of effective evacuation routes and a more educated community so that warnings are promptly heeded.

A review by Danielson & Associates (1997) recommended improvements to flood forecasting including better data and links with Sydney Water and state-of-the-art radar. Recommended improvements to the flood warning system included development of an emergency warning broadcast system for radio and television and installation of a warning siren network that supplements the current reliance on door-knocking teams. A recommendation of the HNFMAC's (1998) *Supplementary Report* following public exhibition broadened the recommendation to allow for the usage of "other appropriate technology" in addition to the use of sirens.

As a result of the *Hawkesbury-Nepean Floodplain Management Strategy*, the Hawkesbury-Nepean rainfall and river gauging network was expanded so that the ALERT radio telemetry system now employs 19 rainfall and 29 river gauges to assist with forecasting (HNFMSC, 2004). Research was also conducted into the effectiveness of various alerting and notification technologies (Molino et al., 2002a,b). No single technology can be relied upon to alert and notify 60,000 people in the Hawkesbury-Nepean floodplain. Free-to-air radio and television broadcasts are highly rated. Fixed Public Address systems are considered essential in the urban parts of the Richmond, Windsor, McGraths Hill and Pitt Town evacuation sectors since these are low flood islands. Personal Notification (i.e. door-knocking) is the preferred supplementary alert and notification strategy in these sectors. It was concluded that Tone Alert Radio and Telephone Dial Out Systems could be useful technologies in particular circumstances.

The brief for the current study specifies that the current flood forecasting/warning system operated by the Bureau of Meteorology is not to be reviewed as part of this project.

TABLE 2.7 – Local Levees for the Windsor/Richmond Area considered in the HNFMS report *Engineering Studies to Modify Flood Behaviour*
Source: WMA, 1997

	Design crest (m AHD)	Levee length	Levee height	Fill volume	Cons	Pros	Recommendation
Windsor	19.0	7km	9m (max); 7m (2km)	1,100,000 m^3	Massive height – serious visual impact and difficult access	Protect 1,100 properties up to 200y event	Unviable
Windsor	16.0	5.2km	6m (max); 4m (2 km); 2-3m (much)	400,000 m^3	Serious visual impact; expense	Protect 700-800 properties up to 50y event	Put to community consultation
Bligh Park	18.0	950m	2-3m (max)	23,000 m^3	Visual impact	Protect 50 properties up to 0.7m higher than 100y event	Put to community consultation
South East Windsor	16.0	1.2km	4-6m	85,000 m^3	Serious visual impact	Protect 60 properties up to 50y event	Unviable
Mulgrave	16.0	1.9km	1-2m (1.1km); up to 4m (800m)	65,000 m^3 plus raising railway line		Protect village up to 50y event	Put to community consultation
McGraths Hill	17.5	4km	2-3.5m	110,000 m^3	Serious visual impact; crest above escape route	Protect 700 properties up to 100y event	Unviable
McGraths Hill	16.0	3.3km	1-2m	30,000 m^3	False sense of security	Protect 700 properties up to 50y event	Put to community consultation (recommended)
Pitt Town	19.0			210,000 m^3	Serious visual impact; expense		Unviable
Pitt Town	16.0	2.2km	3m (half); 1m (half)	50,000 m^3	Visual impact	Protect 110 properties up to 50y event	Put to community consultation
Wilberforce (along King Road and south of Wilberforce Road)	17.5	700m	5m (max)	45,000 m^3	Serious visual impact	Protect 60 properties up to 100y event	Unviable
Wilberforce	16.0	600m	4m (max)	27,000 m^3	Serious visual impact	Protect 40 properties up to 1 in 50y event	Put to community consultation
Richmond-Windsor macro-levee	20.0	15km+	10m	3,700,000 m^3 plus massive flap gate for Rickabys Creek crossing	Access; cost; environmental and visual impact; impacts on heritage buildings; false sense of security	Protect up to 1867 flood plus freeboard	Unviable
Richmond-McGraths Hill macro-levee				As above plus massive gate for South Creek	As above	As above	Unviable

2.5 FLOOD EVACUATION STRATEGY

Emergency response to flooding of the Hawkesbury-Nepean River floodplain needs to deal with three challenges (Bewsher Consulting, 2001):

1) key urban areas are higher than the evacuation routes leading to shrinking islands in a flood;
2) the limited capacity of evacuation routes; and
3) the need for early and accurate flood forecasting.

A vast amount of work has been done under the Hawkesbury-Nepean Flood Management Strategy to assess the capability of the regional road network to evacuate the populations of major flood-prone centres in the Hawkesbury-Nepean Valley, and then to resolve the identified deficiencies to the road network.

In 1997, the Hawkesbury-Nepean Flood Management Advisory Committee (HNFMAC) concluded that evacuation would be frustrated by local flooding and insufficient traffic carrying capacity along the evacuation routes, so that unless a major upgrade of the road infrastructure was carried out, as many as 60,000 persons may not be evacuated and could be drowned when severe flooding occurs (i.e. in excess of about a 250 year ARI event) (Danielson & Associates, 1997; Masson Wilson Pty Ltd, 1997; Patterson Britton & Partners, 1997; HNFMAC, 1997). The HNFMAC identified a preliminary program of road improvements which allowed evacuation routes to be phased in across the valley.

A *Flood Evacuation Route Optimisation Study* followed (Patterson Britton & Partners, 1998), which aimed to facilitate the preparation of preliminary designs for upgrading evacuation routes, taking into consideration the minimum route elevations required, the optimum level of low points with respect to economic criteria and specific route requirements.

A series of Local Hydraulic Specific Studies were conducted to ensure that evacuation would not be compromised by local flooding (see Bewsher Consulting, various dates; SMEC, 2000). The design flood intended to be conveyed along these evacuation routes was the 500 year ARI event.

The *Hawkesbury-Nepean Interim Regional Road Upgrade Plan* (DLWC, 2000) documented progress made to 31 March 2000 in the development and implementation of the detailed Regional Road Upgrade Plan to provide an improved road network capable of supporting an emergency flood evacuation. The study described seven dynamic traffic simulations conducted to determine evacuation route capability. It concluded that an upgrade of Windsor Road (to RL 13.5), a second crossing of South Creek from Windsor (at RL 17.3), two outbound lanes on The Northern Road and traffic management to favour Bligh Park evacuation traffic is required to manage existing evacuation traffic.

Another update was prepared in July 2004 (Patterson Britton & Partners, 2004). This calculated the timing of evacuations with respect to the Quantitative Precipitation Forecast (QPF) limit, which is defined as the earliest point the Bureau of Meteorology can predict that a particular flood evacuation route will be cut, using actual rainfall data. Based on the then planned evacuation upgrades and population data, it was found that McGraths Hill and Bligh Park were obliged to begin evacuating five hours and 2½ hours prior to the QPF limit, respectively. This is undesirable because greater uncertainty is attached to forecasts using only predicted rainfall, increasing the likelihood of false alarms.

The *Hawkesbury-Nepean Flood Emergency Sub Plan* (SEMC, 2005) is the key reference for understanding the flood evacuation strategy for the Hawkesbury-Nepean Valley, and is in process of being updated to reflect recently upgraded road infrastructure and other improvements to the evacuation timeline methodology (see Opper et al., 2009). The regional road evacuation routes for the Hawkesbury-Nepean floodplain are shown in **Figure 2.8**. The current status of evacuation route upgrades is summarised in **Table 2.8**.

An important consideration in respect of the regional flood evacuation strategy concerns the demand for urban growth. The *Hawkesbury-Nepean Flood Management Strategy Implementation* report (HNFMSC, 2004, p.6) makes clear that road upgrades were designed to provide evacuation for *existing* communities and that “any future development would need to incorporate additional upgrading of the evacuation route infrastructure”. Assessments have been made of the implications for the regional evacuation strategy of proposed subdivisions at Pitt Town (e.g. NSW SES, 2002; Molino Stewart, 2007) and at Bligh Park North (e.g. Molino Stewart, 2007). It is understood that an important role for the current study is to develop a strategic approach for new growth areas within the Hawkesbury LGA, mindful of existing flood evacuation constraints.

However, it is recognised that the timeline methodology and parameters which underlie the evacuation strategy are continuing to evolve. Not factored into the original evacuation timeline calculations was the need to evacuate commercial vehicles and vehicles not reported in the Census. Gradual infill development is also known to have increased the number of vehicles requiring evacuation (Molino Stewart, pers. comm.). Hence, Molino Stewart (2007) found that even with the new road infrastructure including the Jim Anderson Bridge across South Creek, there was a 3.2 hour evacuation time deficit for Windsor/South Windsor. Another issue is traffic convergence problems where The Northern Road meets the M4 Motorway, which has only a single-lane on-ramp (Molino Stewart, pers. comm.).

Given this evolving understanding of the intricacies of the evacuation task, including the constraints imposed on local evacuation by regional considerations, it is important that the current study employ the latest evacuation timeline model.

Although it may still be the case that the major control on the effectiveness of a large-scale evacuation strategy is the capacity of the evacuation routes (Opper, 2000), greater recognition is now being given to the difficult environment for decision making and mobilisation and to the vagaries of human behaviour which are expected to delay acceptance of warnings (Opper et al., 2009). The concern with the latter is that based only on *forecast* rainfall, residents will be told to evacuate very early – when no floodwater is in sight from their verandas. If it turns out with hindsight that the evacuation was unnecessary, the level of confidence in flood predictions may decline, leading to increased non-compliance with evacuation orders for future flood emergencies. This concern is underscored by research following the 2009 Grafton floods – where there was substantial non-compliance with an evacuation order – that found residents would not take an evacuation order seriously until they had faith in the accuracy of river predictions (Molino Stewart, 2010). Clearly, a key message for community education will be to explain why residents in the Hawkesbury River floodplain need to evacuate early, even when a false alarm may have been experienced previously (see **Section 2.6**). The current study also needs to give serious consideration to backup risk management strategies, recognising that a real evacuation may not occur as modelled. An example of potential backup strategies for the proposed Bligh Park Stage 2 development are presented in **Table 2.9**.

The *Hawkesbury-Nepean Floodplain Management Strategy Implementation* report (HNFMSC, 2004) recognises that local evacuation constraints need to be examined in the local floodplain risk management study. The literature refers to the following local evacuation issues which will require consideration:

- Multiple local road closures within Bligh Park (see Bewsher Consulting, 2011a). One road low-point on Rifle Range Road just west of Porpoise Crescent can isolate the eastern half of Bligh Park from the Regional Flood Evacuation Route;

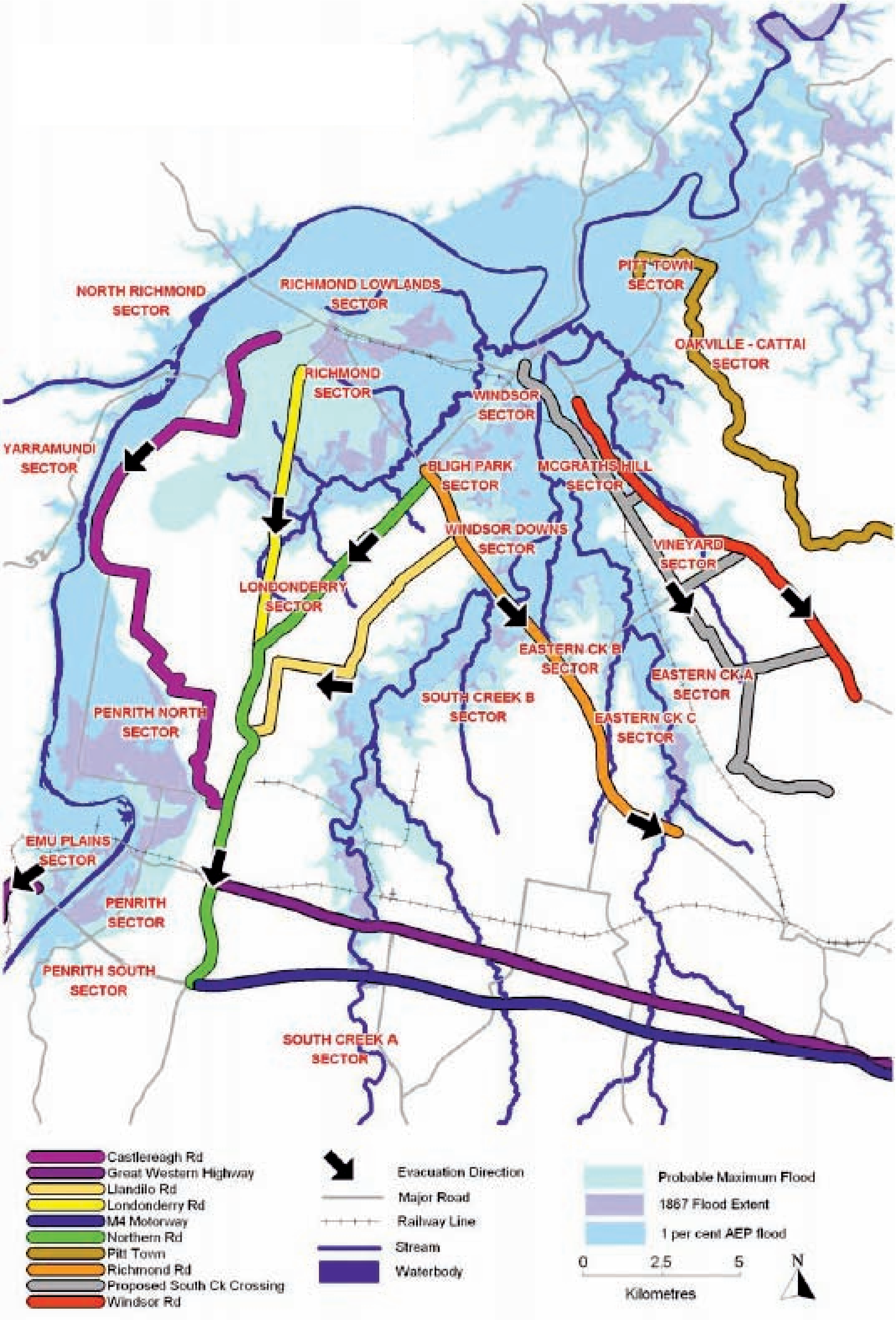

FIGURE 2.8 – Hawkesbury-Nepean Flood Evacuation Routes
Source: SEMC, 2005

TABLE 2.8 – Current Status of Hawkesbury-Nepean Regional Evacuation Route Upgrades
Source: SEMC, 2005; discussions with OEH

Location	**Description**	**Post-Upgrade Road Low-point** (m AHD)	**Submersion Height** (m AHD)	**Current Status** (Jan 2011)	**Comments**
McGraths Hill	McGraths Road – **Windsor Road**	13.5	16.0–18.0	Complete.	Isolated by inundation of local streets at 13.0.
Windsor/ South Windsor	Macquarie Street – Argyle Street – Cox Street – Moses Street – Tebbutt Street – George Street – Christie Street – Macquarie Street – Day Street – Hawkesbury Valley Way (**South Creek crossing**) – Railway Road North – Railway Road South – etc	17.3	26.0	Completed from Windsor to Mulgrave including two level crossings. Many LHS upgrades still to be done east of Groves Avenue.	
Bligh Park *(tertiary)*	Alexander Street – Thorley Street Flood Evacuation Route – **Richmond Road** to Blacktown	14.1 at South Creek Bridge	25.0		Limited opportunity for use.
Bligh Park *(secondary)*	Alexander Street – Thorley Street Flood Evacuation Route – **The Northern Road**		25.0	All LHS upgrades still to be done on The Northern Road.	
Bligh Park *(primary)*	Alexander Street – Thorley Street Flood Evacuation Route – Richmond Road – **Llandilo Road** – Fifth Avenue – Terrybrook Road – Ninth Avenue – The Northern Road	18.5 at Thorley Street; 19.1 on Llandilo Road	25.0	All LHS upgrades still to be done on Llandilo Road route except WN9.	Substantial local flooding issues within Bligh Park
Richmond/ Hobartville *(secondary)*	**Londonderry Road** – The Northern Road	18.0	20.0	Complete.	
Richmond/ Hobartville *(primary)*	**Castlereagh Road** – The Driftway – Jockbet Street – Wilshire Road – Brooks Lane – Castlereagh Road – Hinxman Road – Fire Trail Road – Smeeton Road – Tadmore Road – Cranebrook Road – Vincent Road – The Northern Road	20.2	20.0	Many LHS upgrades still to be done especially on Cranebrook Road and Vincent Road.	Substantial local flooding issues within Hobartville
Pitt Town	Bathurst Street – Bootles Lane – Redfern Place – Mitchell Road – Pitt Town Dural Road – Old Stock Route Road – Old Pitt Town Road – etc	16.0	> PMF	Complete.	

Note: When referring to evacuation routes, "primary" and "secondary" are used here to refer to the route which offers the greatest immunity against flooding, rather than to the route which may be used first in an emergency.

- Multiple local road closures within Hobartville (see Bewsher Consulting, 2011b); and
- The northern part of Windsor is isolated from the Windsor Flood Evacuation Route, with a highest road low-point of 14.6m AHD (from a Digital Elevation Model derived from Council's ALS survey) located on George Street about 50 metres north of the New Street intersection. This road was reportedly blocked in the November 1961 flood (RL 15.0).

TABLE 2.9 – Cascading Flood Risk Management Measures Proposed for Bligh Park Stage 2

Source: Molino Stewart, 2007

Plan "A"	Evacuation via the Windsor Flood Evacuation Route (requiring additional route upgrades)
Plan "B"	Provide a high pedestrian route to Windsor Downs Nature Reserve which has an area above the PMF level
Plan "C"	Site 3-storey commercial developments on high points within developed area, with access from all properties via rising roads and footpaths, and with some floor area above the PMF level
Plan "D"	Houses built with materials and designs so as to maintain structural integrity in flood up to the PMF; tiled roofs so that people who evacuate into the roof cavity have a means of exit

2.6 COMMUNITY EDUCATION

A good deal of work was conducted for the *Hawkesbury-Nepean Floodplain Management Strategy* to assess community attitudes towards flood risk and to inform a Regional Public Awareness Program. Since then the SES has also commissioned investigations towards the same ends.

2.6.1 Community Attitudes

Colmar Brunton Social Research (1999) found that whilst people in Windsor and Richmond are reasonably aware of the risk of a serious flood they are not greatly concerned about the risk to life in a serious flood. This means that people have no reason to feel the need to develop a flood plan, know and practise their evacuation route, understand the warning system or know how to react during an evacuation. Large numbers of people would not evacuate in a flood emergency at that time.

Dovetail Planning (2000) reported that the real flood hazard is poorly understood by the community, who consider that there is a flood hazard only on land below the flood planning level, typically the 100 year ARI flood level. Hawkesbury-Nepean flooding has a high actual risk but a low perceived risk.

Egan National Valuers (2000) found that people believe that all land up to the 100 year ARI level has the same chance of being flooded and that all land between the 100 and 100,000 year ARI levels has an equal chance of being flooded. Many residents also believe that measures such as the construction of Warragamba Dam have alleviated flood risk.

The *Hawkesbury-Nepean Floodplain Management Strategy Implementation* report (HNFMSC, 2004) stated that the community lacks both an *awareness* to plan for and a *preparedness* to respond to severe flooding. Up to 70% of residents on the floodplain were unaware that they lived in an area affected by floods and could one day need to evacuate.

About 50 questionnaires, albeit with an over-representation of long-term residents, were returned from each of McGraths Hill, Windsor/South Windsor and Richmond/Agnes Banks/ Richmond Lowlands/Cornwallis in February 2006 (Becker et al., 2008a). About 50% of respondents from Windsor and Richmond had been affected by a flood in the past, compared to 40% for McGraths Hill, though on the whole the degree of impact was slight. Few respondents had prepared a home flood plan (<13%) or an emergency kit (<7%), which does not accord with the results of the Colmar Brunton (1999) study, which found higher preparedness. About 60% of respondents believe it is necessary to make preparations for floods. Those that did not believe it was necessary did not believe they were in a flood risk area or hadn't been affected. Respondents had only a low to moderate personal concern about floods, highlighting a need for individuals to personalise the risk. Very few respondents planned to seek more information about risk. A moderate to high lack of knowledge of any flood warning systems prevails in the Hawkesbury-Nepean communities, especially at McGraths Hill where residents are newer. The action respondents would most likely take upon hearing a flood warning would be to seek confirmation by contacting the local council or the SES. About 50% of respondents had seen some form of flood information for the river, mostly from the SES or council. Brochures received in the mail were an especially welcome means of receiving information about preparing for floods, while radio, TV and door-knocking were preferred means for receiving information about current flooding.

In April 2008, follow-up questionnaires were issued to the same households in each of McGraths Hill, Windsor/South Windsor and Richmond/Agnes Banks/Richmond Lowlands/ Cornwallis, with a response rate of about 10% (Becker et al., 2008b). The purpose of this second questionnaire appears to have been to assess the benefits of SES educational activities including Business FloodSafe breakfasts in 2006 and displays at the Hawkesbury Show in 2006, 2007 and 2008. On the positive side, there was a noticeable rise in survey respondents from McGraths Hill reporting that they thought flooding was likely to affect their community (54% in 2006 to 90% in 2008). On the negative side, self-reported evacuation compliance dropped substantially from 2006 to 2008, with most people now indicating they would stay inside and wait to be told what to do. There was a slight increase in people preferring community displays as an information source (16% in 2006 to 28% in 2008) and in people preferring to receive SMS during a flood (19% in 2006 to 33% in 2008).

2.6.2 Education Needs

Don Fox Planning and Bewsher Consulting (1997) recommended a multi-faceted education program to raise the awareness of the community to flooding issues, including flood warning poles, video, signage of evacuation routes, flood displays, training of key people and special education measures for new business owners, residents and tenants.

Colmar Brunton Social Research (1999) identified a need for an "awareness and concern phase" and a "ways to become prepared phase" to promote flood preparedness. The first phase is aimed at conveying the seriousness of the flood threat whilst the second phase consists of constructive, positive messages that give people knowledge of what they can do and a sense of control. Key messages for each phase are presented in **Table 2.10**. Since the goal is to build and *sustain* community preparedness, several structural changes were recommended, including full-time staff to coordinate the campaign and to staff an information centre and telephone line.

TABLE 2.10 – Key Messages for Improving Flood Preparedness
Source: Colmar Brunton Social Research, 1999

Awareness and concern phase	Ways to become prepared phase
• A major flood could occur • Thousands of homes could be severely damaged • There is a plan to protect the community BUT • The community must be prepared to ensure personal safety • Flood preparedness will help in preventing loss of cherished personal possessions, personal injury, trauma or even loss of life • The SES/council can be contacted for more information	• Being flood prepared will help keep you/ family/friends safe • You can control the impact of a serious flood by becoming flood prepared • Being flood prepared will ensure you know exactly what to do and who will help in an evacuation • Preparation means you won't have to rely on other people in an emergency • Flood preparation is quick, easy and fun • Flood information is easy to get • If you hear this warning, put your flood plan into action

Dovetail Planning (2000) outlined a Regional Public Awareness Program developed as part of the *Hawkesbury-Nepean Floodplain Management Strategy*. Here also the importance of a long-term *sustained* communication program to overcome people's natural indifference was recognised. An appreciation of different audiences and the targeting of those audiences via particular communications strategies are important, with the aim of moving people towards independence. The Program needs to promote *changed flood protection behaviour*, not just to inform. Five stages of behavioural change can be used to promote changed behaviours (**Table 2.11**).

TABLE 2.11 – Communication Strategies at the Five Stages of Behavioural Change
Source: Dovetail Planning, 2000, Table 2

Stage	Communication strategy
Pre-contemplation	Raise awareness of flooding through education and provision of information.
Contemplation	Emphasise the benefits of being flood prepared.
Preparation	Increase the use of influential others to persuade the target group that it is personally desirable to change.
Action	Improve an individual's ability to act independently. Make the behaviour easier to undertake.
Confirmation	Reward maintaining change.

Egan National Valuers (2000) expressed the opinion that increased use of a variety of flood awareness material such as advice on rates notices, media releases, flood marker poles, information brochures, etc., should not have a negative impact upon property values in the long term for those properties affected by a PMF classification. The authors identified a need to overcome misinformation (e.g. concerning the role of Warragamba Dam) with an ongoing, multi-pronged education strategy.

Becker et al. (2008a) concluded that, *"Simple hazard education is not going to increase levels of preparedness, as levels of knowledge about the hazard are already high. Alternative strategies are required that seek to engage and involve individuals in the process (and help personalise the risk), rather than simply disseminate information"*. There is a need to: 1) motivate people to prepare, 2) facilitate the formation of intentions and 3) promote the conversion of intentions to preparedness.

2.6.3 Implementation

The *Hawkesbury-Nepean Floodplain Management Strategy Implementation* report (HNFMSC, 2004) summarises components of the Regional Public Awareness Program. This included the launch of the Hawkesbury-Nepean FloodSafe website in June 2002,[4] the issuance of flood information to 35,000 homes within the PMF area (see **Figure 2.9**), the development of the Business FloodSafe program, a series of meetings to encourage participants to prepare family flood plans and the installation of flood evacuation route signage. It is understood that the SES has continued to promote flood education since 2004 including displays at the Hawkesbury Show and the provision of resources to schools.

The Hawkesbury-Nepean FloodSafe website includes resources such as a map of the 1867 flood extent. There is also a Warragamba Dam FloodSafe website which includes answers to frequently asked questions (FAQs) such as "Does Warragamba Dam reduce downstream flood levels?"[5]

Hawkesbury City Council's web-site describes some other activities being pursued under the FloodSafe banner. It also provides extent maps for the 100 year and PMF events, flooding FAQs, and information about road closures.[6] Hawkesbury Regional Museum contains displays about historical floods.

However, whilst a number of flood education activities have taken place, it is unclear whether an *ongoing, permanent* and *coordinated* process to build and maintain public awareness and preparedness has been implemented. The current study recommends a review of previous programs with a view to planning for the next 5-10 years.

2.7 PLANNING AND DEVELOPMENT

A third suite of measures previously considered to address the high flood risk in the study area are options which modify human use of the floodplain, including land use planning and building design.

Land use planning offers the greatest potential for reducing the vulnerability of people and property to the full range of flood risks in areas of new development and/or redevelopment (HNFMSC, 2004). The necessity of land use planning to avoid frequent losses was recognised early in the European settlement of the Hawkesbury Valley, resulting in Governor Lachlan Macquarie's oft-cited Government and General Order of 15th December, 1810 which established the five Macquarie towns (Windsor, Richmond, Pitt Town and Wilberforce within the Hawkesbury LGA and Castlereagh within the Penrith LGA)

> *"on the most contiguous and eligible high grounds in the several districts subjected to those inundations for the purpose of rendering every possible accommodation and security to the settlers whose farms are exposed to the floods"* (Stubbs, n.d.).

[4] www.ses.nsw.gov.au/community-safety/floodsafe/hawkesbury-nepean-floodsafe
[5] www.ses.nsw.gov.au/community-safety/floodsafe/warragamba-dam
[6] www.hawkesbury.nsw.gov.au/services/emergency-information/flood-information

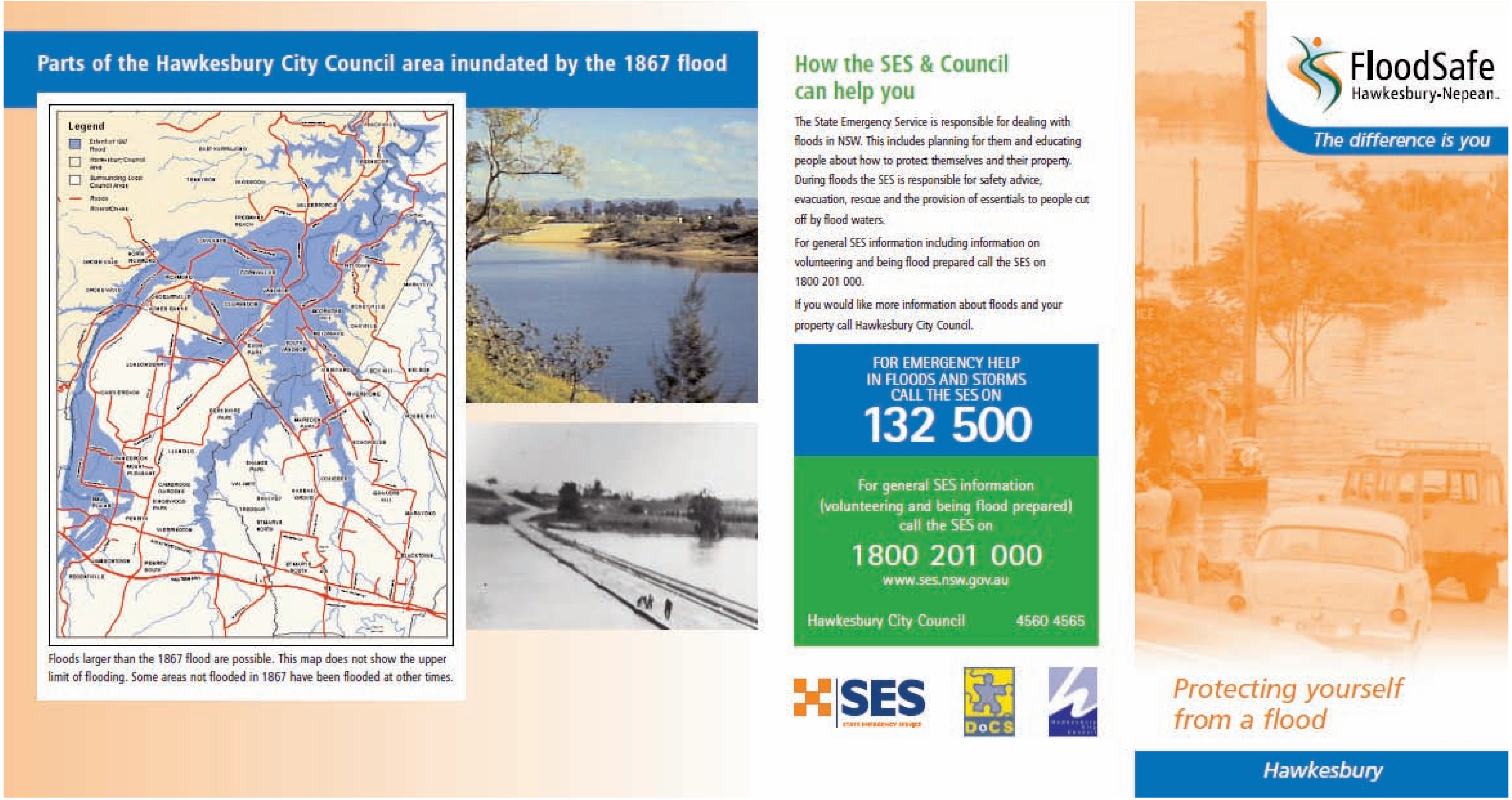

FIGURE 2.9 – Hawkesbury FloodSafe Guide
Source: SES

The difference is you

Are you at risk from floods?

The Hawkesbury River and its tributaries have created a beautiful environment. However, the very nature of this landscape leaves it prone to flooding. In the past, areas of McGraths Hill, Pitt Town, Richmond, Windsor, Oakville, Cattai, North Richmond, Wilberforce and rural areas between them have experienced serious flooding. The largest flood ever recorded was in 1867. An account at the time described the effect of the flood: "Hundreds of people were to be seen clinging to the roofs of houses, to tree-tops, or wherever they could get beyond the reach of the rushing waters". The Hawkesbury River peaked at a staggering 19.26 metres – that's 12 metres above the road on the current Windsor Bridge.

The NSW Government and Hawkesbury City Council are committed to a multi-million dollar program of protecting people against serious floods. This includes ensuring people know how to stay safe and protect belongings, upgrading roads so they will stay open longer when serious floods occur, and discouraging development in the worst affected areas.

You can also be indirectly affected by flooding even if your property is not flooded. If access roads are cut or you have no power or water, you need to know what to do for yourself – and where to turn to for help. This leaflet gives you some suggestions on how to prepare yourself and your property.

Stay informed

The Hawkesbury City Council has information on how flooding can affect your community and your local SES unit can give you information on specific measures you can take now to minimise the effect of flooding on you, your family and your property.

Prepare yourself

Some basic measures you can take right now include keeping a list of emergency numbers near the telephone and assembling an emergency kit. Your emergency kit should contain:

- **A portable radio**
- **A torch**
- **Spare batteries for both the radio and the torch**
- **Candles and waterproof matches**
- **A first aid kit**
- **A good supply of your medication**
- **Fresh water and food (replace these regularly)**
- **Strong shoes and rubber gloves**
- **A waterproof bag for valuables**

When there is a Flood Warning

Flood warnings will refer to predicted river heights at the Windsor Bridge gauge. They will indicate the likely consequences at the predicted heights and tell you what actions to take.

- Listen to your local radio station or (89.9FM Hawkesbury Community Radio) for updates and advice.
- Check that your immediate neighbours have heard the warnings.
- Prepare yourself and your property.

Prepare your belongings

- Stack your possessions on benches and tables, electrical goods on top
- Secure objects that are likely to float and cause damage
- Move garbage containers, chemicals and poisons beyond the reach of the water
- Move stock and equipment to high ground

If you need to evacuate

- Collect your personal papers, valuables, mementoes and medications and take them with you
- Turn off the electricity, gas and water as you leave
- You will be told which evacuation centre you should go to
- Don't leave your pets behind: they may die

During the flood

- Avoid driving or walking through flood water: it may be deeper or faster flowing than you realise
- Keep listening to your local radio station for further information and advice
- Keep in contact with neighbours and be prepared to evacuate

When you evacuate

Help will be available at evacuation centres established by the Department of Community Services (DoCS). They will help with:

- Temporary accommodation
- Financial assistance
- Personal support
- Refreshments and meals
- Clothing and personal needs
- Facilities for contacting family and friends

Recovering from the flood

Recovery Centres will be established by DoCS.

These centres will be staffed by representatives from government departments and community agencies who will provide a range of assistance to help you return to normal living.

FIGURE 2.9 – Hawkesbury FloodSafe Guide

Source: SES

After further damaging flooding in 1817 the Governor issued a Government and General Order on 5th March, 1817, encouraging settlers to

> *"establish their future residences in the townships allotted for [their] preservation … on the high lands"* (HNFMSC, 2006a, p.13).

As discussed in relation to flood behaviour (**Section 2.1**), the natural "choke point" which extends from Ebenezer to downstream of Sackville, causes floods of great depth in the Windsor/Richmond floodplain, even for events not much less frequent than the 100 year ARI flood. The very concerning *consequences* of such flooding (**Section 2.2**) means that the flood *risk* to people and property – understood as the product of likelihood and consequences – is *high* even for events such as the 200 year ARI event, and needs to be managed.

Historically, planning approaches have been slow to recognise this risk. Patterson Britton & Partners (1993) reviewed the *Hawkesbury LEP 1989*, which prohibited development below the 10 year ARI level and permitted development above the 100 year ARI level.[7] But the *Land Use and Development Control Measures* report prepared for the HNFMAC identified a number of problems with the historical reliance on the 100 year flood as a singular flood planning level (FPL) (Don Fox Planning and Bewsher Consulting, 1997):

- lack of recognition of the significant flood hazard that may exist above the FPL (with few measures in place to manage its consequences);
- development within the floodplain which does not recognise the risks to life or the economic costs of flood damage;
- unnecessary restriction of some land uses from occurring below the FPL, while allowing other inappropriate land uses to occur immediately above the FPL;
- polarisation of the floodplain into perceived "flood prone" and "flood free" areas;
- creation of a political climate where redefinition of the FPL is fiercely opposed by some parts of the community; and
- creation of a "hard edge" to all development at the FPL.

The report concluded that a matrix of development controls, based on the flood hazard and the land use, can balance the risk exposure across the floodplain, as well as substantially reduce economic losses. Local planning instruments that incorporate *graduated* development controls, rather than a *singular* FPL, were recommended.

An important outcome of the *Hawkesbury-Nepean Floodplain Management Strategy* was the publication of the *Land Use Guidelines* (HNFMSC, 2006a), which builds on the principles espoused in the 1997 report. These guidelines aim to provide local councils with a regionally consistent approach to developing local policies, plans and development controls which address the hazards associated with the full range of flood events up to the PMF. A starting point for managing risk through land use planning is to *classify* risks throughout the floodplain. The Guidelines present a methodology for mapping risk bands based on the likelihood and consequences of flooding, focussing especially on tangible residential flood damages. (Consideration of what might be termed the "flood evacuation setting" of an area is also important for mapping risk to life – Patterson Britton & Partners, 1993. The *Hawkesbury-Nepean Flood Emergency Sub Plan* describes five types of settings including flood islands, areas accessible overland, areas accessible by road, landlocked areas and indirectly affected areas). An important task for the current study will be to consider and spatially differentiate flood risks across the study area.

[7] Development between the 10 year and 100 year levels was required to have habitable floors above the 100 year level but no more than three metres above existing ground level.

Mapping the risk provides a basis for a more effective approach to managing flood risk through the application of graduated controls. The planning matrix method shown in **Figure 2.10** is an effective way of presenting these graduated controls, recognising that different land uses have different vulnerabilities to the same flood hazard. **Figure 2.11** illustrates in a simplified manner, the distribution of land uses within the floodplain using graduated controls. In addition to responding to flood risk through spatial differentiation of land uses, the method allows for controls in the design of development to manage the consequences of flooding up to the PMF.

In order to reduce flood damages in the Hawkesbury-Nepean floodplain, the *Land Use Guidelines* suggest a range of Flood Planning Levels (FPLs) be used (see **Figure 2.12**):

- If single storey dwellings are proposed, their lowest habitable floor level should be at or above the 200 year ARI flood level plus freeboard;
- Incorporating flood aware building measures for the design, materials and construction methods used in housing on flood prone land;
- For dwellings with a habitable floor level lower than the 200 year ARI flood level, incorporating the following measures can reduce flood damage:
  a) including two or more storeys; and
  b) building all external and load bearing internal walls below the 200 year ARI FPL of masonry construction e.g. double brick, concrete block, concrete panel rather than brick veneer or framed walls with sheet cladding; and
  c) using timber frame walls with sheet cladding only for non load-bearing internal partitions.

Another outcome of the *Hawkesbury-Nepean Floodplain Management Strategy* was the *Subdivision Guidelines* (HNFMSC, 2006b). These provide practical guidance to assist in the planning and designing of safer residential subdivisions on flood prone land. Bligh Park has been cited as an example of a subdivision that did not consider flood evacuation issues, since the entrance to the subdivision is low-lying (Patterson Britton & Partners, 1993). (This situation has been remedied through construction of the Thorley Street Flood Evacuation Route). **Figure 2.13** shows some of the design layout issues that should be considered in future subdivisions.

In addition to the *Land Use Guidelines* and *Subdivision Guidelines*, the Strategy produced *Building Guidelines* (HNFMSC, 2006c). Modern housing construction results in houses that are ill equipped to withstand inundation or fast flowing water. Many homeowners of flood prone property are potentially very vulnerable to major losses. The Guidelines provide specific and detailed information on building designs and styles and house construction materials and methods which can reduce structural damage due to inundation or higher velocities and facilitate the clean up after a flood, thus reducing the costs and shortening the recovery period. Financial benefits of flood-aware design are summarised in **Figure 2.14**. Whilst the cost of flood-aware designs is higher, a survey of households in the Hawkesbury-Nepean Valley found that a majority would be willing to pay up to 10% more for a house if it was built to a standard that offered protection from flood damages (GHD and Cox Consulting, 2001). First home buyers, however, were willing to pay only 5% more.

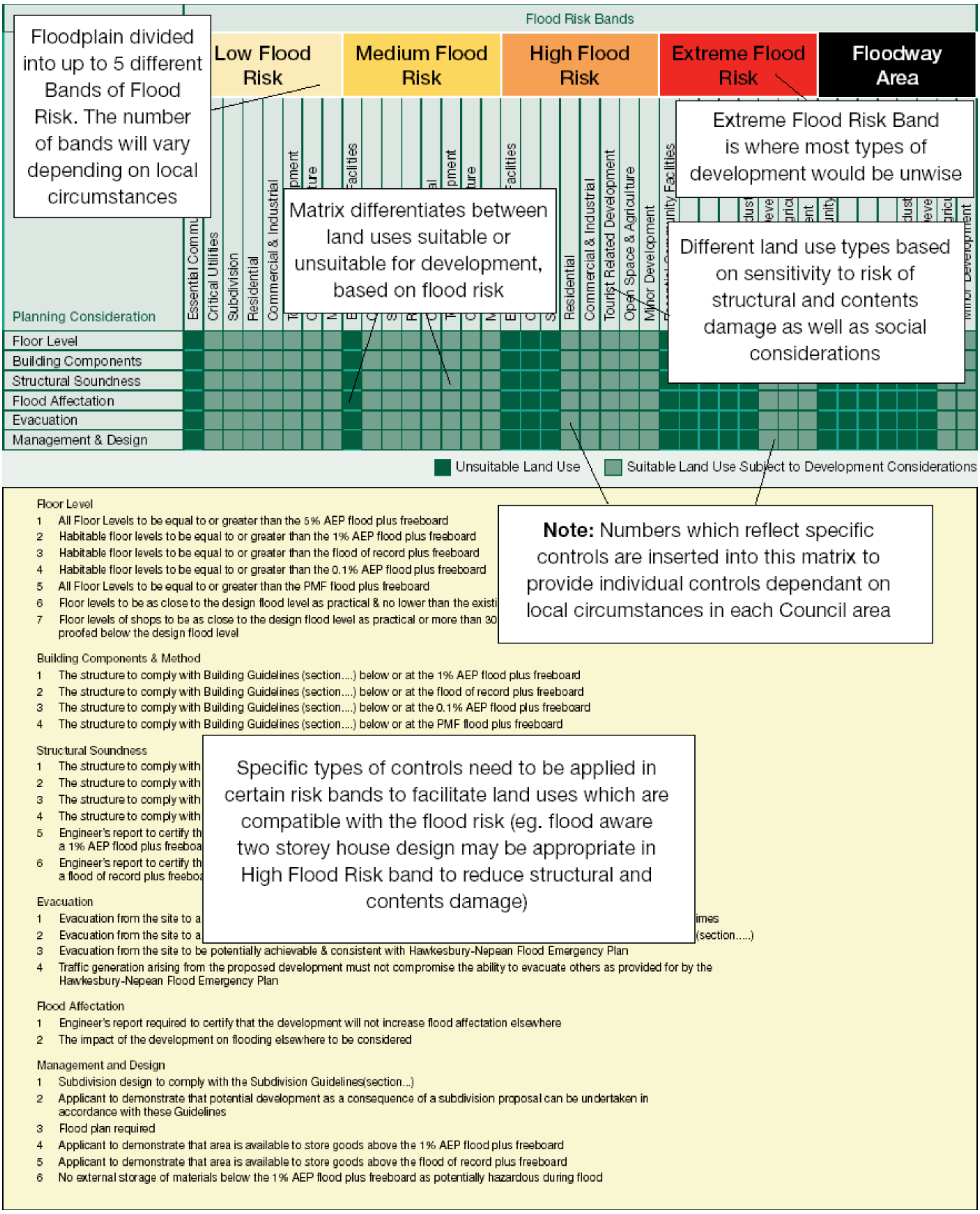

FIGURE 2.10 – Sample Flood Planning Matrix
Source: Land Use Guidelines (HNFMSC, 2006a, p.114)

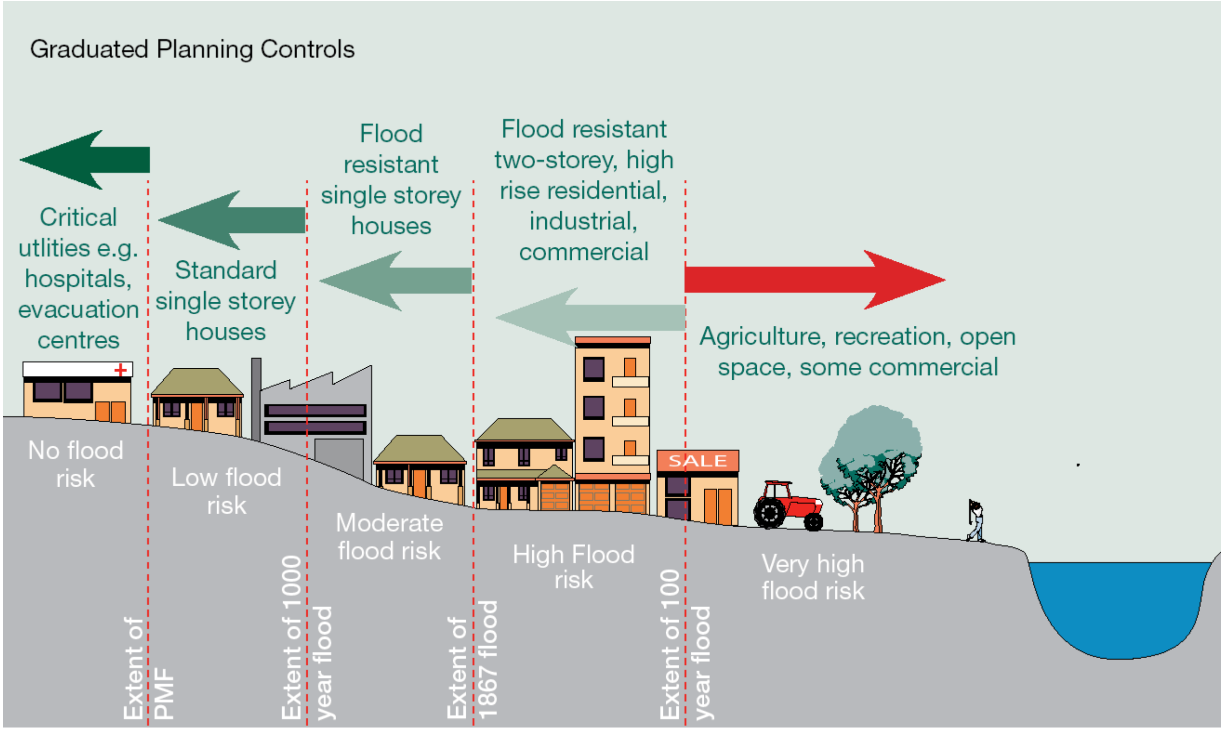

FIGURE 2.11 – Distribution of Land Uses on the Floodplain to Reduce Risk
Source: Land Use Guidelines (HNFMSC, 2006a, p.113)

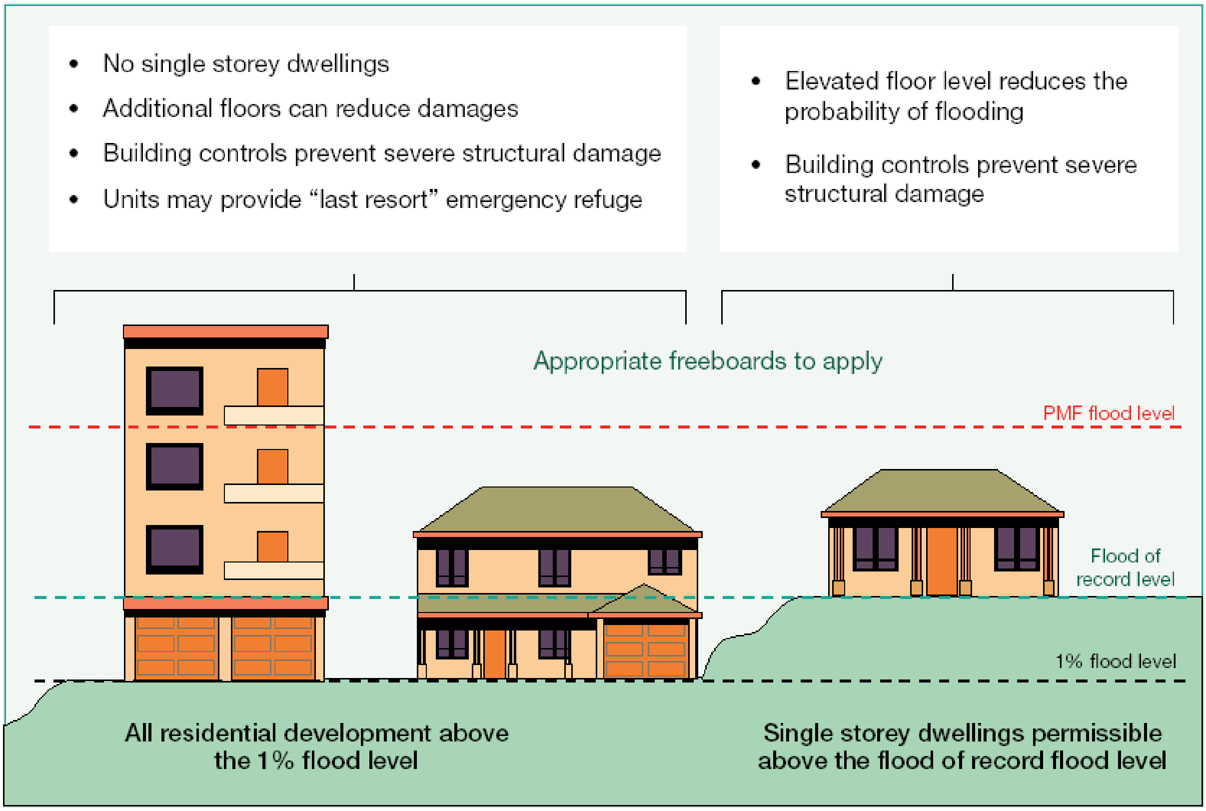

FIGURE 2.12 – Increased Property Protection through Development Controls
Source: Land Use Guidelines (HNFMSC, 2006a, p.108)

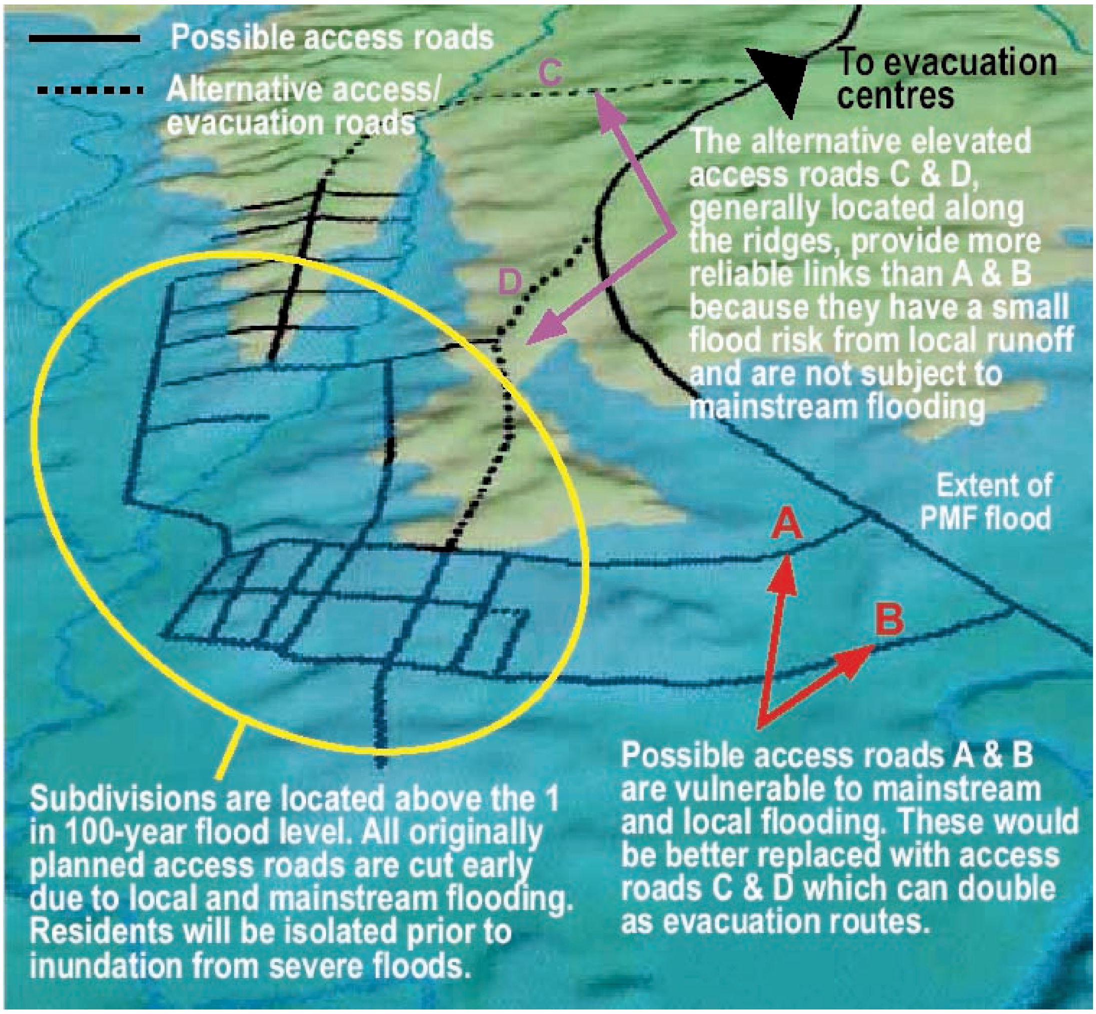

FIGURE 2.13 – Example of Road Layout for Safe Evacuation from a Subdivision
Source: Subdivision Guidelines (HNFMSC, 2006b, p.82)

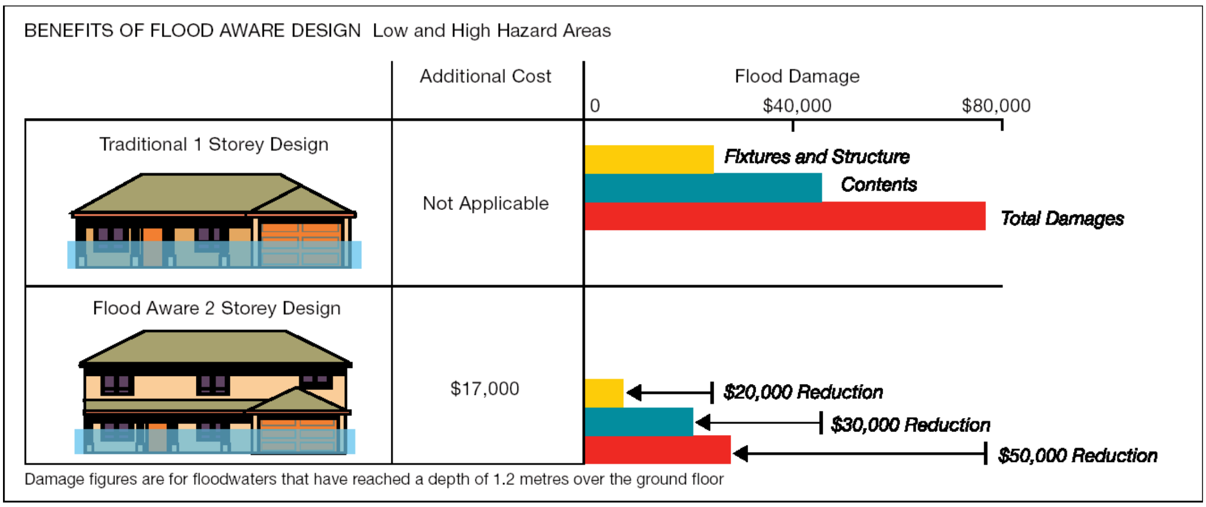

FIGURE 2.14 – Cost Benefits of Flood Aware Housing Design
Source: Building Guidelines (HNFMSC, 2006c, p.12)

One of the most important objectives of the current study is to translate the best practice planning principles encapsulated in the three Guidelines, with the input of the community, into local planning policies. This is especially important in the context of planned urban growth for the Hawkesbury region. It is noted that the draft Hawkesbury Residential Land Strategy 2010 identifies potential areas for future growth but recognises that flood evacuation considerations may impose constraints. Specific tasks for this study include:

- Consideration of existing zonings, the Metropolitan Strategy and the Sub-Regional Strategy;
- Input to the draft Hawkesbury Residential Land Strategy, including recommendations about land use distribution and densities (greenfield and infill);
- LEP recommendations;
- Input to flood risk management provisions in the DCP, including some consideration for incorporating climate change;
- Recommendations for flood planning levels (FPLs);
- A strong case for "exceptional circumstances" approval to be given for the application of flood-related development controls above the 100 year level;
- Associated recommendations (s94, S149 certificates, etc).

Early reports recommended that consideration be given to local refuges (Patterson Britton & Partners, 1993; PWD, 1994). In view of the recognised challenges with implementing the evacuation strategy, plus the regional planning imperatives to provide additional housing in the Hawkesbury LGA, the current study also reassesses the merits of local flood refuges.

2.8 INSURANCE

One of the studies undertaken for the *Hawkesbury-Nepean Floodplain Management Strategy* considered insurance industry perspectives on flooding (Blong, 2000). Since the report was prepared, industry changes have meant that flood insurance is much more widely available for residences and small businesses. Indeed, some insurers routinely include flood cover in their home insurance packages, while others offer it as an option. The uptake of flood insurance in the Hawkesbury-Nepean floodplain is not known. However, around three-quarters of all surveyed households stated that they would take out full house and contents insurance against flood if this was available, though most did not know how much additional building or home contents premiums they would be willing to pay (GHD and Cox Consulting, 2001).

Flood insurance may go some way to providing a measure of financial security to communities living in the Hawkesbury-Nepean floodplain. However, it should not be regarded as a panacea. It is likely that some residents – including the poorest – may not be able to afford the additional premium for flood cover, and even where it is taken up, statistics show that under-insurance of household buildings and contents is commonplace (Blong, 2000). If frequent or severe flooding occurs, the experience of the United Kingdom indicates that some insurers may choose not to accept insurance risks where their loss experience indicates it is not sensible (HNFMSC, 2006a). As detailed in the *Hawkesbury-Nepean Floodplain Management Strategy* it is therefore imperative that measures are introduced to reduce the overall risk, thus reducing premiums to levels where they are affordable.

Flooding in Queensland and Victoria in late 2010 and early 2011 has again raised questions about flood insurance in Australia, and led to the formation of the Natural Disaster Insurance Review in March 2011, with the release of an Issues Paper in June 2011 (CoA, 2011). This national review may have significant implications for the availability and affordability of flood insurance in the Hawkesbury region. Given the review is in progress at the time of writing, the consultation with the insurance industry that was initially envisaged as part of the current study has been deferred. Nevertheless, Risk Frontiers provided some initial perspectives on the issue.

2.9 FOCUS OF THIS STUDY

Based on this review of previous flood investigations in the Hawkesbury Valley, and consistent with the brief, the following priorities emerge for the current study:

1) Map design flood behaviour using the Flood Hazard Definition Tool (see **Chapter 3**);
2) Report consequences of flooding at more local scales;
3) Consider the merits of local flood modification measures (not regional);
4) Employ the latest regional flood evacuation timeline model, consider backup risk management strategies (e.g. local flood refuges) and investigate local evacuation constraints to provide input to a future growth strategy for the Hawkesbury LGA;
5) Develop recommendations for an ongoing, permanent and coordinated process to build and maintain public awareness and preparedness over the next 5-10 years;
6) Translate the best practice planning principles encapsulated in the Land Use, Subdivision and Building Guidelines, with the input of the community, into local planning policies. Specific tasks include:
   - consideration of existing zonings, the Metropolitan Strategy and the Sub-Regional Strategy;
   - input to the draft Hawkesbury Residential Land Strategy, including recommendations about land use distribution and densities (greenfield and infill);
   - LEP recommendations;
   - input to flood risk management provisions in the DCP, including some consideration for incorporating climate change;
   - recommendations for flood planning levels (FPLs);
   - a strong case for “exceptional circumstances” approval to be given for the application of flood-related development controls above the 100 year level; and
   - associated recommendations (s94, S149 certificates, etc).

3. FLOOD MAPPING

3.1 INTRODUCTION

The study brief requires mapping of design flood behaviour for the Hawkesbury-Nepean floodplain that is within the Hawkesbury Local Government Area, using results from the *Flood Hazard Definition Tool* derived from earlier studies. This includes mapping of flood extents, flood contours, and flood hazards for a range of floods from the 5 year ARI event up to the probable maximum flood (PMF). The mapping assists in identifying existing flood problem areas and the need for floodplain management measures, including where various types of future development may be appropriate.

This chapter presents the results of the flood mapping undertaken within the current study. Some 24 flood maps have been produced and these have been bound separately in **Volume 3**.

3.2 SOURCE OF FLOOD DATA

3.2.1 Previous Studies

Flooding problems in the Hawkesbury-Nepean Valley have been extensively investigated over recent years under the auspices of the *Hawkesbury-Nepean Floodplain Management Strategy.* One outcome of the Strategy was a *Regional Floodplain Management Study*. An important component of the Regional Study was a *Flood Hazard Definition Tool* used to define flood behaviour in the valley. This represents the baseline Flood Study used by the current study.

The *Flood Hazard Definition Tool* is based on results from:

i) The *Warragamba Dam Auxiliary Spillway Environmental Impact Study* (WMA, 1996). This investigation utilised RORB and RUBICON modelling software, which was subsequently converted to RMA-2 for inclusion in the *Flood Hazard Definition Tool*.

ii) The *Lower Hawkesbury River Flood Study* (AWACS, 1997). This investigation utilised the RMA-2 model to define flood behaviour downstream of Sackville in the *Flood Hazard Definition Tool*.

iii) The *Penrith Lakes Scheme Report on Floodplain Management Issues* (Patterson Britton & Partners, 2002). This investigation considers in greater detail the change to the floodplain associated with the proposed development at Penrith Lakes. The model extends upstream of the M4 Motorway to cover the Penrith LGA.

Flood behaviour within the study area is predominantly sourced from the *Warragamba Dam Auxiliary Spillway Environmental Impact Study*. The study includes the development of a RUBICON hydraulic model of the floodplain downstream of Warragamba Dam. The model was calibrated and verified against 10 historic floods, and has been subject to a comprehensive review process involving local, national and international experts. The study brief notes that this provides the best available mainstream design flood level information for the study area.

The RUBICON model is a one-dimensional hydraulic model that assumes a constant water level perpendicular to the direction of flow. The model provides average flood conditions along the river, tributary creeks and other defined flow paths, but does not allow for two-dimensional flow behaviour, such as the elevation of flooding around the outside bend of a river or other variations that may occur across a floodplain. A two-dimensional (RMA-2) hydraulic model was subsequently prepared by Patterson Britton & Partners to replicate the main RUBICON model results, and to facilitate the input of flood behaviour to the *Flood Hazard Definition Tool*.

A comparison of results from the *Flood Hazard Definition Tool* with the original RUBICON model results was undertaken for the 20 year, 50 year and 100 year ARI floods. Results from the *Flood Hazard Definition Tool* closely agree with the original RUBICON model results in the main area of interest for this study (from Wilberforce to North Richmond). Some differences in flood levels were noted outside this area. These differences are typically within 0.2 to 0.3m and are most likely related to the different structure of the RMA-2 model to the original RUBICON model. Other differences may be due to two-dimensional flood behaviour which is not accurately represented in the RUBICON model. As the *Flood Hazard Definition Tool* has been prepared to provide a consistent flood level database throughout the Hawkesbury-Nepean Valley, these results have been adopted for mapping flood behaviour throughout the study area.

3.2.2 Flood Hazard Definition Tool

The *Flood Hazard Definition Tool* has been developed in conjunction with the waterRIDE™ computer program which is trademarked by Worley Parsons (refer www.waterride.net). The program provides an interface to spatially display information on flooding across the floodplain. This data can be overlaid on cadastral property boundaries, aerial photography, or other GIS layers. Information on flooding includes:

- water surface elevation;
- depth;
- velocity;
- velocity x depth; and
- provisional flood hazard.

At the commencement of the current study, the *Flood Hazard Definition Tool* contained information on flooding for only the 100 year, 200 year, 500 year, 1000 year and PMF flood events. It is understood that more frequent floods (5 year, 20 year and 50 year events) were incorporated during the course of the study however the data for these more frequent floods were not available from the *Tool* in sufficient time to be utilised during the study.

The *Flood Hazard Definition Tool* also includes a digital elevation model (DEM) of the terrain surface, and is able to determine the extent of flood inundation by comparing the water surface elevation with the terrain surface. The terrain surface was originally based on contours from topographic maps, overbank surveys in specific areas, and a series of cross sections used from the previous studies. The DEM was recently upgraded to include Airborne Laser Scanning (ALS) data acquired between 2007 and 2008 by Hawkesbury City Council. The new DEM will not affect the flood level information within the *Flood Hazard Definition Tool*, but it will change the flood inundation extent.

The *Flood Hazard Definition Tool* is an excellent system for interrogating flood behaviour in different parts of the floodplain or at a local property scale. However, there are some minor limitations in the use of this data for the current study, including:

- flood extents rely on the underlying DEM, which was noted to contain some anomalies along the boundary of the ALS survey and other “gaps” along some sections of the river;
- the program generates a flood extent that consists of a series of unconnected polylines rather than a single region that can be interrogated to determine numbers of properties at risk;

- the flood extent was curtailed in some areas where the flood grid did not extend up to the limit of flooding (based on the new DEM); and
- some filtering of the raw results (e.g. flood extents and flood contours) is desirable to remove minor irregularities due to the underlying base data.

It was considered desirable to convert the WaterRide results into separate GIS layers that can be interrogated by other GIS systems for the current study. This also facilitated minor filtering of the raw results and the presentation of hard copy plans of flood behaviour covering the whole study area.

Flood grids were extracted from the WaterRide model by Hawkesbury City Council in August 2010. These grids were subsequently imported into the MapInfo program. MapInfo is a commercially available GIS package that is compatible with most other GIS systems.

3.2.3 Frequent Floods

The brief also requires flood mapping for more frequent floods, namely the 5 year, 20 year and 50 year ARI events. As discussed in the previous section, the data for these events were not available within WaterRide in sufficient time to be utilised in the current study. Consequently this information was obtained from the original RUBICON flood modelling results.

The original RUBICON model results were provided by OEH. These files contained the maximum flood height at cross sections included in the model. Cross section locations were digitised from a RUBICON network diagram, and the peak flood level assigned to each section. A flood surface grid was interpolated between each section using MapInfo. This surface was then subtracted from the DEM to determine the extent of flood inundation. Flood level contours and flood depths could also be generated from the flood surface grid.

It was not possible to generate a flood velocity grid or flood hazard grid (which relies on velocity data) in this manner, as the flood velocity varies across each cross section. Consequently flood level mapping for these frequent floods is limited to flood extents and flood contours.

The flood level data from the RUBICON model was not available downstream of Sackville. This forms the downstream limit of mapping for the frequent flood events.

The flood mapping results provided for the 5 year, 20 year and 50 year floods should be considered preliminary only. At the time this report was finalised in 2012, it is understood that more detailed results for these frequent events had been incorporated into the *Flood Hazard Definition Tool*.

3.3 MAPPING OF FLOOD BEHAVIOUR

3.3.1 Methodology

The flood data contained in the *Flood Hazard Definition Tool* was extracted from the WaterRide model by Hawkesbury City Council in August 2010. Flood surface grids were provided for peak flood levels, velocities, velocity x depth, and provisional flood hazards for the 100 year, 200 year, 500 year, 1000 year and PMF floods. Each flood surface was provided as a 5m grid across the floodplain, and divided into a ‘northern’ section and ‘southern’ section. The boundary between the two sections was just upstream of Sackville. Flood extents were provided as a series of unconnected polylines.

The terrain surface included in the WaterRide model was also provided. This surface is based on the ALS survey that was acquired in 2007 and 2008. The terrain surface was also provided as a 5m grid, and divided into northern and southern sections.

The flood grids and terrain surface were imported into the MapInfo grid manager, where further manipulation of the data was possible. The flood extent polylines were reviewed and in some cases found to be artificially curtailed from the expected extent of flooding. There were some other minor anomalies that were traced to problems with new terrain surface (such as 'gaps' in parts of the river and extrapolation problems along the boundary of the ALS survey). It was also desirable to represent the area of inundation as a single polygon, rather than a series of polylines.

All flood extents were further revised using the following procedure:

i) the flood height grid was extrapolated a further 500m across the floodplain;

ii) the extrapolated flood height grid was then subtracted from the terrain surface to form a flood depth grid;

iii) the intersection of the flood surface with the terrain surface was identified by contouring the region with zero depth;

iv) manual filtering of the flood extent region to remove anomalies caused by problems with the terrain surface or minor areas of isolated flooding beyond the main flood boundary; and

v) results for the northern and southern halves were combined to provide a single flood extent region for the whole study area.

Flood height contours were derived directly using the grid manager in MapInfo. Some manual filtering of flood contours was undertaken to improve the clarity of the mapping.

A separate procedure was applied for more frequent floods (5 year, 20 year and 50 year), as described in **Section 3.2.3**.

3.3.2 Study Area and Sheet Layout

The study area shown in Figure A.1 of Appendix A of **Volume 3** has been divided into two map sheets:

- Sheet A represents the floodplain from Yarramundi to Sackville;
- Sheet B represents the floodplain between Sackville and Wisemans Ferry.

Flood behaviour for the 5 year, 20 year and 50 year flood is only available upstream of Sackville (Sheet A). Flood behaviour for the 100 year, 200 year, 500 year, 1000 year and PMF floods is available over the full study area (Sheets A and B).

3.3.3 Flood Extents and Flood Contours

The estimated extent of flood inundation and flood level contours for floods ranging from the 5 year ARI event up to the PMF event are included in Figures A.2 to A.9b in Appendix A of **Volume 3**. Flood level contours are provided at 0.1m intervals throughout the study area. These contours can be used to determine the relevant flood levels at any location within the floodplain.

Figures A.10a and A.10b in Appendix A of **Volume 3** compare the extent of flooding over the full range of floods that have been investigated. The results illustrate the relatively narrow floodplain that exists downstream of Ebenezer and Cattai, where there is little difference in the extent of inundation over the full range of flooding. The variation in flood extents becomes more evident upstream of Wilberforce, where the floodplain expands to incorporate the main towns of Windsor, South Windsor, McGraths Hill, Bligh Park, Richmond and North Richmond. The extent of flooding gradually increases from the 5 year flood to the 100 year flood, and continues to increase in more extreme floods up to the PMF. The effect of 'shrinking islands' is also evident on these maps, where communities become isolated well before major flooding is experienced.

A longitudinal flood profile is included in Figure A.11 of Appendix A in **Volume 3**, which illustrates the difference in water levels for each flood. Most floods respond in a similar manner, with a relatively steep gradient between Wisemans Ferry and Ebenezer, before flattening to an almost level pool within the Wilberforce-Windsor-North Richmond area. Flood gradients again increase upstream of North Richmond. The figure also illustrates the potential increase in flooding beyond the 100 year event that is possible. The 500 year flood at Windsor is almost 3m higher than the 100 year flood, whilst the PMF is over 9m higher.

3.3.4 Flood Hazard Categorisation

The Hawkesbury-Nepean *Flood Hazard Definition Tool* divides the floodplain into five different categories of provisional flood hazard. The flood hazard categories range from Low to Extreme. These hazards are based on consideration of flood depths and flood velocities, and are primarily linked to the potential for failure of different types of buildings. The five flood categories are shown in **Figure 3.1** below. The flood hazard categories are considered to be provisional, as other factors such as the rate of rise of floodwater, evacuation difficulties and threat of isolation also need to be taken into consideration.

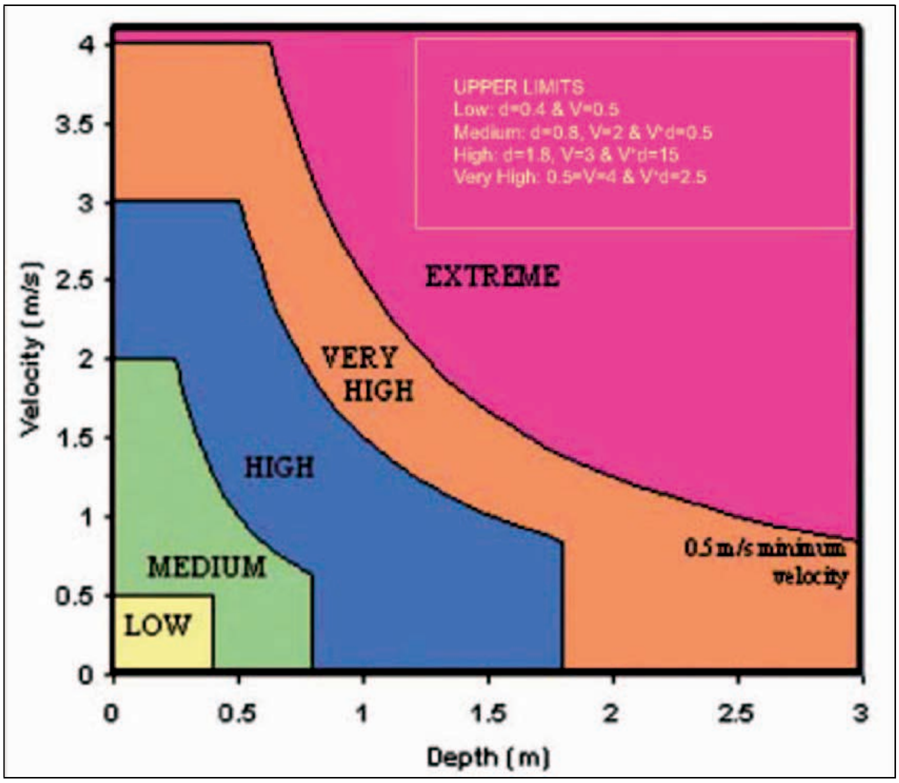

FIGURE 3.1 – Flood Hazard Categories used in Flood Hazard Definition Tool
Source: Designing Safer Subdivisions – Guidance on Subdivision Design in Flood Prone Areas (HNFMSC, 2006)

The five provisional flood hazard categories are shown on Figures A.12a to A.14b in Appendix A of **Volume 3** for the 100 year, 200 year and 500 year ARI floods. It was not possible to include the flood hazard categorisation for floods more frequent than the 100 year event as these events had not been included in the *Flood Hazard Definition Tool* in time for use during the study.

The hazard mapping indicates that the majority of the floodplain experiences a 'very high' to 'extreme' flood hazard in the 100 year flood. The hazard mainly results from the high depth of flooding experienced throughout the study area.

3.3.5 Hydraulic Categorisation

Maps identifying different hydraulic categories (floodways, flood storage and flood fringe) were requested in the study brief. These areas are defined in the *Floodplain Development Manual* as:

- *Floodway areas: − those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels*;
- *Flood storage areas:− those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas*; and
- *Flood fringe areas: − the remaining area of flood prone land after floodway and flood storage areas have been defined*.

The purpose of this mapping is usually to identify areas of the floodplain that will be subject to different planning and development controls. In particular, development inside floodway areas is normally not permitted because of the potential for diversion and obstruction of moving flood waters. Similarly inside flood storage areas, any filling of the floodplain is usually not permitted because of the consequential reduction in flood storage and the reduction in flood attenuation. Development within flood fringe areas is not subject to the hydraulic impacts associated with development in floodway and flood fringe areas.

For the purposes of the current study it was decided not to prepare separate mapping of hydraulic categories for the following reasons:

- The flood behaviour in the Hawkesbury-Nepean Valley is complex and unusual. Some areas closer to the main river channel function as floodways in the rising phases of floods when flows are breaking out from the main river channel and then subsequently, prior to and during the peak of the flood, function more as flood storage areas and experience lower velocities when wide scale ponding of water occurs over much of the Valley. Classification of these areas as flood storage may mask the floodway function of these areas.
- The hydraulic categorisation would also vary with the flood probability and the relative contributions of major tributaries such as South Creek and the Colo River. The large number of possible combinations would mean numerous hydraulic categorisation maps may be required. As this information is to be used to guide development decisions it was considered that alternative forms of mapping may be of more assistance to planners and decision makers.

- *Flood Hazard Definition Tool* already provides Council with a useful tool to visualise hydraulic behaviour in the various phases of a large number of floods with different probabilities of occurrence.

Consequently it was determined to use an alternative approach to categorise the floodplain based on flood risks as discussed in the following section.

3.3.6 Flood Risk Categorisation

An important outcome of the *Hawkesbury-Nepean Floodplain Management Strategy* was the promotion of flood risk considerations in guiding development decisions. This was discussed in detail in the *Land Use Guidelines* (HNFMSC, 2006a). These guidelines aim to provide local councils with a regionally consistent approach to developing local policies, plans and development controls which address the hazards associated with the full range of flood events up to the PMF. A starting point for managing risk through land use planning is to *classify* risks throughout the floodplain. The Guidelines present a methodology for mapping risk bands based on the likelihood and consequences of flooding, focussing especially on tangible residential flood damages.

3.3.6.1 What is Flood Risk?

Within the context of this report, '*flood risk*' is defined as the combination of probabilities and consequences that may occur over the full spectrum of floods that are possible at a particular location.

It is important not to confuse '*flood risk*' with '*flood hazard*' or '*provisional flood hazard*'. The terms '*hazard*' and '*provisional hazard*' are defined in the *Floodplain Development Manual* and are associated with the magnitude of a specific flood. For example, a site may experience high hazard conditions in a 100 year flood and low hazard conditions in a 5 year flood. On the other hand, the term flood risk does not relate to a single flood, but rather to all floods. It presents a single measure of a site's exposure to all its flood threats.

As flood risk combines all the probabilities and consequences of flooding over the full spectrum of flood frequencies that might occur at a site, it can be expressed in mathematical notation as follows:

$$\textit{Flood Risk} = \int_{\substack{\textit{all}\\\textit{floods}}} \textit{Probability x Consequence}$$

where probability is the chance of a flood occurring, and consequence is the property damage and personal danger resulting from the site's flood characteristics.

3.3.6.2 Components of Flood Risk

There are two components of flood risk:

i) <u>risk to property:</u> – this comprises not only the potential damage that floods cause to residential, commercial, industrial and rural developments in the study area but also the flow-on effects due to loss of trade, loss of employment, health, social and physiological impacts, etc. These potential impacts have been well documented during the *Hawkesbury-Nepean Floodplain Management Strategy* (and prior studies) and this work has now been extended as part of the current study with further details of impacts to the Hawkesbury LGA (see **Section 4**);

ii) risk to life: − the major risks to personal safety that exist within the floodplains of the study area were identified in the *Hawkesbury-Nepean Floodplain Management Strategy*. These include the potential for communities to be isolated into 'islands' as flood waters rise, if for whatever reason, people do not evacuate before floodwaters rise to a sufficient level to cut off the available egress from the floodplain. In the most serious situation, people could ultimately drown if flood waters continue to rise and overwhelm the island[8] before rescue occurs. **Section 5** of this report addresses these risks in further detail.

3.3.6.3 Flood Risk Mapping

In order to understand the severity of flood risk, it is therefore necessary to consider the potential hazards that can occur to people and property in various flood magnitudes which have different probabilities of occurrence. To assist in this task, analyses have been undertaken as part of the study to better understand these hazards including:

- depth of inundation;
- flood velocities;
- duration of inundation;
- rates of rise of flood waters;
- warning times available;
- evacuation capabilities given potential closure of routes due to flooding or traffic congestion on the available routes; and
- isolation of areas.

Categorisation of floodplains into different grades of flood risk has been carried out in many NSW council areas, typically into flood risk bands of 'high', 'medium' and 'low' (Bewsher & Grech, 2009). These bands have usually been derived from consideration of hydraulic characteristics as well as evacuation constraints. Given the special evacuation concerns in parts of the study area, it was decided for the purposes of the current study to prepare flood risk classifications based solely on hydraulic considerations and to provide a separate system for classifying evacuation risks.

The flood risks in the study area were then classified into five bands (**Figure 3.2**). These bands were chosen having regard to the detailed considerations undertaken during the preparation of the *Land Use Guidelines* (HNFMSC, 2006a), as well as the hydraulic considerations listed above and the large flood range in the study area:

- *extreme flood risk*: − areas inundated by a 20 year event;
- *high flood risk*: − areas of the floodplain inundated in a 100 year flood event but not classified as extreme flood risk;
- *medium flood risk*: − areas inundated in a 200 year flood but not classified as either extreme or high flood risk; and
- *low flood risk*: − areas inundated in a 1000 year flood but not classified as either extreme, high or medium flood risk; and
- *very low flood risk*: − areas inundated in a probable maximum flood (PMF) but not classified as either extreme, high, medium or low flood risk.

As discussed, the above flood risk classification system is based solely on hydraulic considerations and has not included for evacuation constraints. A separate system for classification of evacuation constraints is presented in **Section 5**.

[8] If these islands might ultimately be overwhelmed in a major flood (up to the PMF) the areas are referred to as 'low flood islands'. If they are not overwhelmed, they are referred to as 'high flood islands'. Refer **Section 5.2.2**.

Mapping of these five flood risk bands has been prepared and is presented in **Figure 3.3**. **Volume 2** of this report discusses this classification system in more detail and its application for future development assessments within the LGA.

Very Low Flood	Low Flood Risk	Medium Flood	High Flood	Extreme Flood
Chance of damages is low and modifications to building structures are not likely to be cost effective. Most land uses are acceptable except critical facilities & sensitive uses.	Chance of flood damages to buildings warrants consideration of modifications to building structures as this would substantially to minimise post flood reconstruction costs.	Significant chance of flood damages to single storey residential dwellings but can be mitigated with substantial modifications to building structures & other planning controls.	Very high chance of flood damages to most building structures without substantial modifications & other planning controls.	Severe erosion to foundations of buildings & collapse of building structures likely. Ameliorative measures such as filling unlikely to be acceptable.

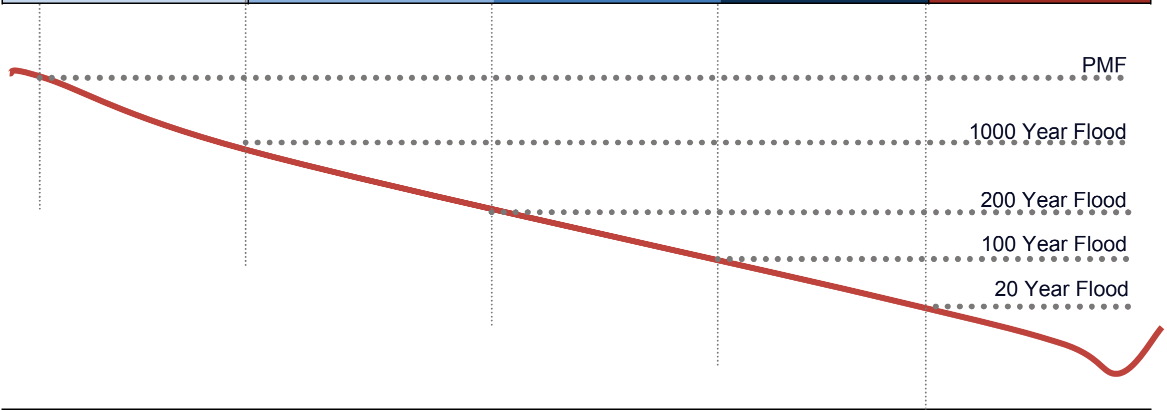

FIGURE 3.2 – Flood Risk Categories used for Development Control Purposes

3.3.7 Use of Maps in Council's GIS

Flood behaviour represented in the *Flood Hazard Definition Tool* can be viewed using the WaterRide program. The mapping of flood extents, flood contours and flood hazards that are presented in **Volume 3** can be imported to Council's GIS system as separate layers, and used as a supplementary resource to that available from the WaterRide program. The main advantage is that this mapping has been reviewed and some filtering of results undertaken to remove anomalies from problems with the source data. The flood extents are also available as complete regions, which will be more practical for GIS queries, such as the identification of all properties inundated by a particular event.

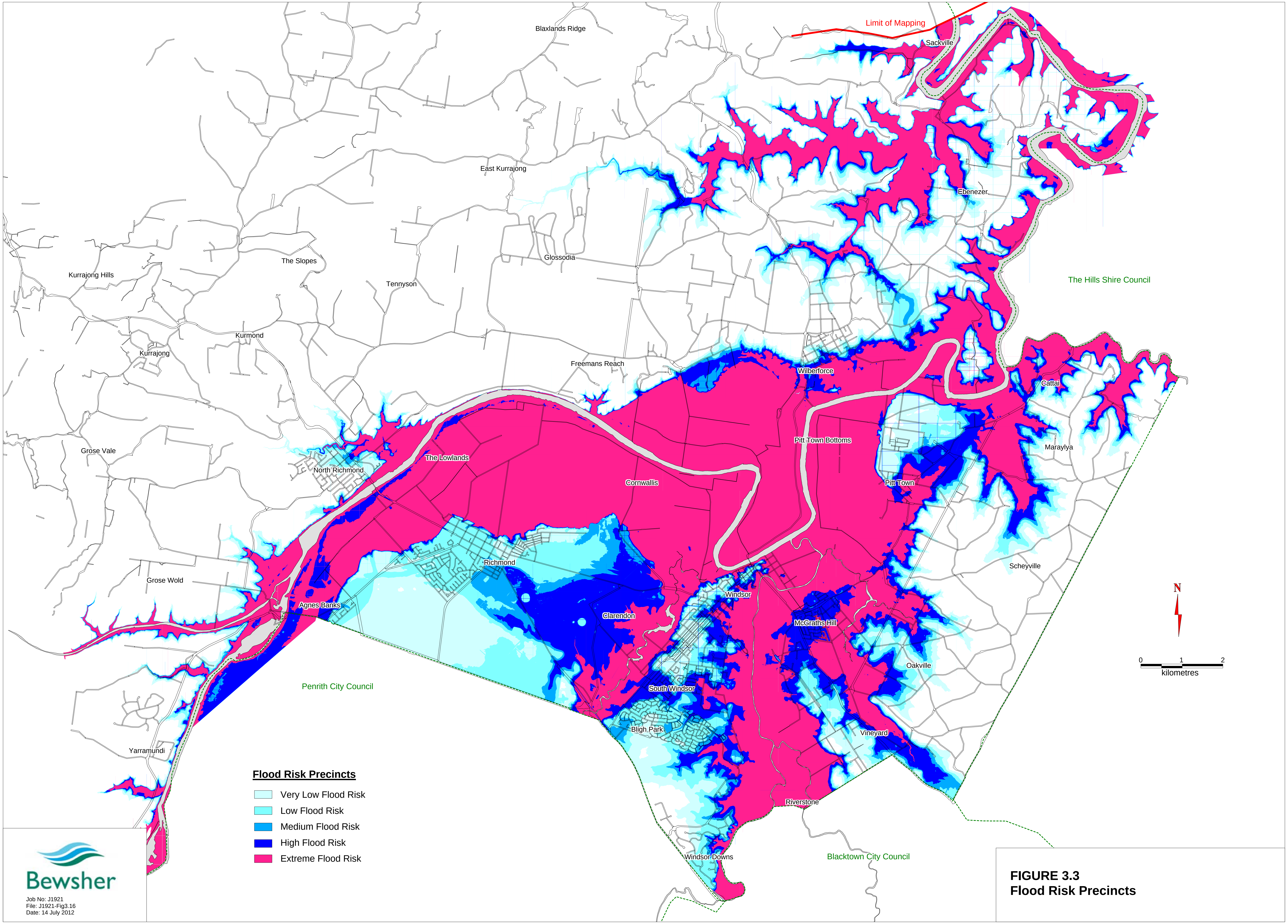

FIGURE 3.3
Flood Risk Precincts

3.4 FUTURE WORK

As described above there have been a number of detailed and complementary studies of flood behaviour and flood mapping which provide a solid basis for managing flood risk within the study area to the present time. Nevertheless in looking to the future, there is a need to provide improved and more extensive flood behaviour data. Consequently it is recommended that Council consider preparation of an updated flood study within five years. The development of the new flood study would allow:

i) Opportunity to re-model flood behaviour using the latest two-dimensional hydrodynamic modelling techniques. Whilst this may not alter the overall flood levels throughout the valley to any great extent, it would allow a more reliable prediction of the spatial distribution of flood levels.[9]

ii) Updating of flood behaviour to account for revised rainfall information. The Bureau of Meteorology is currently undertaking an extensive review of the design intensity-frequency-duration (IFD) rainfall data for all of Australia as part of the updating of *Australian Rainfall and Runoff* (IEAust, 1987). This revised IFD information will be published in 2014 and draft IFD data will likely be available sooner. The revised data will also include for climate change considerations and provide a more rigorous basis for updating the climate change analyses which have been carried out in the Valley to date.

iii) The flood study modelling which forms the basis of our current understanding of flood behaviour in the Valley has been based on limited topographic information. The original RUBICON model which is the basis of all the current design flood levels, utilised topographic data obtained from cross sections of the floodplain based on limited information. In 2007/08 Council obtained airborne laser scanning (ALS) survey data for all of the study area which provides a much more comprehensive description of ground levels and which can now be used in two-dimensional flood modelling.[10]

iv) The existing flood modelling provides only limited flood behaviour data on some of the River's tributaries.[11] The development of a new two-dimensional flood model could provide for prediction of flood behaviour further upstream along of the main tributaries. The model could also include local tributary runoff and simulate tributary flood behaviour upstream of the backwater influences from the Hawkesbury River.

v) The provision of a new flood model would also allow more improved definition of flood behaviour in the lower reaches of the study area that were previously investigated (AWACS, 1997).[12]

vi) The new flood study would also allow the opportunity for more rigorous documentation of the flood behaviour to be provided.[13]

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[9] Current flood levels have been derived originally from the RUBICON model which is a one dimensional model and unable to account for the variation in flood levels which occurs laterally across the floodplain in actual flood events (e.g. superelevation of water levels around bends). These effects have been in part estimated through use of the RMA-2 model nevertheless, comprehensive two-dimensional modelling of the whole study area has not been undertaken.

[10] Note that the ALS data capture process does not collect data below water level and there may be a need to supplement the ALS data with additional bathymetric surveys of the bed and banks of the river and its tributaries in some places.

[11] In addition it appears there has been some attempt to estimate flood levels along tributaries based on extrapolation of results from the RUBICON model. Such procedures however are approximate and need to be revised.

[12] Concerns over accuracy of the flood analyses utilised by AWACS have been raised by the Office of Environment and Heritage (OEH) during the course of this study.

[13] By current standards, the existing flood study documentation is limited particularly when one considers the importance of flood behaviour in the study area. The existing information is also scattered amongst numerous documents prepared at different times. This makes it difficult to determine the technical basis of existing flood levels in parts of the study area.

vii) The Committee also requested that in addition to consideration of larger floods, some attention also needed to be given to the behaviour of smaller more frequent flood events. Flood events during the first half of 2012 identified a need for the SES to be provided with improved flood behaviour data to assist them in managing these smaller flood emergencies.

4. RISK TO PROPERTY

4.1 BACKGROUND

The definitions and methodology used in estimating flood damages are well established. **Figure 4.1** summarises the types of flood damages considered in this study. The two main categories are “tangible” and “intangible” damages. Tangible flood damages are those that can be more readily evaluated in monetary terms. Intangible damages relate to the social cost of flooding and therefore are much more difficult to quantify.

Tangible flood damages are divided further into direct and indirect damages. Direct flood damages relate to the loss or loss in value of an object or a piece of property caused by direct contact with floodwaters, flood-borne debris or sediment deposited by the flood. Indirect flood damages relate to loss in production or revenue, loss of wages, additional accommodation and living expenses, and any extra outlays that occur because of the flood.

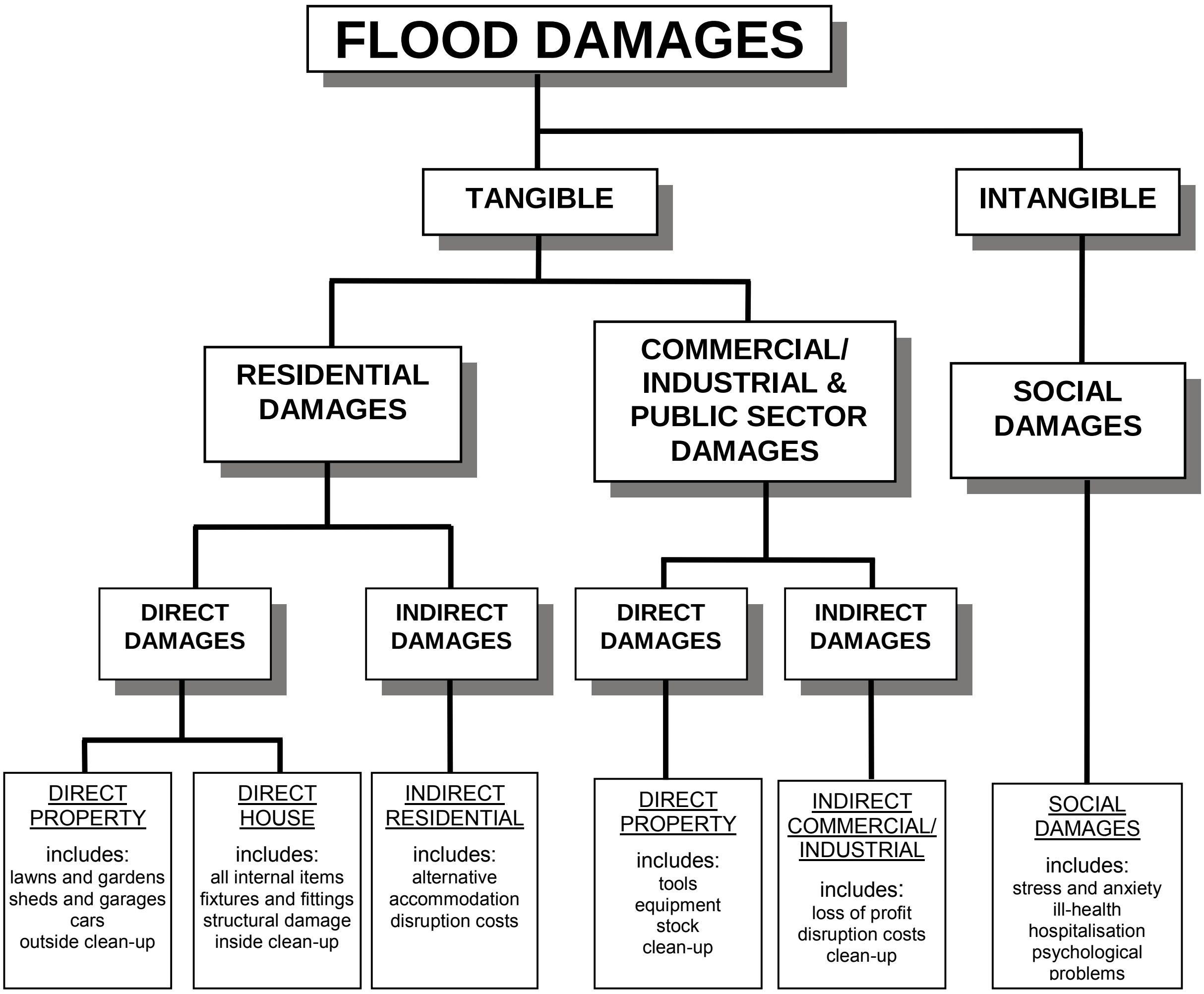

FIGURE 4.1 – Types of Flood Damage

As indicated in **Section 2.2**, substantial work has been done to assess the potential impacts of flooding in the Hawkesbury-Nepean Valley, including infrastructure assets such as roads and bridges, railways, electricity, telecommunications, gas and oil, water, sewerage, defence, health facilities and emergency services.

Much of information about the potential consequences of flooding in the Hawkesbury-Nepean catchment presents consequences only at the macro (catchment-wide) level. The current study reports consequences in terms of number of houses and population liable to inundation for each suburb.

4.2 METHODOLOGY

4.2.1 Number of Buildings Affected

Council provided a cadastre GIS file containing 25,307 property parcels as well as a spreadsheet listing 24,664 properties receiving a garbage service (hence, not vacant). The cadastre was combined with the garbage service using the "Land_No" as the common attribute. Garbage service attributes were added to 20,841 out of the 25,307 cadastral parcels. The number of buildings (or offices) on each property parcel was estimated using either the "Number_Uni" attribute in the cadastre, which appears to pick up strata units, or the "No. of Services" attribute from the garbage service spreadsheet, which picks up other multiple buildings. Land uses were initially allocated using the zoning at each parcel, following the protocols in **Table 4.1**. The decision to classify the various "agriculture" zones as "residential" reflects the knowledge that these properties often contain dwelling houses in addition to the sheds used for agricultural activities. It also reflects the priority of assessing risk to life. The implication of this decision is that the "commercial" aspects of these farms will be understated, since only one land use is applied to each entry. It is also noted that "3(a)" commercial zones often include some residential uses, but these have been classed as "commercial" since this is expected to be the major use – residential land uses will be understated for such properties. The "7(d)" land use is known to include some flood-prone dwellings at Yarramundi. Although such coarse estimates of land use based on zonings have obvious limitations, it was the most practicable means available for quickly deriving a land use. More rigorous assessments could be undertaken using the NEXUS database described in relation to flood evacuation modelling. For this study, the designated land use was manually changed at some properties based on a visual inspection using the 2008 aerial photograph base provided by Council, as well as internet searches. In particular, several properties were allocated a "special" land use despite the earlier rating, when it was apparent that the actual land use was a caravan park, motel, large development, etc.

Flood levels at each property were derived from flood grid surfaces developed for the flood mapping described in **Chapter 3**. Grids for the 100 year flood and rarer events were taken from the *Flood Hazard Definition Tool* (slightly amended), whilst grids for the more frequent events were developed by the Consultant using the RUBICON model cross sections. A limitation of the grids developed for the frequent events is they are truncated at the lowermost cross section at Sackville (i.e. they do not extent all the way to Wisemans Ferry).

Flood levels for each property within the PMF extent were extracted at the centroid of the cadastral parcel (for lots smaller than 1,500 m^2). For larger lots or elongated lots where flooding covered only a portion of the site, flood levels were extracted from points which were manually shifted to coincide with the main building.

No information about floor heights is available. Whilst a GIS file containing data from an ANU survey conducted in the late 1980s or early 1990s was obtained, the XY locations do not plot consistently within cadastral parcels and so cannot be tied to individual properties with confidence. Assessments of the number of buildings affected by flooding are therefore based on ground level at the building, though a sensitivity test was also carried out with a global assumed floor level of 0.3m.

TABLE 4.1 – Allocated Land Uses based on Zoning (HLEP 1989*)

Zone	Zone_Description	Proposed Description for Damages Assessment
3(a)	Zone No.3(a) (Business General "A") HLEP 1989	Commercial/industrial
3(b)	Zone No.3(b) (Business Special "B") HLEP 1989	Commercial/industrial
4(a)	Zone No.4(a) (Industry General "A") HLEP 1989	Commercial/industrial
4(b)	Zone No.4(b) (Industry Light "B") HLEP 1989	Commercial/industrial
5(a)	Zone No.5(a) (Special Uses "A") HLEP 1989	Special
5(a)	Zone No.5(a) (Special Uses "A" (Waste Management)) HELP 1989	Commercial/industrial
5(b)	Zone No.5(b) (Special Uses (Railways)) HLEP 1989	Commercial/industrial
6(a)	Zone No.6(a) (Open Space (Existing Recreation)) HLEP 1989	Reserve
6(b)	Zone No.6(b) (Open Space (Proposed Recreation)) HLEP 1989	Reserve
6(c)	Zone No.6(c) (Open Space (Private Recreation)) HLEP 1989	Reserve
7(a)	Zone No.7(a) (Environmental Protection (Wetlands)) HLEP 1989	Reserve
7(d)	Zone No.7(d) (Environmental Protection (Scenic)) HELP 1989	Residential
7(e)	Zone No.7(e) (Environmental Protection (Consolidated Land Holdings)) HLEP 1989	Reserve
8(a)	Zone No.8(a) (Nature Reserves) HLEP 1989	Reserve
8(a) NP	Zone No.8(a) (Nature Reserves) HLEP 1989	Reserve
8(a) SRA	Zone No.8(a) (Nature Reserves) HLEP 1989	Reserve
9(b)	Zone No.9(b) (Proposed Road) HLEP 1989	Reserve
ag-protection	Environmental Protection - Agriculture Protection	Residential
consolidated-lands	Consolidated Lands	Residential
Housing	Housing	Residential
mixed-ag	Mixed Agriculture	Residential
mixed-ag-enviro	Environmental Protection - Mixed Agriculture	Residential
MU	Multi-Unit Housing Zone	Residential
Rural-Housing	Rural Housing	Residential
rural-living	Rural Living	Residential
rural-village	Rural Village	Residential
[blank]		[disregard]

* Note that on 21 September 2012 HLEP 1989 was repealed and HLEP 2012 commenced.

4.2.2 Financial Costs

Estimated costs of flooding for the residential sector were calculated following the *Residential Flood Damages Guideline* prepared by DECC (2007). The inputs to the derivation of a stage-damage curve for the Hawkesbury study area are shown in **Appendix B**. For this financial assessment, it was assumed that floor levels were set 0.3m above the ground level taken from the DEM, and that the single-storey slab-on-ground category was most representative of dwellings in the study area. It is noted that the calculated damages for the 5 year, 20 year and 50 year floods will be understated because the flood grids for these frequent events do not extend downstream of Sackville, where some settled areas are particularly low-lying. Financial costs have not been estimated for the commercial/industrial sector or for infrastructure or special uses including caravan parks, the RAAF base or the UWS Hawkesbury campus. Potential damages to motor vehicles have not been included since most are expected to be evacuated due to the long warning times. It is also noted that whilst an allowance is made in the DECC (2007) stage-damage data for structural damage to buildings, the data does not allow for actual building failure, which could be considerable in the Hawkesbury study area given extreme flood depths. Middleman-Fernandes (2010) demonstrated that where buildings fail, stage-damage functions underestimate loss.

An economic appraisal is required for all proposed capital works in NSW, including flood mitigation measures, in order to attract funding from the State Government's Capital Works Program. The NSW Government has published two Treasury Policy Papers to guide this process: *NSW Guidelines for Economic Appraisal* (NSW Treasury, 2007) and a summary in *Economic Appraisal Principles and Procedures Simplified* (NSW Treasury, 2007).

An economic appraisal is a systematic means of analysing all the costs and benefits of a variety of proposals. In terms of flood mitigation measures, benefits of a proposal are generally quantified as "the avoided costs associated with flood damages". The avoided costs of flood damage are then compared to the capital (and on-going) costs of a particular proposal in the economic appraisal process.

<u>Average annual damage</u> (AAD) is a measure of the cost of flood damage that could be expected each year by the community, on average. It is a convenient yardstick to compare the economic benefits of various proposed mitigation measures with each other and the existing situation.

The "<u>present value</u>" of flood damage is the sum of all future flood damages that can be expected over a fixed period (50 years is recommended in DECC, 2007) expressed as a cost in today's value. The present value is determined by discounting the future flood damage costs back to the present day situation, using a discount rate of 7%.

A flood mitigation proposal may be considered to be potentially worthwhile if the <u>benefit–cost ratio</u> (the present value of benefits divided by the present value of costs) is greater than 1.0. In other words, the present value of benefits (in terms of flood damage avoided) exceeds the present value of (capital and on-going) costs of the project.

However, whilst this direct economic analysis is important, it is not unusual to proceed with urban flood mitigation schemes largely on social grounds, that is, on the basis of the reduction of intangible costs and social and community disruption. In other words, the benefit–cost ratio could be calculated to be less than 1.0.

4.3 RESULTS

During the course of the study, the numbers of buildings in the study area flooded in different design events were assessed and the results are presented by depth and land use in **Table 4.2** and **Figure 4.2**. Excluding farm sheds (due to the methodology), relatively few buildings are expected to be flooded in a 5 year event, but 10 times as many would be flooded in a 20 year event. Over 1,500 dwellings are expected to be flooded above floor in a 50 year event, doubling to over 3,000 in a 100 year event. Fewer businesses are affected, but over 500 would be inundated above floor in a 100 year event. Over 13,000 dwellings and 1,700 businesses would be inundated in the PMF. A feature of flooding in the Hawkesbury is the very high depths of flooding – in the 100 year flood, over 2,200 dwellings would be flooded to depths of more than one metre, and over 1,300 dwellings would be flooded to depths of more than two metres, causing severe damage.

TABLE 4.2 – Estimated Number of Buildings Flooded by Design Event, Depth and Land Use, Hawkesbury River within Hawkesbury LGA

	5 year*	20 year*	50 year*	100 year	200 year	500 year	1000 year	PMF
Ground level at building								
Residential	40	466	1,839	3,386	4,897	7,480	10,316	13,418
Commercial/Industrial#	14	86	297	609	778	1,093	1,571	1,754
Over floor *(assumed 0.3m)*								
Residential	33	348	1,591	3,165	4,538	6,958	9,974	13,344
Commercial/Industrial#	11	60	219	527	731	925	1,520	1,753
1m over floor								
Residential	12	139	933	2,240	3,453	5,178	8,014	13,012
Commercial/Industrial#	6	36	128	358	627	792	1,250	1,740
2m over floor								
Residential	1	67	360	1,380	2,699	3,874	6,081	12,395
Commercial/Industrial#	2	21	79	173	453	705	859	1,679

* Excludes areas downstream of Sackville
\# Excludes "special" uses such as schools, caravan parks and infrastructure.

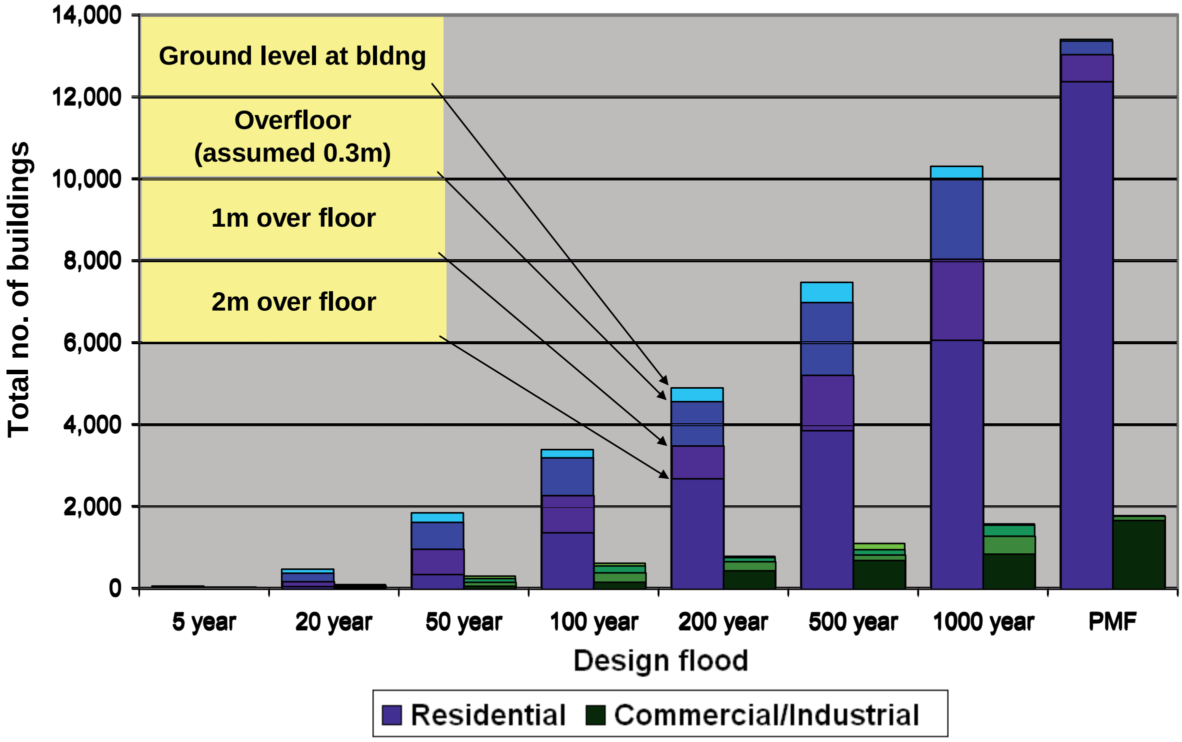

FIGURE 4.2 – Estimated Number of Buildings Flooded by Design Event, Depth and Land Use, Hawkesbury River within Hawkesbury LGA

Note: Results for 5 year, 20 year and 50 year floods are understated because of the limited extent of flood grids; commercial/industrial excludes "special" uses such as schools, caravan parks and infrastructure.

4.3.1 Residential

Table 4.3 shows the number of dwellings flooded by suburb, and **Figure 4.3** plots this information for the nine suburbs with more than 500 dwellings flooded in the PMF. In very frequent events, a dozen or so dwellings in each of Ebenezer and Wilberforce are exposed to flooding (note that digital flood information is not available for frequent events in areas downstream of Sackville, including Lower Macdonald where there may also be a relatively high flood risk exposure in frequent events). In the 20 year event, more than 50 dwellings would be affected in McGraths Hill and Pitt Town and more than 100 in Windsor. In the 50 year event, more than 500 dwellings would be affected in McGraths Hill, with large numbers also affected in South Windsor, Windsor, Pitt Town and Wilberforce. Up to and including the 50 year event, few or no dwellings would be affected in Bligh Park, Windsor Downs, Richmond or Hobartville. Almost all 900+ houses in McGraths Hill would be flooded in the 100 year event, while over 800 would be affected in South Windsor, with large numbers in Windsor, Pitt Town and Wilberforce. Hundreds of houses in Bligh Park and Richmond are affected by the 200 year level, and about 100 houses in each of North Richmond, Oakville and Vineyard, whilst Hobartville would still be little affected. A very large number (>1,000) of houses would be flooded in Bligh Park and South Windsor in the 500 year event, and to this list would be added Richmond by the 1,000 year flood level and Hobartville by the PMF level.

Table 4.4 shows the estimated flood damages for the residential sector. A 100 year flood is estimated to cost over $400 million to the residential sector alone. The average annual cost of residential damages is estimated at about $18 million, and the present value of damage over a 50 year timeframe and using a 7% discount rate is estimated at about $260 million. It is noted that these values are regarded as lower estimates because they do not include allowance for building failure.

4.3.2 Commercial/Industrial

Table 4.5 shows the number of business premises flooded by suburb. It is noted that this does not include buildings on rural zoned land such as farm buildings (due to the methodology). Nor does it include land uses that have been categorised as “special” including schools, police stations, retirement villages, caravan parks, motels and infrastructure. A sizeable number of businesses would be flooded in Windsor in the 20 year event. Windsor, Mulgrave and Vineyard would all have a substantial number of businesses affected in the 50 year flood. South Windsor and Wilberforce would also contribute significant numbers in the 100 year flood, and Richmond in the 500 year flood.

4.3.3 Special Uses

4.3.3.1 Caravan Parks

Caravan parks are regarded as a “special” use because they typically contain structures with a high susceptibility to flood damage, and people with a low awareness of flood risks (in the case of tourist parks) or inadequate resources to recover from floods (in the case of residential parks). Caravan parks are often located next to rivers to take advantage of recreational opportunities, with commensurately high flood risk exposure (see Yeo & Grech, 2006).

TABLE 4.3 – Estimated Number of Dwellings Flooded to Ground Level by Design Event and Suburb

	5 year	20 year	50 year	100 year	200 year	500 year	1000 year	PMF
Agnes Banks	0	4	26	37	59	115	153	154
Blaxlands Ridge	n.a.	n.a.	n.a.	0	0	0	0	2
Bligh Park	0	0	0	58	438	1,381	1,965	2,285
Cattai	0	5	11	35	50	61	72	81
Central Macdonald	n.a.	n.a.	n.a.	0	0	1	1	2
Clarendon	0	4	28	60	65	65	65	65
Colo	n.a.	n.a.	n.a.	0	0	7	9	12
Cornwallis	2	10	10	11	11	11	11	11
Cumberland Reach	n.a.	n.a.	n.a.	10	17	27	37	64
East Kurrajong	0*	0*	0*	0	0	1	2	13
Ebenezer	12	37	54	70	81	92	104	144
Freemans Reach	4	29	32	48	66	67	72	84
Glossodia	0	0	0	0	1	1	1	7
Grose Wold	0	0	1	1	1	1	3	14
Hobartville	0	0	0	0	21	342	917	1,076
Leets Vale	n.a.	n.a.	n.a.	22	25	26	26	34
Lower Macdonald	n.a.	n.a.	n.a.	60	73	87	109	153
Lower Portland	n.a.	n.a.	n.a.	25	29	40	42	68
Maraylya	0	9	12	19	25	29	38	54
McGraths Hill	0	51	576	913	923	923	923	923
Mulgrave	0	7	16	22	23	23	28	29
North Richmond	0	5	6	13	107	171	303	664
Oakville	0	19	53	80	100	119	139	205
Pitt Town	0	64	177	280	305	328	361	521
Pitt Town Bottoms	5	15	15	15	15	15	15	15
Richmond	0	1	11	31	328	858	1,711	2,327
Richmond Lowlands	0	1	10	11	11	11	12	12
Sackville	2*	9*	14*	21	32	42	52	67
South Windsor	0	30	374	833	1,120	1,383	1,637	2,383
Vineyard	0	18	39	57	112	136	169	247
Webbs Creek	n.a.	n.a.	n.a.	5	6	10	11	13
Wheeny Creek	n.a.	n.a.	n.a.	0	0	0	0	3
Wilberforce	14	40	124	220	280	338	389	528
Windsor	1	108	249	392	462	580	654	803
Windsor Downs	0	0	0	31	94	167	257	291
Wisemans Ferry	n.a.	n.a.	n.a.	5	11	14	17	29
Yarramundi	0	0	1	1	6	8	11	35
TOTAL	40	466	1,839	3,386	4,897	7,480	10,316	13,418

n.a. = not assessed due to limited extent of flood grid

* = potentially understated count due to limited extent of flood grid

Legend

374	100-500 properties
833	500-1000 properties
1,120	>1000 properties

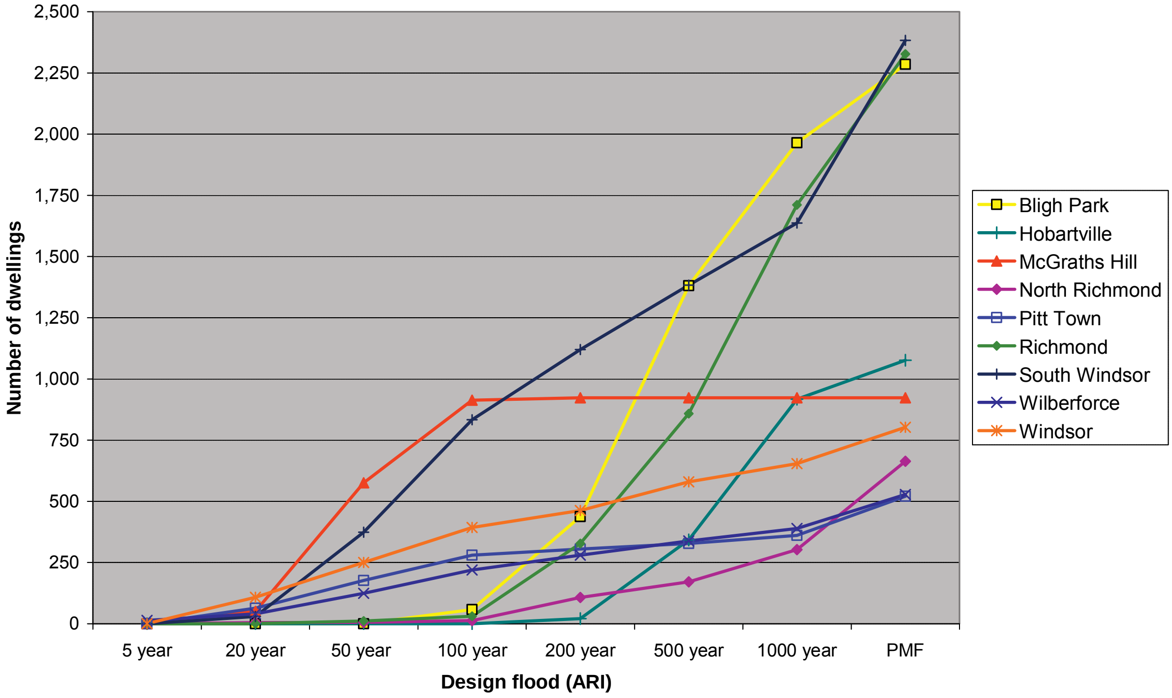

FIGURE 4.3 – Estimated Number of Dwellings Flooded to Ground Level by Design Event and Suburb

Note: only suburbs with >500 dwellings affected in PMF shown

TABLE 4.4 – Summary of Residential Flood Damages by Event

Flood Event	Predicted Actual Damage in Flood Event ($2010)	Contribution to AAD ($2010)		Present Value of Damage over 50 Years ($2010)
5 year	$3M	$0.5M	3%	
20 year	$37M	$3.1M	17%	
50 year	$183M	$3.3M	19%	
100 year	$402M	$2.9M	17%	
200 year	$613M	$2.5M	14%	
500 year	$946M	$2.3M	13%	
1000 year	$1,408M	$1.2M	7%	
PMF	$2,215M	$1.8M	10%	
TOTAL	–	**$17.6M**	100%	$397M (4% discount rate) **$261M** (7% discount rate) $177M (11% discount rate)

TABLE 4.5 – Estimated Number of Commercial/Industrial Buildings Flooded to Ground Level by Design Event and Suburb

	5 year	20 year	50 year	100 year	200 year	500 year	1000 year	PMF
Agnes Banks	0	0	1	1	1	1	1	1
Blaxlands Ridge	n.a.	n.a.	n.a.	0	0	0	0	0
Bligh Park	0	0	0	1	1	2	2	2
Cattai	0	0	0	0	0	0	0	0
Central Macdonald	n.a.	n.a.	n.a.	0	0	0	0	0
Clarendon	0	0	3	4	4	4	4	4
Colo	n.a.	n.a.	n.a.	0	0	0	0	0
Cornwallis	5	12	13	13	13	13	13	13
Cumberland Reach	n.a.	n.a.	n.a.	0	0	0	0	0
East Kurrajong	0*	0*	0*	0	0	0	0	0
Ebenezer	0	0	0	0	0	0	0	0
Freemans Reach	1	9	10	10	11	11	11	11
Glossodia	0	0	0	0	0	0	0	0
Grose Wold	0	0	0	0	0	0	0	0
Hobartville	0	0	0	0	0	11	15	15
Leets Vale	n.a.	n.a.	n.a.	0	0	0	0	0
Lower Macdonald	n.a.	n.a.	n.a.	0	0	0	0	0
Lower Portland	n.a.	n.a.	n.a.	0	0	0	0	0
Maraylya	0	0	0	0	0	0	0	0
McGraths Hill	0	1	2	20	20	20	20	20
Mulgrave	0	3	69	115	135	159	178	185
North Richmond	0	0	2	7	23	36	64	120
Oakville	0	0	3	3	5	5	5	6
Pitt Town	0	1	2	2	2	2	13	13
Pitt Town Bottoms	5	7	7	7	7	7	7	7
Richmond	0	0	0	1	10	199	454	456
Richmond Lowlands	0	0	0	0	1	1	2	2
Sackville	0*	0*	0*	0	0	0	0	0
South Windsor	0	5	5	126	166	195	259	340
Vineyard	0	2	30	78	80	83	84	90
Webbs Creek	n.a.	n.a.	n.a.	1	1	1	1	1
Wheeny Creek	n.a.	n.a.	n.a.	0	0	0	0	0
Wilberforce	1	1	13	49	54	58	72	89
Windsor	2	45	137	171	244	285	365	378
Windsor Downs	0	0	0	0	0	0	0	0
Wisemans Ferry	n.a.	n.a.	n.a.	0	0	0	0	0
Yarramundi	0	0	0	0	0	0	1	1
TOTAL	14	86	297	609	778	1,093	1,571	1,754

n.a. = not assessed due to limited extent of flood grid

* = potentially understated count due to limited extent of flood grid

Legend

374	100-500 properties
833	500-1000 properties
1,120	>1000 properties

Information provided by Council indicates that at least 14 caravan parks are located within flood prone areas of Hawkesbury City and the historical records suggest these parks are often affected by flooding (see **Figure 4.4**). The degree of exposure of these parks to inundation in the various design floods is summarised in **Table 4.6**. Only one park at Vineyard is located entirely above the PMF (but could nevertheless be affected indirectly). Two parks (at Pitt Town Bottoms and at Sackville) would be entirely inundated in the 5 year event. (Note that information for frequent floods is not available for caravan parks located downstream of Sackville).

Table 4.6 shows that the over-ground depths of inundation in the 100 year event would reach 9 metres at several parks. Access would be lost early for most of these parks, requiring early evacuation.

4.3.3.2 Utilities and Public Infrastructure

Flooding in the Valley has the potential to impact on a range of critical utilities including:

- road and rail transport;
- electricity;
- communications;
- natural gas;
- water supply; and
- sewerage.

These utilities service communities within the study area and beyond.

A separate study is currently being undertaken for the SES to document the impacts of flooding on critical utilities in the Hawkesbury-Nepean Valley (Molino Stewart, 2011b). These investigations include information which is the subject of confidentiality agreements between the utility companies and the SES (supposedly because of fierce competition between these companies). Consequently the information has not been provided to the Committee for the use in the current study.

Nevertheless, a summary of the potential impacts of flooding based on information in the *Proposed Warragamba Flood Mitigation Dam EIS* (ERM Mitchell McCotter, 1995) is provided below, recognising that some material is now dated.

a. Kallawatta Ski Garden, Coromandel Road, Ebenezer, with amenities building in distance

(Source: Council)

b. Hawkesbury Waters Leisure Park, Port Erringhi Road, Ebenezer

(Source: Council)

c. Bundarra Ski Gardens, Cumberland Reach, with at least 2 metres floodwater through park

(Source: Council)

FIGURE 4.4 – Hawkesbury River Caravan Parks, August 1990 Flood

TABLE 4.6 – Direct Flood Affectation of Hawkesbury River Caravan Parks

Name	Locality	Number of sites				Extent of flood affectation in design floods									100y flood level (m AHD)	Approx. max. 100y depth at sites
		Long-term	Short-term	Holiday cabin	Camping	5 year	10 year	20 year	50 year	100 year	200 year	500 year	1000 year	PMF		
Riverside Ski Park	CATTAI	0	27	0	0	Some	Some	Some	All	All	All	All	All	All	17.1	9m
Bundarra Ski Gardens	CUMBERLAND REACH	0	21	0	0	No info	No info	No info	No info	All	All	All	All	All	11.6	6m
Greenfield Caravan Park	EBENEZER	0	3	0	0	Some	Some	Some	Some	Some	Some	Some	Some	Some	16.8	6m
Kallawatta Ski Garden	EBENEZER	0	50	0	0	Some	Some	Some	Some	Some	Some	Some	Some	Some	16.8	8m
The Hawkesbury Waters Leisure Park	EBENEZER	0	68	8	0	Some	Some	Some	All	All	All	All	All	All	16.3	9m
Tizzana Downs	EBENEZER	0	7	0	0	Some	Some	Some	Some	Some	Some	Some	Some	Some	14.0	7m
Hawkesbury Riverside Retreat	LOWER PORTLAND	7	64	6	0	No info	No info	No info	No info	Some	Some	Some	Some	All	9.8	5m
Mt Andrew Caravan & Ski Park	LOWER PORTLAND	0	42	0	0	No info	No info	No info	No info	Some	Some	Some	Some	Some	9.6	4m
Ponderosa Ski Resort	LOWER PORTLAND	0	24	0	0	No info	No info	No info	No info	Some	Some	Some	Some	Some	10.9	6m
Percy Place Caravan and Ski Park	PITT TOWN	0	30	0	0	Some	Some	Some	Some	Some	All	All	All	All	17.2	9m
Hawkesbury Riverside Tourist Park	PITT TOWN BOTTOMS	6	54	0	0	All	All	All	All	All	All	All	All	All	17.3	9m
Sackville Ski Garden	SACKVILLE	21	142	0	4	All	All	All	All	All	All	All	All	All	13.1	7m
A-vina Caravan Park	VINEYARD	196	48	70	25	None	None	None	None	None	None	None	None	None	n/a	n/a
Del-Rio Riverside Resort	WEBBS CREEK	2	88	28	80	No info	No info	No info	No info	All	All	All	All	All	6.9	5m
Windsor Riverside Van Park	WILBERFORCE	85	55	2	0	Some	Some	Some	All	All	All	All	All	All	17.3	8m

Road and Rail Transport

The major roads affected by flooding are Richmond Road, Windsor Road, Castlereagh Road, Hawkesbury Road (including the low-lying Yarramundi Bridge), Bells Line of Road (including the low-lying North Richmond Bridge – see **Figure 4.5a**) and Putty Road/Wilberforce Road (including the low-lying Windsor Bridge). Roads can be damaged by scour where velocities are high, and by traffic loadings when the subgrade under the roads becomes saturated in deep and long-duration floods.

NSW Roads and Maritime Services (RMS) operates vehicle ferries across the Hawkesbury River at Sackville, Webbs Creek and Wisemans Ferry. As in-channel assets, vehicle ferries are highly exposed to the forces of floodwater and impact of debris during flooding. In the 1978 flood, a vehicle ferry was transported downstream to Brooklyn (**Figure 4.5b**).

a. North Richmond Bridge, July 1988 flood

Source: Council

b. Vehicular Ferry carried downstream to Brooklyn, March 1978 flood

Source: Council

FIGURE 4.5 – Effect of Floods on Transport Infrastructure

The Blacktown to Richmond Railway could be affected by Hawkesbury River flooding west of Schofields station, and seven stations could subject to flooding under different scenarios. Damage to stations, tracks, and signalling, communications and electrical equipment would be damaged. Some scour is anticipated where velocities are higher.

Electricity

Transmission lines and substations are vulnerable to flooding. Steel lattice towers could fail structurally at high depths of flooding or due to debris impact. Tower bases at Windsor are inundated even at levels of 8m AHD. Scour and debris impact caused mechanical failure of a low voltage line between Windsor and Cattai in the 1990 flood.

Substations are damaged when water enters electrical equipment, but would have to be about 1.5m deep across the floor of the switch room before this occurred. Based on the flood extent mapping which used the Digital Elevation Model, **Table 4.8** describes the degree of flood affectation for the substations within the study area. The Windsor zone substation is the most exposed substation, and would be damaged when floodwaters exceed 16m AHD. The Hawkesbury Transmission substation, located next to the South Windsor zone substation in Ham Street, South Windsor, would not be inundated until water reached 20m AHD.

It is noted, however, that a loss of power is expected at lower levels. For floods exceeding 18.5m AHD at Windsor, transmission lines feeding into the Hawkesbury Transmission substation will be shut down, cutting electricity supply to every property in the Hawkesbury LGA for possibly a few days (for floods up to 20m AHD), or for much longer periods (3-6 months) if in larger floods significant damage to the substation is sustained (Steven Molino, pers. comm.).

Communications

Telecommunications cabling and conduits are designed to withstand minor flooding, but floodwater may infiltrate pressurised cables at depths exceeding two metres above cable level. Optical fibre cables are not affected by moisture penetration.

Switching centres and terminal exchanges are damaged when water enters the buildings. Most electrical and some mechanical equipment would have to be replaced if inundated. **Table 4.7** indicates the levels at which various facilities are inundated.

TABLE 4.7 – Floor Levels at Telecom Switching Centres and Exchanges in Hawkesbury LGA

Source: ERM Mitchell McCotter, 1995, Appendix H, Table H.12

Centre or Exchange	Floor Level (m AHD)
Windsor	15.5
Pitt Town	16.0
Wilberforce	16.0
Lower Portland	16.0
Richmond	21.5
Maraylya	22.0
North Richmond	25.0
Cattai	25.0
Upper Colo	26.0

TABLE 4.8 – Direct Flood Affectation of Electricity Substations in the Hawkesbury LGA

Design flood	5y	10y	20y	50y	100y	200y	500y	1000y	PMF
Electricity substations — Windsor Bridge level (m AHD)	11.1	12.3	13.7	15.7	17.3	18.7	20.2	21.9	26.4
Hawkesbury Transmission	none	none	none	none	none	none	all	all	all
Glossodia zone	none	none	none	none	none	none	none	none	none
Kurrajong zone	none	none	none	none	none	none	none	none	none
North Richmond zone	none	none	none	none	none	none	none	none	none
Richmond zone	none	none	none	none	none	none	none	some	all
South Windsor zone	none	none	none	none	none	none	some	all	all
Windsor zone	none	none	none	none	all	all	all	all	all

TABLE 4.9 – Direct Flood Affectation of Sewerage Treatment Plants in the Hawkesbury LGA

Design flood	5y	10y	20y	50y	100y	200y	500y	1000y	PMF
STP — Windsor Bridge level (m AHD)	11.1	12.3	13.7	15.7	17.3	18.7	20.2	21.9	26.4
McGraths Hill (HCC)	some	some	some	all	all	all	all	all	all
North Richmond (SW)	none	none	none	none	none	none	some	some	all
Richmond (SW)	none	none	none	none	some	all	all	all	all
Richmond RAAF base (RAAF)	some	all	all	all	all	all	all	all	all
South Windsor (HCC)	none	none	none	none	none	some	some	all	all

Natural Gas

Windsor trunk receiving station (TRS) supplies gas to the Richmond-Windsor area. It consists of pressure reducing equipment, pipework and a control building. Flooding exceeding 19m AHD would damage electrical and mechanical equipment, and at higher levels, the building itself.

When floodwaters enter the inlet of a customer's meter, water could enter the pressure regulator, meter assembly, internal reticulation and appliances, but is not expected to cause any permanent damage.

Water Supply

Richmond and Windsor have a discrete water supply system, whereby water is pumped from the Hawkesbury River and treated at the North Richmond Water Treatment Plant. Treated water is pumped to two storage reservoirs and then gravity fed to Richmond and Windsor via mains which cross the North Richmond Bridge. A trunk main from Windsor to Wilberforce crosses the river on the Windsor Bridge. The trunk mains at the bridges are vulnerable to flood damage including from scour of the approaches.

The elevation of pumping stations in the study area is listed in **Table 4.10**. Initially, pumps and electrical equipment would be damaged. More severe flooding could also damage pumping station buildings. At 18m AHD, the sludge lagoons at North Richmond Water Treatment Plant are affected, but the remainder of the plant would not be flooded even for a PMF event.

TABLE 4.10 – Pumping Station Elevations in Hawkesbury LGA

Source: ERM Mitchell McCotter, 1995, Appendix H, Table H.13

Pumping Station No.	Location	Floor Level (m AHD)
65	North Richmond	21.5
130	South Windsor	14.5
136	Richmond	22.0
191	North Richmond	21.5
221	Yarramundi	21.5
225	Windsor	21.4
227	South Windsor	24.8

Sewerage

Whilst large parts of Hawkesbury LGA are unsewered, there are five Sewerage Treatment Plants (STPs), along with many sewage pumping stations. All five STPs are subject to inundation at various levels (see **Table 4.9**). The RAAF and McGraths Hill STPs are directly affected during relatively frequent floods (see **Figure 4.6**).[14] However, the STPs are expected to cease to operate earlier than implied from **Table 4.9** due to the loss of power, which is anticipated to occur above 14.5m AHD for the Richmond STP. Most pumping stations feeding McGraths Hill STP are quite low, with the first being inundated when floodwaters reach 8.6m AHD, and another four inundated by 10m AHD. Also, most pumping stations feeding South Windsor STP are low-lying, with the first shutting down at about 10m AHD.

[14] It is understood that the Department of Defence is investigating the possibility of retiring the Richmond RAAF Sewerage Treatment Plant (STP) and connecting the base to the Richmond STP owned by Sydney Water. This would be done via a connection to the new sewer mains installed along the Commonwealth owned section of Dight St, which passes the RAAF STP.

a. McGraths Hill STP

b. Richmond RAAF STP, 1992 flood

Source: RAAF

FIGURE 4.6 – Flooded Sewage Treatment Plants

4.3.3.3 Hawkesbury Hospital

Hawkesbury Hospital was opened at its current site at 2 Day Street (110 Macquarie Street), Windsor, in 1996. The level of the ground floor is 17.5m AHD, which is just above the 100 year flood level, while the first floor would be inundated in about the 500 year event. Inundation would cause significant damages, and much equipment in the pathology and radiology departments on the ground floor is bolted to the ground and could not be shifted to the first floor using the lifts. The hospital has its own emergency generators, but these are located at ground level. According to the hospital's business continuity plan, evacuations are expected to occur from about 12.5m AHD.

The ground level at the Community Health complex immediately to the west of the hospital is 16.7m AHD.

4.3.3.4 Richmond RAAF Base

Richmond Air Base is the principal transport facility for the RAAF and has developed into a large establishment of about 400 buildings including a hospital, aircraft maintenance hangars (and aircraft), offices, commercial buildings and residences. There are also about 300 various facilities including storage tanks, electrical equipment, hazardous material lockers and dog compounds. The base population is about 2,300 during the day and 800 during the night.

Percival Street, which provides access to the site from the Windsor direction, is cut even in a 5 year event. The site is largely flood-free up to and including the 50 year flood, but a sizeable portion would be inundated in the 100 year flood and access to the main gate via Dight Street would be lost by flooding at the corner of Percival Street and Cupitts Lane (but other gates would be accessible). A large proportion of the base would be affected in the 200 year flood, and virtually the whole site would be wet in the 500 year flood.

5. RISK TO LIFE

5.1 BACKGROUND

During major floods there is a serious risk to life within existing communities in some parts of the study area. The most significant danger occurs during extreme floods if for any reason people do not evacuate the floodplain and rising water then traps and subsequently overwhelms the community.

The potential to mitigate risks to the existing population and the potential for new development to exacerbate these risks are some of the most important considerations of the current study.

Options to reduce the risks to life of existing flood prone communities within the study area are considered and evaluated in **Sections 5.4** and **6**. Evaluating the appropriateness of future development is assisted through use of an evacuation risk classification system to guide planners and decision makers (see **Sections 5.5** and **5.6**).

5.1.1 General Principles

The primary objective of the NSW Government's *Flood Prone Land Policy* is to "*reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property*" and to "*reduce private and public losses resulting from floods*".

At the same time, the policy recognises the benefits flowing from the use, occupation and development of flood prone land. The only way to completely remove flood risks from a development is for it to be located outside the extent of the PMF[15]. This is a very risk-averse approach to floodplain management which is generally not supported by the *Floodplain Development Manual*[16]. In particular one of the principle tenets of the *Flood Prone Lands Policy* is that "*flood prone land is a valuable resource that should not be sterilised by unnecessarily precluding its development"*.

When considering future development, both the *Policy* and the *Floodplain Development Manual* promote the use of a *"merit approach which balances social, economic, environmental and flood risk parameters to determine whether particular development or use of the floodplain is appropriate and sustainable. In this way the policy avoids the unnecessary sterilisation of flood prone land. Equally it ensures that flood prone land is not the subject of uncontrolled development inconsistent with its exposure to flooding".*

In view of the above, and considering the FRMS process which is being undertaken for the Hawkesbury LGA under the *Floodplain Development Manual*, a key issue to be determined is the level of risk that the community considers to be acceptable, noting that the elimination of all risk is generally not practical or appropriate. As a general rule, almost any development involves some risks to property or people. For example, construction of a new subdivision introduces traffic risks which may be managed (e.g. through construction of traffic lights, signage, etc) but are not completely eliminated. Rather the risks are reduced to a level which is considered acceptable to the community. Flood risks are managed in a similar fashion. Nevertheless in some situations if the residual risks remain unacceptably high, alternative safer forms of development must be pursued.

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[15] But even then it may be indirectly affected, if for example, power is lost.

[16] Nevertheless the Manual recognises that some sensitive or critical land uses (e.g. vital infrastructure) may need to be located outside the reach of a probable maximum flood in order to appropriately manage the consequences of inundation.

5.1.2 What are Acceptable Risks to Life from Flooding?

There are no prescriptive standards for an acceptable risk to life for floodplain developments. Within the NSW context, floodplain risk management plans provide guidance to consent authorities on the appropriateness of flood-related safety risks having regard to the characteristics of the floodplain, matters of best practice and levels of risk considered acceptable to the community.

Research carried out by Higson (1990) and discussed in SCARM (2000) indicates that during the 1980s the risk of death by flooding in NSW was 0.2 "per million person years" (i.e. pmpy). This risk was several orders of magnitude lower than many other every day risks such as being hit by a vehicle or accidents at home. Many health risks (e.g. fatal cancers) are much more frequent even than traffic related fatalities.

Experience from floods across the nation suggests that flooding is dangerous but not particularly so when compared with other everyday risks[17]. The most serious loss of life in floods in recent times occurred during the January 2011 floods in the Toowoomba, Lockyer Valley, Brisbane and Ipswich areas when around 30 people lost their lives. About 90 people lost their lives when a large part of the township of Gundagai was washed away in one night in 1852. Within the Hawkesbury district 12 people lost their lives during the 1867 flood (see **Section 2.2**) when the population of the LGA was significantly smaller than it is today.

When deaths occur during floods, most die due to misadventure, exposure to unidentified risks, or by foolhardiness.

When viewed against other voluntary and involuntary lifestyle risks, a risk of 1 pmpy is not seen as large compared with many other everyday risks that the community accepts. Therefore it has been suggested that a risk of 1 pmpy is acceptable or negligible to an individual (SCARM, 2000). However this individual risk is different to what a society might consider acceptable because a number of people might be involved and their identity is unknown. These societal risks reflect the community's aversion to disasters and it has been suggested that in respect of flooding, society might accept one fatality in a 100 year flood increasing to about 20 fatalities in a PMF[18].

What is important here is not the mathematical value of the acceptable risk which is by nature imprecise and likely to vary significantly between communities, but that society does accept some risk of fatalities from flooding.

5.1.3 How Does the Planning Process Address Risks to Life?

The planning process considers risks to life associated with numerous different activities. Different risks sources include:

- natural hazards (fire, flood, land stability, acid sulphate soils, salinity, earthquakes, cyclones, etc); and
- man-made hazards (traffic and pedestrian accidents, crime related assaults, hazardous industry, fire and explosions, etc).

[17] Nevertheless flood remains Australia's most deadly natural hazard. Between 1788 and 1996 there were at least 2213 people killed in the country as a results of floods (Coates, 1999). This was less than the nation's average <u>annual</u> road toll measured over the latter half of the 20th century (www.aaa.asn.au).

[18] This is based on a provisional relationship presented in (SCARM, 2000) after considering 1994 interim data for societal risk for dam failure, with adjustment for rainfall induced flooding. SCARM also goes on to suggest that if the expected fatalities are greater than these numbers, measures should be introduced to reduce the risk to as low as reasonably practical (ALARP).

The process generally provides for reduction in risk not total elimination of risk. Minimising one type of risk must be considered in connection with the effect this may have on other risks. For example, a decision to not allow development of additional housing in established areas of the LGA could necessitate the location of additional housing in satellite locations. Additional vehicular travel times for future residents could expose them to other risks of traffic accidents (in addition to additional commuting time and costs).

It is the role of the planning process to balance all issues, including competing issues, in order to obtain the solution that best provides for land uses and infrastructure to meet the changing needs of the community. It is accepted that in some cases there may be no planning solution that provides for development which delivers additional housing and employment opportunities within acceptable levels of risk.

5.1.4 Managing Flood Risks to People when Planning for New Development

When new development proposals are evaluated by Council, it has a key responsibility to consider the risks to life, when deciding whether to approve the development and if so, the type of controls to be applied. A range of potential emergency management and evacuation constraints may exist which Council needs to consider including:

- *flood warning constraints* − there may be insufficient time to warn people in some areas of impending inundation;
- *evacuation infrastructure constraints* − there may be insufficient road capacity available to leave the floodplain before inundation occurs;
- *emergency management resourcing constraints* − there may be insufficient emergency management resources available to facilitate the evacuation within the available warning time; and
- *behavioural constraints* − some people may not evacuate when asked to do so or may otherwise act in a manner which unnecessarily places their lives at risk[19].

Measures that need to be considered by Council to address these constraints include:

- *location of new development* – in areas free of flood risk or where evacuation away from the flood risk is possible;
- *form of development* – so that it is designed to allow for pedestrian and/or vehicular evacuation, and buildings that are structurally resilient to the forces of floodwaters if unavoidably required to provide a refuge;
- *connections between developments and safe refuges or support facilities* – to ensure that pedestrian paths and road systems are designed to facilitate evacuation and access to safe refuges, support facilities and/or evacuation centres; and
- *community education* − to make the reality of the flood threat known to the community and to educate them in the most appropriate ways to prepare for a flood and the most appropriate ways to act during a flood.

The manner in which emergency management considerations are addressed within the planning process, are discussed in **Sections 4.2** and **4.3**.

[19] Such actions may also endanger the lives of emergency services personnel at risk who may be called on to rescue such people.

5.2 PERSONAL SAFETY DURING FLOODS

5.2.1 Evacuation

Emergency management is concerned with both risk to life and risk to property although risk to life is of paramount concern.

Emergency management comprises four components:
- prevention;
- preparedness;
- response; and
- recovery.

The prevention and preparedness (or planning) phases are carried out prior to the onset of flood. The response phase is carried out during a flood and the recovery phase is carried out afterwards. When the prevention and preparedness phases have been implemented to the fullest extent possible, evacuation is the preferred response strategy of the State Emergency Service (SES) during flood events. Evacuation has been defined as:

> "*the temporary movement (relocation) of people from a dangerous or potentially dangerous place to a safe location, and their eventual return. It is a safety strategy that uses distance to separate people from the danger created by a hazard.*" (Opper et al., 2009)

Within NSW the SES is the combat agency of flooding. It is the principal government agency responsible for emergency management during floods, including evacuation.

5.2.2 Consideration of Topography

The shape of the land form (i.e. its topography), has a significant influence on the manner in which flood waters inundate the landscape and the ability of its occupants to evacuate. In the emergency management context, this influences the formation of 'islands' during a flood or in other ways, restricts access to/from different areas of the floodplain. People, animals and equipment can become isolated on such islands and if floodwaters continue to rise and they are not rescued, drowning and loss will occur if the island is overtopped.

Figure 5.1 illustrates the problems that flood islands can create within the context of the Hawkesbury-Nepean Valley.

Figure 5.2 provides a more complete description of a variety of different land forms that can influence emergency management considerations. Whilst the classifications of these land forms is normally determined by reference to the PMF, in smaller flood events, lower flood levels will occur and the conditions shown on **Figure 5.2,** or less severe conditions, may occur[20]. The classifications are also consistent with those presented in a Floodplain Risk Management Guideline (DECC, 2007) which are reproduced below.

[20] It is normal practice to classify the land forms for a range of floods. In respect of the key existing development areas in the Hawkesbury, this classification has been carried out for key flood events from the 5 year ARI through to the PMF, and is presented in **Figures 5.4** to **5.13**.

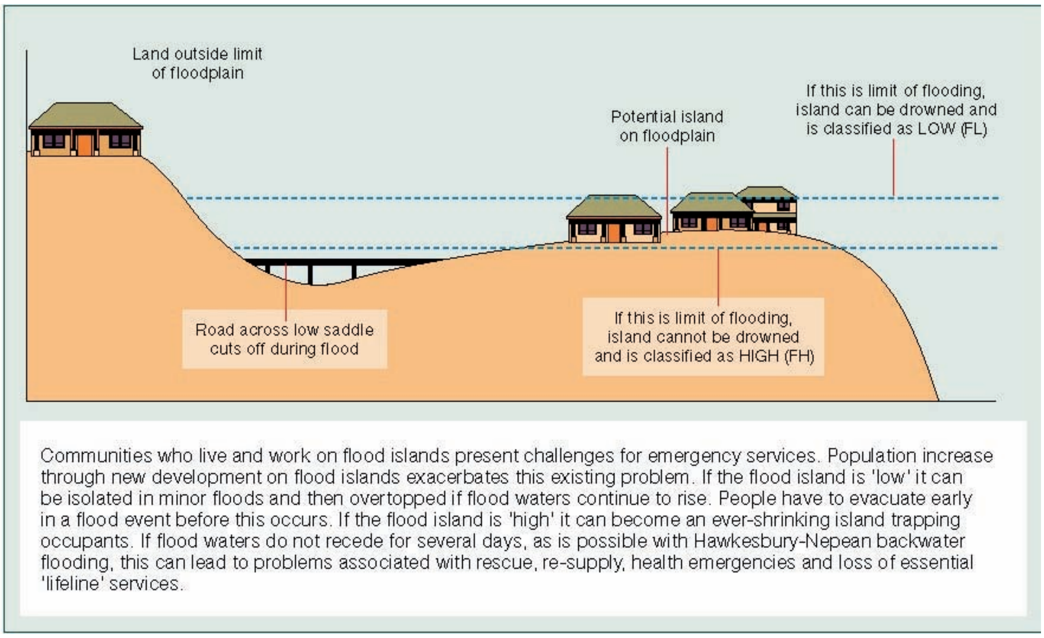

FIGURE 5.1 − Implications of Flood Islands for Emergency Management
(Source: H-N Guidelines: Managing Flood Risk Through Planning Opportunities, HNFMAC 2006a p.36)

5.2.2.1 Flood Islands

These are areas of high ground within the floodplain linked to the flood free valley sides by road access across the floodplain and with no alternative overland access. The road can be cut by flood water, closing the evacuation route and creating an island. After closure of the road the only access to the area is by boat or by aircraft.

Flood islands are classified according to what can happen after the evacuation route is cut as follows:

- *Low Flood Islands (LFI)* − these islands are lower than the limit of flooding (i.e. the tops of the islands are below the PMF) or do not have enough land above the limit of flooding to cope with the number of people in the area. During a flood event the area is isolated by floodwaters and property will be inundated. If floodwater continues to rise, the island will eventually be covered. People left stranded on the island may drown and property will be inundated.
- *High Flood Islands (HFI)* − these flood islands include enough land higher than the limit of flooding to cope with the number of people in the area. During a flood event the area is surrounded by floodwater and property may be inundated. However there is opportunity for people to retreat to high ground on the island and therefore the direct risk to life is limited. The area will require resupply by boat or air if not evacuated before the road is cut. If it would not be possible to provide adequate support during the period of isolation, evacuation will have to take place before isolation occurs.

5.2.2.2 Trapped Perimeter Areas

These would generally be areas on the fringe of the floodplain where the only practical road or overland access is through flooded land and there is an inability to retreat to high ground due to topography or impassable structures. (There are a few of these areas in the Hawkesbury). Trapped perimeter areas are classified according to what can happen after the evacuation route is cut as follows:

- *Low Trapped Perimeter (LTP) Area* − the area is lower than the limit of flooding or does not have enough land above the limit of flooding to cope with the number of people in the area. During a flood event the area is isolated by floodwaters and property may be inundated. If flood waters continue to rise after it is isolated, the area will eventually be covered. People trapped may drown.
- *High Trapped Perimeter (HTP) Area* − the area includes enough land to cope with the number of people and is higher than the limit of flooding. During a flood event the area is isolated by floodwaters and property may be inundated. However as there is an opportunity for people to retreat to high ground, the direct risk to life is limited. The area will require resupply by boat or air if not evacuated before the road is cut. If it would not be possible to provide adequate support during the period of isolation, evacuation will have to take place before isolation occurs.

5.2.2.3 Areas Able to be Evacuated

These are inhabited areas on flood prone ridges jutting into the floodplain or on the valley side that are able to be evacuated. However, the categorisation depends on the type of evacuation access available, as follows:

- *Areas with Overland Escape Route (OER)* − these are areas where access roads to flood free land cross lower lying flood prone land. Evacuation can take place until access roads are closed by flood water. Escape from rising flood water is possible by walking overland to high ground. Anyone not able to walk must be rescued by using boats, heavy vehicles or aircraft. If people cannot get out before inundation occurs, rescue will most likely be from rooftops.

- *Areas with Rising Road Access (RRA)* − these are areas where access roads rise steadily uphill and away from floodwaters. The community cannot be completely isolated. Evacuation can take place by vehicle or on foot along the road as floodwaters advance. People should not be trapped unless they delay the evacuation from their homes. For example people living in two-storey homes may initially decide to stay but reconsider after water surrounds them.

These communities are in low lying areas where people can be progressively evacuated to higher ground as the level of inundation increases. This inundation could be caused either by direct flooding from the River or by localised flooding from tributary creeks.

5.2.2.4 Indirectly Affected Areas (IAA)

These areas are outside the limit of flooding and therefore will not be inundated nor will they lose road access. However they may be indirectly affected as result of flood damaged infrastructure or the loss of transport links, electricity supply, water supply, sewerage and telecommunication services. They may therefore require resupply, or in the worst case, evacuation[21].

The emergency responses required in the different areas of the floodplain noted above, are listed in **Table 5.1**.

[21] **Section 4.3.3.2** provides a description of the likely impact of floods on utilities and public infrastructure.

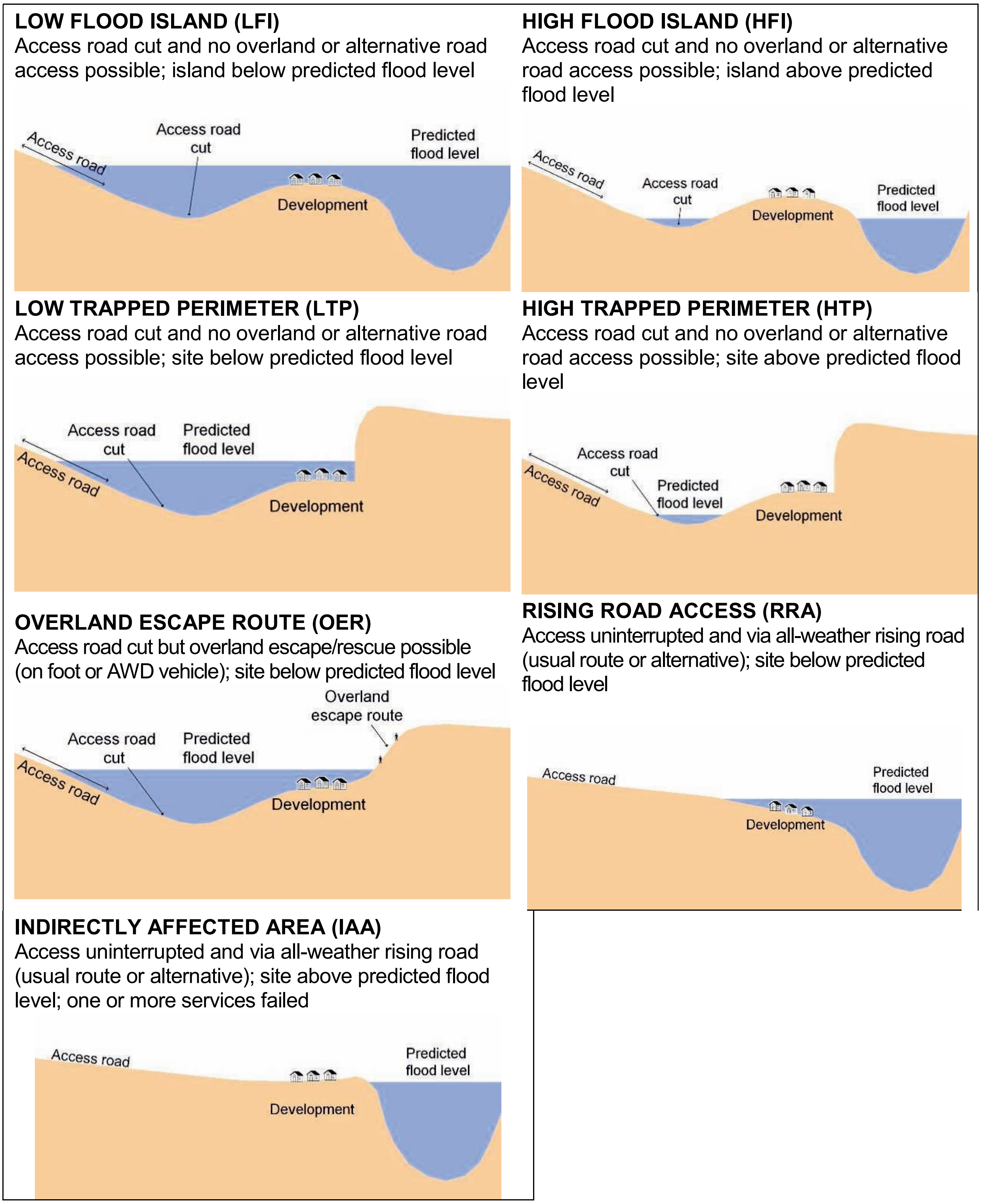

FIGURE 5.2 – Topographical Considerations Influencing Emergency Management
(Adapted from Victorian Caravan Park Flood Emergency Management Plan Template [Bewsher Consulting, 2008]).

TABLE 5.1 − Emergency Response Required for Different Areas[22]

CLASSIFICATION	RESPONSE REQUIRED		
	Resupply	Rescue	Evacuation
Low Flood Island (LFI)	No	Yes	Yes
High Flood Island (HFI)	Yes	Possibly	Possibly
Low Trapped Perimeter (LTP)	No	Yes	Yes
High Trapped Perimeter (HTP)	Yes	Possibly	Possibly
Overland Escape Route (OER)	No	Possibly	Yes
Rising Road Access (RRA)	No	Possibly	Yes
Indirectly Affected Area (IAA)	Possibly	Possibly	Possibly

5.2.3 Proceeding to the Safest Place

The principle of proceeding to the safest place is a key strategy that minimises risk to life during a flood event. This principle needs to be considered:

i) *during development approval* − when developments are being evaluated by the consent authority, consideration needs to be given to:

- the provision of access to places of safety. These places could comprise the nearest evacuation centre, high ground beyond the reach of flood waters, community facilities with access to food, shelter, medical services, etc. These safe places would normally be reached by road but where distances are short, access by foot is appropriate. Roads (and pedestrian pathways) across floodplains can often be inundated by floodwaters, cutting access. Therefore if the access is being relied upon to reach a place of safety, it is important that the propensity for the loss of the access be considered during the evaluation of the development proposal;

- the provision of safe places themselves. It has been common practice in some NSW LGAs for safe places to be constructed within private dwellings through the provision of a second storey or access to a loft space above the PMF. Given the large flood range in the Valley, within most areas a second storey would not be above the PMF. Therefore this strategy is of limited benefit except on higher areas (e.g. above 23mAHD). However provision of places of refuge within large public and semi-public buildings located on the upper parts of the major flood islands where significant numbers of people could take refuge may be appropriate. Whilst these community refuges may not necessarily provide all the facilities that could be available within an evacuation centre, in some cases these may provide an appropriate level of safety for those who take refuge there. Depending on the scale of the development, it may be possible for much larger ‘safe places’ with more extensive facilities to be provided;

ii) *during the prevention and preparedness phases prior to a flood* − these activities are normally undertaken by the SES and landholders. Information concerning flood risks needs to be available so that informed plans and preparations can be made well in advance of the flood threat;

iii) *during a flood emergency* − in exercising their role as the combat agency for floods in NSW, the SES give directions to residents and other people in the floodplain, concerning the safest place to which to evacuate. These directions will usually be in accordance with the plans they have previously prepared. Nevertheless if unforeseen

[22] Sourced from DECC’s 2007 Floodplain Risk Management Guideline - Flood Emergency Response Planning – Classification of Communities.

circumstances arise, the SES will make decisions at that time concerning the safest place for people to move to. Similarly should for any reason people be unable to receive directions from the SES, or otherwise be unable to follow any pre-determined plans, people will logically proceed to what they believe is the safest place, based on the information available to them at the time. For people who have become isolated in flooded houses with more dangerous floodwaters outside, this on occasions has meant taking refuge in the ceiling space or on the roof.

In each of these situations the SES or the people at risk make decisions about where is the safest place and how best to access it based on the information available to them at the time. There is a role for the SES, Council and other government agencies in educating the community so that they are best able to make these decisions, particularly if they find themselves in situations where they become isolated or are not in direct contact with emergency services personnel.

5.2.4 Where is the Safest Place?

In actual flood events there may be considerable uncertainty in deciding what is the safest thing to do. Nevertheless the following courses of action are likely to produce the safest overall outcomes:

i) *Firstly* − leave the inundated area, or the area about to be inundated, and travel to an area outside the floodplain where sufficient support facilities are available to sustain health and wellbeing. This may be an evacuation centre but it might also be homes of family or friends, or rented accommodation, outside the floodplain. Nevertheless such travel can of itself be dangerous if the evacuation route can be cut by flood waters. It is possible that in some situations, the travel may be more dangerous than the risks associated with seeking shelter in the local area.

ii) *Secondly* − when it is no longer possible to evacuate, or when the risks of evacuation are too great, sheltering in place is the next preferable option, (or possibly may be the only option available). This sheltering may be for the duration of the flood or until being rescued (e.g. by boat, helicopter or heavy vehicle).

There are potential difficulties in undertaking either of these courses of action, as listed in **Table 5.2**.

5.2.5 Factors Influencing Safety Risks Associated with Evacuating and/or Sheltering

There are a range of factors which influence safety considerations when evacuating beyond the floodplain or sheltering within it. These factors include:

- velocity and depth of floodwaters at the site and along the evacuation route;
- duration of inundation and the duration of the post-flood recovery phase including time for restoration of water, sewerage and other facilities;
- available warning time;
- history of flooding including community awareness of recent major flood;
- history of past evacuations including community awareness of successful evacuations and false alarms;
- demographic characteristics of the community including age, mobility, language, level of disability, car ownership, etc;
- building standards (if building is used as a refuge), including ability to withstand the forces of flood debris and buoyancy;
- risk of erosion and collapse of land or building used for shelter;
- availability of shelter from wind, rain, sun, cold, etc;
- driving hazards along the evacuation route including weather induced visibility hazards, flood induced hazards, fallen trees, etc;

- number of people to be evacuated;
- the availability of facilities for the continued health and wellbeing of people who are evacuated or who remain and shelter within the floodplain. This includes access to amenities (toilets, bedding, food, warmth, washing), medical assistance, financial assistance, counselling support, communication services, law and order services, etc;
- distance that has to be travelled; and
- frequency of inundation of the flood.

Having regard to the above factors, selection of the safest course of action is a potentially complex issue. It would appear that there is no one course of action that is the answer for all situations. Whilst evacuating to outside the floodplain would normally be the safest course of action if sufficient warning time is available, it may not be the superior option in every situation.

5.2.6 Scale of Development

The range of support facilities that can be provided to service evacuees and isolated communities is influenced by the number of people involved. As a general rule, the greater the "critical mass" of people, the greater the ability to provide safety.

For example, Windsor already has a significant range of facilities including a hospital, supermarkets, communications, hotels, medical centres, financial services, some government offices, etc. Whilst this area can be isolated during a flood and some of these facilities may be shut down, a significant number of support facilities will likely still be available during many floods. This contrasts with smaller isolated rural communities and single houses where many fewer facilities are likely to be available.

Further when planning new support facilities to service future population increases, larger development proposals will likely have access to the greater resources (including Section 94 development contributions funds), and therefore are better able to provide a larger range of support facilities than smaller scale developments[23].

5.2.7 Medical and Fire Emergencies During Floods

In discussions with the SES, they have raised concerns relating to increased risks from medical and fire emergencies which communities isolated by flood waters may have to face. For example, the use of candles during power blackouts might lead to a greater risk of fire than would otherwise be the case. Further, fire appliances will likely be unable to reach the fire and therefore fire fighters and fire equipment would not be available to assist fight the fire. A greater risk of medical emergencies may occur due to the increased trauma induced by isolation, or by a failure to be able to reach medical vital supplies or treatment.

As part of the *Tweed Valley Flood Risk Management Study and Plan* (Bewsher Consulting and Grech Planners, 2011), various discussions were held with the NSW Ambulance Service and Fire and Rescue NSW (FRNSW)[24] concerning the potential for flood emergencies to be compounded by concurrent fire and/or medical emergencies. Whilst these discussions focussed on considerations of future development in the Tweed, a number of relevant findings emerged which will likely have wider application across the State including in the Hawkesbury:

[23] For example, the proposed development of Bligh Park Stage 2 (Molino Stewart, 2007) included for the construction of commercial buildings of at least three storeys on the highest parts of each of the low flood islands within the development. As well as being designed to withstand flood waters, these buildings were to provide a large floor space under cover, a fire suppression system and fresh water for three days.

[24] In January 2011 NSW Fire Brigades changed its name to Fire and Rescue NSW (FRNSW).

TABLE 5.2 − Potential Difficulties associated with Alternative Evacuation Scenarios

Evacuation to Area Outside the Floodplain	Sheltering within the Floodplain
1. *Misadventure or Other Accident on Route*. Vehicles being washed off roads or causeways is the most common form of death during floods. 2. *Local Flooding*. The evacuation route may be cut by local flooding which is difficult to predict. This may expose evacuees to further dangers or result in evacuees being isolated in a location which is more dangerous than the one they left. 3. *Insufficient Time or Route Capacity.* Conditions along the access route may be such that there is insufficient time or road capacity available to reach safety before evacuees are overtaken by more dangerous conditions than those they left. 4. *Failure to Heed Evacuation Directions.* Experience in Australia has shown that people often do not heed evacuation warnings, preferring 'lay' advice to that of the emergency services personnel. Also false alarms reduce the credibility of future warnings. Consequently a much larger percentage of people may not heed evacuation directions, than otherwise may have been expected. There may be inadequate facilities on site to adequately cater for those who don't evacuate. 5. *Immobility*. Disadvantaged, infirm and immobile sectors of the population may be unable to evacuate, or unable to evacuate in the time available.	1. *Sanitation, Food or Medical supplies*. Isolation resulting from not evacuating may create significant hardship or in the case of inability to access vital medical supplies, could lead to death. 2. *Building Fire*. People trapped in buildings isolated by floodwaters may be subject to increased risks due to an inability to evacuate, or due to the inability of fire crews to reach the building (or to transport necessary fire fighting equipment to the building). 3. *Medical Emergencies*. People isolated by floodwaters may be subject to increased risks due to the inability of paramedics to reach them. In this situation, people subject to life threatening emergencies could die. 4. *Isolation Induced Trauma*. People trapped in buildings or otherwise isolated by floodwaters may be subject to increased trauma. This trauma could be exacerbated if communication facilities are disrupted. 5. *Building Collapse/Inundation*. People trapped in buildings may be drowned if the building is subsequently washed away, or if the building (or 'island') where they are sheltering becomes overwhelmed by floodwaters. 6. *Inability to Climb*. Those disabled or the infirm, may be unable to climb stairs or otherwise be unable to reach the higher areas of the site in order to avoid drowning. 7. *Exposure to the Weather*. This includes associated effects such as hypothermia.

- neither agency has evidence for increased fire/medical emergencies occurring concurrently with flood emergencies;
- in terms of calls to '000' for medical assistance, the NSW Ambulance Service's records indicate there are fewer '000' calls during flood emergencies. This is likely to be because much fewer unnecessary '000' calls are made at such times;
- neither agency considered that the fire/medical risks associated with new development in potentially flood isolated communities were intolerable, or that the risks were so severe that they were unable to be managed as part of the development process[25].

[25] These comments related to Tweed Heads. Nevertheless given the similar scale of development and similar access to facilities in the isolated portions of Tweed Heads and Windsor/Richmond, they will likely also apply to Windsor and to a lesser extent Richmond. There are a few key differences between the two communities however. The Tweed can be isolated by floods much more frequent than 100 year (i.e. the flood that in the Hawkesbury will just overtop the South Creek regional flood evacuation route), and more importantly, Windsor and Richmond are low flood islands in a PMF, whereas Tweed Heads remains a high flood island with significant access to high ground.

Nevertheless the potential for increased risk of fire or medical emergencies during floods remains and important consideration.

5.3 EVACUATION CAPABILITY ASSESSMENT (ECA)

5.3.1 Background

An evacuation capability assessment (ECA) calculates the time required to evacuate a community away from an impending flood threat. It does this by considering the time required for a range of activities including mobilisation of emergency services personnel, delivery of an evacuation warning to the community, acceptance of the warning by the community, preparation of the community to leave their homes (and businesses), and eventually travel by vehicle away from the floodplain.

ECAs have been prepared during the course of the current study for all the major population centres within the study area. As part of these assessments it has also been important to consider the potential influence of evacuations that might be occurring concurrently within the adjacent local government areas (LGAs) in the Valley. The most important of these is the Penrith LGA as evacuation traffic to the south from the Hawkesbury LGA can conflict with evacuees from Penrith particularly along the old Northern Road and other roads. Evacuation from The Hills Shire and Blacktown LGAs also has influence on evacuation away from the study area towards the south-east, but these are less significant.

Because Molino Stewart had previously carried out ECAs which included for the influence of the adjacent LGAs, they were engaged to assist the consultants in the preparation of an ECA for the study area. Immediately prior to their engagement they had completed an ECA for the Penrith Lakes development for the Department of Planning and Infrastructure. This assessment necessitated consideration of evacuation issues within the Hawkesbury LGA given that evacuation from some parts of the Penrith and Hawkesbury LGAs share the same evacuation routes.

Molino Stewart's previous ECAs were based largely on the evacuation procedures presented in the Hawkesbury Nepean Flood Emergency Sub Plan (SEMC, 2005). However during the course of the study various additional discussions were held between Molino Stewart, Bewshers and the SES to clarify and update the methodology presented in the Sub Plan[26]. This additional information was then incorporated in the Hawkesbury ECAs as well as in Molino Stewart's advice (Molino Stewart, 2011c).

The ECAs for the study area for existing conditions and for the future are presented in **Appendices E** and **F**.

[26] The Sub Plan was prepared prior to the construction of the Jim Anderson Bridge in 2007. The ECAs which have been prepared for the current study take account of the Bridge although the Sub Plan has not yet been formally upgraded to include for it. Most importantly, the previous ECAs in the Valley including those for private developers and for the Department of Planning and Infrastructure were based on evacuation commencing in anticipation of a gauge height of 14.1m being reached at Windsor. After review by the SES in May 2011 (refer **Appendix C**), an alternative trigger based on anticipation of overtopping of the egress route from each Sector was adopted. For example, in respect of Windsor this means that the SES proposes evacuation to commence in anticipation of the South Creek regional flood evacuation route being overtopped (i.e. when the River reaches a level of 17.3mAHD at Windsor). In respect of Richmond, anticipation of 20.1mAHD being reached was used as the evacuation trigger (i.e. the level at which the Castlereagh Road route is cut near The Driftway). This resulted in significant changes to the assessment compared with previous assessments based on anticipation of a level of 14.1m being reached at Windsor. Further, as the changes for Windsor and Richmond resulted in modelling evacuations commencing later in a flood, the newer modelling assessed a reduced evacuation capability compared with the previous assessments based on anticipation of a 14.1m River level.

5.3.2 Evacuation Strategy − Overview

Under the Hawkesbury Nepean Flood Emergency Sub Plan (SEMC, 2005), the study area (and other others of the Valley) have been divided into 'sectors' and 'sub-sectors'. Although copies of the sector and sub-sector boundaries were not published in the Sub Plan, these were subsequently provided digitally to Molino Stewart and Bewshers during the course of the study.

Regional evacuation routes generally service the key sectors which include the low flood islands (and therefore represent the most serious risks to life). These low flood islands comprise McGraths Hill, Pitt Town, Windsor, South Windsor, Bligh Park, Richmond and Hobartville.

There are also local evacuation issues within some sub-sectors which influence the ability of residents to reach the start of the regional evacuation routes. As noted in **Section 2.5** separate local evacuation studies have previously been commissioned including those for Bligh Park and Hobartville.

The regional evacuation routes and some of the key sectors are shown in **Figure 2.8**. It is noted that this figure, which is reproduced from the Sub Plan, was prepared prior to the construction of the Jim Anderson Bridge in 2007 but includes for the 'Proposed South Creek Crossing'.

5.3.3 'Timeline' Analyses for Evacuation Operations

A key activity undertaken as part of an ECA involves the comparison of the time required for evacuation of an area with the time available for its evacuation. This comparison has traditionally been carried out using a 'timeline' analysis.

The timeline methodology was initially developed by the SES during the preparation of the Hawkesbury Nepean Floodplain Management Strategy in 1997. The procedures have subsequently been updated and refined and most recently published in Opper et al. (2009).

There are four main phases within a timeline analysis and these mimic those which are likely to occur during an actual flood emergency, i.e.:

- flood forecasting;
- initiation of response and mobilisation of emergency services personnel;
- warning delivery; and
- evacuation of the occupants.

The consideration of these four phases defines the time required for evacuation and this can then be compared with the time available (i.e. the time until the evacuation route is cut). After a flood forecast has been made, the processes considered in the timeline analysis are shown schematically in **Figure 5.3**.

In considering the time available for the evacuation shown in **Figure 5.3**, the ECAs carried out by Bewshers and Molino Stewart for the current study have made the following assumptions (in consultation with the SES):

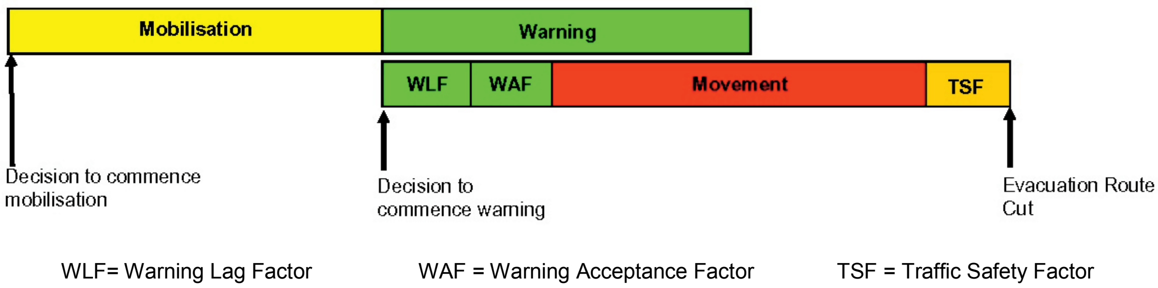

FIGURE 5.3 − Timeline Analyses for Assessing Evacuation Capability
(Source: Hawkesbury Nepean Flood Emergency Sub Plan [SEMC, 2005]).

- *mobilisation*: − this is the time required to mobilise emergency services personnel. Based on advice from the SES, a mobilisation time of 6 hours has been adopted during the current analysis (and the previous timeline analyses carried out within the Hawkesbury-Nepean Valley);
- *warning acceptance factor (WAF)*: − the evacuation planning has assumed that sufficient time needs to be allowed for every building to be doorknocked. Nevertheless it is understood that the SES intends to use various means of warning dissemination including mass broadcasting of warning messages. It is been assumed that evacuees might take some time to accept the warning message. Based on the experience of the SES and Molino Stewart, an average WAF of one hour has been adopted;
- *warning lag factor (WLF)*: − the WLF allows for the time needed for evacuees to organise themselves and their possessions before leaving the premises. A WLF of one hour has been adopted;
- *traffic safety factor (TSF)*: − based on advice from the SES, an allowance for traffic disruption that could occur (e.g. due to fallen trees, vehicle collisions, etc) has been included. The TSF is based on the duration of the movement phase and is assumed to be 1 hour for a movement phase of 1−3 hours, and thence 0.5 hour for each subsequent 3 hours of movement duration; and
- *movement*: − in line with the analyses undertaken as part of the *Hawkesbury-Nepean Floodplain Management Strategy*, a traffic capacity of 600 vehicles per hour per lane has been assumed on all evacuation routes.

5.3.4 Assumptions about Population and Vehicle Numbers

The timeline analysis is essentially the calculation of the time required to evacuate vehicles from the floodplain. Consequently the number of vehicles to be evacuated is a key input parameter into the analysis.

5.3.4.1 Different Classes of Vehicles to be Evacuated

There are likely to be three different types of vehicles using the flood evacuation routes during an evacuation:

- *residents' vehicles* − these will be the vehicles which residents use to evacuate the floodplain. Where a household has more than one vehicle, it is possible that not all vehicles will be used. It is likely that the SES will ask the community to leave 'unnecessary' vehicles behind (and so reduce evacuation traffic). Some residents may be away from the area (e.g. on holiday) which may reduce the total number of resident vehicles on the evacuation routes. The number of such vehicles however would be offset by visitors to the area, whose vehicles would also need to be evacuated;

- *non-resident worker vehicles* − these will be the vehicles of employees and proprietors of businesses, industries, institutions, located within the study area but whose drivers are non-residents. If the call to evacuate is made after hours or on weekends, a large number of these vehicles may not be present;

- *other non-private vehicles* − there will be a small number of other vehicles using the evacuation routes which are not included in the above two categories. For example there are a number of residents who do not have a vehicle and will require assistance to evacuate. The SES Sub Plan has provision for a large number of buses to service these people as well as for assisting residents whose vehicles may have broken down or to move other people requiring evacuation. There will also likely be a significant number of emergency services personnel entering and leaving the area who will add to the evacuation traffic.

5.3.4.2 Numbers of Buildings with Vehicles to be Evacuated

In order to estimate vehicle numbers, estimates of the numbers of dwellings and the numbers of businesses are required. In order to prepare estimates of these dwelling/business numbers for the study area, three different procedures have been considered:

- *NEXIS data* − 'NEXIS' refers to the National Exposure Information System used by Geoscience Australia (Nadimpalli et al., 2007). It is understood that Geoscience Australia have been commissioned by the SES to provide estimates of the number of residential dwellings and the population, as well as the number of commercial and industrial buildings within the floodplains, which would need to be evacuated. NEXIS does this by making use of the Geocoded National Address File (G-NAF). The system is useful because it is addressed based and therefore it is possible to extract information for each SES sector and subsector (or any other area). Nevertheless it may overestimate the number of buildings/vehicles requiring evacuation as it does not adequately exclude addresses with vacant land uses (Molino Stewart, 2011c);

- *Census data* − there is a wide variety of Census information collected which is of direct relevance in computing the number of vehicles in the study area that may require evacuation during a flood emergency. The data is collected every five years of which the Census of 2001 and 2006 are of most relevance. At the commencement of this study, the 2011 Census had not been undertaken.[27] Of the various procedures available for estimating vehicle numbers, those using Census data are considered to be the most accurate. However the data is collected over geographical areas referred to as Census districts. In many parts of the Valley these districts do not coincide with SES sectors and subsectors and therefore this presents a drawback in using Census data for evacuation purposes. However within the key evacuation constrained areas of relevance to this study, e.g. Windsor, Bligh Park/Windsor Downs and Richmond, there is a close correlation between the SES sectors and the Census districts. Further details of the application of Census data to the study area is provided in Appendix B of **Volume 2**;

[27] Whilst the Census data subsequently became available during the late stages of the study, there was insufficient time for it to be incorporated.

- *Council data* − Hawkesbury City Council maintains a database of all land parcels within the LGA which is used for a variety of purposes including collection of rates. This rates database cannot be used directly to determine whether the land parcel is vacant or not. However Council also has associated information indicating aerial photography, land use zonings and other records such as the presence of a garbage service, which can be used to determine whether the land parcel is occupied. This procedure has also been used to identify flood prone buildings within the study area and is discussed further in **Section 4.2.1**.

A comparison of the number of residential dwellings estimated by the above three methods for the key evacuation constrained areas within the study area is provided in **Table 5.3**.

TABLE 5.3 − Comparison of 2010 Residential Dwelling Numbers (by SES Sector)

Data Procedure	**NEXIS**	**Census Data***	**Council Data**
Source of Data Estimate	Table 2, Molino Stewart (2011a)	Appendix B, Volume 2	Refer procedure discussed in Section 4.2.1
Windsor	3621	3653	3177
Bligh Park and Windsor Downs	3086	2715	2661
Richmond and Richmond Lowlands	4102	3631	3644
Total	10809	9999	9482

*The Census data presented here is based on 2006 data plus an allowance for projected growth from 2006 to 2010 as discussed in Appendix B of **Volume 2**. Note where a Census district boundary did not coincide exactly with the SES Sector boundary, adjustments were made using aerial photographs.

Because the Census district boundaries coincide closely with the SES sector boundaries within the study area, and because of the deficiencies with the NEXIS procedure identified by Molino Stewart, it was decided to adopt the Census data for the purposes of the current study[28]. It is noted that checks of the Census data with the Council data showed excellent agreement except in Windsor[29] where NEXIS data more closely matched the Census data.

5.3.4.3 Other Assumptions in Deriving Numbers of Vehicles to be Evacuated

The derivation of the numbers of vehicles to be evacuated which have been utilised in this study have been derived from the Census data as discussed in Appendix B of **Volume 2**. These estimates are for 2010 and 2031.

Once the number of buildings in each SES Sector were established, a range of other assumptions were necessary in order to determine vehicle numbers. These included:

- *average number of vehicles per dwelling* − the Census data was used directly to determine this. A value of 1.58 vehicles per dwelling was adopted[30]. This included an allowance for the observed upward trend in this parameter;

- *growth in dwelling numbers* − analysis of all Council development application approvals between April 2006 and April 2011 indicated that only 289 new dwellings

[28] Nevertheless as it is recognised that the NEXIS data may have application in other parts of the Valley particularly where the Census district boundaries do not coincide closely with the SES Sector boundaries.
[29] Council data for Windsor may have been unable to properly account for multiple occupancies in the one building which is likely more prevalent in Windsor.
[30] It is noted that Molino Stewart had used higher values (e.g. 1.80 vehicles per dwelling) but these appeared to be based on data from Penrith and therefore were not directly applicable to the Hawkesbury LGA.

had been approved over this five year period, or approximately 60 dwellings per year;

- *use of all cars in an evacuation* − it was estimated that in a flood evacuation, approximately 10% of cars would not be utilised;

- *numbers of workers* − the numbers of workers in each of the SES sectors has been determined based on the procedures described in Appendix B of **Volume 2**. This also utilised published data from the NSW Transport Data Centre;

- *numbers of workers needing evacuation* − although conservative, it has been assumed that concurrent evacuation of workers and residents would need to occur. Each worker was assumed to evacuate in one vehicle, but only those workers who were non-resident, were included. (Note that around 80% of jobs within the Hawkesbury LGA are filled by local residents);

- *additional vehicles* − an additional allowance of 5% has been included to provide for buses, special commercial traffic and vehicles used by emergency services personnel.

5.3.5 Capacity of the Jim Anderson Bridge during Evacuations

Discussions with the SES and Molino Stewart have confirmed that under the current evacuation arrangements[31], the SES has assumed that evacuation from Windsor by the Jim Anderson Bridge would occur using one outbound lane on the Bridge and one inbound lane. This lane configuration reflects the current everyday arrangements.

Molino Stewart (2007) identified the potential to utilise two outbound vehicle lanes whilst retaining one inbound lane. This reconfiguration of lanes would be used only during flood emergencies and could be used to significantly increase the outbound traffic capacity. Given that evacuation from Windsor is constrained by this capacity, reconfiguration of the lanes has the potential to significantly improve evacuation from the Windsor flood island.

A review of the *Windsor Flood Evacuation Route EIS* (Connell Wagner, 2002) indicates that the bridge design was to provide for the "*opportunity for two lane outgoing flow if required during flood evacuation*" (Section 6.4.1 of EIS)[32]. In order to investigate the potential further, Halcrow (traffic engineers) were engaged to provide advice on the feasibility of reconfiguring the lanes on the Bridge as suggested by Molino Stewart. A copy of Halcrow's advice is provided in **Appendix G** and is summarised below:

- the currently assumed traffic rate of 600 vehicles per hour per lane on the bridge is appropriate for evacuation planning purposes. Halcrow's note that this rate is conservative and that it is likely that higher traffic flows may be achieved;

- the road geometry would allow for the safe provision of three separated traffic lanes comprising two outbound lanes and one inbound lane;

- provision of dual outbound lanes would significantly increase evacuation capacity; and

[31] i.e. evacuation plans and ECAs (for existing and future developments).

[32] During the course of the study, telephone discussions with the RMS and Aurecon (previously Connell Wagner, who were consulting engineers involved in the original design of the Bridge) also confirmed that the design intent did allow for such a reconfiguration of lanes.

- implementation of dual outbound lanes would incur significant set up costs and require additional operational personnel. Guidance as to the practicalities of such management arrangements should be sought from the SES.

Subject to the approval of the SES, it would appear feasible to increase the evacuation capacity from Windsor by utilising dual outbound lanes on the Jim Anderson Bridge during flood emergencies.

During the course of the study, given the critical importance of this issue, the Committee requested separate advice from the NSW Roads and Maritime Services (RMS). The RMS' response which is provided in **Appendix H** also confirmed that "*the bridge was designed to accommodate two lanes outbound and one emergency lane inbound during evacuation events, should this be required*".[33]

It is understood from discussions with the SES and Council staff that in order to implement dual outbound lanes on the Bridge, additional traffic management arrangements will also be required at the eastern and western ends of the bridge. In addition, it will be necessary to provide additional road capacity from the eastern end of the Bridge through to Bandon Road or other alternative access onto Windsor Road[34].

5.3.6 Time at which 'Decision to Commence Mobilisation' is made

Based on advice from the SES which was received during May 2011, the decision to commence mobilisation of any sector or sub-sector is to be based on an anticipation of the egress route from the sector/sub-sector being cut by floodwaters and the time required for the various phases of the evacuation noted in the previous section. The flood levels at which egress routes are cut for key sectors/sub-sectors are listed in **Table 5.4** below.

In other words, the SES proposes to commence evacuation early enough to ensure sufficient time is allowed for evacuation in accordance with that determined by the timeline analysis. By way of example, as the timeline analysis carried indicates that 15 hours is currently required for the evacuation of Windsor, such an evacuation must commence at least 15 hours prior to floodwaters cutting access to the Jim Anderson Bridge.

A key consideration is the confidence with which predictions of the need for evacuations can be made so that evacuations are not called unnecessarily. The calling of an evacuation within the Hawkesbury-Nepean Valley is a significant decision as it may involve evacuation of many tens of thousands of people. If called unnecessarily, it could impose very significant social and economic costs on the community and could potentially dissuade the community from responding to evacuation requests during future flood events[35].

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[33] Separate advice from the Chairman of the Committee following his meeting with senior staff from the SES HQ and SES Sydney Western Region on 25 January 2012 confirmed that "*the physical capacity to carry three lanes (two outbound and one inbound) exists on the bridge that it should be used this way in emergency situations. This additional lane is essential to allow full evacuation of the Windsor / South Windsor sector with some safety margin*".

[34] Note that without this additional road capacity from the eastern end of the Bridge, the existing dual outbound lanes on Groves Road can be used initially until this route is cut (when flood waters rise above about 13.5mAHD). Thus dual outbound lanes on the Bridge can still be utilised for a significant period of time during a flood emergency. (If flood evacuations commence when the River level rises to 9.6m on the Windsor gauge and are halted once the levels reach 17.1m on the gauge, the dual outbound lanes would still be available for about 50% of the duration of the evacuation and therefore would provide significant benefit).

[35] However most of the low points listed are inundated in quite rare events. For example, in the case of evacuations from most of Windsor, the level of 17.3mAHD corresponds to a 100 year flood level which has a 1% chance of occurrence in any given year. Whilst possible, it would be unlikely that two 'unnecessary' evacuations would be called over say a 10−20 year period, and therefore it would also be unlikely to be remembered by the majority of the community and influence their decision making in responding to a further call to evacuate. Evacuations from Richmond would be even less frequent noting that its egress is not cut until floods rarer than about a 500 year ARI, occur.

TABLE 5.4 − Levels at Which Egress Routes Are Cut by Flood Waters

Sector	Level of Road Point	Corresponding Gauge Height at Windsor
McGraths Hill	13.5mAHD	13.3m
Pitt Town	16.0mAHD	15.8m
Windsor	17.3mAHD	17.1m
Bligh Park (East)	17.2mAHD	17.0m
Bligh Park (West)	18.5mAHD	18.3m
Windsor Downs	19.1mAHD	18.9m
Richmond	20.2mAHD	19.8m

1. All data derived from Table 7 of Hawkesbury Nepean Flood Emergency Sub Plan (SEMC, 2005) unless otherwise stated.
2. Windsor egress cut once access to Jim Anderson Bridge overtopped at 17.3mAHD.
3. Bligh Park egress cut once the upgraded Thorley Street evacuation route is overtopped at 18.5mAHD.
4. Windsor Downs egress cut on Llandilo Road at 19.1mAHD.
5. Richmond egress cut on Castlereagh Road regional evacuation route near The Driftway (refer Section 3.2 of Molino Stewart, 2011a).

Thus the key issues are:

- how much time is required for evacuation? (Which can be determined by the timeline analysis discussed above); and
- once this time is known, can flood level predictions be made this far in advance so that there is a reasonable certainty that the evacuation would not be called unnecessarily? (This question relates to the reliability of flood warning predictions and is discussed in the following section).

5.3.7 How Far in Advance can Flood Warnings be Made?

The decision to commence mobilisation would be made by the SES based on flood prediction advice provided by the Bureau of Meteorology. The NSW Flood Forecasting and Warning Section of the Bureau provide a hydrological flood warning service to 175 key locations in NSW including the Hawkesbury-Nepean Valley.

Of the various types of advice that the Bureau provides, the two most relevant to this discussion are:

- <u>*Flood Watch*:</u> − a flood watch is issued if flood producing rain is expected in the near future. Across NSW, about 70% of flood watches are followed by actual flooding. Flood watches are published on the Internet and advice is also provided directly to the SES (in a similar fashion to the previous 'confidential flood advice'). Flood Watches issued in NSW usually contain a statement such as:

  > *"This Flood Watch is a 'heads up' for possible future flooding and is NOT a Flood Warning. This Flood Watch means that people living or working along rivers and streams must monitor the latest weather forecasts and warnings and be ready to move to higher ground should flooding develop…."*

- <u>*Flood Warning*:</u> − the Bureau provides a range of flood warning services. In some valleys they may provide a generalised flood warning or predictions of 'minor', 'moderate' or 'major' levels of flooding. However in the Hawkesbury-Nepean Valley where a formalised flood warning system has been developed, the Bureau provides predictions of the height that the River will reach. Of most importance to the study area are the Bureau's predictions of the River height at Windsor.

When flood warnings are prepared they are based on a range of meteorological information available to the Bureau including observed and predicted rainfall. It takes about nine hours for rainfall on the local catchment between Wallacia and Windsor to be reflected in the River levels at Windsor. Runoff within the Nepean and Warragamba catchments takes much longer to arrive at Windsor.

Because significant flooding can occur at Windsor as a result of rainfall on the local catchment, nine hours is referred to as the quantitative precipitation forecast limit (i.e. QPF limit). Predictions of River levels at Windsor can be made greater than nine hours in advance; however this necessitates use of forecast rainfall rather than observed rainfall. Forecast rainfall totals have lower confidence than observations of actual rainfall and therefore flood warning predictions made earlier than the QPF limit (i.e. more than nine hours in advance), have a lower level of confidence. Molino Stewart has advised that forecasts made within the QPF limit have a confidence level of 95%.

The nine hour QPF limit has been adopted by the SES for all previous timeline assessments in the Valley[36]. If the evacuation timeline for a sector indicates that less than nine hours is required then the relevant community can be evacuated satisfactorily. Applying the SES methodology, if more than nine hours is required, then the evacuation must be commenced earlier than nine hours, and at a point in time when the risk of calling an unnecessary evacuation is considered unacceptable because of uncertainties in the flood predictions.

During the course of the study, discussions were held with the Bureau of Meteorology concerning the maximum prior time within which confident flood predictions can be made ahead of a major flood. This can be referred to as the limit of confident flood prediction or LCFP. A summary of the discussions with the Bureau is provided in **Appendix D**. It appears that whilst during the 1990s a LCFP of around nine hours was thought to be appropriate, given various improvements in weather forecasting and other advances in technology, it is now possible to provide flood warning predictions for Windsor with a LCFP of 15 to 18 hours.

A decision to use a LCFP of 15 hours in lieu of nine hours will have a significant impact on the outcome of evacuation assessments within the study area. It is therefore a critical issue for the current study. It is also of vital importance when considering the appropriateness of new development within the study area (see further discussion in **Section 5.6**).

In view of this, during the course of the study Council's Committee had numerous discussions about this issue. They also invited the Bureau to make a presentation to their meeting on 12 October 2011. In addition, the Committee wrote to the Bureau requesting advice and the Bureau's response has been reproduced in **Appendix H**. As a result of these discussions and the Bureau's advice, it was concluded that use of a LCFP of 15 hours was appropriate[37].

The next **Section 5.4** discusses risk to life issues within the existing population centres in the study area.

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[36] Molino Stewart (2011a and 2011c) has adopted nine hours as the time within which evacuations have to be made, for consistency with past SES ECA procedures.

[37] Council's staff also advised that this decision by the Committee was also backed up by very good predictions from the Bureau for the flood events in March and April 2012.

5.4 FLOOD RISK ASSESSMENTS FOR EXISTING POPULATION CENTRES

A summary of flood risks and evacuation issues for each of the main localities within the study area is presented below. Flood risk considerations for ten suburbs are summarised in **Figures 5.4** to **5.13** which are provided within this section of the report. (Note that there is a common legend for all figures and this appears on the next page).

5.4.1 McGraths Hill

Flood risk considerations for McGraths Hill (population ~2,500 at the 2006 Census) are summarised in **Figure 5.4**. It shows that many houses will be inundated in a 50 year event. Indeed, up to 50 houses could be flooded even in a 20 year event (**Table 4.3**). Evacuation from McGraths Hill will be via the Windsor Road Regional Flood Evacuation Route to the south-east, which has a low-point of 13.5m AHD between Mulgrave and Vineyard. Hence, the suburb will be isolated in a 20 year event (13.7m AHD), which corresponds to a High Flood Island topographic setting. Much of the island will be inundated in a 50 year flood, though there would be some areas to the north-east and west of the developed area that would not be inundated. Nearly all 923 houses would be inundated in a 100 year flood, which would more or less entirely overwhelm the remaining islands.

5.4.2 Pitt Town

Flood risk considerations for Pitt Town (population ~1,300) are summarised in **Figure 5.5**. A significant number of dwellings (60+) would be flooded even in a 20 year flood (**Table 4.3**). The August 1990 flood (13.5m AHD) affected several houses (e.g. **Figure 5.14a**). Evacuation from Pitt Town will be towards the east then south along the roads listed in **Table 2.8**. The evacuation route will be cut at 16.0m AHD, which is just rarer than a 50 year flood. But there is a substantial area (>170 dwellings) above the 1000 year flood level (21.9m AHD), quite a large area above the 25.0m contour, and a small area (~15 dwellings) above the PMF level (26.4m AHD), with a high-point on Pitt Town 'island' of 29.2m AHD. Given the concerns about the hazards associated with isolation, the SES' strategy of evacuating Pitt Town prior to loss of egress is appropriate; however, the availability of a small high island even in the PMF suggests that risk to life may be tolerable for those who for whatever reason fail to evacuate.

5.4.3 Windsor

Flood risk considerations for Windsor (population ~1,900) are summarised in **Figure 5.6**. Of all the communities in the study area, Windsor has the largest number of dwellings (up to 110) exposed to flooding in the 20 year event, though it is overtaken by McGraths Hill and South Windsor for the 50 year event (**Table 4.3**). Evacuation from Windsor has been greatly enhanced by construction of the Jim Anderson Bridge (South Creek Crossing) in 2007, though it offers immunity only to the 100 year flood level of 17.3m AHD. There are a number of local evacuation constraints impacting on the ability of residents to reach the Jim Anderson Bridge and the regional evacuation route. For example, residents in the Windsor (Central) SES sub-sector will become isolated from the remaining areas of Windsor once floodwaters reach a level of about 14.6m AHD at the George Street low-point. The historical Tebbutt observatory is isolated even in the 5 year flood (see **Figure 5.14b**). The islands that are formed during a rising flood are gradually overwhelmed (see the vivid description of this occurrence in the 1867 flood in **Section 2.1.1**): the Tebbutt observatory island at 16.3m AHD, the Windsor (Central) island at 22.3m AHD. The Windsor (Central) sector is classified as a Low Flood Island in the 1000 year flood (21.9m AHD) because very little space is available above this level. In Windsor, there is a reasonably sized area above 25.0m AHD near the historic St Matthew's Anglican Church, and at one spot the ground level is higher than the PMF level. This topography suggests that it would be beneficial and practical to

FIGURES 5.4 TO 5.13

GENERAL LEGEND

Flood extent

- 5 year
- 20 year
- 50 year
- 100 year
- 200 year
- 500 year
- 1,000 year
- PMF

Building inundation

- House floor flooded in 50 year ARI event (flood level >=0.3m over ground level)
- House floor flooded in 200 year ARI event (flood level >=0.3m over ground level)

Topography

25m contour

26.9m AHD Spot height (low-point or high-point as inferred from mapping)

Topographic class

HFI = High flood island
IAA = Indirectly affected area
LFI = Low flood island
OER = Overland escape route
RRA = Rising road access

Note: topo classes take into consideration the broad topographic setting and low-points on the highest regional flood evacuation route (but make no allowance for evacuation route capacity).

Other topo classes may apply when local road low-points are considered, and some of these are indicated.

Refer to "Flood Emergency Response Planning Classification of Communities", Floodplain Risk Management Guideline, DECC, August 2007.

Evacuation routes

SES evacuation sub-sector

Hawkesbury-Nepean regional flood evacuation route (and low-point on route)

Sector evacuation route

Bewsher

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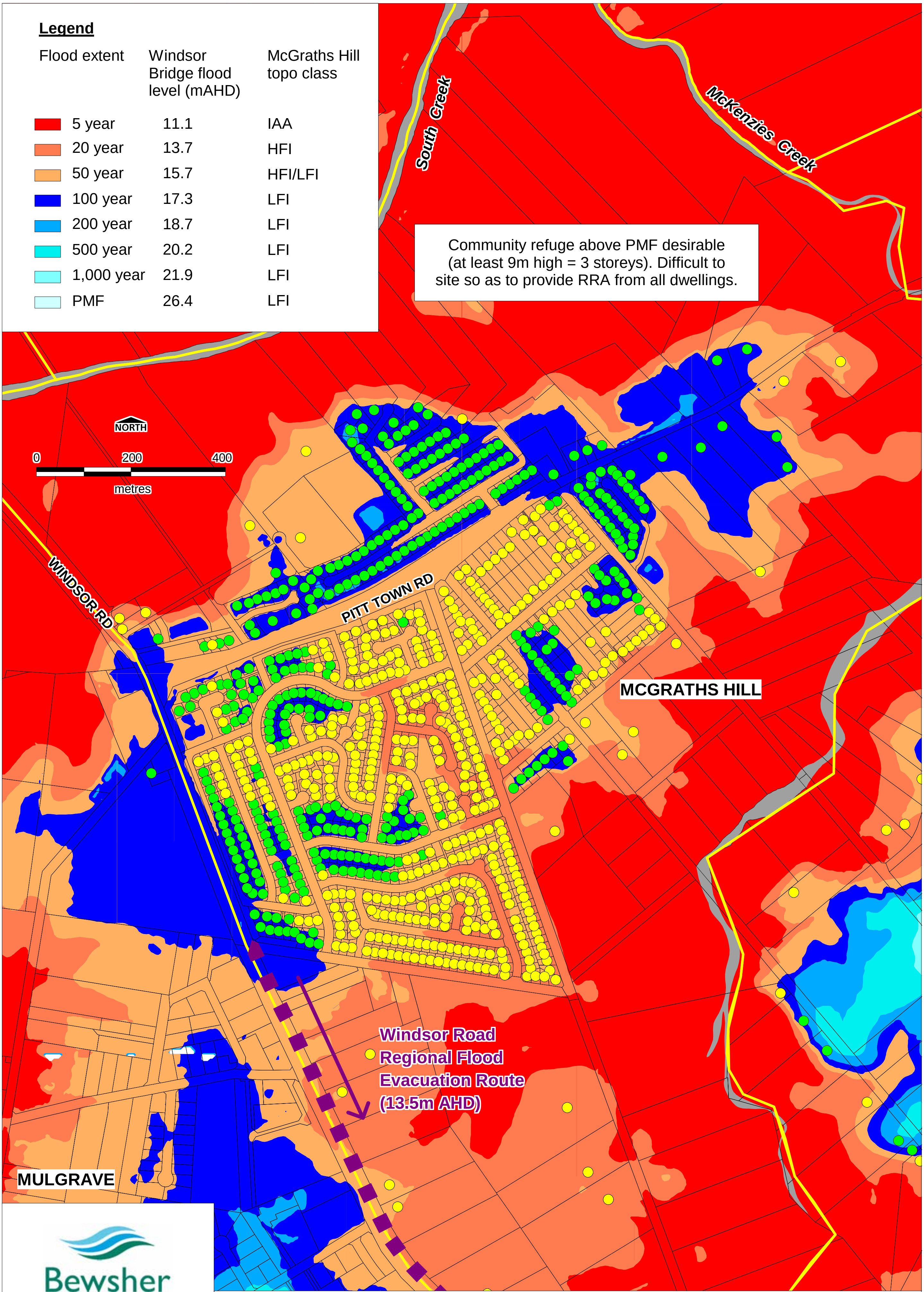
File: Flood_risk_considerations_leg.WOR
Date: 23 Jun 2010



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Date: 16 Jun 2011

FIGURE 5.4 - MCGRATHS HILL FLOOD RISK CONSIDERATIONS

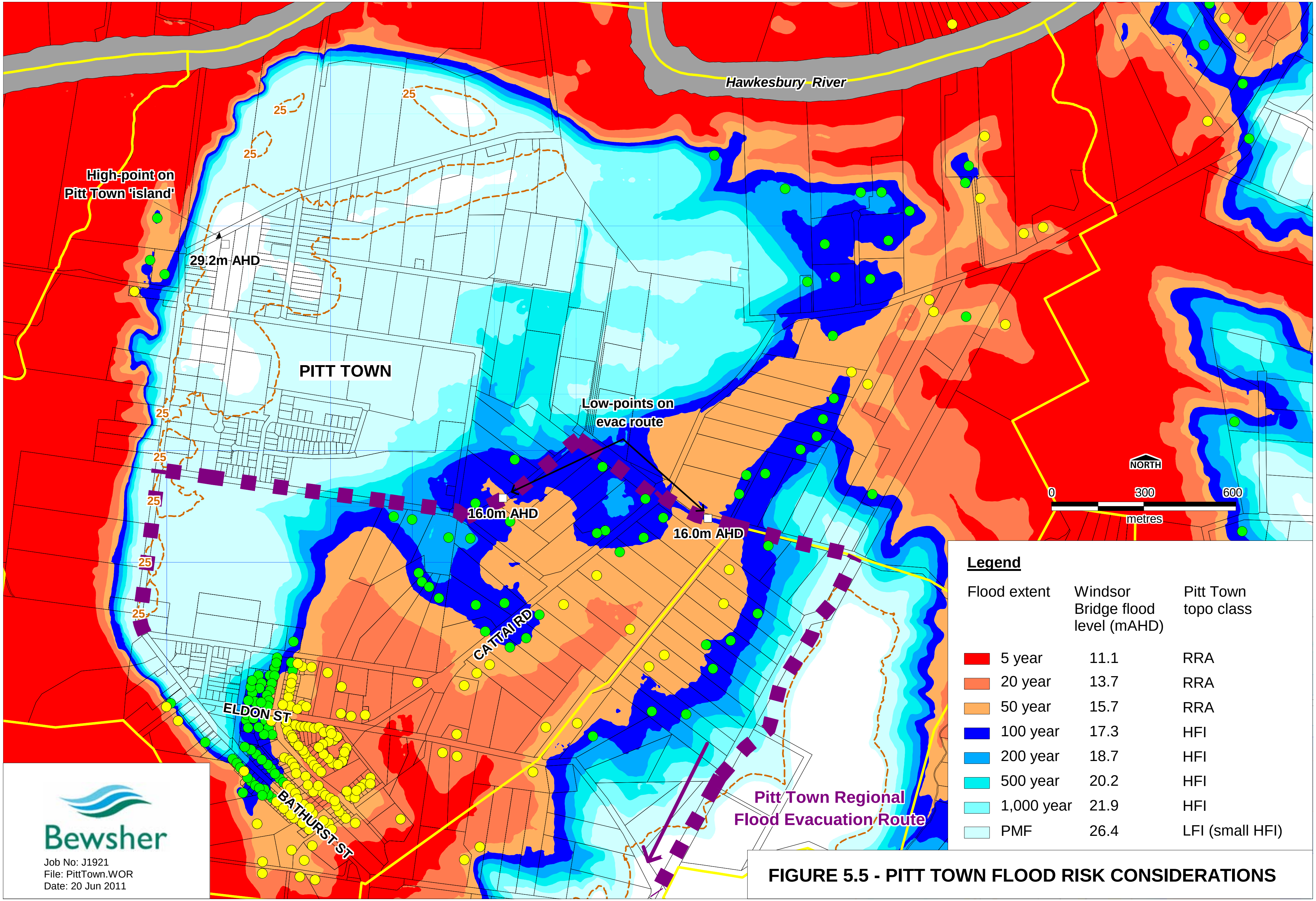


FIGURE 5.5 - PITT TOWN FLOOD RISK CONSIDERATIONS

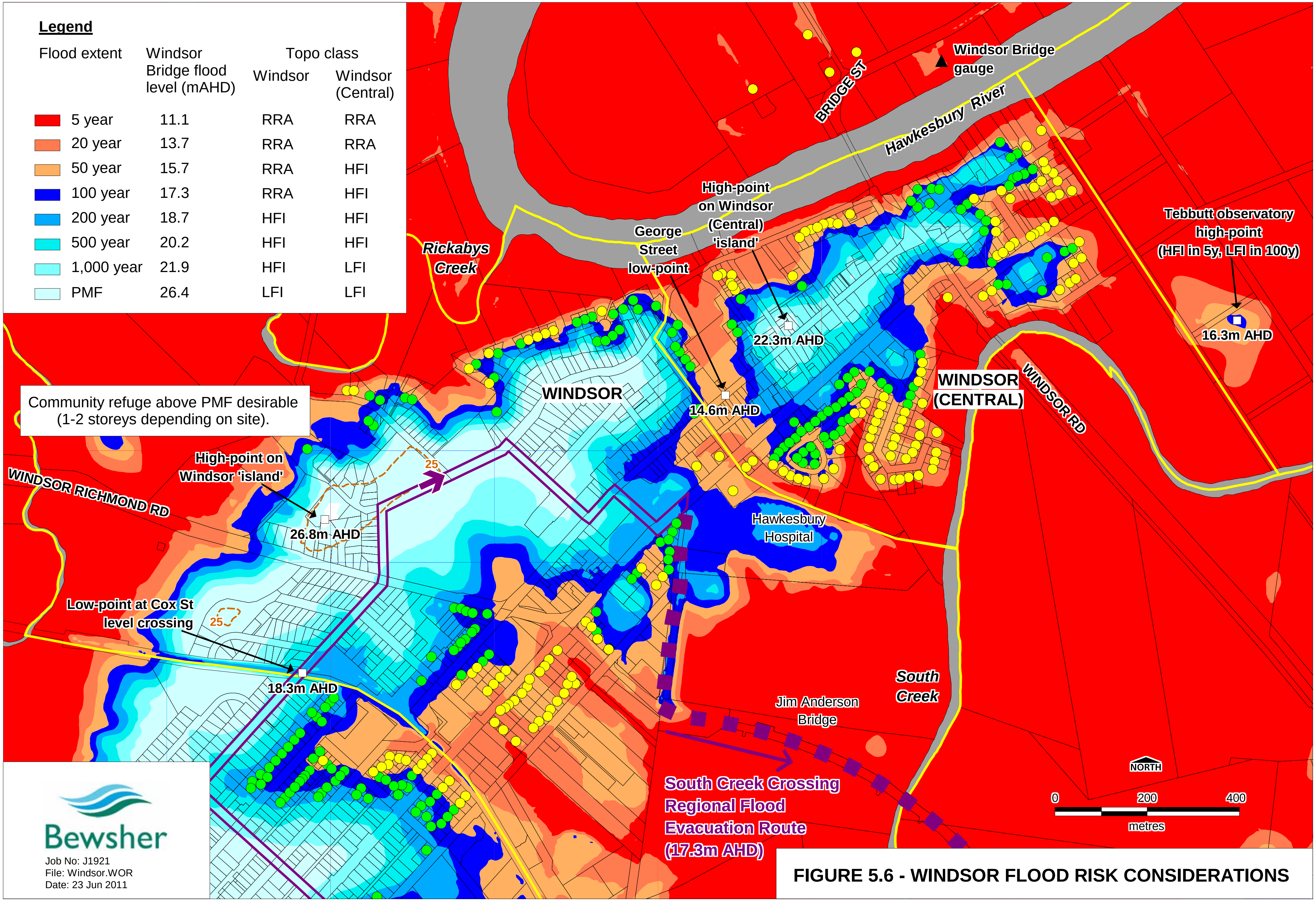


FIGURE 5.6 - WINDSOR FLOOD RISK CONSIDERATIONS

encourage community refuges with floor space above the PMF on one or more of these 'islands', as a life-saving measure should people fail to evacuate in time (see **Section 6.6.4**).

5.4.4 South Windsor

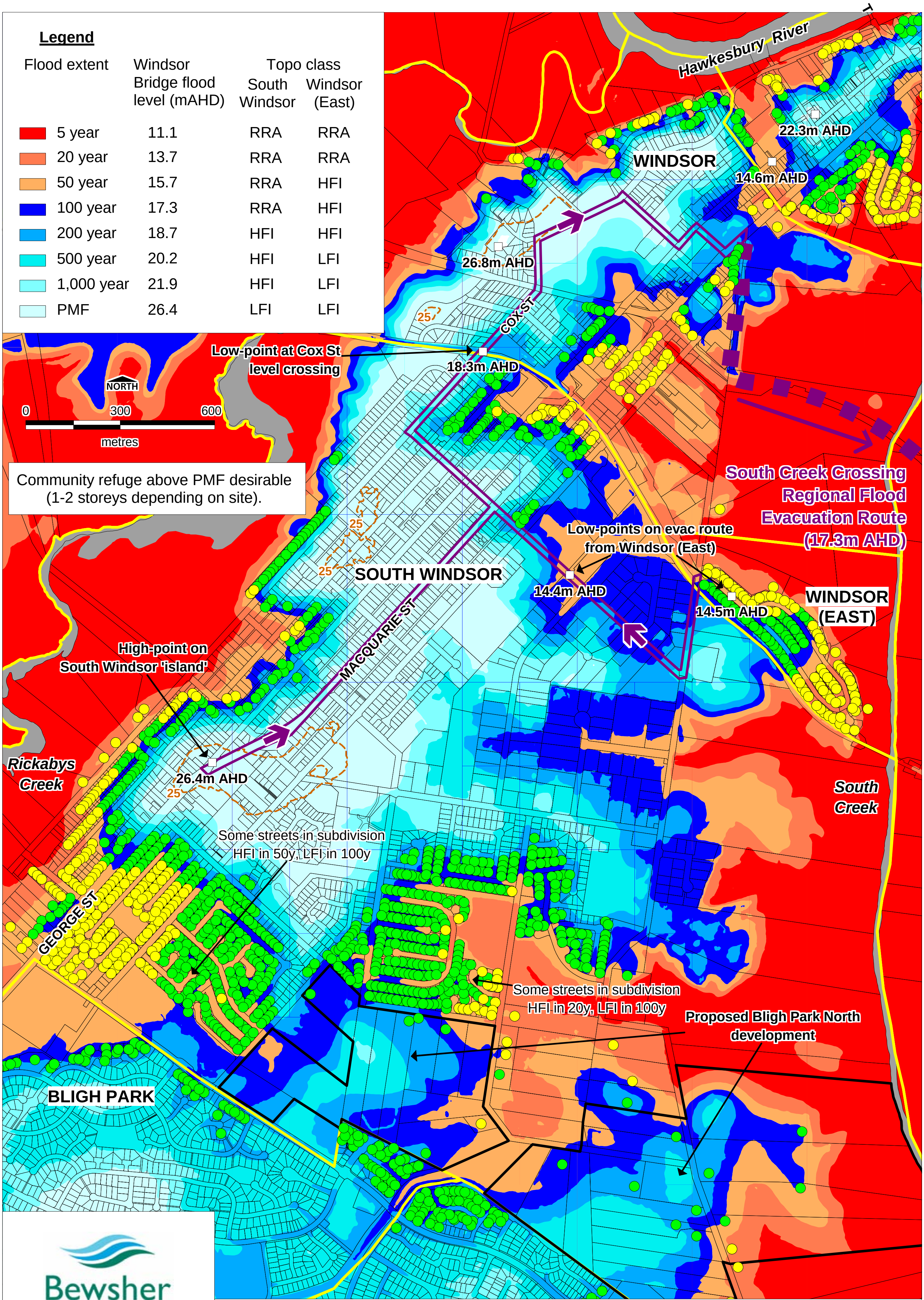
Flood risk considerations for South Windsor (population ~5,600) are summarised in **Figure 5.7**. South Windsor contains a very large number of dwellings which are progressively inundated in rarer floods, with up to 380 inundated in a 50 year event, 840 in a 100 year event and almost 2,400 in a PMF (**Table 4.3**). Evacuation is via the Windsor Flood Evacuation Route (South Creek Crossing). The main route to the start of the regional flood evacuation route is described in **Table 2.8** and marked on the figure. Egress by road from South Windsor will cease at 17.3m AHD when the regional route is cut near its entry. Road travel between South Windsor and Windsor will cease at about 18.3m AHD when the Cox Street level crossing is inundated. As noted on the figure, the Windsor (East) SES sub-sector will become isolated from the route that takes traffic to the start of the regional route at about 14.4m AHD. Some houses towards the south of the suburb will also become flood islands in the 20 year or 50 year events because their only road access will be inundated; these houses would be inundated in the 100 year flood. On a broader scale, the South Windsor 'island' would be entirely overwhelmed only in the PMF. The availability of land over 25m AHD suggests that the provision of community refuges where possible would be practical and of benefit for people who failed to evacuate in time (see **Section 6.6.4**).

5.4.5 Bligh Park

Flood risk considerations for Bligh Park (population ~6,500) are summarised in **Figure 5.8**. About 60 houses are inundated in the 100 year event, 440 in the 200 year flood, 1,400 in the 500 year event, and 2,000 in the 1,000 year flood (**Table 4.3**). Evacuation is via the recently upgraded Thorley Street flood evacuation route (which is cut by rising floodwaters at 18.5m AHD), and thence towards the south-east via the Richmond Road Regional Flood Evacuation Route (which is cut at South Creek at only 14.1m AHD) or towards the south via the Llandilo Road Regional Flood Evacuation Route (cut at 19.1m AHD). The figure shows that there are a number of road low-points within the suburb which influence the evacuation process, especially a 17.2m AHD low-point on Rifle Range Road on the sole egress route from the Bligh Park (East) SES sub-sector. Further, there is potential for flooding of important roads during significant local catchment storms, which, if coincident with Hawkesbury River flooding, would add to the evacuation problems (these are investigated in the *Bligh Park Evacuation Route Options Study* [Bewsher Consulting, 2011a]). In the Bligh Park (West) SES sub-sector, there is a substantial area above the 1,000 year ARI level. But the entire suburb would be overwhelmed in a PMF, although it might be possible to escape overland to an island within the Windsor Downs Nature Reserve. In Bligh Park, as for Windsor and South Windsor, there would be merit in providing a community refuge to which anyone who failed to evacuate in time could flee (see **Section 6.6.4**.

5.4.6 Windsor Downs

Flood risk considerations for Windsor Downs (population ~1,300) are summarised in **Figure 5.9**. Like Bligh Park, no houses are inundated in events up to and including the 50 year flood. About 30 are flooded in the 100 year event and almost 300 in the PMF (**Table 4.3**), though there is a sizeable area of land (~76 residential properties) above the PMF, which accounts for the High Flood Island topographic setting in that area. Evacuation is via the Richmond Road or Llandilo Road Regional Flood Evacuation Routes, with the latter cut at 19.1m AHD. About 35 dwellings would need to be evacuated before a 16.7m AHD low-point on Sanctuary Drive is cut. All those houses would be inundated in the 1,000 year flood, though there is a well-formed track into the Windsor Downs Nature Reserve which would provide refuge above the 1,000 year flood level. Another 35 dwellings would



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Date: 6 Jul 2011

FIGURE 5.7 - SOUTH WINDSOR FLOOD RISK CONSIDERATIONS

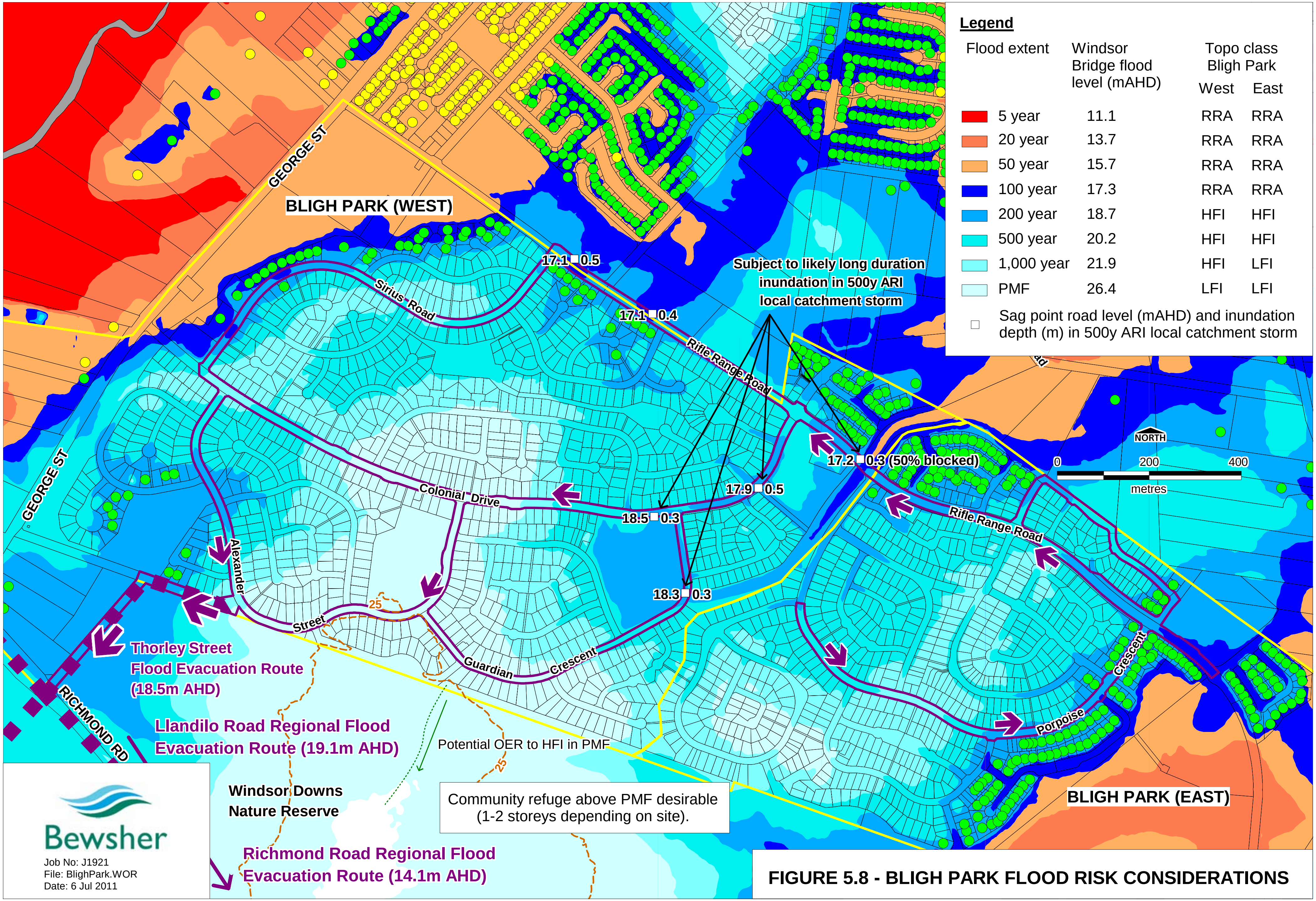
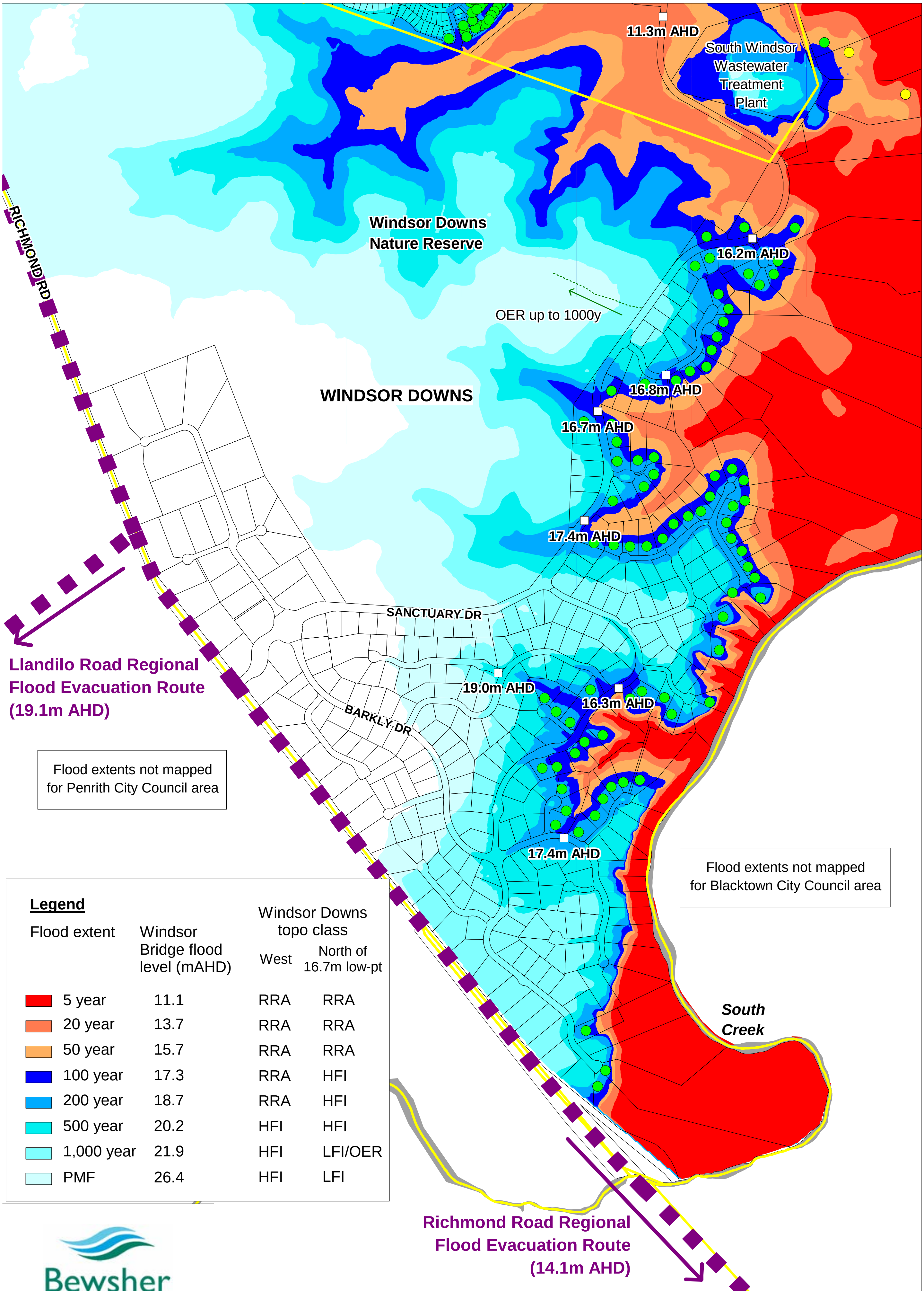


FIGURE 5.8 - BLIGH PARK FLOOD RISK CONSIDERATIONS



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Date: 4 Jul 2011

FIGURE 5.9 - WINDSOR DOWNS FLOOD RISK CONSIDERATIONS

need to be evacuated before a 17.4m AHD low-point on Barkly Drive is cut. Those dwellings would all be inundated in the 1,000 year flood.

5.4.7 Richmond

Flood risk considerations for Richmond (population ~4,400) are summarised in **Figure 5.10**. Houses are little affected in events up to and including the 100 year flood (**Table 4.3**), but over 300 houses are expected to be inundated in the 200 year flood, especially in the south-east between Paget Street and Bourke Street. As the entire Richmond and Richmond Lowlands sectors can be inundated during an extreme flood event, evacuation of all of these areas may need to occur. The highest ground level on the Richmond 'island' is 23.6 m AHD, which is some 6m above the 100 year flood level and 3m below the PMF level. Evacuation will occur either via Londonderry Road (low-point 18.0m AHD) or Castlereagh Road (low-point 20.2m AHD) (see **Table 2.5** for a full description). There is a low-point of 19.3m AHD on Windsor Street, which will prevent any late road evacuations from east of that point (including the Richmond RAAF SES sub-sector) and prevent any road evacuations from west of that point to the highest part of the remaining 'island'. Nevertheless, there appears to be benefit in providing a community refuge to which anyone who failed to evacuate in time could flee (see **Section 6.6.4**).

It is noted that evacuation traffic travelling south towards Penrith on the Northern Road can potentially conflict with evacuees from the floodplains within the Penrith LGA (e.g. Waterside Green). This could result in considerable queuing times which whilst inconvenient, would occur in areas above the limit of floodwaters and therefore does not directly represent a risk to life from drowning.

5.4.8 Hobartville

Flood risk considerations for Hobartville (population ~2,500) are summarised in **Figure 5.11**. A few houses are inundated in the 200 year flood in the eastern corner of the suburb, rising to over 1,000 houses in the PMF (**Table 4.3**). About 100 houses would be free of inundation in the 1,000 year flood, but the entire suburb would be overwhelmed in a PMF. Evacuation will occur either via Londonderry Road (low-point 18.0m AHD) or Castlereagh Road (low-point 20.2m AHD) (see **Table 2.5** for a full description). The figure shows that there are some road low-points within the suburb which influence the evacuation process. Further, there is potential for flooding of roads during significant local catchment storms, which, if coincident with Hawkesbury River flooding, would add to the evacuation problems (these are investigated in the *Hobartville Evacuation Route Options Study* [Bewsher Consulting, 2011b]). The map shows that there is a substantial area above 25.0m AHD, and small 'islands' above the PMF, within the Yarramundi Paddocks which form part of the University of Western Sydney's Hawkesbury campus. Possibly this area could house a community refuge to which anyone who failed to evacuate in time could flee (see **Section 6.6.4**).

5.4.9 North Richmond

Flood risk considerations for North Richmond (population ~4,400) are summarised in **Figure 5.12**. Whilst few dwellings are inundated in events up to and including the 100 year flood, over 100 are affected in the 200 year event, and over 600 in the PMF (**Table 4.3**). A large area in the suburb is not inundated in the PMF. Evacuation from North Richmond is via Bells Line of Road (low-point of 17.7m AHD at Redbank Creek) or Grose Vale Road (then Old Bells Line of Road through Kurrajong to Bells Line of Road), with the latter providing Rising Road Access for all Hawkesbury flood events. Terrace Road is cut near Redbank Creek in very frequent events.

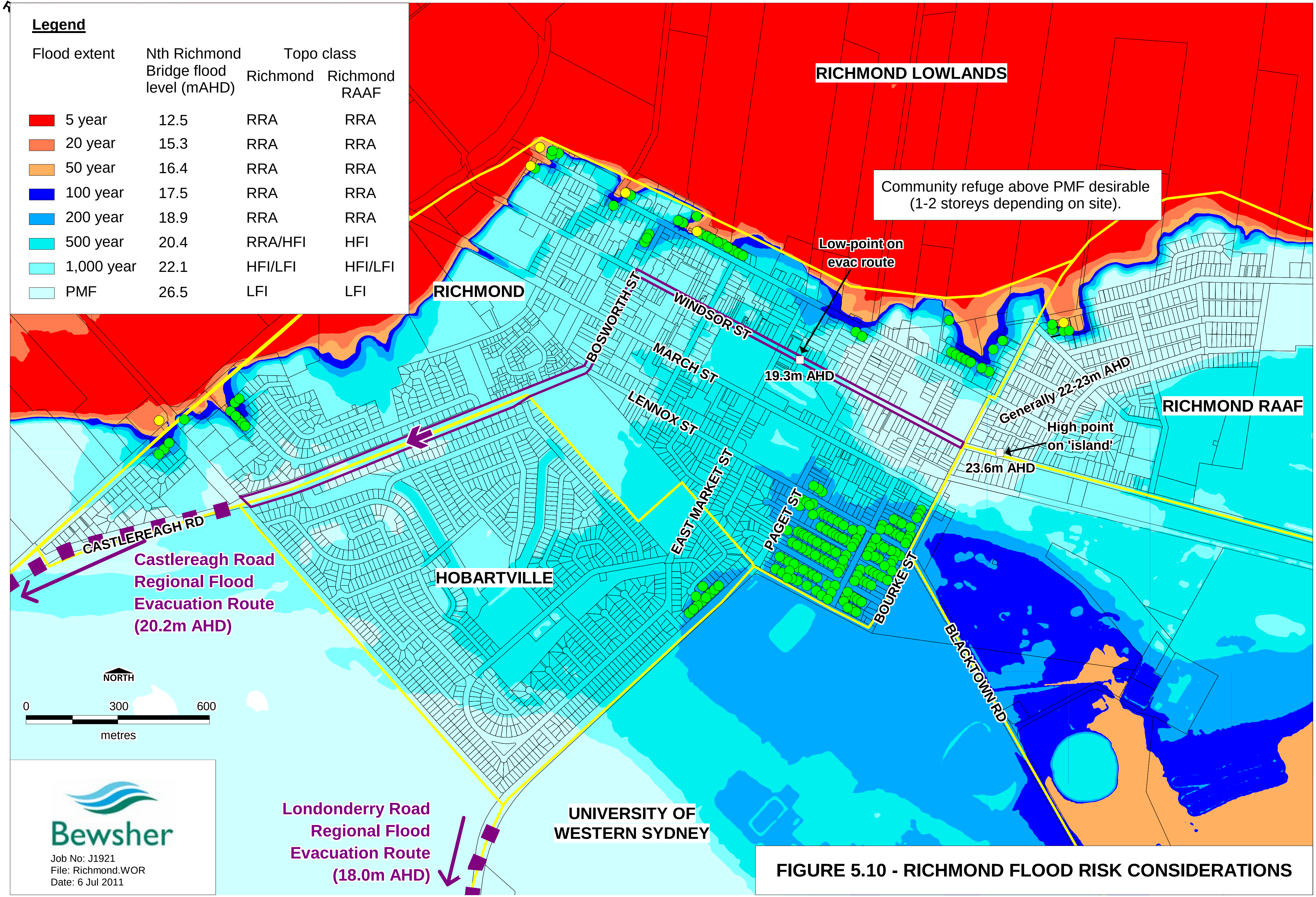


FIGURE 5.10 - RICHMOND FLOOD RISK CONSIDERATIONS

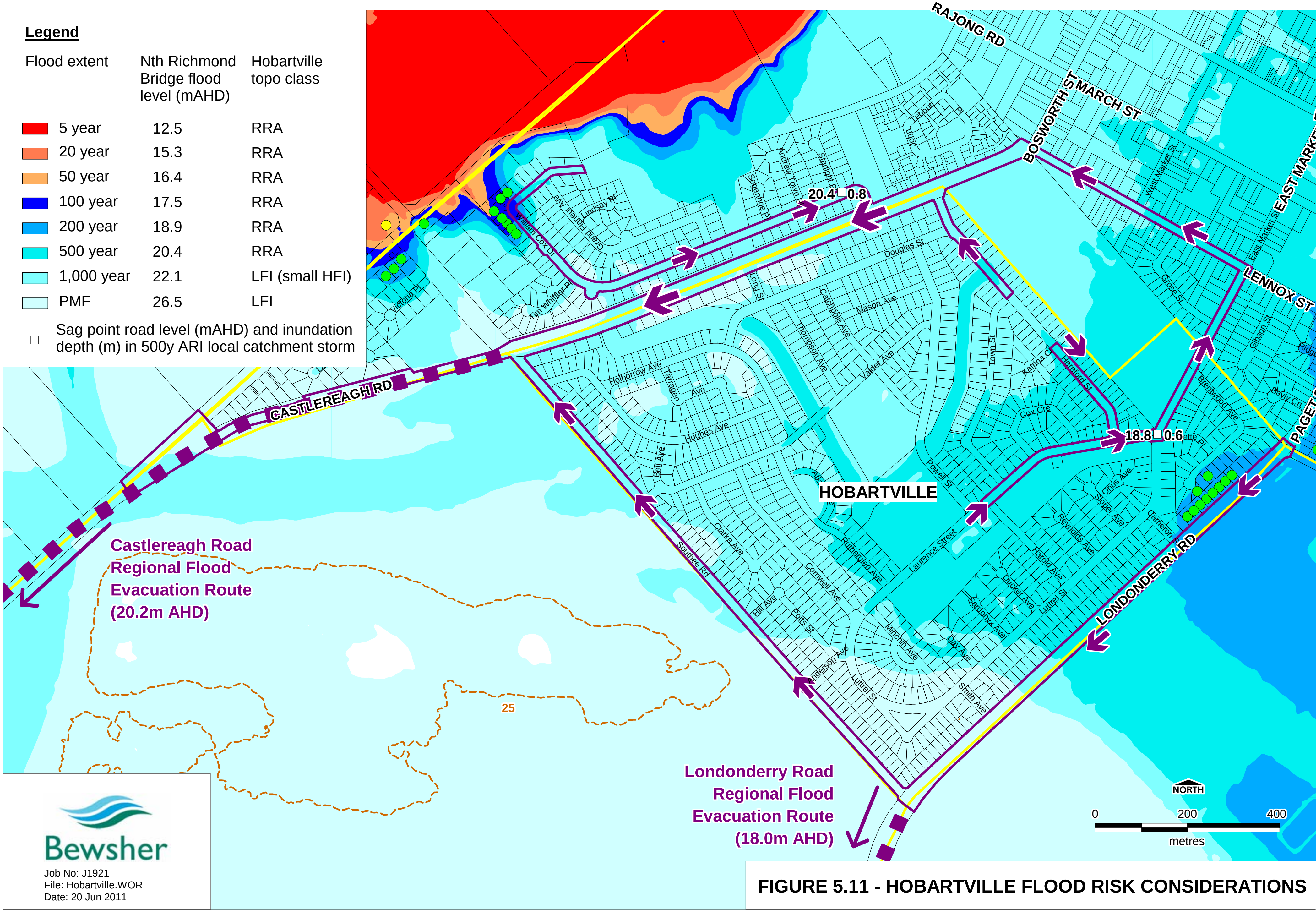
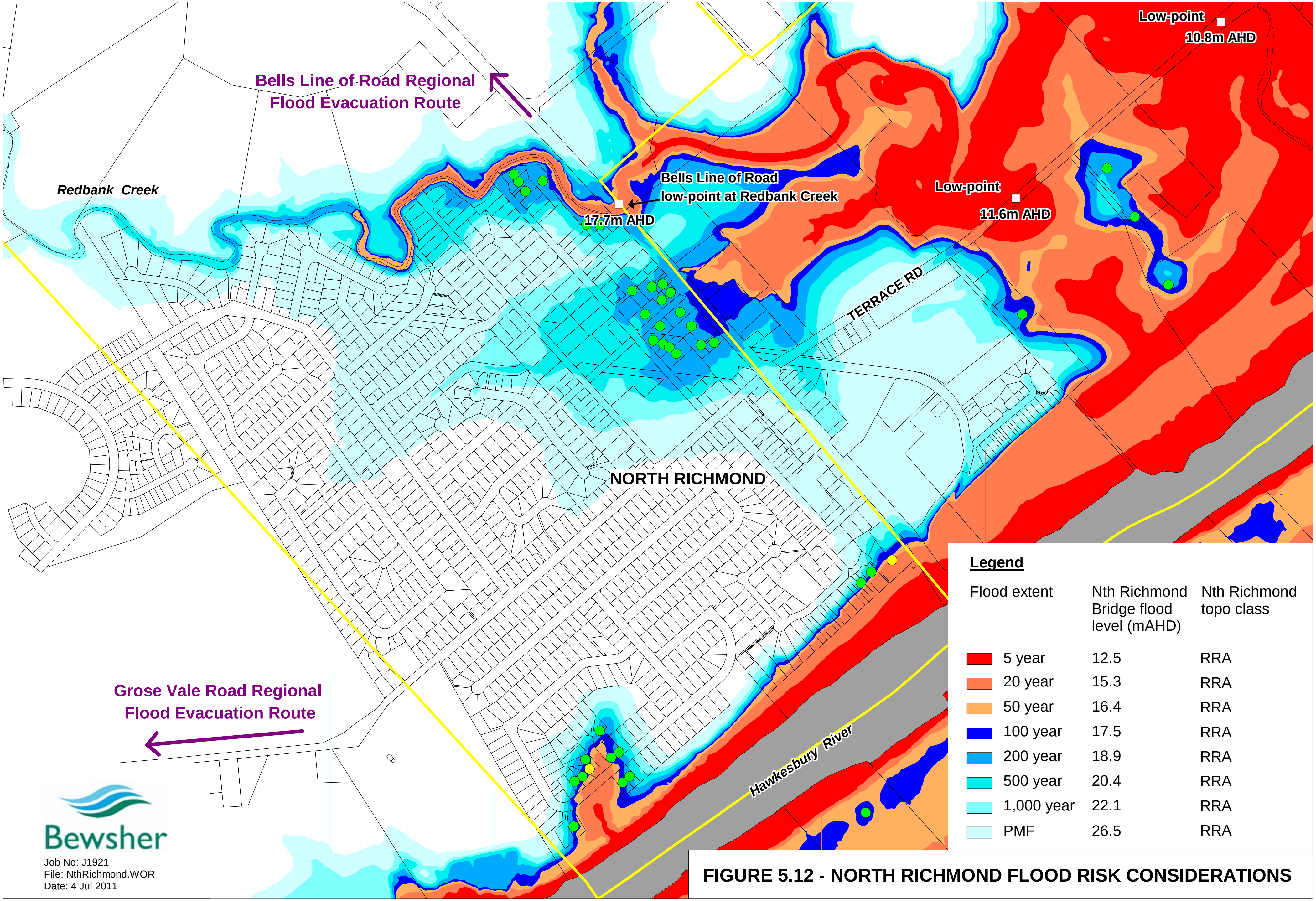


FIGURE 5.11 - HOBARTVILLE FLOOD RISK CONSIDERATIONS



Legend

Flood extent	Nth Richmond Bridge flood level (mAHD)	Nth Richmond topo class
5 year	12.5	RRA
20 year	15.3	RRA
50 year	16.4	RRA
100 year	17.5	RRA
200 year	18.9	RRA
500 year	20.4	RRA
1,000 year	22.1	RRA
PMF	26.5	RRA

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File: NthRichmond.WOR
Date: 4 Jul 2011

FIGURE 5.12 - NORTH RICHMOND FLOOD RISK CONSIDERATIONS

5.4.10 Wilberforce

Flood risk considerations for Wilberforce (population ~3,000) are summarised in **Figure 5.13**. Much of Wilberforce is located on higher ground above the reach of the PMF, but about 40 houses are expected to be flooded in the 20 year event, 120 in the 50 year event and 220 in the 100 year event (**Table 4.3**). **Figure 5.14c** shows inundation of two houses in the August 1990 flood (13.5m AHD). Wilberforce would be evacuated to the west via Kurmond Road and Bells Line of Road, which is not expected to be cut by floodwater even in extreme events. Some areas would be isolated in frequent events however, including properties in Pitt Town Ferry Road trapped by a 9.6m AHD low-point, properties in Rose Street south of a 13.4m AHD low-point in Wilberforce Road, and properties in Earl Street south of a 13.9m AHD low-point.

5.4.11 Other Areas

Of the other areas, more than 100 dwellings are subject to inundation in the PMF in Vineyard, Oakville, Agnes Banks, Lower Macdonald and Ebenezer (**Table 4.3**). Other settlements are subject to isolation.

5.4.11.1 Vineyard

About 40 houses in Vineyard would be inundated from Hawkesbury River flooding in the 50 year event, and 110 in the 200 year event (**Table 4.3**), particularly as floodwaters back up Killarney Chain of Ponds. The suburb is traversed by two Regional Flood Evacuation Routes – the Windsor Route which follows Railway Road South and Wallace Road, and the Windsor Road Route. Hence evacuation is considered relatively straight-forward.

5.4.11.2 Oakville

Despite its larger lot sizes, Oakville has over 50 properties subject to flooding in the 50 year event, and 100 properties in the 200 year event (**Table 4.3**). Rising road access to the east appears to be generally available.

5.4.11.3 Agnes Banks

Almost 30 properties in Agnes Banks would be inundated in a 50 year flood, and over 150 in a PMF (**Table 4.3**). The village is located close to the Castlereagh Regional Flood Evacuation Route. Evacuating residents would join the route by travelling north along Castlereagh Road or east along Bonner Street to The Driftway.

5.4.11.4 Lower Macdonald

Lower Macdonald has a significant number of properties flooded in the 100 year event (**Table 4.3**) and very probably, in more frequent events given the setting of the dwellings in narrow valley floors. There is some access to high ground locally. However, vehicular egress from the area is via a low level road which generally follows the Macdonald River along the floor of the valley. Unless these properties are evacuated *very* early in a flood, they become isolated with no means of retreat from the floodwaters other than climbing the valley sides or using local fire trails which might be accessible to a few properties.

5.4.11.5 Ebenezer

Ebenezer has several low-lying properties – especially in Coromandel Road – that are flooded in frequent events (see **Table 4.3**). Rising road access to land above the PMF is readily available. However, the population of Ebenezer can be isolated by a major flood.

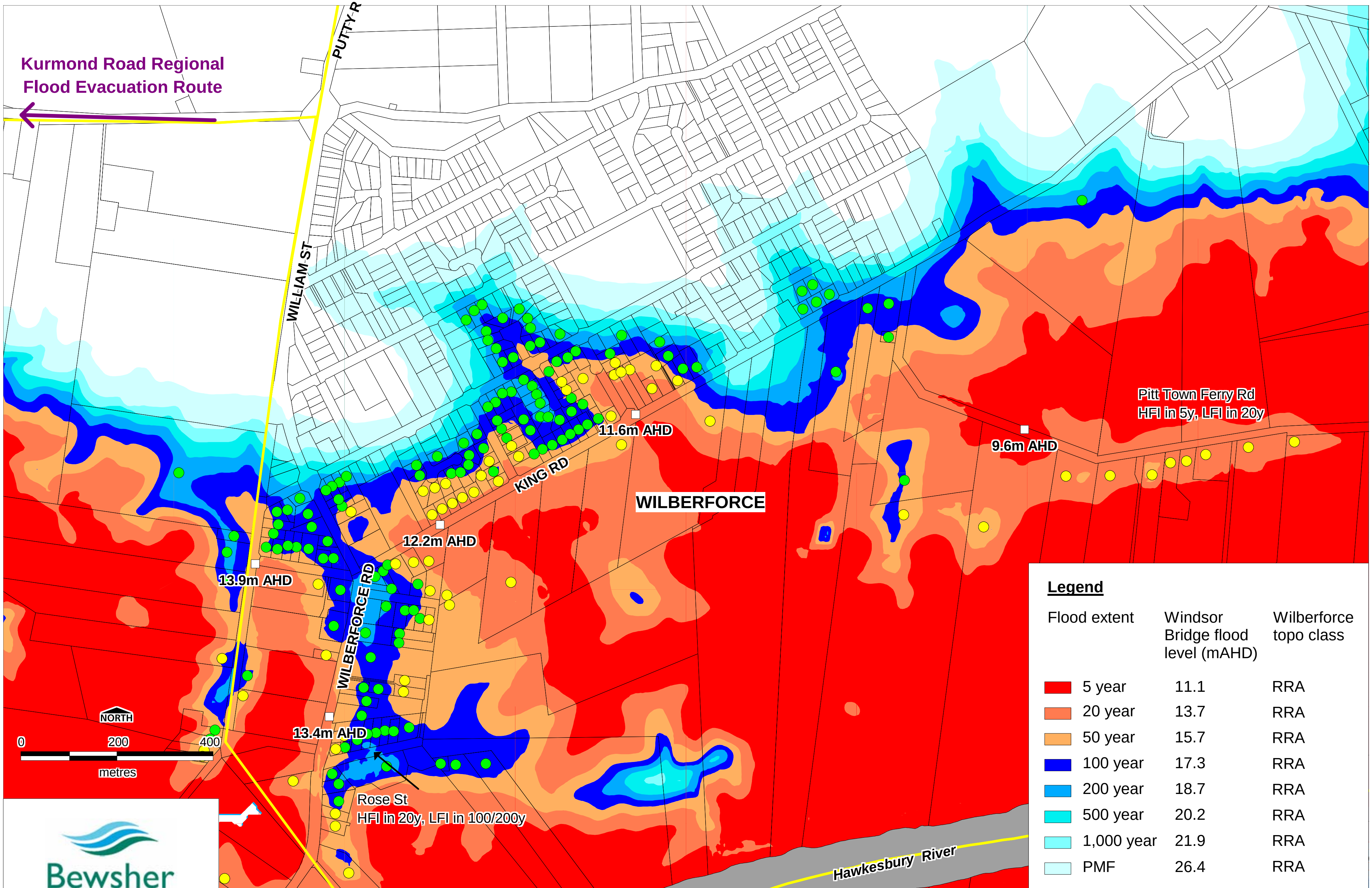

FIGURE 5.13 - WILBERFORCE FLOOD RISK CONSIDERATIONS

a. Inundation of Mawson Place, **Pitt Town**, in August 1990 flood

Source: Neil Duffy, Molino Stewart

b. 'The Peninsula' (Tebbutt observatory), **Windsor**, has become a flood island in the July 1988 flood

Source: Council

c. Houses in King Street, **Wilberforce**, in August 1990 flood

Source: Council

FIGURE 5.14 – Historic Flood Photos

The primary exit route south along Sackville Road will be cut at Chain of Ponds Creek when water levels in the river reach 15.5m AHD.

5.4.11.6 Yarramundi

Few properties in Yarramundi would be inundated even in a PMF. However, Yarramundi Bridge over the Hawkesbury River is cut at very low levels, and Springwood Road is also cut, isolating the entire population by a flood smaller than a 100 year event. The entire population would be expected to evacuate southwest along Springwood Road and then west along Hawkesbury Road.

Springwood Road would be cut in three places by floods smaller than the 100 year event. The road would initially be cut in the north when water levels reach 15.1m AHD in Mahons Creek. Most of the population is located south of this cut-off location. Evacuation streams heading south towards Hawkesbury Road would take place until flood waters backed up Lynchs Creek, cutting off this route at 15.5m AHD. This would effectively isolate most of the Yarramundi population. A small proportion of the population residing to the south of this area could continue evacuating along Springwood Road until flooding backed up Shaws Creek at 19.5m AHD.

5.5 CONSIDERING EVACUATION CONSTRAINTS IN PLANNING APPROVALS

5.5.1 Making Evacuation Constraint Advice Available to the Planning Process

Planners and consent authorities must deal with a range of considerations when assessing the suitability of potential developments. This may occur at the strategic planning stage, when considering proposed rezonings and when evaluating matters that are the subject of development approvals under the NSW EP&A Act. These considerations are very broad and include social, economic and environmental matters as well as those listed under Section 79C of the EP&A Act. Of all these considerations, flood risk is but one.

When floodplain risk management studies (FRMSs) and floodplain risk management plans (FRMPs) are developed such as those currently in preparation for Hawkesbury a significant amount of flood related information becomes available for specific areas in a floodplain. Much of this information is valuable to the planning process. The challenge presented to those preparing FRMSs and FRMPs however is to convey the relevant information to planners and consent authorities in a manner that can be clearly understood and applied by them. Traditionally this has occurred through the preparation of maps and/or classification of land according to its flood hazard[38] or hydraulic category[39]. However when providing advice on flood evacuation constraints, mapping or the existing classification systems are not particularly useful. Maps may be of only limited assistance as evacuation constraints are often related to the components of the proposed development (including its proposed population) and therefore they are not unique to land parcels. That is, the actual scale of development that may be proposed and its exact location can vary across land within the same or similar zoning.

More importantly, when providing advice to the planning process, there is a gradation in the level of advice that could be provided. In extreme situations where the evacuation constraint is so severe that the development is inappropriate because the potential personal safety risks are considered intolerable and unacceptable, this needs to be clearly conveyed.

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[38] Under the *Floodplain Development Manual*, 'low hazard' and 'high hazard' classifications are often prepared for land subject to a specific design flood (e.g. 100 year ARI).
[39] Under the *Floodplain Development Manual*, three hydraulic classifications are typically used – 'floodway', 'flood fringe' and 'flood storage'.

However in less constrained situations, significant safety risks may still exist that need to be conveyed as a relevant consideration within the planning process. Serious evacuation constraints, whilst when viewed in isolation are not in themselves 'fatal' to the development proposal, may, when assessed in conjunction with a range of other planning considerations, be sufficient for rejection of the development proposal by the planning process.

In order to provide the planning process with appropriate advice on evacuation safety risks, the classification system described in the following section has been developed.

5.5.2 Classification of Advice on Evacuation Risk

The advice to be provided to planners and the consent authorities has been graded into four classes as set out in **Table 5.5**. This advice relates to the development proposal including any mitigation measures that have been incorporated to minimise evacuation risks within the floodplain.

TABLE 5.5 − Advice to Planning Process on Evacuation Risk Considerations

Class A	**Risks are Minor – Limited Consideration is Required** Whilst potential for inundation and/or isolation exists, there are no significant evacuation constraints.
Class B	**Risks are Moderate – Detailed Consideration is Required** Evacuation constraints exist although in most situations these are not so severe as to significantly influence the planning decision.
Class C	**Risks are Serious – Very Detailed Consideration is Required** Serious evacuation risks exist. These may be close to the limit of community acceptance. Careful consideration of these risks must be undertaken when evaluating the appropriateness of the development having regard to all social, economic and environmental issues.
Class D	**Risks are Intolerable/Unacceptable – Development Should Not Proceed** Evacuation risks are so serious that irrespective of other considerations, the development should not proceed.

The four classes of advice range from *Class A*, where the evacuation risks are so minor or insignificant to require no detailed consideration, through to *Class D*, where the evacuation risks are so severe that they are considered intolerable and unacceptable to the community. A consequence of the *Class D* classification is that irrespective of other planning considerations, the development proposal should not proceed.

Class B and *Class C* are intermediate classifications where detailed consideration of the evacuation risks needs to be made by planners and consent authorities. Under *Class B*, whilst the evacuation constraints need to be considered in the planning process, in most situations it is likely that these evacuation risks will only be of moderate importance in determining the overall appropriateness of the development proposal. The *Class C* classification however indicates that serious evacuation risks exist which will require very detailed consideration in the planning process and it is likely that in many situations developments with these classifications will be considered inappropriate in the planning process. Certainly if other unconstrained land is available and suitable for development, development proposals with these *Class C* risks should not normally proceed.

5.5.3 Determining the Evacuation Risk Advice to be Provided

A range of factors influence the evacuation risk advice to be provided to the planning process. These factors are dependent not only on the flood characteristics of the site but also the nature of the proposed development including the demographics of its occupants. These factors are discussed below.

5.5.3.1 Proposed Land Use and Demographic Characteristics of Occupants

Some land uses such as recreational and non-urban, generally have much lower susceptibility to flooding and lower safety risks than other types of development, e.g. residential. It is also important to consider the characteristics of the people who will occupy or use the proposed development. For example evacuating a nursing home will be a considerably more difficult task, take much longer, could potentially require significantly greater resources and may be more detrimental to the occupants than evacuating the same number of people from standard housing.

5.5.3.2 Access to Evacuation Facility including Time Available/Required to Evacuate

It is normal practice when considering evacuation risks in evacuation constrained areas, to carry out an evacuation capability assessment (ECA). This type of assessment makes use of ‘timeline procedures‘ (Opper et al., 2009) and calculates the time required to achieve evacuation and compares it with the time available (after making allowance for mobilisation time, flood warning time, vehicle travel times, times at which road access becomes cut, etc).

The ECA attempts to estimate the time constraints involved in implementing an SES evacuation plan which has the objective of moving residents out of the floodplain to an evacuation centre[40].

When the area being evacuated becomes overwhelmed or the access route becomes cut by floodwaters, the time available for evacuation is limited. When the time required for evacuation is less than the time available, the ECA predicts that it is possible for all evacuees to reach the evacuation centre. The extra time is referred to as the safety factor.

When a deficit in time exists, not all evacuees will be able to reach the evacuation centre and a rescue will be required.

The prediction of both the time required for evacuation and the time available, is particularly complex and of necessity the ECA must make a number of assumptions concerning key parameters, for example the time required for warning, vehicle travel times, the community’s acceptance of evacuation directions, etc. These assumptions are usually conservative noting the potential impediments to successful evacuation which occur in real emergencies. Due to the numerous assumptions and the number of potential ‘unknowns’, there is a considerable uncertainty in predictions made using timeline procedures in an ECA. Whilst they represent the best available science, the potential for unpredictable meteorological and human behaviour is very real.

Consequently even if the ECA predicts that an adequate safety factor is available for evacuation to be completed, the possibility that a number of residents will remain behind (either voluntarily or as a result of their inability to evacuate) is very real and therefore other measures to provide for their safety need to be considered.

[40] The SES recognises that wherever possible, it is preferable for evacuees to find shelter with family and friends outside the floodplain rather than travel to an evacuation centre. Nevertheless the ECA is usually carried out assuming all evacuees travel to an evacuation centre. In the case of the Hawkesbury, the SES has assumed that all eastward bound evacuees will travel to an evacuation centre set up at the Homebush Bay Olympic Site.

5.5.3.3 Topographical Constraints

The topography within the floodplain and low points along the evacuation routes can create localised islands and close evacuation routes which will influence evacuation capability. As discussed in **Section 5.2.2**, the floodplain can be categorised into various topographical classes and these need to be considered when evaluating evacuation risks and emergency responses.

5.5.3.4 Availability of a Refuge above the Reach of Flood Waters

As discussed in **Section 5.2**, in most situations it is preferable for residents subject to potential inundation, to evacuate to areas beyond the floodplain prior to the onset of flooding. When for whatever reason this is not possible, and floodwaters overwhelm an inhabited area, the provision of an elevated refuge can provide a safe haven that prevents people from drowning. It may also provide an area above the reach of flood waters to which valuable goods, animals and personal memorabilia can be relocated.

There is some debate in the flood risk management profession as to whether the provision of an on-site refuge (i.e. within a dwelling) is appropriate as it may provide a disincentive for individuals to flee the floodplain. Nevertheless given the compelling evidence from numerous recent flood evacuations[41] that even when adequate time for evacuation exists, residents may not heed the evacuation advice given to them, it is imperative that wherever there is potential for land to be overwhelmed by floodwaters and people drowned, elevated refuges should be provided somewhere on the higher parts of low flood islands[42]. These would most appropriately be in the form of community refuges within public buildings or other private buildings such as shopping centres or gymnasiums (see **Section 6.6.4**).

5.5.3.5 Availability of Support Facilities within the Refuge

A critical issue encountered by people who take refuge in such facilities is the potential isolation. As listed in **Table 5.2**, isolation can be accompanied by additional safety risks to the occupants including the inability to reach medical assistance, lack of food, sanitation, potential for additional fire risks, trauma induced isolation, exposure to extremes of temperature, etc.

To some extent these isolation risks can be mitigated by the provision of adequate support facilities within the refuge. In some instances these support facilities might be comparable to those available at an evacuation centre. The scope of facilities that could potentially be provided is dependent on the scale of development involved. Such facilities need to ensure the health and safety of occupants for the likely duration of flood emergencies and must recognise the age, health, mobility, medical needs and the level of resilience of the occupants.

5.5.3.6 Summary of Advice to Planning Process

Having regard to the above considerations, the evacuation risk advice to be provided to the planning process for a range of development types is depicted in **Table 5.6**.

The advice provided in **Table 5.6** relates to the assessment of development applications. Nevertheless advice in relation to strategic planning and rezoning proposals can be inferred from **Table 5.6**.

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[41] Grafton 2001, Grafton 2009, Brisbane 2011.
[42] where practical to do so, whether within existing or proposed developments.

TABLE 5.6 – Determining the Classification of Evacuation Risk Advice to be provided to Planners and Consent Authorities

Refer to explanatory notes on next page. Refer **Table 5.5** for a description of the Evacuation Risk Advice depicted by the colour coding.

ACCESS TO EVACUATION FACILITY AS DETERMINED BY EVACUATION CAPABILITY ASSESSMENT (ECA)	FLOOD DURATION	REFUGE WITH SUPPORT FACILITIES AVAILABLE	REFUGE WITHOUT SUPPORT FACILITIES AVAILABLE	TOPO CLASS							RESIDENTIAL See Note (d)		COMMERCIAL & INDUSTRIAL	REC & NON URBAN	CONCESSIONAL DEVELOPMENT
				LFI	HFI	LTP	HTP	OER	RRA	IAA	Major Subdivision	New Development on Zoned Land			
Access likely to be Continuously Available. (Access between site and evacuation facility not cut by flood waters).	n.a.	n.a.	n.a.								Note (a)	Note (a)	Note (c)		
		n.a.	n.a.								Note (a)	Note (a)	Note (c)		
Access is Constrained. (Access will be cut during floods but the *ECA* indicates a *Safety Factor* exists).	n.a.	Yes	No										Note (c)		
		No	Yes									Note (a)			
		No	No								Note (b)	Note (b)	Note (b)	Note (b)	Note (b)
Access is Seriously Constrained. (Access will be cut during floods. A *Rescue* is indicated by the ECA).	Short	Yes	No												
		No	Yes												
		No	No										Note (b)	Note (b)	Note (b)
	Long	Yes	No												
		No	Yes												
		No	No										Note (b)	Note (b)	Note (b)

<u>Notes for Table 5.6:</u>

Access to Evacuation Facility:

1. Availability of this access would normally be determined by an evacuation capability assessment (ECA). The assessment is carried out using 'timeline procedures' (Opper et al., 2009) and it is assumed that the evacuation would likely be initiated and managed by the SES in accordance with the SES' local or regional emergency management plan.
2. The ECA usually assumes evacuation to a government evacuation centre and recognises that it is preferable for evacuees to seek shelter amongst relatives and friends outside the floodplain, in preference to attending an evacuation centre, wherever possible.
3. The ECA utilises various assumptions concerning warning time, mobilisation time, vehicle travel speeds, etc, and compares the time required for evacuation with the time available. Where a deficit exists, a *Rescue* is assumed. Where the available time available exceeds the time required, the difference in time is referred to as the *Safety Factor*.

Flood Duration:

1. Short duration floods would typically be flash floods (i.e. up to six hours to flood peak from start of rainfall). This might be adjusted subject to the demographics of the population being evacuated or sheltering on site. For example a shorter period may be appropriate for occupants of a nursing home (requiring frequent assistance) whilst a longer period may be appropriate for agricultural communities with experience and resilience in coping with flood isolation.

Topo Class:

1. The topographic classes referred to here are discussed in **Section 5.2.2** and **Figure 5.2**. They comprise:

LFI = Low Flood Island	HFI = High Flood Island	LTP = Low Trapped Perimeter	HTP = High Trapped Perimeter
OER = Overland Escape Route	RRA = Rising Road Access	IAA = Indirectly Affected Area	

2. ☐ Shading indicates that this topo class will likely apply to this combination of access and refuge conditions.

Refuge Available with/without Support Facilities:

1. Fail-safe access to a place of refuge above the reach of the probable maximum flood (PMF) either on or off site, is assumed.
2. If this is provided in a building or other structure it must be structurally sound and able to resist the buoyancy and debris loads imposed by floodwaters.
3. The access needs to be available at the critical inundation level (usually the level at which the main floor becomes inundated). The critical inundation level represents the likely highest flood level at which occupants who fail to heed evacuation warnings, or otherwise choose to remain on site, must flee to the place of refuge.
4. *Support Facilities*. These facilities are those necessary for health and safety during emergencies, having regard to the probability of the emergency occurring, the duration of use, the number of the people using the facility, and their needs. When the number of people likely to use the facility will exceed those residing in a single dwelling, the facility would normally need to provide for back-up power, water, sanitation, bedding, food and communications.

Concessional Development:

1. This comprises alterations and additions, or redevelopment that *significantly reduces the existing flood risk at the site*.

Note (a): This will be Class C if the probability and consequence of loss of services is high and likely to significantly influence the wellbeing of the residents.

Note (b): Assumes that loss of life is not expected in major flood events up to the PMF. If new development on a vacant site is proposed and loss of life is expected, then upgrade to Class D. If loss of life is expected in a redevelopment scenario, then the first priority should be voluntary purchase of the existing development.

Note (c): This will be Class B if the probability and consequence of loss of services is high and likely to significantly influence the viability of the enterprise.

Note (d): Critical and sensitive uses and facilities have not been shown in **Table 5.6**. Proposals for these types of land uses need to be treated more conservatively than residential proposals. However given the diverse nature of these types of land uses and their often complex considerations, determination of an Evacuation Risk Class will be dependent on many site-specific and use-specific issues.

For example an area such as a major city centre with access to substantial existing facilities and services and with high amenity due to proximity to the coast may be considered on most planning grounds to be a desirable location to accommodate projected demand for additional housing, except that it may be subject to flood evacuation risks. If these risks were identified as Class A then they would not preclude the progressing of the otherwise desired planning outcome, while if Class D then this would alone be a reason to discontinue consideration. If categorised as Class B or C then further investigations would be required to determine whether mitigation measures (such as a high level evacuation route or building design controls to allow for stranded people to congregate in a sufficient critical mass with access to facilities) would be acceptable, or whether the planning proposal should be abandoned.

Typical planning considerations that would be applied in evaluating land use planning options are summarised in **Table 5.7**. These considerations consequently coincide with the core elements of the merit based approach to flood risk management that is the foundation of the NSW Flood Prone Lands Policy.

TABLE 5.7 − Analysing Evacuation Class B or C Advice in the Planning Process[43]

Acceptability Factors	Proceed with Development with Mitigation Measures?	Do Not Proceed With Development?
Social	Is the risk at a level that the community would tolerate? Will the measures make it Class A?	Is the lost opportunity for providing housing able to be met elsewhere?
Economic	Is it at a level of cost that the community or individual development could afford?	Is the cost of providing housing elsewhere (including additional travelling times, need for new major infrastructure, etc) affordable?
Environmental	Do the consequent structures have no significant ecological or amenity impacts and are they compatible with the existing and planned character of an area?	How does it compare with the environmental impact and amenity opportunities of alternate potential locations for additional housing?

5.6 APPROPRIATENESS OF FUTURE GROWTH IN THE STUDY AREA

5.6.1 Development Proposals

A discussed in **Volume 2**, the State Government as part of its Metropolitan Development Program (MDP) has made plans for additional development to service Sydney's continued growth and expansion. In 2007 the then Department of Planning prepared the Northwest Subregion, Draft Subregional Strategy as a means of translating the Metropolitan Strategy to the local level. The Subregional Strategy has set a housing target of 5000 dwellings for the Hawkesbury LGA to be reached by 2031. This target is in addition to housing proposed in Vineyard within the North-West Growth Centre.

[43] The application of the assessment in this table to employment generating land uses (i.e. commercial and industrial development) would be dependent on whether such development predominantly served the resident population of a floodplain or an external population. If such development served a sufficiently sized external population that warranted a separate ECA assessment then the analysis would equally apply. However, this would be more relevant where major CBDs occupied the majority of the floodplain independent of residential accommodation, which would not likely be relevant to the Hawkesbury LGA.

.
The current MDP has identified Bligh Park Stage 2 with potential for about 800 lots. It is understood this development is currently 'stalled' at the gateway stage pending resolution of flood risk management issues relating to evacuation. Many of the other areas proposed for development in the LGA also have flood evacuation and other flood risk management constraints that need to be addressed before development can proceed.

A significant area of Pitt Town was approved by the Minister for Planning in July 2008 for urban development. The MDP shows that there is potential for an additional 893 dwellings in Pitt Town over the next 10 years. Evacuation from Pitt town is constrained but nevertheless the development was approved after detailed investigations of the flood evacuation risks.

Council has prepared a Residential Land Strategy to identify land capable of accommodating between 5000 and 6000 additional dwellings by 2031 primarily within existing urban areas such as those prescribed in the Subregional Strategy. Council's Strategy is based on the potential for future housing in and around existing centres which comprise:

- Richmond;
- North Richmond;
- Windsor;
- Wilberforce; and
- Glossodia.

The development of each of these areas is also subject to resolution of flood evacuation issues.

The current Floodplain Risk Management Study and Plan are therefore of vital importance to Council and the State Government in providing sound flood risk advice for these potential developments, and in particular, advice concerning each development's capacity for safe evacuation in times of flood.

5.6.2 Evacuation Risk Advice for Hawkesbury's Development Proposals

The consultant understands that if all of the proposed development areas were developed, Council would have little difficulty in meeting its dwelling targets. In other words, the State Government's targets could be met without developing all the proposed areas. Whilst flood evacuation is an important consideration, clearly the decisions about which areas are to be developed and in what order, will also be based on a range of other planning considerations which are beyond the scope of this study. The advice of this study relates only to flood risk and consequently should not be inferred as approving or rejecting any of the future development proposals which are decisions for the consent authorities based on many other considerations.

To assist Council and the State Government in making these development decisions, advice concerning the evacuation risks associated with each of the proposed development areas has been prepared using the principles discussed earlier in this chapter. Evacuation Risk Classes (ERCs) have been prepared consistent with the methodology presented in **Section 5.5** and **Table 5.6**. Application of the resulting ERCs in the planning process should be undertaken using **Tables 5.5 and 5.7**.

The ERCs for each of the proposed development areas are presented in **Tables 5.8** and **5.9** based on:

- evacuation capability assessments (ECAs) reported in **Appendices E** and **F**;
- development proposals described in detail in **Volume 2** and summarised briefly above in **Section 5.6.1**;

- two alternative limits of confident flood prediction (LCFP) of 9 hours and 15 hours – refer **Section 5.3.7**;
- topographic classifications and flood risk considerations presented in **Section 5.4**;
- future risk mitigation measures comprising the provision of dual outbound lanes on Jim Anderson Bridge and associated works proposed by Molino Stewart (2007), and the construction of community refuges (refer **Section 6.6.4**).

As discussed in **Section 5.3.7** based on advice from the Bureau of Meteorology it appears that an LCFP of at least 15 hours is appropriate in most situations when predicting flood heights at Windsor. This would suggest that the evacuation risk advice to be provided to consent authorities in relation to the new developments proposals previously discussed could be based on **Table 5.9** (LCFP of 15 hours) rather than **Table 5.8** (LCFP of hours). The most important implications of this would be that:

- *for future development in Richmond* over the next two decades, the evacuation risk advice would be Class B (i.e. 'moderate') rather than Class C (i.e. 'serious'); and

- *for future development in Windsor*, assuming dual outbound lanes on the Jim Anderson Bridge could be utilised during flood evacuations, then the evacuation risk advice could be immediately lowered from Class D (i.e. 'intolerable/unacceptable') to Class C (i.e. 'serious'), and once community flood refuges were provided, the evacuation risk advice could be further lowered to Class B (i.e. 'moderate'); and

- *for future development of Bligh Park Stage 2,* a Class B (i.e. 'moderate') would apply rather than Class D (i.e. intolerable/unacceptable').

During the course of the study, a number of discussions were held with the SES concerning the LCFP to be used when assessing new developments. The SES expressed reservations about using a LCFP of 15 hours for new developments as they believe a more conservative approach may be appropriate in some situations. Despite various requests however, clear written advice from the SES on this issue was not provided. Council's Committee considered this issue on a number of occasions and heard many points of view including those of the SES and the Bureau of Meteorology[44]. After weighing up the various views expressed, the Committee decided to proceed with a LCFP of 15 hours (i.e. use of on **Table 5.9** rather than **Table 5.8**).

[44] Refer to the Bureau's advice provided in **Appendix H** and reported in **Section 5.3.7**.

TABLE 5.8 – Evacuation Times (Hours) and ERCs based on LCFP = 9 Hours

INVESTIGATION AREAS	2010#	2010#	2031*
	One outbound lane on JAB	Two outbound lanes on JAB	Two outbound lanes on JAB plus other measures
Residential Land Strategy Areas			
Richmond	12.5	12.5	15.0
Windsor	15.0	8.7	11.5
N Richmond	6.1	6.1	6.9
Wilberforce	5.5	5.5	6.2
Glossodia	%	%	%
Windsor Downs/Bligh Pk	@	@	@
Metropolitan Development Program (MDP) Areas			
Bligh Park Stage 2	n.a.	n.a.	11.5
Pitt Town	5.2	5.2	8.4
Vineyard	n.a.	n.a.	n.a.

TABLE 5.9 – Evacuation Times (Hours) and ERCs based on LCFP = 15 Hours

INVESTIGATION AREAS	2010#	2010#	2031*
	One outbound lane on JAB	Two outbound lanes on JAB	Two outbound lanes on JAB plus other measures
Residential Land Strategy Areas			
Richmond	12.5	12.5	15.0
Windsor	15.0	8.7	11.5
N Richmond	6.1	6.1	6.9
Wilberforce	5.5	5.5	6.2
Glossodia	%	%	%
Windsor Downs/Bligh Pk	@	@	@
Metropolitan Development Program (MDP) Areas			
Bligh Park Stage 2	n.a.	n.a.	11.5
Pitt Town	5.2	5.2	8.4
Vineyard	n.a.	n.a.	n.a.

NOTES

- LCFP = Limit of Confident Flood Prediction. JAB = Jim Anderson Bridge
- Evacuation times for Richmond, Windsor, North Richmond, Windsor Downs and Bligh Park based assessments in **Appendices E** and **F**. Estimates for other areas derived from Table 7 of Molino Stewart (2011a). The time required for SES mobilisation is additional to the evacuation times quoted here.

@ ERCs for Windsor Downs and Bligh Park times have been inferred from the preliminary sub sector times in **Appendix F**.

% Inferred from Molino Stewart (2011a).

n.a. Not applicable as development not currently present.

The ERC assessment for the 2010 scenario is for infill only.

* The 2031 scenario includes for infill and additional dwellings under the Residential Land Strategy and the MDP (i.e. including for Bligh Park Stage 2). The 'other measures' for 2031 include the provision of community refuges as recommended in **Section 6.6.4**.

6. OPTIONS TO MITIGATE EXISTING FLOOD RISKS

6.1 BUILDING ON THE HNFMS

The normal practice when undertaking floodplain risk management studies in NSW is to consider a broad range of structural and non-structural options that can potentially mitigate flood risks to people and property within the study area. Guidance on the range of options to be considered and the methods of evaluation are presented in the *Floodplain Development Manual* (NSW Government, 2005). The types of options to be considered comprise those that modify the flood, modify the affected property or modify the community's responses to flooding.

This however is not a typical floodplain risk management study because unlike other studies carried out in NSW, this study is being prepared following an extensive regional floodplain risk management assessment that was carried out in 1997 under the guidance of the State Government, i.e. the Hawkesbury Nepean Floodplain Management Strategy (HNFMS).

Under the HNFMS a floodplain risk strategy was developed and implemented[45] at a regional scale. Regional works and measures resulting from the strategy included:

- regional flood evacuation route upgrades;
- guidance on land use planning including foreshadowing a methodology to identify and manage flood risk to property;
- guidance on subdivision design in flood prone areas;
- guidance on building in flood prone areas;
- preparation of a flood hazard definition tool;
- development of concepts from which a regional public awareness program could be prepared;
- plans to assist utility providers to design flood compatibility utilities and to prepare appropriate recovery plans; and
- improved flood forecasting and flood warning.

Given the extensive work already undertaken during the HNFMS, it was a key requirement of the brief for the current study to "*build on existing information rather than redoing work already completed*".

As discussed in **Section 2.3**, it is of particular note that large-scale regional flood mitigation works such as flood mitigation dams, river dredging and flow diversions have already been investigated by the community-based Hawkesbury Nepean Flood Management Advisory Committee (HNFMAC) that oversaw the preparation of the HNFMS. These options were rejected at the time based largely on the grounds of adverse environmental impacts. Further there is a clear statement in the current study brief that "*the study is not to reinvestigate these regional flood modification measures*".

Nevertheless it is the role of this study to investigate other floodplain management measures including both structural and non-structural management options that have been agreed with the Committee that is overseeing the current study during the meetings held during the first half of 2011. These options comprise:

- local flood modification measures involving:
    - o diversion of river flows via Currency Creek; and
    - o construction of levee around McGraths Hill;

[45] "Implemented" is used because it appears that the majority of the Strategy has been implemented. Some items are yet to be implemented or are in the process of being implemented, although it has not been possible during the course of the study to determine the precise implementation status of the Strategy.

- voluntary purchase;
- voluntary house raising;
- review of flood evacuation issues;
- community education to improve the community's awareness and response to the flood threat;
- consideration of flood insurance; and
- revisions to Council's planning controls to better manage flood risk.

All these options are discussed in detail in the remainder of this section except for the proposed revisions to Council's existing planning controls. This issue is of such importance that it has been documented separately in **Volume 2**.

6.2 LOCAL FLOOD MODIFICATION MEASURES

6.2.1 Currency Creek Floodway Diversion

Consideration of this option was requested by a member of Council's Committee and the option itself has been discussed at a number of the Committee's meetings.

The option involves lowering the level of the saddle at which the Hawkesbury River flows over into Chain of Ponds Creek which is a tributary of Currency Creek. The route that floodwaters might take is shown on **Figure 6.1**. Flows leave the Hawkesbury River from the York Reach about 3km downstream from Wilberforce and then re-enter the River approximately 10km downstream at Sackville. This is some 13km less than the 23km route via the River itself.

If the channel is of sufficient size, it can have capacity to carry a considerable volume of flood flows on a more direct route and in a more hydraulically efficient manner than provided by the existing river channel. This proposed flowpath currently acts as a floodway in major flood events somewhere between the 200 year and 500 year ARI flood events[46]. The route chosen is shown on **Figure 6.1** and has been optimised (to minimise excavation quantities) using the recent topographical data acquired by for Council (based on airborne laser scanning techniques). Although the route has been chosen to minimise the quantity of excavation involved, as can be seen from **Figure 6.2**, many metres of excavation below the saddle height will be required. The deeper and wider the excavated channel is constructed, the greater will be its capacity to carry additional floodwaters.

The option has received some consideration in (WMA, 1997) including an hydraulic assessment. Based on a 160m wide channel it was determined that flood levels in the vicinity of Windsor would reduce by about 0.8m during a 100 year ARI flood and about 1.0m in a 500 year ARI event. This is a considerable reduction in flood levels and based on the methodology discussed in **Section 4.2** and **4.3**, it has been determined that the net present value of flood damage savings resulting from implementation of the channel would be $35 million based on savings to residential property alone. After allowance for the potential damage reduction to other land uses including commercial and industrial uses, the total economic benefit resulting from WMA's scheme is likely to be about $45 million.

[46] The existing saddle has a level of about 19mAHD and therefore once the River levels exceeds this height a natural flow diversion will commence. The route that flows take can be seen on Figures A.7a, A.8a and A.9a in Appendix A of **Volume 3**.

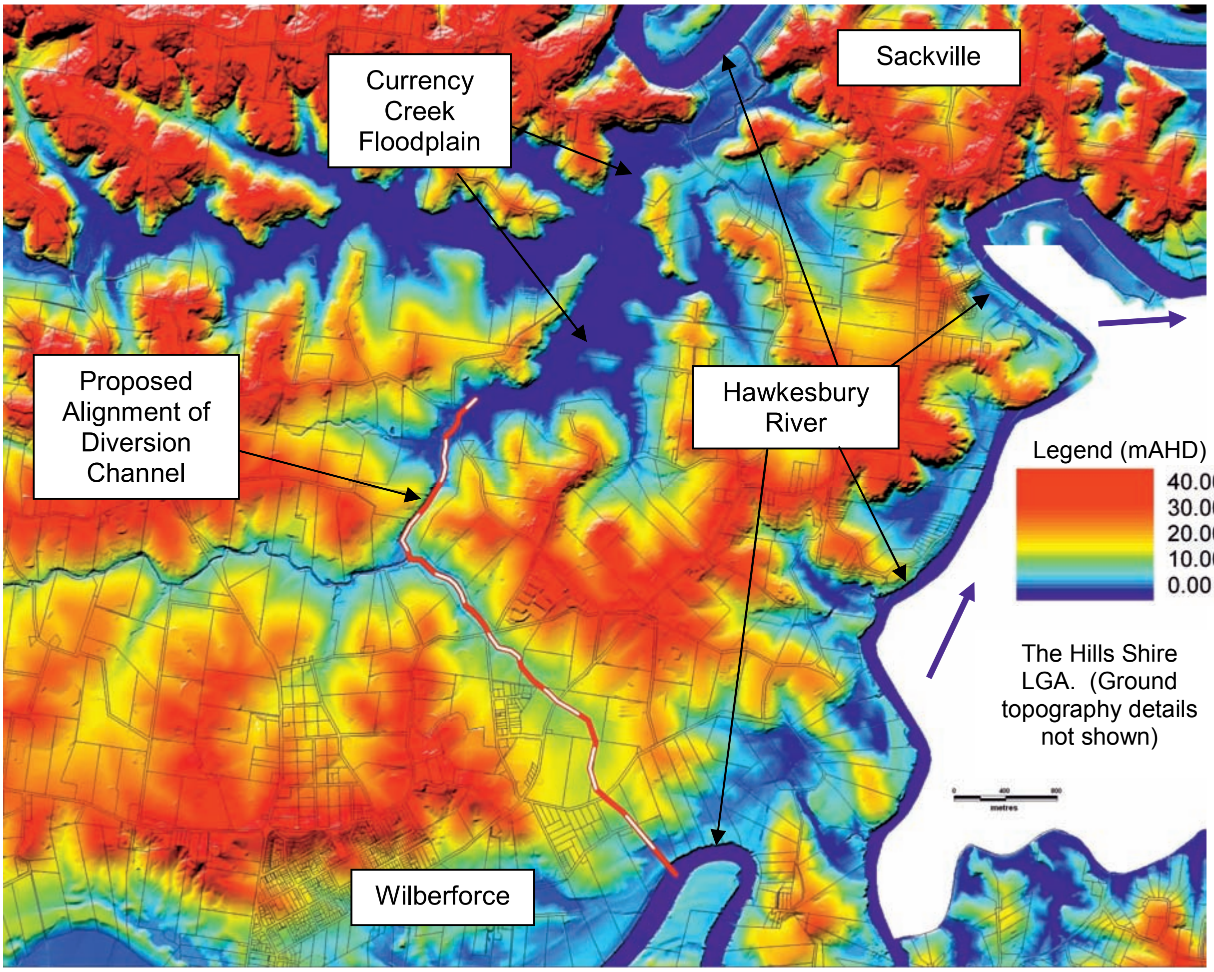

FIGURE 6.1 – Proposed Alignment of Currency Creek Diversion Channel

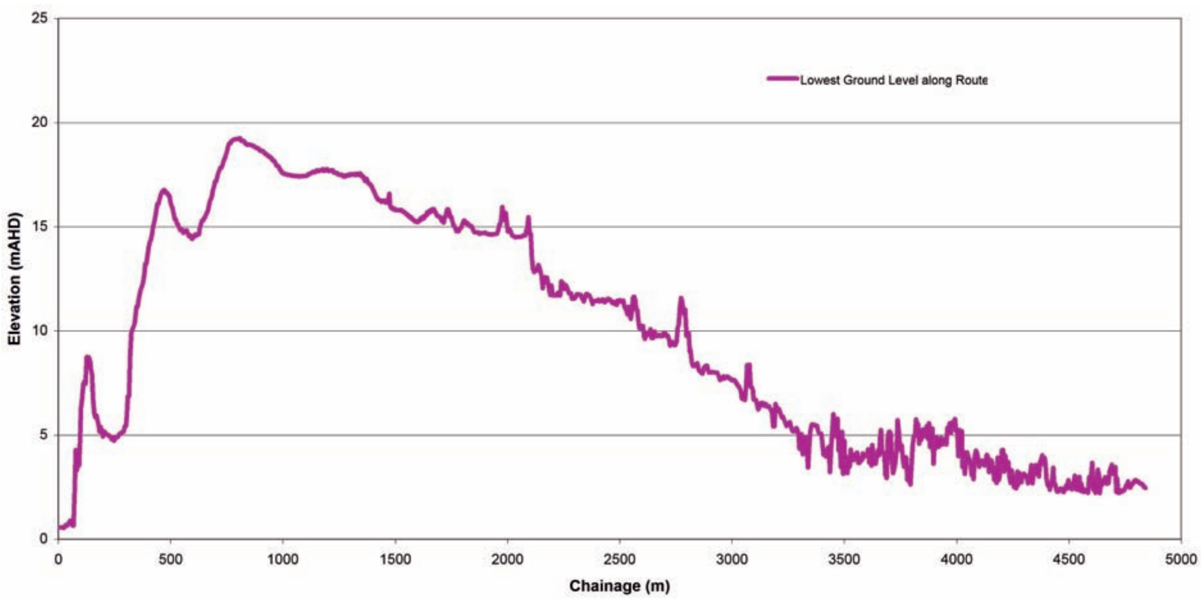

FIGURE 6.2 – Ground Profile along Route of Diversion Channel

The initial construction costs of the scheme will include:

- excavation and disposal involving excavation in excess of one million cubic metres of rock[47];
- construction of about four bridges over the new channel including one over Sackville Road. Each of these bridges will need to span a channel approximately 200 m wide and will come at considerable cost[48]; and
- land acquisition of approximately 120ha of rural farmland in addition to other acquisition costs associated with the severance of existing rural allotments by the proposed channel.

Initial costings carried out as part of the current study suggest the likely cost of the scheme would be $250−$350 million. This yields a relatively low benefit-cost ratio (BCR) of 0.1−0.2. Based on its poor economic performance, the scheme is not considered practical. Further there are a number of potential environmental impacts including the risk of major scour and erosion of the lower reaches of Currency Creek and adverse geomorphological changes within the River that require further investigation. There may also be possible opposition to the scheme from the adjacent rural community, environmental groups and a number of government agencies.

Based on the information available, WMA's scheme is unlikely to be viable and has not been recommended. However as discussed in **Section 6.3** the Committee has expressed ongoing interest in the scheme (i.e. WMA's or an alternate scheme) and it is recommended that more detailed engineering feasibility studies (including a geotechnical assessment, hydraulic modelling and the consideration of a range of diversion channel widths and depths), be undertaken. Without this information it appears that the Committee will be unable to make a decision on this proposal.

6.2.2 McGraths Hill Levee

At the request of the Committee, the previous investigations of a levee to protect McGraths Hill that were reported in (WMA, 1997) have been reviewed and updated as part of the current study. As discussed in **Section 5.5**, much of McGraths Hill is inundated by the 50 year ARI flood and is almost entirely submerged in a 100 year ARI event (refer **Figure 5.4**).

The previous proposals investigated by WMA involved construction of a levee to protect against either the 50 year or the 100 year ARI flood. Whilst initially it may seem appropriate to build such a levee as high as possible, possibly even higher than the 100 year ARI event, there are very real flood risk management issues associated with higher levees. These include the very rapid and dangerous inundation which occurs once water levels rise higher than the levee crest or during failure of the levee embankment. Given the large flood height range, it would be impossible to build the levee so that it was never overtopped therefore the consequences of overtopping need to be considered. In addition, the construction of levees can create a 'false sense of security' amongst the occupants living behind the levee. This engenders a belief that the levee protects residents from all events and thus once a flood large enough to overtop the levee occurs, residents may be caught unawares in a very dangerous situation.

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[47] It appears that the presence of rock was assumed by WMA without any geotechnical assessment at the site. One of the Committee members has local knowledge of past drilling in the area and this suggests there may be no rock up to 6m below the surface. It is noted that the presence or otherwise of rock significantly influences the engineering feasibility and cost of the scheme.

[48] Alternatively it may be possible for some of all of the existing roads to be diverted along the sides and across the base of the diversion channel, thus reducing overall construction costs.

Consequently a levee to provide protection to the 50 year ARI flood event has been considered. The levee would be about 3.5km long and would have a typical height of about 2m (i.e. crest height to 16.0mAHD). Assuming that the levee could be built on rural land surrounding the existing urban area, the majority of the levee could be of earth construction involving approximately 50,000m³ of material.

Preliminary engineering assessment of the levee suggests its construction cost would be about $7.2 million. The corresponding reduction in flood damage costs would be of the order of $17 million. This indicates that the benefit-cost ratio (BCR) would be 2.4 which is attractive.

However construction of such a levee may be opposed by many of the affected landholders due to its visual intrusion and the severance impacts on existing land parcels and activities.

The levee may also provide a disincentive for residents to leave McGraths Hill during an evacuation, or otherwise result in residents delaying the commencement of the evacuation. As noted by Molino Stewart (2011a, c) is important that evacuations from McGraths Hill occur earlier than currently planned in order to minimise conflict with other evacuation traffic utilising Windsor Road.

On balance it is considered that the construction of the levee is worthy of further consideration. Experience in planning and design of levees in other parts of NSW suggests that extensive community consultation will be required to determine preferred levee alignments and community attitudes before the viability of the proposal can be assessed. Consequently it is recommended that if this option is considered favourably by the Committee, a separate detailed levee scoping study be undertaken in close consultation with the McGraths Hill community before a final decision on the levee is made.

6.3 FURTHER CONSIDERATION OF LARGE-SCALE FLOOD MITIGATION WORKS AND MEASURES

As discussed in **Sections 2.3** and **6.1** it has not been within the terms of reference of the current study to investigate large scale regional flood mitigation works.

Nevertheless the Committee was very keen to see these options pursued further. Options that the Committee considered worthy of further assessment included:

- raising of Warragamba Dam and/or changing its flood operation procedures to provide flood mitigation storage to reduce downstream flood levels;
- river dredging to lower the bed level and create additional flood conveyance to reduce flood levels;
- further feasibility assessment of the Currency Creek flood diversion option (refer **Section 6.2.1**); and
- other river shortening proposals including excavation of a more hydraulically efficient river channel through the Sackville gorge.

In view of the heightened and ongoing interest in these options the Committee recommended to Council that an engineering study be commissioned to further look at these large scale mitigation proposals (and any others that might arise during community consultation)[49]. This recommendation was made separately from the current FRMS&P.

6.4 VOLUNTARY HOUSE PURCHASE

In the case of dwellings subject to such serious flood risks that people's lives would be placed in considerable danger, one option is for Council to offer to purchase properties under a voluntary house purchase (VP) scheme, remove the dwelling, and return the land to public open space. This strategy has been used successfully in several areas of the State. Generally, State Government guidelines stipulate that only residential dwellings on freehold or strata title land are eligible for voluntary purchase. The property should also not be benefiting substantively from other floodplain management measures. Because VP is an expensive measure, and given the increasing competition for limited State Government funds to subsidise the cost for VP, generally only the most severely flood-prone houses should be considered for VP, and then only after exhausting other options.

In the case of the Hawkesbury, a large number of dwellings could be considered eligible using typically adopted depth-over-floor criteria, although a building floor survey is required to confirm actual design flood depths above house floors. The inclusion of hundreds of properties in a VP scheme is considered impractical. Also, it could be argued that sufficient warning time is available in the study area to evacuate existing floodplain residents, mitigating risk to life. Furthermore, if part of the intention is to reduce losses to property, first consideration should be given to the feasibility of more affordable voluntary house raising (VHR) schemes (including house redevelopment). But if VHR is not feasible, where single-storey houses are flooded above floor to substantial depths (>2m) in relatively frequent events such as the 20 year ARI flood (corresponding to up to 67 dwellings from **Table 4.2**), VP should be considered further.

6.5 VOLUNTARY HOUSE RAISING

Raising houses with low-set floor levels has proved to be an effective floodplain management measure for various locations throughout NSW. For example, Fairfield City Council has been implementing a successful house raising program in the Prospect Creek catchment for many years.

Advantages of house raising include:

- reducing tangible flood damages and alleviating anxiety about future floods;
- providing under-house space for non-habitable uses such as garages; and
- an enhanced resale value.

[49] Evaluation of such options will require use of a hydraulic model. Consequently there may be benefit in carrying out the proposed engineering study after (or in conjunction with) updating of the flood behaviour data as suggested in **Section 3.4**. Note further that the Office of Environment and Heritage have indicated they would be unlikely to fund any further study of large scale regional flood mitigation works out of the State's Flood Program. The study could cost around $50,000 to $100,000 to undertake (subject to its scope) and would appear to require funding entirely by Council.

Disadvantages of house raising include:

- an altered streetscape unless all the houses in an area are raised;
- difficult access for some people (e.g. elderly, people with a disability); and
- people living in raised houses are often less likely to evacuate, which can exacerbate risk to life in rare floods that overtop the raised floor or when people panic with water below the house.

Various forms of house raising schemes can be considered. The easiest form of house raising occurs where houses are of either timber or fibro construction. Fairfield Council's experience in Prospect Creek has shown that such houses can be raised by 1-2m for a cost of $60K-$80K (in 2010 dollar values).

Physically raising houses of brick veneer or full brick construction is more costly, and in most cases impractical. One solution for these dwellings is to completely rebuild the house at a higher level, which may or may not be accompanied by a change in home ownership. (With a change in ownership, Council would acquire the property, demolish the existing house and sell the vacant building lot with appropriate development controls). Based on the experience of Fairfield Council, net costs are slightly higher than for raising timber or fibro dwellings.

The State Government provides financial subsidies for house raising schemes, depending on the availability of funds and the relative priority of works on a State-wide basis. Partial subsidy schemes may be preferred to full subsidy schemes because of the reduced financial and administrative burden on Council (e.g. up to $40K/house funded by the State, $20K/house by Council and the remainder by the owner), enabling more residents to be assisted, more quickly. Partial schemes also engender the resident's ownership of the works and are more flexible for owners of difficult-to-raise houses (provided that the ultimate goal of raising habitable floor levels is achieved).

There are potentially over 300 dwellings within the study area that may have their floors inundated in a 20 year ARI flood event (**Table 4.2**). Whilst the location and vulnerability of these dwellings has been assessed based on aerial photography and topographic information, there is a need for verification of the affected properties through field survey of floor levels and an assessment of the building type and usage (and its vulnerability to damage and suitability for raising/redevelopment). A number of old buildings may be heritage listed and not suitable for raising. An inspection of properties in Coromandel Road, Ebenezer, using Google Street View, indicates that many dwellings are either high-set or two-storey, or holiday shacks which would have a low priority for mitigation given the number of primary dwellings around the State confronted by flood problems.

A detailed scoping study to identify which of the 300 plus dwellings potentially inundated in a 20 year flood are suitable for inclusion in a VHR scheme is therefore required. Once the extent of this exposure has been quantified, the potential exists for the more severely affected dwellings to be raised or redeveloped as a means of reducing flood risks and flood damages. Given the large flood height range in the Hawkesbury, consideration will also need to be given to the practicality of compliance with the DCP in terms of height regulations.

If Council wishes to pursue inclusion of redevelopment within a VHR scheme (as has occurred at Fairfield) it is recommended that advice be sought from OEH on its policy position, noting that there have been some changes in policy since the Fairfield scheme was implemented.

6.6 EMERGENCY MANAGEMENT

6.6.1 Enhanced Emergency Management Assessment Tools

In fulfilling their legislated role as the 'combat agency' for floods, the SES has ultimate responsibility for the planning and the execution of emergency management operations for floods in NSW. In this role, the SES are assisted by local councils and various government agencies. It is not within the terms of reference for the current study to review the SES' emergency management plans nevertheless it is the role of each local council to give every assistance to the SES to ensure proper and effective emergency management in their LGAs.

The current emergency management strategy for the Hawkesbury relies on evacuation of communities away from the floodplain ahead of the arrival of floodwaters that cut egress routes. The capability to achieve this evacuation in the time available is determined using timeline analyses as part of evacuation capability assessments (ECAs).

After reviewing the information and assessment tools available to the SES to plan for flood emergencies, the following recommendations are made to assist the SES fulfil their responsibilities:

- *Provision of improved flood information* – improved flood extent data is now available as a result of improvements in topographic mapping. This allows the flood characteristics of smaller areas within sectors and sub-sectors to be better understood and addressed. It is recommended that digital copies of the flood mapping data presented in **Volume 3** be provided to the SES together with the enhanced *Flood Hazard Definition Tool* including data for the more frequent flood events (which is understood to be available at the time this report was finalised in 2012).
- *Best practice traffic modelling tools* – current ECAs have been prepared in spreadsheets and utilise simple traffic models which are unable to properly account for local behaviour within sectors and sub-sectors, intersection issues, variable road standards, and time varying flood behaviour. The preparation of an integrated evacuation traffic model, purpose built for the Hawkesbury[50], would allow the SES to conduct numerous sensitivity analyses and 'what-if' scenarios for a large range of potential floods (including for spatial and temporal variability from the design floods). The current ECAs include numerous conservative assumptions which whilst appropriate for a 'worst case' assessment, may not provide a realistic picture of the likely outcomes in most events. The ability to easily and rigorously model a range of assumptions would assist the SES in planning for the various types of flood emergencies that may present themselves in the future. The modelling tools might also have a role in real-time evacuations.

6.6.2 Communicating Flood Warnings

A critical component of the "total flood warning system" is the communication of flood predictions and instruction as to appropriate behaviours to the at-risk population. Much research has been done to assess the pros and cons of various alerting and notification technologies (see **Section 2.4**). It is understood that door-knocking and free-to-air media continue to be relied upon as the primary means of communicating flood warnings to Hawkesbury communities. The experience of flooding in Australia over the summer of

[50] The recent MapInfo based evacuation model built by BMT-WBM for the Tweed is an example of the type of evacuation simulation model that could be developed (Wallace et al, 2010). To provide a suitable model for the Hawkesbury however much work would need to be done including the development and integration of further traffic assessments.

2010/2011 has demonstrated the potential utility of emerging technologies including social media for disseminating flood advice. Given the limited time available for emergency responses in the Hawkesbury, it is recommended that the SES investigate the potential role of emerging technologies for enhancing flood warning communications.

6.6.3 Road Evacuation Infrastructure

6.6.3.1 Regional Evacuation Routes

It is a recommendation of this study that the SES consider use of dual outbound lanes on the Jim Anderson Bridge to enhance vehicle evacuation from Windsor during flood emergencies. It is understood from discussions with the SES and Council staff that in order to implement dual outbound lanes on the Bridge, additional traffic management arrangements will also be required at the eastern and western ends of the bridge. In addition, it will be necessary to provide additional road capacity from the eastern end of the Bridge through to Bandon Road or other alternative access onto Windsor Road. Further details can be found in **Section 5.3.5**.

Given that large areas of the LGA are evacuation constrained, there is merit in providing additional evacuation capacity from the Windsor/Bligh Park area across South Creek to the south-east. As identified by Molino Stewart (2011a,c) this might be achieved by upgrading roads around Eighth Avenue, Llandilo, to provide an alternative high level access[51].

6.6.3.2 Local Evacuation Routes

Considerable attention has been given to flood evacuation issues in this study. Nevertheless there remains some lack of understanding and documentation of local evacuation issues in parts of the LGA. As noted in **Section 2.5** these include for example, areas of Bligh Park (east of the low-point in Rifle Range Road) and the northern part of Windsor (north of the New/George Street intersection).

The more rigorous assessment of evacuation proposals for all local areas within the LGA that will be possible with the detailed vehicle modelling recommended in **Section 6.6.1,** will likely identify local evacuation upgrades in addition to those that have been identified to date.

It should be noted that whilst studies of local hydraulic issues have been undertaken such as those for Bligh Park and Hobartville (Bewsher Consulting, 2011a,b) these were essentially drainage modelling studies and it was not within their terms of reference to determine whether all sub-areas could be safely evacuated (or to identify options to achieve such an objective).

Consequently it is recommended that further local evacuation route studies be undertaken for all evacuation constrained areas within the LGA in conjunction with the development of the improved assessment tools recommended in **Section 6.6.1**. These studies would likely identify a further list of measures to improve local evacuation onto the regional evacuation routes in various parts of the LGA including measures such as the following for Bligh Park:

- eastwards extension of the Thorley Street flood evacuation route to provide egress from the Bligh Park (East) SES sub-sector. This may also require acquisition of one property to link access with the adjacent public road;

[51] Molino Stewart have advised that whilst this does not currently appear on any plans, the RMS have suggested this route. Once the Marsden Park area is developed there is likely to be justification for a link road through here.

- potential to utilise the existing width of Thorley Street to provide for two outbound lanes of evacuation traffic; and
- road raising and/or construction of slip lanes to improve traffic movements at the following intersections:
  - Colonial Drive traffic exiting left onto George Street; and
  - George Street traffic turning left onto Richmond Road.

6.6.4 Community Refuges

There are a number of low flood islands scattered throughout the study area that present significant safety risks in the event of major or extreme flooding. The largest urban flood island exposed to frequent flooding is McGraths Hill with its population of about 2,500 people which becomes isolated in a 20 year ARI event and is overwhelmed in a 100 year ARI event.

There is a much greater population at risk on the other urban flood islands within the study area; however most of these become inundated in much rarer flood events. These include Windsor/South Windsor which becomes isolated at the 100 year ARI flood level (when the Jim Anderson Bridge access is cut) and overwhelmed in the PMF.

The SES have confirmed that they will take every possible action to ensure the populations of all flood islands are evacuated. Nevertheless despite the diligent efforts of the SES, there is a very real possibility that significant numbers of people will remain on flood islands as a result of their unwillingness to leave, their inability to evacuate before egress routes become cut by floodwater, meteorological uncertainty in forecasting the flood or for other reasons. The provision of elevated building floor levels located above the reach of floodwaters on the higher portions of flood islands, would provide locations where trapped people could take refuge. While such facilities might not necessarily provide comfortable conditions for the occupants until such time as they were rescued, they could serve as an option of last resort to avert many deaths by drowning.

It needs to be recognised that the frequency of the flood events when such refuges might be used, is rare or very rare. Whilst a refuge within McGraths Hill might be used every 50 years on average, the refuges on the higher parts of Richmond and Windsor would be vital less often than once every 1000 years on average. Consequently buildings purpose-built solely to service this refuge requirement, may be an unnecessary impost on the community. Rather, refuges could be provided within public or private buildings such as schools, government offices, gymnasiums, etc, as an ancillary use to the main function of the building.

It is the recommendation of this study that Council and the State Government condition future development approvals to ensure that safe refuges be constructed on the higher parts of the major flood islands within Windsor, South Windsor, Bligh Park, Richmond and McGraths Hill. With Council approval, a relaxation of building height limits might be justified in some circumstances in order to allow buildings with refuge facilities to be constructed.

There is also some potential to consider refuges on high flood islands where these are adjacent to regional evacuation routes. One such example raised by the Committee was the land adjacent to Windsor Downs and the Llandilo Road evacuation route. A facility such as a sports stadium in such a location could be used a 'temporary' refuge for evacuating traffic in order to alleviate congestion on evacuating routes. Once the congestion had eased, evacuees could continue to their destinations.

6.6.5 Flood Emergency Plans

6.6.5.1 Hawkesbury-Nepean Flood Emergency Sub-Plan, NSW State Flood Sub Plan

A key document for guiding flood response operations in the Hawkesbury-Nepean Valley is the Hawkesbury-Nepean Flood Emergency Sub Plan (SEMC, 2005), which was last updated in December 2005. Given the improved flood mapping now available as a result of the acquisition of ALS survey, and the upgraded regional flood evacuation infrastructure such as construction of the Jim Anderson Bridge and the Thorley Street Flood Evacuate Route Upgrade, it is recommended that the Sub Plan is now suitably updated – and it is understood that the SES has begun this process. Also, if accepted by the SES in view of the information set out in **Section 5.3.5**, the Sub Plan should allow for the use of two lanes out across the Jim Anderson Bridge in a flood evacuation. The Sub Plan will also require amendment after the proposed best practice traffic modelling is completed, road infrastructure upgrades are constructed, community refuges are built, and the flood modelling is revised.

Further, the NSW State Flood Sub Plan (Annex C) prepared in June 2008 describes the flood warning requirements for the Hawkesbury River including at Richmond and Windsor. Given that the SES proposes evacuation will now commence in anticipation of egress from each local area being cut, there will be a number of additional evacuation triggers for which the SES will require flood predictions from the Bureau of Meteorology (not just those listed in the current version of Annex C). Consequently it is recommended that the NSW State Flood Sub Plan be updated accordingly.

6.6.5.2 Utilities

As noted in **Section 4.3.3.2**, a separate study is currently being undertaken for the SES to document the impacts of flooding on critical utilities in the Hawkesbury-Nepean Valley (Molino Stewart, 2011b). These investigations include information which is the subject of confidentiality agreements between the utility companies and the SES. Consequently the information has not been provided to the Committee for the use in the current study.

Nevertheless it is recommended that for each critical utility, separate assessments of measures to protect utility infrastructure and to minimise disruption to the community from the loss of the utility be undertaken. These assessments need to be undertaken by the SES and the State Government, in consultation with Hawkesbury City Council and adjacent councils, and the utility providers. A strategy for addressing each of the utility problems is to be developed having regard to risk management principles. Options may include various flood-proofing measures. At the very least, each utility must maintain a rigorous flood emergency plan.

It is noted that these recommendations are generally consistent with those of the *Hawkesbury-Nepean Floodplain Management Strategy* however based on the information currently available to Council, it has not been possible to determine how the implementation of these measures has progressed. Accordingly there may be merit in Council requesting a status report from the SES.

6.6.5.3 Caravan Parks

Many caravan parks in the Hawkesbury LGA are highly exposed to flood risks (**Section 4.3.3.1**). Over recent years there has been a growing understanding of the vulnerability of caravan parks to flooding, with commensurate efforts to raise the quality of flood risk assessments and management plans. A flood emergency management plan template was prepared as part of the Shoalhaven *Caravan Parks Flood Safety Study* (Bewsher

Consulting, 2008). It is recommended that the managers of the flood-affected caravan parks listed in **Table 4.6**, with assistance from Council and the SES, prepare up-to-date plans using this template, which contains sections for flood risk assessment, key priorities and triggers and flood response.

6.7 COMMUNITY FLOOD EDUCATION AND RESILIENCE

6.7.1 Background

Actual flood damages can be reduced, and safety increased, where communities are "flood-ready".

> *"People who understand the environmental threats they face and have considered how they will manage them when they arise will cope better than people who lack such comprehension… Many people who live and work in flood liable areas have little idea of what flooding could mean to them – especially in the case of large floods of severities well beyond their experience or if a long period has elapsed since flooding last occurred. It falls to the [SES], with assistance from councils and other agencies, to raise the level of flood consciousness and to ensure that people are made ready for flooding. In other words, flood-ready communities must be purposefully created. Once created, their flood-readiness must be purposefully maintained and enhanced".* (Keys, 2002, p.52)
>
> *"The challenge is not in gaining the attention of the community… but in changing the community's attitude and behaviour towards flooding".* (FEAC, 2006)

Creating and maintaining flood-aware, flood-ready and flood-resilient communities is especially important for the Hawkesbury due to the following factors:

- severe floods have been infrequent; many people living or working in the Hawkesbury floodplain would not have experienced the highest 20th century flood which occurred in November 1961 (15.0m AHD at Windsor, see **Table 2.1**); only once in recorded history has the Hawkesbury risen to a level that would cut off the (now present) Windsor Flood Evacuation Route; accordingly, until a severe flood is again experienced, educators face a constant battle against complacency;
- the flood height range in the study area is such that floods not much rarer than the 100 year ARI flood may reach much greater depths, posing substantial risks to life and property (e.g. the 1867 flood which was a 200-300 year ARI event reached 19.7m AHD at Windsor, see **Table 2.1**);
- currently the main flood response strategy is large-scale evacuation; however, it is generally recognised that voluntary evacuation will be more difficult for communities sceptical about the possibility of flooding; hence there is a need to ensure people accept the need to evacuate and know what to do in the event of a flood evacuation order.

A good deal of work was done under the auspices of the *Hawkesbury-Nepean Floodplain Management Strategy* to assess community attitudes towards flood risk and to inform a Regional Public Awareness Program. The SES commissioned separate investigations towards the same end. **Section 2.6** reviewed this research and documented some examples of implementation. The *Flood Preparedness* Australian Emergency Manual (AGD, 2009) recognises that a vital component of an education program is "periodic review and evaluation to ensure continued reach, relevance and effectiveness". A recommendation of this *Hawkesbury Floodplain Risk Management Plan* (FRMP) is that a review of the elements of the Regional Public Awareness Program be carried out, involving both the SES and Hawkesbury Council. This should document and evaluate flood education initiatives implemented to date, and would set the basis for ongoing and coordinated flood education measures for the next 5-10 years.

From a review of the previous research and education measures in the Hawkesbury, and drawing upon experience elsewhere in the State, the following sections contain a number of recommendations which could be considered in the proposed review of the Regional Public Awareness Program.

6.7.2 Approaches

First, there appears to be <u>a need for more geographically targeted approaches</u>. This study has shown the flood risks are not the same at the main communities within the Hawkesbury floodplain (e.g. see **Figures 5.4** to **5.13**). Also, appropriate responses at each sector vary e.g. when and where to evacuate. Moreover, residents may be more receptive to information targeted at the scale of a suburb (e.g. a McGraths Hill FloodSafe guide) rather than at the scale of the entire LGA.

Second, a <u>greater usage of the well-documented 1867 flood</u> is desirable to overcome some of the barriers to preparedness such as the myth that only properties below the 100 year ARI flood planning level are flood-prone, and to persuade people that floods can be very dangerous, requiring early evacuation. Some information for this event in collated in **Appendix A**. Extracts that could be used for some of the major population centres are shown below:

McGraths Hill

> *"The residents at McGrath's Hill had a very narrow escape. One of the crew happened to see the flickering gleams of a light burning very faintly and hardly visible. It was about 3 o'clock in the morning when the boat pulled up and found nearly eighty men, women, and children crowded into a few places. Thirty were taken out of one loft, and there was just time for the return of the boats for the rest before the flood rose above the building in which they had taken refuge. The poor folks had given themselves up for lost".*
>
> (Sydney Morning Herald, Monday 24th June 1867 p.5, 'The flood at Windsor')

Windsor

> *"The town is divided into islands, which are gradually and terribly diminishing. The greater portion of the town is now inundated… The people themselves are every hour being driven closer and closer together as the mighty flood encroaches on the land. Houses are giving way before the sweeping current… Unless a change takes place very soon… the whole town will be deluged. Hairbreadth escapes are heard of from all points, and at best nothing but utter ruin and desolation stares us in the face".*
>
> (Sydney Morning Herald, Tuesday 25th June 1867, p.2, 'The Floods – Windsor')

Richmond

> *"There have been several narrow escapes from drowning, partly through the rapidity with which the waters rose and partly through the obstinacy of some in refusing to leave their dwellings in time… Many families were rescued from the very verge of drowning, taken from the tops of trees or the ridges of submerging and falling dwellings… The water from the common entered the streets on the south-east side of the town, and soon after dark the town was intersected by the meeting of the waters… The flood continued on the increase, remained for a time stationary, and then began shortly to fall… We went through several of the streets in a boat, finding houses full of water to a depth of five or six feet".*
>
> (Sydney Morning Herald, Wednesday 26th June 1867, p.2, 'The Floods – Richmond')

6.7.3 Messages

The published research offers direction about the messages that need to be conveyed to Hawkesbury communities, which includes answers to the following questions:

- Why is flooding such a high risk in the Windsor/Richmond area?
- How are flood levels calculated and what do probabilities mean?
- What is the role of Warragamba Dam, if any, in alleviating flooding?
- What is the Hawkesbury-Nepean flood warning system?
- Why do I need to evacuate so early when I can't even see the flood?
- Where is my evacuation route?
- Why should I evacuate in this flood when the previous event was a 'false alarm'?
- What could happen if I decide not to evacuate?

6.7.4 Proposed Communication Modes

6.7.4.1 Flood Certificates

Perhaps the key measure for raising a community's awareness of flooding is via the regular issuing of flood certificates to all occupiers of the floodplain. These flood certificates would inform individual property owners of the flood situation at their *particular property*. It is the site-specific nature of this advice that offers the best chance of overcoming scepticism. Only after floodplain occupants accept that *they* could have a problem are they ready to take on board ideas about addressing that problem. A certificate would contain information such as the expected flood levels in a range of design floods and could also provide information on ground and floor levels where this information is available. This would allow an assessment of the depths of flooding over the property and building floor. In the case of the Hawkesbury, it could also contain the relevant evacuation route.

Flood certificates, such as the sample included as **Figure 6.3**, could be distributed (free) with every Section 149 certificate that is issued. They could also be delivered with Council's rates notices every 2 years, along with advice about what people can do to prepare for flooding (e.g. a suburb-specific FloodSafe brochure). Additional certificates could be provided on request and the payment of a fee to Council[52].

Such certificates can also be prepared on an as-needed basis by a web-based tool such as that which has been very successfully implemented by Pittwater Council (refer www.pittwater.nsw.gov.au) or by the 'FloodWise' property reports provided by Brisbane City Council (refer www.brisbane.qld.gov.au).

[52] Utilities are available, or can be developed, to allow such certificates to be automatically generated from flood information held in a Council's GIS, for any land parcel that is specified. Such systems ensure consistency and accuracy in the advice provided and minimise the production cost. A number of councils in NSW already use such systems. In areas of an LGA where flood information is not available or incomplete, the certificates should be appropriately qualified. Within the floodplains of the study area where an extensive database of flood information is already available in GIS, it is a technically straight-forward task to automatically prepare such certificates using WaterRide or via software routines in Council's GIS.

Hawkesbury City Council

Flood Certificate

Certificate Issued for Property at: 25 Flood Street, Flood Town
Lot 25, DP 25252

Owners Name: Mr D. & Mrs I. Citizen

1. Classification of Flood Risk

Council records indicate that the above property is located within a **High** Flood Risk area.

Land that is potentially subject to inundation is classified as low, medium, high or extreme flood risk. Council has prepared a development control plan that provides details of flood related development controls that may be applicable.

2. Known Floor and Ground Levels

The lowest habitable floor level of the main building on this property is: Source of information:	15.3m AHD Estimated
The lowest ground level on this property is: Source of information:	15.0m AHD Council Digital Terrain Model

If the floor level and/or ground level are currently unknown and you would like to know what the levels are, this can be surveyed by a registered surveyor.

3. Estimated Flood Levels

Flood levels in the vicinity of the above property have been extracted from the Flood Hazard Definition Tool (*).

Size of Flood*	Flood Level	Depth over Lowest Floor Level	Depth over Lowest Ground Level
Probable Maximum Flood	26.3 m AHD	11.0 m	11.3 m
1000 Year Flood	21.8 m AHD	6.5 m	6.8 m
500 Year Flood	20.2 m AHD	4.9 m	5.2 m
200 Year Flood	18.7 m AHD	3.4 m	3.7 m
100 Year Flood	17.3 m AHD	2.0 m	2.3 m
50 Year Flood	15.7 m AHD	0.4 m	0.7 m
20 Year Flood	n/a	n/a	n/a
5 Year Flood	n/a	n/a	n/a

**The Probable Maximum Flood (or PMF) is extremely rare.*
A 500 year flood is a very large flood. It has a 1 in 500 (i.e. 0.2%) chance of occurring in any year.
A 100 year flood is a large flood. It has a 1 in 100 (i.e. 1%) chance of occurring in any year.
A 20 year flood has a 1 in 20 (i.e. 5%) chance of occurring in any year.
Note: The 1867 flood is regarded as about a 280 year flood in the Hawkesbury LGA.

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Issued by Hawkesbury City Council
1st July 2011

FIGURE 6.3 – Sample Flood Certificate

6.7.4.2 Local FloodSafe Guides

As discussed above, there is a need to develop and distribute *suburb-specific* FloodSafe guides so that people better understand their local flood risks, the flood warning system, and their local and regional flood evacuation routes. Separate FloodSafe guides should be prepared for McGraths Hill (top priority), Windsor/South Windsor, Bligh Park, Windsor Downs, Richmond/Hobartville and Pitt Town. Effort should be made to include the messages listed in **Section 6.7.3**.

6.7.4.3 Flood Tolerant Housing Poster and Brochure

The *Building Guidelines* prepared for the Hawkesbury-Nepean Floodplain Management Steering Committee (2006) are considered world best practice for the promotion of building designs that will result in significant cost savings when houses built in the floodplain are inevitably inundated. To alert builders and prospective home-owners to the existence of these Guidelines, to make their main findings more accessible, and to persuade residents about the financial sense of investing in flood-aware design, there appears to be a need to prepare a Flood Tolerant Housing poster and brochure. A starting point for a poster and brochure is the three page summary provided in the *Hawkesbury-Nepean FMS Implementation* report (HNFMSC, 2004). These resources could be displayed/made available at Council offices and distributed to local building firms.

6.7.4.4 Web-site Enhancement

As described in **Section 2.6**, Council's website contains some valuable flood information pertaining to flooding. Comparison with some other Council websites in the State suggests that there is scope for enhancing this increasingly important source of information, particularly considering the very significant flood risks encountered in the Hawkesbury LGA. A 'one-shop stop' website resource of everything pertaining to floods in the Hawkesbury is therefore recommended. It would include:

- an authoritative list of historic flood peaks, and brief descriptions of consequences where known;
- flood photo gallery (invite residents to submit historic flood photos);
- links to the current and proposed FloodSafe Guides, the proposed Flood Tolerant Housing brochure, and the three Guidelines developed for the Hawkesbury-Nepean Floodplain Management Steering Committee (especially the Building Guidelines);
- provision of on-line flood certificates or similar type information as discussed at the end of **Section 6.7.4.1**;
- information used during a flood including a list of local radio stations with their frequencies, links to flood warnings, guidelines of what to do, maps of evacuation routes and updated information about road closures; and
- information about Council's floodplain management initiatives, including links to its various flood studies and floodplain risk management studies, when adopted.

6.7.4.5 Hawkesbury Flooding Book

A number of local histories have been prepared which provide good coverage of Hawkesbury flooding. One example is a chapter in D.G. Bowd's *Macquarie Country* (1982). Michelle Nichols' *Disastrous Decade* (2001) covers the 1867 flood in some detail. Nevertheless, there would be value in <u>preparing a comprehensive flood history</u> in the manner of the one Chas Keys prepared for Maitland (2008). As well as providing a historical resource, this book functions as an instrument of persuasion, seeking to convince residents that future flooding is inevitable, requiring individual preparedness. The historical descriptions, photos and personal stories make the book appealing to any locals interested in history, but weaved throughout the book are important insights about vital community responses to flooding. It is noted that in July 2010, the Hawkesbury SES unit widely requested flood photos and stories from the public for a book being written about flood rescues. This information would be useful to the broader book proposed here.

It is recommended that the book (and accompanying video) be prepared well in advance of the proposed 2017 commemoration of the 1867 flood (see **Section 6.7.4.6**).

6.7.4.6 150th Anniversary of the 1867 Flood

The commemoration of severe floods, in round-number anniversary years, has been an important means of raising flood awareness. The SES has led or participated in several such ventures, including in 1999 the 50th anniversary of the devastating Kempsey flood of 1949. Commemorative events have featured:

- public meetings to discuss floods, flood plans and flood management strategies;
- radio interviews;
- newspaper articles;
- the production of flood books and videos;
- the display of flood photographs and other flood memorabilia;
- guided tours to explain the flood risk and management measures;
- street parades featuring flood response agency personnel; and
- school projects with flood themes.

June 2017 will mark the 150th anniversary of the devastating 1867 flood. This represents an opportune time for a concentrated campaign to raise the profile of flood risks in the Hawkesbury Valley, seeking to change attitudes and behaviours. An obvious message from the 1867 flood which is not available to many other communities is that big floods – rarer than the 100 year ARI and with unprecedented depths – have occurred in the past and will occur in the future, requiring individual planning to increase safety and reduce losses. Other initiatives could be planned to build momentum in the lead-up to 2017, such as the launch of the proposed flood history book, and the development of an 1867 flood heritage tour.[53] A novel idea to engage younger generations is a song-writing contest on the theme of flood preparedness, with prizes sourced from local sponsors.

6.7.4.7 Flood Icons/Markers

Another method of raising flood awareness is the construction of several permanent flood icons or markers in the floodplain. Evaluation of flood education methods has shown that well-designed permanent signage is a widely received and retained method (Molino & Huybrechs, 2004). A few 1867 flood markers already exist in the Hawkesbury (**Figure 6.4**). However, these are not designed or located in such a way as to be readily seen and understood by the community. One concern sometimes raised in opposition to the installation of flood markers, or used to limit their placement to parkland where their effectiveness is limited, is the perceived effect of this form of flood disclosure on property values. This effect, however, appears to be largely illusory (Yeo, 2003). And on the other hand is Council's duty of care to advise property owners on the extent and level of flooding (*Floodplain Development Manual*, 2005). The advantage of using the 1867 flood is that flood levels are well established and cannot be disputed like so-called 'hypothetical' floods.

[53] Maitland has hosted "walk and talk flood tours" for several years as part of its community flood education initiatives.

Several types of flood icons or markers have been used across the State, including marks on telegraph poles, a customised sign at Woronora, a sculpture at Fairfield which was shaped by artists and school children, and a totem pole at the Kempsey commercial centre marking the height of historical and design floods up to the PMF (see **Figure 6.5**). There would be merit in employing several different styles of flood marker in the Hawkesbury. It may be especially important to install markers on the low flood islands.

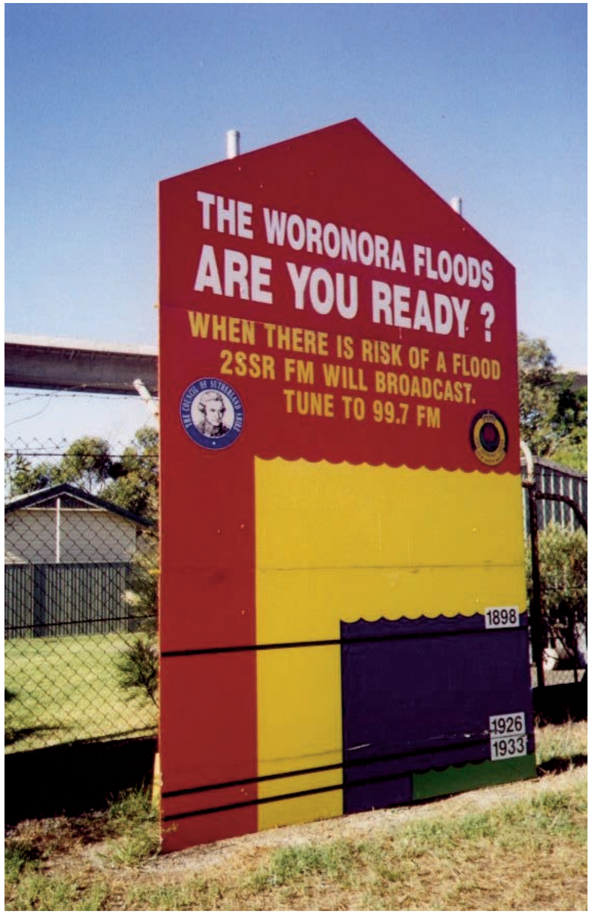
6.7.4.8 Business FloodSafe Breakfast

A significant number of businesses in the Hawkesbury LGA are flood prone. Inundation of these could have crippling flow-on effects. Ongoing efforts to encourage businesses to plan for flooding using the Business FloodSafe resource are required. The SES and Council could work with the Hawkesbury City Chamber of Commerce to promote flood readiness. Business FloodSafe breakfasts could rotate from one commercial centre to another over the course of several years.

1867 flood memorial below
St James Anglican Church Pitt Town
The line at the base of this stone marks the level of the "terrible flood".
"The water had reached its greatest height at 5 o'clock in the morning of Sunday June 23, 1867".
From entry of register of baptisms by Rev. H.A. Palmer. River rose 63ft. 2ins. at Windsor.
Erected by Hawkesbury Historical Society 1976.

1867 flood marker on wall of
Macquarie Arms Hotel, Windsor

FIGURE 6.4 – 1867 Flood Markers in the Hawkesbury Region



Woronora flood sign

Fairfield flood icon

Kempsey flood totem pole

FIGURE 6.5 – Examples of Flood Markers in NSW

6.8 INSURANCE ISSUES

As outlined in **Section 2.8**, following flooding in Queensland and Victoria in late 2010 and early 2011, a Natural Disaster Insurance Review is underway to consider ways of increasing the availability and affordability of flood insurance. This review will likely have implications for flood insurance in the Hawkesbury LGA.

Prior to the final report of this review scheduled for 30 September 2011, Risk Frontiers[54] offers the following considerations:

1) Insurance is not an alternative to risk reduction or good land use planning decisions.
2) Insurance is a means of transferring the *residual* risk (after risk reduction efforts) from the homeowner to the insurer and works by pooling risks of similar profile in terms of frequency and magnitude of likely claims.
3) Home and contents insurance premiums reflect the cost of this risk transfer together with costs for the provision of policies (which include the costs of transferring much of this risk offshore to global reinsurers who insure insurance companies against catastrophe risks like large floods), the costs of servicing claims and a margin for profit.
4) Like emergency management services, insurers have to deal with the accumulation of risks over the catchment and further research is needed to examine how individual premiums might change in response to more flood-resilient construction – better materials or the raising of floor levels, etc. One home owner undertaking such efforts will not materially alter the concentration of risks as seen by the insurer. So there is a need for research to identify who truly captures the benefit of mitigation efforts – individual policy holders via reduced premiums and/or the (re)insurer through a reduced risk exposure.
5) It is likely that a small subset of homes will be uninsurable by the market because the risk is perceived as too high and too certain. The Natural Disaster Insurance Review is currently looking at this question, but whatever the outcome of this review, it is likely that whether paid in full by individuals or discounted in some way through a pool of some sort, actual premiums will be set by the market at the true cost of risk. To do otherwise would only subsidise risky development on floodplains.
6) In summary, insurance is not an alternative to risk reduction efforts or good land use planning decisions, but through market-based pricing may provide an incentive for risk-informed land use planning and construction methods that allow sensible development of the floodplain without augmenting community exposure to risk.

[54] Risk Frontiers is part of the Natural Hazards Research Centre of Macquarie University. Risk Frontiers has had a long association with the consultants preparing this study and their assistance (provide gratis) is gratefully acknowledged.

7. TOWN PLANNING

7.1 ASSESSMENT OF TOWN PLANNING ISSUES

A comprehensive assessment of town planning issues associated with flood risk management in the study area has been undertaken and it is reported in **Volume 2**. The assessment was prepared by Grech Planners who are recognised as leading town planners in the provision of floodplain risk management advice in NSW.

The specific objectives of this planning assessment were to:

- review the current population and dwelling characteristics of the Hawkesbury LGA and study area, particularly since the preparation of the HNFMS;
- investigate and report on potential population and dwelling growth within the study area, based on both Council and Department of Planning and Infrastructure (DPI) targets and projections;
- review existing planning policies (both local and State) and evaluate where they may be inconsistent with flood risk management objectives. Identify where opportunities are available to improve flood risk management; and
- provide recommendations for incorporation within planning strategies and policies to improve flood risk management in the study area.

7.2 KEY FINDINGS AND RECOMMENDATIONS

The following provides a summary of the key town planning findings and recommendations contained within **Volume 2**:

(a) Between the 1986 and 2006 Censuses, the total number of persons within the floodplain have increased by around 17,000 and dwellings increased by about 7,700. This growth would likely have reached a plateau over recent years with the recognition of significant flood risks since the preparation of the HNFMS and the subsequent adoption of modest growth targets for the LGA in recognition of these risks.

(b) Key population characteristics of the floodplain as drawn from the 2006 Census include:
   - an aging population with about 4000 persons aged 65 or over, with the elderly being a potential sector requiring evacuation assistance;
   - approximately 1500 persons within the Census category of "*Has Need for Assistance with Core Activity*" which is a further indicator of the number of persons that may require special attention during an evacuation;
   - an average car ownership of 1.6 per dwelling but noting that there are approximately 1020 dwellings with no vehicle and these may also need evacuation assistance.

(c) An approach to grade the advice to be provided to planners and the consent authorities has been developed. This provides for four classes of evacuation risk as discussed in **Section 5.5**.

(d) There are a number of State Environmental Planning Policies (SEPPs) which have inconsistent definitions of flood liable land. Whilst Council does not have control of these Policies, Council should refer the current Study and its Plan to the DPI when adopted with a request that any future SEPP reviews have regard to this Plan.

(e) Council's existing comprehensive DCP does include peripheral provisions that address some flood issues but not include a specific flood risk management component. Consequently a specific flood risk chapter has been prepared to reflect the detailed planning recommendations of this study and the preceding HNFMS for Council's consideration and incorporation within the comprehensive DCP. This should occur in conjunction with a future review of Draft LEP 2011 (subsequent to it being made).

(f) The adopted comprehensive Draft LEP 2011 (in the Standard Instrument format) does incorporate flood related provisions but was prepared prior to the adoption of a standard local provision by the DPI. It is recommended that Council review the flood related provisions of the Draft LEP in consultation with the DPI to generally incorporate the relevant parts of the standard local provisions, and ensure it consistently defines flood liable land as all land up to and inclusive of the PMF. The LEP flood map should simply delineate the known extent of the PMF.

(g) Climate change flood risk is not an issue that requires to be specifically addressed in planning controls at this stage. Nevertheless the recommendations for floor level controls on residential development will provide some buffer against the erosion of flood immunity by climate change in the future.

(h) Maps should be prepared to support the DCP, which delineate five flood risk precincts – Extreme, High, Medium, Low and Very Low. The maps could provide a separate line that depicts the floodway extent. Once these maps are available, the draft DCP provisions (Appendix C of **Volume 2**) should be reviewed and finalised. The review should examine the practicality of the recommended controls with regard to development otherwise permissible in existing urban areas (e.g. whether a requirement for more than one storey for a dwelling house with a ground floor at the 100 year level would be of an appropriate scale with regard to streetscape and amenity considerations).

(i) It is recommended that only areas mapped by Council to be Medium, Low or Very Low Flood Risk are deemed to not be 'high risk' for the purposes of State Environmental Planning Policy (Exempt and Complying Development Codes) 2008 (the 'Codes SEPP'). This would have the effect of excluding the application of the Codes SEPP in areas where flood risk information is not currently available as well as in the High and Extreme Flood Risk precincts, which would consequently require the lodgement of a DA where such issues could be reviewed by Council.

(j) Existing S149 notifications generally reflect the legislative requirements of such documents plus some additional advice that have been historically provided. The recommended LEP and DCP provisions, together with the adoption of this FRMP will provide a basis for the rationalisation of S149 Notifications.

(k) An 'exceptional circumstances' application should be formally drafted and issued to the respective approving Departments (i.e. DPI and DPC) as a matter of priority to allow for the eventual implementation of planning controls above the 100 year flood level for residential development. An outline of the justification is provided in **Volume 2** which includes:

- the current existence of planning controls for residential development above the 100 year flood level;
- the exceptional risk to life and property due to the peculiar nature of flooding in the study area; and
- the decision not to apply a freeboard.

The application should be accompanied by copies of the FRMS and the FRMP.

(l) A more detailed tabulated summary of the existing and proposed planning policies and the associated recommendations is provided at the end of Chapter 7 of **Volume 2**.

8. COMMUNITY CONSULTATION

8.1 PREVIOUS CONSULTATION

Consulting with the community is essential for gaining the acceptance of any floodplain management plan. In the case of the Hawkesbury floodplain, substantial community consultation was done as part of the preparation of the *Hawkesbury-Nepean Floodplain Management Strategy* (see HNFMAC, 1998) (see **Section 2.6**). A good deal of research was also undertaken to assess community attitudes to flooding as a basis for formulating a regional public awareness strategy (see Colmar Brunton Social Research, 1999; Dovetail Planning Pty Ltd, 2000; Egan National Valuers, 2000; GHD and Cox Consulting, 2001). In recent years, the SES commissioned direct social research to inform its policies for communicating warnings during flood emergencies and promoting community readiness (see Becker et al., 2008a,b).

Given the number of previous studies, much knowledge about the attitudes of Hawkesbury residents to flooding has already been reported, obviating the need for the current study to ask questions of the community which would unnecessarily duplicate earlier efforts. It was also suggested that some Hawkesbury communities may have a kind of questionnaire “fatigue”. In the context of a local floodplain management study following the regional floodplain management study, it was decided that the most beneficial stage of the study to seek the community’s input was after a draft report was prepared, when proposals to address the existing and future flood risk have been considered.

8.2 MEETINGS OF THE FLOODPLAIN RISK MANAGEMENT ADVISORY COMMITTEE

The study has been overseen by Hawkesbury Council’s Floodplain Risk Management Advisory Committee. This Committee comprises representatives from:

- Hawkesbury City Council;
- NSW Office of Environment and Heritage (OEH);
- NSW State Emergency Service;
- Department of Defence;
- Department of Primary Industries; and
- Local communities.

The Committee has met regularly to hear progress reports by the consultant, and to provide input as the study progressed. The Committee has provided a valuable mechanism for the views of many interested parties to be represented. The main agenda items at each meeting are summarised in **Table 8.1**.

TABLE 8.1 – Meetings of the Floodplain Risk Management Advisory Committee
(relevant to the *Hawkesbury FRMS&P.* Meetings after July are not listed.)

DATE OF MEETING	MAIN AGENDA ITEMS
1 Nov 2010	Identification of key issues
18 Jan 2010	Project update
7 Feb 2011	Flood risk considerations; data collection and review; flood mapping
18 Apr 2011	Flood problems; regional flood evacuation assessment; planning issues
27 June 2011	Presentation of draft floodplain risk management plan
12 October 2011	Presentation by Bureau of Meteorology
12 December 2011	Progress of study
5 March 2012	Committee completed its review of the draft report and requested the Consultant to proceed with preparation of a draft for public exhibition.
23 July 2012	Committee recommended to Council that the draft report be placed on public exhibition.

8.3 MEETINGS WITH AGENCIES

During the course of the study and the preparation of the three report volumes for public exhibition there has been continual liaison with Council and other Government agencies with a direct interest in the study. The flood risk management issues in the study are some of the most important of any study carried out in the State and have required extensive amounts of agency liaison.

This liaison has occurred largely by telephone and email correspondence in addition to the following meetings (in person):

- Hawkesbury City Council – 5 meetings (in Windsor and Epping)
- NSW Office of Environment and Heritage (OEH) – 6 meetings (in Parramatta and Epping);
- State Emergency Service – 5 meetings (in Seven Hills and Wollongong); and
- Bureau of Meteorology – 1 meeting (in Sydney City).

In addition to liaison with agencies, there have also been a number of meetings with key individuals who have expressed interest in the study.

8.4 PUBLIC EXHIBITION AND ADOPTION BY COUNCIL

At its meeting on 23 July 2012 the Committee recommended to Council that the July 2012 draft report of the *Hawkesbury Floodplain Risk Management Study & Plan* be placed on public exhibition. Council subsequently considered this matter at its meeting on 31 July 2012 and resolved to place the draft report on public exhibition for a minimum of 60 days.

The exhibition took place over 13 September 2012 to 16 November 2012 with advertisements placed in the *Hawkesbury Courier* on 13 September 2012 and 1 November 2012. The draft Study and Plan were also made available for viewing at Council's Main

Administration Building, the Hawkesbury Central Library and the Richmond Branch Library during this period. In addition the draft reports were also displayed on Council's website during the formal exhibition period and for a number of weeks prior to the commencement of the exhibition period.

At its meeting on 11 December 2012, Council considered the draft reports and the submissions from the exhibition. At this meeting Council formally adopted the draft Study and Plan as exhibited, subject to minor editing and layout amendments. (These minor editing and layout amendments have subsequently been made in producing this current report).

It is noted that the adopted Plan recommends changes to Council's planning controls to manage flood risk as detailed in **Volume 2**. The formal changes to Council's Planning Instruments to implement these controls will occur through a separate statutory process that will consider the recommendations of the Study and Plan, recent changes to planning legislation and additional public consultation. Council's committee will continue to have a role in the consideration of these issues and the implementation of the Plan.

9. FLOODPLAIN RISK MANAGEMENT PLAN

9.1 RECOMMENDATIONS

The Floodplain Risk Management Plan (FRMP) showing the preferred floodplain risk management measures for the Hawkesbury study area is presented in this chapter. The recommended measures have been selected from the range of measures discussed in **Chapter 6**, after an assessment of each measure's impact on flood risk, as well as consideration of environmental, social, and economic factors. The recommended measures are presented in **Table 9.1**. The principal components of the Plan are presented below according to priority, which is assessed on the basis of how easily (quickly) each measure can be implemented and on value for money. The timing of the proposed works will depend on Council's overall budgetary commitments, and the availability of funds from other sources.

9.2 PRIORITISED MEASURES

9.2.1 High Priority Measures

- Item 1: Community Flood Education
- Item 2(a): Dual Outbound Lanes on Jim Anderson Bridge
- Item 2(c): Construction of Community Refuges
- Item 2(d): Flood Emergency Plans for Special Uses and Utilities
- Item 2(e): Flood Emergency Plan Templates for Caravan Parks
- Item 2(f): Review and Update Hawkesbury-Nepean Flood Emergency Sub Plan and NSW State Flood Sub Plan (Annex C)
- Item 2(i): Investigation of Road Duplication Options at the Eastern End of the Jim Anderson Bridge
- Item 3(a): Provision of Evacuation Risk Advice for Existing Development Proposals
- Item 4: A range of Town Planning Measures including revisions to the Flood Risk chapter of Council's DCP

9.2.2 Medium Priority Measures

- Item 2(b): Enhance Emergency Management Assessment Tools
- Item 5: Study of Voluntary House Raising and Redevelopment Options
- Item 6: Assessment of a Levee and Refuge Mound for McGraths Hill

9.2.3 Low Priority Measures

- Item 2(g): Provide additional crossing of South Creek
- Item 7: Update Flood Behaviour Data for Valley

9.3 FUNDING AND IMPLEMENTATION

The total capital cost of implementing the Plan is estimated to be $1.5M, with maintenance costs of about $150K p.a. (including for on-going costs associated with establishing and maintaining the community's 'flood readiness'). The timing of proposed works will depend on overall budgetary commitments of Council and the availability of funds from other sources. It is envisaged that the Plan would be implemented progressively over a 5 to 10 year time frame.

A variety of sources of funding may be drawn upon to implement the Hawkesbury FRMP including:

- Council's funds;
- State funding for flood and property modification measures through the NSW Government's Floodplain Management Program;
- Commonwealth and State funding through the Natural Disaster Resilience Program;
- funds from other organisations (e.g. SES) and private owners; and
- volunteer labour from community groups.

Council can expect to receive the majority of financial assistance through OEH who administer some of these programs on behalf of the State and Commonwealth. These funds are available to implement measures that contribute to reducing existing flood problems. Funding assistance is usually provided on a 2:1 basis (State:Council) or a 1:1:1 basis (Commonwealth:State:Council).

Although much of the Plan may be eligible for Government assistance, funding cannot be guaranteed, since the limited Government funds are allocated on an annual basis to competing projects throughout the State. Options that receive Government funding must be of significant benefit to the community. Funding of investigation and design activities as well as any works is normally available. Maintenance, however, is usually the responsibility of Council.

It should also be noted that the plan involves feasibility assessments and investigations of various work option (e.g. voluntary house raising, additional road works at the eastern end of Jim Anderson Bridge) which will significantly increase the cost of the Plan when included.

9.4 ON-GOING REVIEW OF PLAN

The *Hawkesbury Floodplain Risk Management Plan* should be regarded as a dynamic instrument requiring review and modification over time. The catalyst for change could include flood events, revised flood modelling, better information about potential climate change flood impacts, legislative change, alterations in the availability of funding, or changes to the area's planning strategies. In any event, a thorough review every five years is recommended to ensure the ongoing relevance of the Plan.

TABLE 9.1 – Hawkesbury Floodplain Risk Management Plan

ITEM	CAPITAL COST	AGENCY	PRIORITY
1. **Community Flood Education and Resilience** (a) Review and evaluate Regional Public Awareness Program. (b) Issue flood certificates on regular basis. (c) Prepare suburb-specific FloodSafe guides. (d) Prepare flood tolerant housing poster and brochure. (e) Enhance flood information on Council's web-site. (f) Commission book and video production on Hawkesbury flooding and vital community responses. (g) 150 year commemoration of 1867 flood. (h) Install flood icons/markers at key locations. (i) Continue to host Business FloodSafe breakfasts.	$300K	HCC, SES	High
2. **Emergency Management** (a) Implement dual outbound lanes on Jim Anderson Bridge during flood emergencies.	$100K	SES, RTA	High
(b) Enhance emergency management assessment tools. Develop best practice traffic modelling to better assess implications of various evacuation scenarios. Integrate with flood modelling.	$200K	SES	Medium
(c) Promote construction of community refuges within major new buildings on flood islands to service the existing communities.	–	HCC, State	High
(d) Continue to prepare and maintain flood emergency management plans for special uses and utilities. (e) Use caravan park emergency management plan template to raise awareness and increase preparedness.	–	Private Sector, HCC, SES, State	High
(f) Review and update Hawkesbury-Nepean Flood Emergency Sub Plan and NSW State Flood Sub Plan (Annex C).	–	SES, BoM, State	High
(g) Provide additional evacuation capacity possibly through a new crossing of South Creek at Eighth Ave, Llandilo.	(not costed)*	HCC, RTA, State	Low-Medium
(h) Identify local evacuation route upgrades and revise FRMP.	$100K*	HCC, SES	Medium
(i) Investigate lane duplication options, east of Jim Anderson Bridge.	$150K*	HCC, SES	High
3. **Future Development – Flood Risk Advice to Consent Authorities** (a) Provide advice to Council and State Government concerning severity of flood evacuation risks as per **Tables 5.5** and **5.9**.	–	HCC, State	High
4. **Town Planning** (a) Advise DPI of principal planning recommendations of this Plan. (b) Amend flood risk provisions of Council's existing DCP. (c) Amend LEP in accordance with Volume 3. (d) Prepare maps to guide application of Codes SEPP. (e) Revise S149 notifications in accordance with **Volume 3**. (f) Lodge application for 'exceptional circumstances' with DPI & OEH.	–	HCC, State	High
5. **VHR and Redevelopment** (a) Survey all houses inundated in 20 year ARI events. (b) Assess eligibility for voluntary house raising (VHR)/ redevelopment and possibly for voluntary house purchase (VP). (c) Report back to Council. Revise FRMP if required.	$100K*	HCC	Medium
6. **McGraths Hill** (a) Feasibility study of 50 year levee including consultation. (b) Assess community attitudes to levee and refuge mound. (c) Report back to Council. Revise FRMP if required.	$60K*	HCC	Medium
7. **Updating Flood Behaviour Data in Valley** (a) Utilise latest 2D flood modelling and latest topographical data. (b) Extend along main tributaries. (c) Include revised IFD rainfall. (d) Include for revised climate change influences. (e) Update data for smaller more frequent flood events.	$500K	HCC, other Councils, State	Low
TOTAL (rounded)	**$1.5M***		

*Note: Construction costs are not included. Plan to be revised to include these costs once investigations are completed.

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11. FREQUENTLY ASKED QUESTIONS

Why do flood levels change over time?

There is a chance that floods of various magnitudes will occur in the future. As the size of a flood increases, the chance that it will occur becomes rarer. Because some of these rare floods have never been experienced or accurately recorded since European settlement, the height of future floodwaters is normally predicted using computer models. These computer models simulate flood levels and velocities for a range of flood sizes and flood probabilities. Given the importance of estimating flood levels accurately, councils and the NSW Office of Environment and Heritage (OEH) engage experts to establish and operate the computer models.

From time to time the computer models are revised and predicted flood levels can change. The resultant change in flood levels however is normally very small. The reasons why the computer models are revised can include:

- new rainfall or ground topography information becomes available;
- new floods occur which provide additional data from which to fine-tune the models;
- better computer models become available as the science of flood modelling improves and computer capabilities increase; or
- flood mitigation works may have been carried out, or development within the catchment may have occurred, that was not previously simulated in the models.

How are these studies funded?

Flood studies and floodplain risk management studies are normally carried out under State Government guidelines and are often funded on a 1:1:1 basis among the Federal and State Governments, and councils. This funding arrangement is also available for the construction of flood mitigation works.

My property is in a Very Low Flood Risk Precinct. What does this mean?

The classification of a 'Very Low Flood Risk Precinct' can differ slightly between councils. In the case of the current study, it means that whilst your property would not be inundated in a 1000 year flood, it still has a very slight chance of inundation from larger (i.e. rarer) floods.

If you are a residential property owner, there will be virtually no change to how you may develop your property. However, there may be controls on the location of essential services such as hospitals, evacuation centres, nursing homes and emergency services.

My property is in a Low Flood Risk Precinct. What does this mean?

The classification of a 'Low Flood Risk Precinct' can differ slightly between councils. In the case of the current study, it means that whilst your property would not be inundated in a 200 year flood, it still has a slight chance of inundation from larger (i.e. rarer) floods.

If you are a residential property owner, there will be virtually no change to how you may develop your property. However, there may be controls on the location of essential services such as hospitals, evacuation centres, nursing homes and emergency services.

My property is in a Medium Flood Risk Precinct. What does this mean?

The classification of a 'Medium Flood Risk Precinct' can differ slightly between councils. In the case of the current study, it means that whilst your property is inundated in a 200 year flood, it is not subject to inundation in a 100 year event.

My property is in a High Flood Risk Precinct. What does this mean?

The classification of a 'High Flood Risk Precinct' can differ slightly between councils. In the case of the current study, it means that your property is inundated in a 100 year flood but is not in an Extreme Flood Risk Precinct.

My property is in an Extreme Flood Risk Precinct. What does this mean?

The classification of an 'Extreme Flood Risk Precinct' can differ slightly between councils. In the case of the current study, it means that your property is inundated in a 20 year flood. It is likely to be near a watercourse or major drainage system and very hazardous inundation may occur in some floods. This could mean that there would be a possible danger to personal safety, able bodied adults may have difficulty wading to safety, evacuation by trucks may be difficult, or there may be a potential for significant structural damage to buildings. This is an area of higher hazard where stricter controls may be applied.

Will my property value be altered if I am in a Flood Risk Precinct?

Any change in a council's classification of properties can have some impact on property values. Nevertheless, councils normally give due consideration to such impacts before introducing a system of flood risk classifications or any other classification system (e.g. bushfire risks, acid sulphate soil risk, etc). If your property is now classified as being in a Flood Risk Precinct, the real flood risks on your property have not changed, only its classification has altered. A prospective purchaser of your property could have previously discovered this risk if they had made enquiries themselves.

If you are in a Low or Very Low Flood Risk Precinct, generally there will be no controls on normal residential type development. Previous valuation studies have shown that under these circumstances, your property values will not alter significantly over the long term. Certainly, when a new system of classifying flood risks is introduced, there may be some short-term effect, particularly if the development implications of the precinct classification are not understood properly. This should only be a short-term effect however until the property market understands that over the long-term, the Low and Very Low Flood Risk Precinct classification will not change the way you use or develop your property.

Ultimately, however, the market determines the value of any residential property. Individual owners should seek their own valuation advice if they are concerned that the flood risk precinct categorisation may influence their property value.

My property was never classified as 'flood prone' or 'flood liable' before. Now it is in a Very Low, Low or Medium Flood Risk Precinct. Why?

The State Government changed the meaning of the terms 'flood prone', 'flood liable' and 'floodplain' in 2001. Prior to this time, these terms generally related to land below the 100 year flood level. Now it is different. These terms now relate to all land that could possibly be inundated, up to an extreme flood known as the probable maximum flood (PMF). This is a very rare flood.

The reason the Government changed the definition of these terms was because there was always some land above the 100 year flood level that was at risk of being inundated in rarer and more extreme flood events. History has shown that these rarer flood events can and do happen (e.g. the June 1867 Hawkesbury River flood, the April 1990 flood in Nyngan, the November 1996 flood in Coffs Harbour, the January 1998 flood in Katherine, the August 1998 flood in Wollongong, the 2002 floods in Europe, Hurricane Katrina in 2005, etc).

Will I be able to get house and contents insurance if my house is in a Flood Risk Precinct?

In contrast to the USA and many European countries, flood insurance has generally not been available in Australia for residential property. Following the disastrous floods in Coffs Harbour in November 1996 and in Wollongong in August 1998, very limited flood cover began to be offered by some insurance companies. From 2008, many insurance companies started offering wider cover although the extent of the cover particularly for very flood prone properties is still not well known and may differ between insurers. The most likely situation is that your insurer will now offer you some flood cover although this will be dependent of the flood level information that the insurer has for your property. (This may not necessarily be the same as that available from Council). If flood cover is offered, the classification of your property within a Flood Risk Precinct per se, is unlikely to alter the availability of cover. Obviously insurance policies and conditions may change over time or between insurance companies, and you should confirm the specific details of your situation with your insurer.

Will I be able to get a home loan if my land is in a Flood Risk Precinct?

Most banks and lending institutions do not account for flood risks when assessing home loan applications unless there is a very significant risk of flooding at your property. The system of Flood Risk Precinct classification will make it clear to all concerned, the nature of the flood risks. Under the previous system, if a prospective lending authority made appropriate enquiries, they could have identified the nature of the flood risk during assessment of home loan applications. As a result, it is not likely that the classification of your property within a Flood Risk Precinct will alter your ability to obtain a home loan. Nevertheless, property owners who are concerned about their ability to obtain a loan should clarify the situation with their own lending authority.

How have the flood risk maps been prepared?

Because some large and rare floods have often not been experienced or accurately recorded since European settlement commenced, computer models are used to simulate the depths and velocities of major floods. These computer models are normally established and operated by flooding experts employed by local and state government authorities. Because of the critical importance of the flood level estimates produced by the models, such modelling is subjected to very close scrutiny before flood information is formally adopted by a council. Maps of flood risks (e.g. 'very low', 'low', 'medium', 'high' and 'extreme') are prepared after consideration of such issues as flood depths and velocities for a range of possible floods.

What is the probable maximum flood (PMF)?

The PMF is the largest flood that could possibly occur. It is a very rare and improbable flood. Despite this, a number of historical floods in Australia have approached the magnitude of a PMF. Every property potentially inundated by a PMF will have some flood risk, even if it is very small. Under the State Government's Floodplain Development Manual (2005), councils must consider all flood risks, even these potentially small ones, when managing floodplains. As part of the State Government's Manual, the definitions of the terms 'flood liable', flood prone' and 'floodplain' refer to land inundated by the PMF.

What is the 100 year flood?

A 100 year flood is the flood that will occur or be exceeded on average once every 100 years. It has a probability of 1% of occurring in any given year. If your area has had a 100 year flood, it is a fallacy to think you will need to wait another 99 years before the next flood arrives. Floods do not happen like that. Some parts of Australia have received a couple of 100 year floods in one decade. On average, if you live to be 70 years old, you have a better than even chance of experiencing a 100 year flood.

Why do councils prepare floodplain management studies and plans?

Under NSW legislation, councils have the primary responsibility for management of development within floodplains. To appropriately manage development, councils need a strategic plan which considers the potential flood risks and balances these against the beneficial use of the floodplain by development. To do this, councils have to consider a range of environmental, social, economic, financial and engineering issues. This is what happens in a floodplain risk management study. The outcome of the study is the floodplain risk management plan, which details how best to manage flood risks in the floodplain for the foreseeable future.

Floodplain risk management plans normally comprise a range of works and measures such as:

- improvements to flood warning and emergency management;
- works (e.g. levees or detention basins) to protect existing development;
- voluntary purchase or house raising of severely flood-affected houses;

- planning and building controls to ensure future development is compatible with the flood risks; and
- measures to raise the community's awareness of flooding so that they are better able to deal with the flood risks they face.

Will the Flood Risk Precinct maps be changed?

Yes. All mapping undertaken by council is subjected to ongoing review. As these reviews take place, it is conceivable that changes to the mapping will occur, particularly if new flood level information or ground topography information becomes available. However, this is not expected to occur very often and the intervals between revisions to the maps would normally be many years. Many councils have a policy of reviewing and updating floodplain management studies and plans about every five to ten years. This is the likely frequency at which the maps may be amended.

12. GLOSSARY

Note that terms shown in bold are described elsewhere in this Glossary.

1% AEP flood	A **flood** that occurs (or is exceeded) on average once every 100 years. Also known as a 100 year flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
2% AEP flood	A **flood** that occurs (or is exceeded) on average once every 50 years. Also known as a 50 year flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
5% AEP flood	A **flood** that occurs (or is exceeded) on average once every 20 years. Also known as a 20 year flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
10% AEP flood	A **flood** that occurs (or is exceeded) on average once every 10 years. Also known as a 10 year flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
20% AEP flood	A **flood** that occurs (or is exceeded) on average once every 5 years. Also known as a 5 year flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
100 year ARI flood	A **flood** that occurs (or is exceeded) on average once every 100 years. Also known as a 1% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
50 year ARI flood	A **flood** that occurs (or is exceeded) on average once every 50 years. Also known as a 2% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
20 year ARI flood	A **flood** that occurs (or is exceeded) on average once every 20 years. Also known as a 5% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
10 year ARI flood	A **flood** that occurs (or is exceeded) on average once every 10 years. Also known as a 10% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
5 year ARI flood	A **flood** that occurs (or is exceeded) on average once every 5 years. Also known as a 20% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
afflux	The increase in flood level upstream of a constriction of flood flows. A road culvert, a pipe or a narrowing of the stream channel could cause the constriction.
ALS	Airborne laser scanning (ALS) is a procedure for surveying ground levels over large areas from an overflying aircraft.
annual exceedance probability (AEP)	AEP (measured as a percentage) is a term used to describe the frequency or probability of floods occurring. Large floods occur rarely, whereas small floods occur more frequently. For example, a 1% AEP flood occurs (or is exceeded) on average once every 100 years. It is also referred to as the ‘100 year flood’ or the ‘1 in 100 year flood’.

Australian Height Datum (AHD)	A common national plane of level approximately equivalent to the height above sea level. All flood levels, floor levels and ground levels are normally provided in metres AHD.
average annual damage (AAD)	Average annual damage is the average flood damage per year that would occur in an area over a long period of time.
average recurrence interval (ARI)	ARI (measured in years) is a term used to describe the frequency or probability of floods occurring. Large floods occur rarely, whereas small floods occur more frequently. For example, a 100 year ARI flood is a flood that occurs (or is exceeded) on average once every 100 years. See also **annual exceedance probability (AEP)**.
BoM	The Australian Bureau of Meteorology.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site.
DPC	NSW Department of Premier and Cabinet.
DPI	NSW Department of Planning and Infrastructure.
Development Control Plan (DCP)	A DCP is a plan prepared in accordance with Section 72 of the *Environmental Planning and Assessment Act, 1979* that provides detailed guidelines for the assessment of development applications.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (**m^3/s**). Discharge is different from the speed or **velocity** of flow, which is a measure of how fast the water is moving.
ECA	Evacuation Capability Assessment (ECA) compares the time required for an evacuation from an area with the time available based on the available flood warning.
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the *Local Government Act 1993*.
effective warning time	The time available after receiving advice of an impending **flood** and before the floodwaters prevent appropriate flood response actions being undertaken. The **effective warning time** is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding. In NSW, the State Emergency Service (SES) is the principal agency involved in emergency management during floods.
ERC	Evacuation Risk Class (ERC) is advice provided to consent authorities in relation to the evacuation risks for new development proposals.
Flood	A relatively high stream flow that overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam. It includes local overland flooding associated with major drainage before entering a watercourse. In addition, it includes coastal inundation resulting from raised sea levels, or waves overtopping the coastline.

Flood awareness	An appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood hazard	The potential for damage to property or risk to persons during a **flood**. Flood hazard is a key tool used to determine flood severity and is used for assessing the suitability of future types of land use.
flood liable land	Land susceptible to flooding up to the **probable maximum flood (PMF)**. Also called **flood prone land**. Note that the term 'flood liable land' now covers the whole of the **floodplain**, not just that part below the 100 year flood level.
flood planning levels (FPLs)	The combination of flood levels and **freeboards** selected for planning purposes, as determined in **floodplain risk management studies** and incorporated in **floodplain risk management plans**. The concept of flood planning levels supersedes the designated flood or the flood standard used in earlier studies.
flood prone land	Land susceptible to flooding up to the **probable maximum flood (PMF**). Also called **flood liable land**.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate damages during a **flood**.
flood risk precinct	An area of land with similar flood risks and where similar development controls may be applied by a council to manage the flood **risk**. (The flood risk is determined based on the existing development in the precinct or assuming the precinct is developed with normal residential uses). Usually the floodplain is categorised into three flood risk precincts — 'low', 'medium' and 'high' — although other classifications can sometimes be used such as the five flood risk precincts 'very low', 'low', 'medium', 'high' and 'extreme' classifications proposed in the current study . (See also **risk**).
Flood Study	A study that investigates flood behaviour, including identification of flood extents, flood levels and flood velocities for a range of flood sizes.
floodplain	The area of land that is subject to inundation by floods up to and including the **probable maximum flood** (PMF) event, that is, **flood prone land** or **flood liable land**.
Floodplain Risk Management Plan	The outcome of a **Floodplain Risk Management Study**. (Note that the term 'risk' is often dropped in common usage and 'Floodplain Risk Management Studies or Plans' are referred to as 'Floodplain Management Studies and Plans'.)
Floodplain Risk Management Study	These studies are carried out in accordance with the *Floodplain Development Manual* (NSW Government, 2005) and assess options for minimising the danger to life and property during **floods**. These options aim to achieve an equitable balance between environmental, social, economic, financial and engineering considerations. The outcome of a Floodplain Risk Management Study is a **Floodplain Risk Management Plan**.
floodway	Floodways are those parts of a floodplain where a significant discharge of water occurs during **floods**. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.

flow	See **discharge**
freeboard	A factor of safety expressed as the height above the flood level. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the **floodplain**, such and wave action, localised **hydraulic** behaviour and impacts that are specific event related, such as levee and embankment settlement, and other effects such as 'greenhouse' and climate change.
FRM	Floodplain risk management.
FRMS	Floodplain Risk Management Study
FRMP	Floodplain Risk Management Plan
geographical information system (GIS)	A system of software designed to support the management, manipulation, analysis and display of spatially referenced data.
geomorphology	The study of landforms.
high flood hazard	For a particular size **flood**, there may be a possible danger to personal safety, able-bodied adults may have difficulty wading to safety, evacuation by trucks may be difficult and/or there may be a potential for significant structural damage to buildings.
HNFMS	The Hawkesbury-Nepean Floodplain Management Strategy (HNFMS) was prepared under the guidance of the State Government following the establishment of the Hawkesbury-Nepean Flood Management Advisory Committee in 1997.
hydraulics	Term given to the study of water flow; in particular, the assessment of flow parameters such as water level and **velocity**.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the estimation of **peak discharges**, flow volumes and the derivation of hydrographs (graphs that show how the discharge at any particular location varies with time during a flood).
LCFP	When a flood is imminent, the Limit of Confident Flood Prediction (LCFP) is the time (in hours) ahead of a flood level being reached, at which confident flood predictions can be made.
Local Environmental Plan (LEP)	A Local Environmental Plan is a plan prepared in accordance with the *Environmental Planning and Assessment Act*, 1979, that defines zones, permissible uses within those zones and specifies development standards and other special matters for consideration with regard to the use or development of land.
LGA	Local Government Area.
Low flood hazard	For a particular size flood, able-bodied adults would generally have little difficulty wading and trucks could be used to evacuate people and their possessions should it be necessary.
m AHD	Metres **Australian Height Datum (AHD)**.
m/s	Metres per second. Unit used to describe the **velocity** of floodwaters. 10km/h ≈ 2.8m/s.

m^3/s	Cubic metres per second or 'cumecs'. A unit of measurement for flows or **discharges**. It is the rate of flow of water measured in terms of volume per unit time.
merit approach	The principles of the merit approach are embodied in the *Floodplain Development Manual* (NSW Government, 2005) and weigh up social, economic, ecological and cultural impacts of land use options for different **flood prone** areas together with flood damage, **hazard** and behaviour implications, and environmental protection and well-being of the State's rivers and **floodplains**.
OEH	NSW Office of Environment and Heritage was formed in April 2011. Previously the State Government's Flooding Unit was part of the NSW Department of Environment, Climate Change and Water (DECCW). Prior to that it was part of the Department of Environment and Climate Change (DECC), the Department of Natural Resources (DNR), and the Department of Infrastructure, Planning and Natural Resources (DIPNR).
overland flow path	The path that floodwaters can follow when not confined within a flow channel. Overland flow paths can occur through private property or along roads.
peak discharge	The maximum **flow** or **discharge** during a flood.
present value	In relation to flood damage, is the sum of all future flood damages that can be expected over a fixed period (usually 20 years) expressed as a cost in today's value.
probable maximum flood (PMF)	The largest flood likely to ever occur. It has a very rare chance of occurring. The PMF defines the extent of **flood prone land** or **flood liable land**, that is, the **floodplain**.
QPF Limit	The Quantitative Precipitation Forecast (QPF) Limit is a time (in hours) beyond which flood predictions issued by the Bureau of Meteorology must be based on consideration of predicted rainfall rather than measured rainfall.
reliable access	During a **flood**, reliable access means the ability for people to safely evacuate an area subject to imminent flooding within the **effective warning time**, having regard to the depth and **velocity** of floodwaters, the suitability of the evacuation route and other relevant factors.
risk	Risk is measured in terms of consequences and likelihood. In the context of floodplain management, it is the likelihood and consequences arising from the interaction of floods, communities and the environment. For example, the potential inundation of an aged person's facility presents a greater flood risk than the potential inundation of a sportsground amenities block (if both buildings were to experience the same type and probability of flooding). Reducing the probability of flooding reduces the risk, increasing the consequences increases risk. (See also **flood risk precinct**).
risk management	The process of identifying, analysing, evaluating, treating, monitoring and communicating risks. A generic framework for risk management in Australia is provided in the joint Australian and New Zealand Standard AS/NZS 4360;1999.
runoff	The amount of rainfall that ends up as flow in a stream, also known as rainfall excess.

SES State Emergency Service of New South Wales.

Section 149 Certificates In NSW, councils issue these certificates to potential property purchasers under Section 149 of the NSW Environmental Planning and Assessment Act. It is compulsory to attach S149(2) certificates to contracts for sale of land and these certificates generally identify policies affecting development of the land. Other information and risks concerning the property are generally provided on S149(5) certificates (which are not compulsory in contracts for sale of land).

stage–damage curve A relationship between different water depths and the predicted flood damage at that depth.

velocity The term used to describe the speed of floodwaters, usually in **m/s** (metres per second). 10km/h = 2.8m/s.

APPENDIX A

INFORMATION ABOUT THE 1867 FLOOD

- **Images**
- **Newspaper extracts**
- **Flood hydrograph at Windsor**
- **Flood extent**

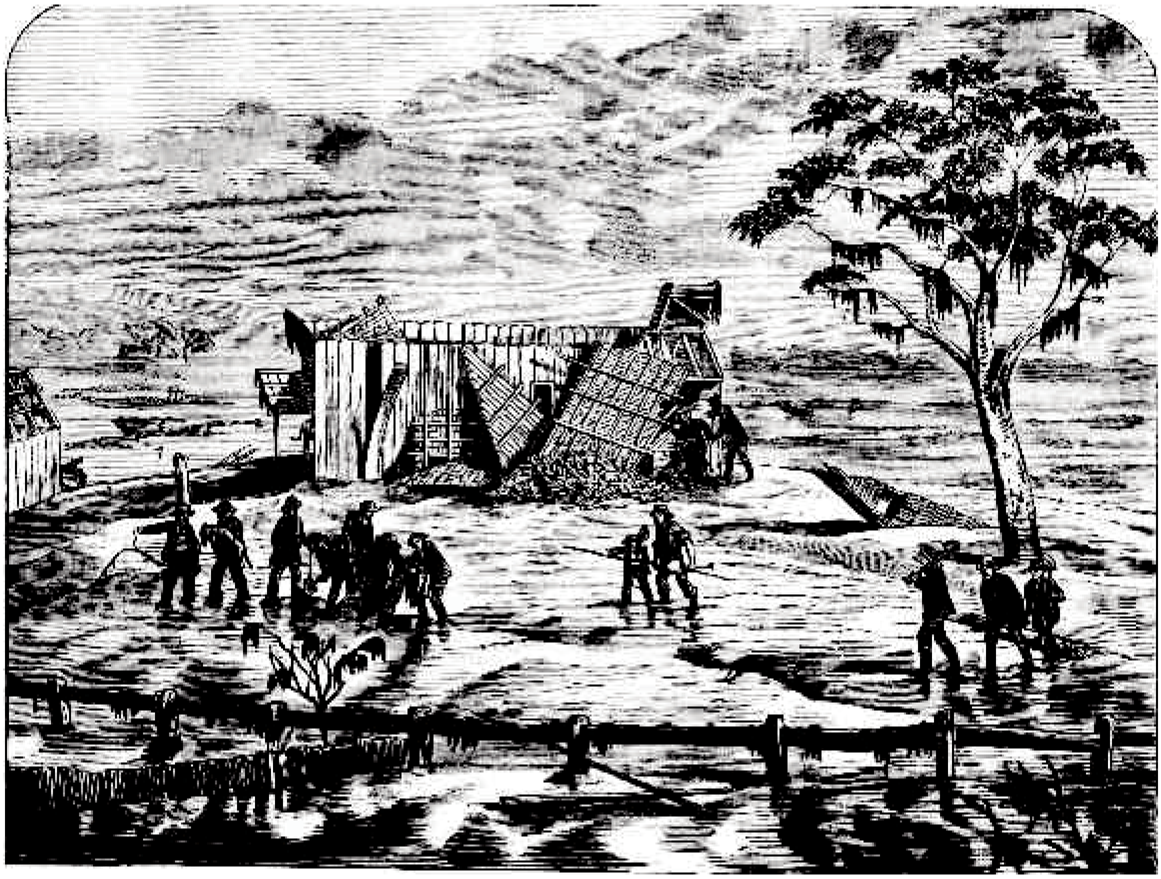
IMAGES

Night rescue scene
Source: *Illustrated Sydney News*, 16 July 1867, p.1

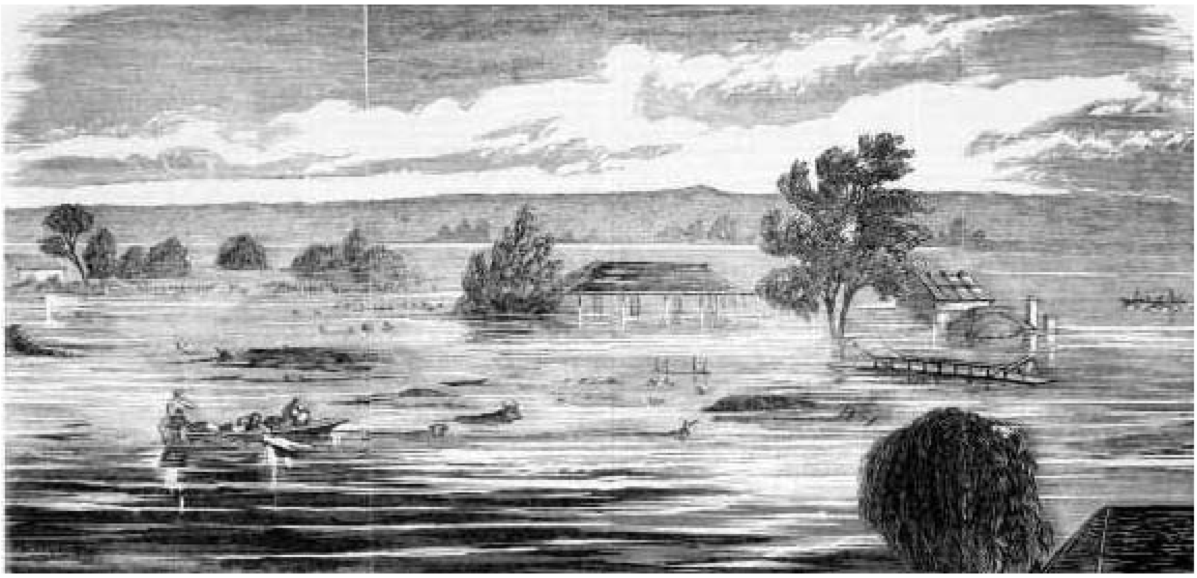
The drowning of the families of William and Thomas Eather
Source: *Illustrated Sydney News*, 16 July 1867, p.8

Rescue boats rowing through the bush at night
Source: *Illustrated Sydney News*, 16 July 1867, p.9

Bush scene during the floods
Source: *Illustrated Sydney News*, 16 July 1867, p.9



The ruins of the Eathers' house and the finding of the drowned
Source: *Illustrated Sydney News*, 16 August 1867, p.8



Ryans Punt near Windsor
Source: Wood engraving, 27 July 1867 (State Library of Victoria, Image Number: mp001184)

Windsor at Nightfall
Source: W.H. Harrison wood engraving, 27 July 1867 (State Library of Victoria, Image Number: mp001185)

NEWSPAPER EXTRACTS

Sydney Morning Herald (SMH), Monday 24th June 1867 p.5 'The flood at Windsor'

(extracted from Bracewell & McDermott, 1985, with a few revisions based on Walker, 1887)

The flood in this district is said to be by far the highest which has occurred since its settlement by Europeans. The town of Windsor itself is almost entirely submerged, and the country for miles around is under water. The only parts of the township now habitable are a portion of George Street, Fairfield (the residence of the Rev. C.F. Garnsey), Hopkins Hill (the residence of Mr. W. Walker, M.L.A.), McQuades Corner, and the ground on which stands the Roman Catholic Church. These form only a small part of the area built upon, and the rest is almost altogether out of sight, the line of the other thoroughfares being in some places merely recognisable by means of the chimneys and roofs of the higher houses projecting above the surface of the water. The place has an appearance inconceivably dreary and desolate, and the inhabitants are in sore distress. The calamity which has befallen them is truly appalling, and it is heartrending to witness their condition. The settlers from miles round have been brought into Windsor, but not a vestige of their property is left to them. Many who last week were in circumstances of comfort, if not of affluence, are now reduced to utter destitution, and are wholly dependent on the kindness of friends or the aid of Government for the means of subsistence. The School of Arts is crowded with houseless sufferers, so too are the court-house, the Anglican, the Roman Catholic and the Wesleyan churches. Nothing can exceed the hospitality shown by the inhabitants whose houses are above the flood line towards their less fortunate townsfolk. They have been up night and day during the latter part of the week, and have spared no trouble or expense to rescue the endangered and to mitigate the sufferings. Though worn out by anxiety, fatigue, and exposure, their generous sympathy is not repressed, and they are now relieving the necessities of the more wretched as best they can. Nearly all their dwellings are inconveniently crowded by those who have been washed out; and I may mention, that last night the residence and premises of the Rev, C.F. Garnsey - not extraordinarily large - afforded a lodgement to about two hundred persons. At a place at Pitt Town, there are thirty-five children in charge of one lady. Other houses .are crowded in similar proportion. There are only three hotels above water. One is the Fitzroy, and the names of the others I forget; but the accommodation available is small. The only bakehouse left is that of Mr. Moses. Hundreds of persons who have fled to the high lands are without food and shelter, and will have to be brought into Windsor to-day. Many are already feeling the pangs of hunger, or suffering from the cold; and the distress which must inevitably prevail is frightful to contemplate, and the resources of the inhabitants are altogether inadequate to meet it.

The Government have authorised Mr. William Walker, the representative of the district in the Legislative Assembly, to expend any reasonable sum of money to meet pressing necessities, and the lot of the sufferers will thus to some extent be alleviated. The colonists, however, though prone to look to the Executive for the appointment of poundkeepers and the building of bridges, are not wont to delegate the expression of their sympathy to Government, and in the presence of a disaster of this magnitude will not rest satisfied with the assistance which it is advisable and convenient that the Government should temporarily dispense. Doubtless, as soon as the extent of the calamity becomes known, the commiseration which is already felt will take the form of active spontaneous benevolence.

The gloomiest forebodings as to probable loss of life are prevalent. It is reported that William and [Thomas] Eather, farmers living at Cornwallis, placed their wives and children on the roofs of their houses, and there clung with them awaiting help until the rising waters washed them off. The two wives and their ten children were overwhelmed in the flood, and the husbands saved themselves and one little boy by swimming to a willow tree from which they were shortly afterwards rescued and taken in a boat to Richmond. It is said that they made fruitless attempts to save their wives and children; and that one of the poor women seeing the impossibility of escape, begged of her husband to save himself and not to mind her. *[Text deleted]*

The volume of water has astoundingly increased since Thursday. On Friday many buildings in the town were in jeopardy and on Saturday the whole township, excepting the two or three patches already named, was overwhelmed. The water rose very rapidly, and the inhabitants were in dread of being swamped altogether. Most of them thought that they would have to betake themselves to the Terrace, the nearest and most accessible town in the Blue Mountains. The water continued to rise slowly during the night, but at 5 o'clock yesterday (Sunday) morning it was at a standstill, and by 8 o'clock the water had gone down three or four inches. It was at first thought that the fall was partly owing to the tidal influence of the Hawkesbury. Happily, however, the flood line slowly receded all the forenoon, and in the afternoon, at Riverstone, it was evident that the fall, though very gradual was never the less steady. Some portions of George Street, the main thoroughfare in Windsor, must be fifteen or sixteen feet deep, and in several places about the township the telegraph posts and wires were not visible. Mr. Ascough's house is under water, so also are the Royal, The Australian, and Houlding's Hotel. The properties belonging to Mr. T. Primrose, Mr. T. Gollison, Mr. Eather, and Mrs. Donovan are submerged. Mr. Byrons's chemist shop, Mr. Freeman's place (formerly the White Horse), Mr. P. Doyles Hotel, and most of the other principal buildings in their localities are in a like condition. The Scots kirk is partly covered. Mr. Dawson's drapery warehouse in George-street is half under water, and the flood went to within a few feet of the Commercial Hotel. It was three feet in the cellars of the Fitzroy. The piece of George-street immediately above these premises on the summit of the hill was of very small extent as the water was round at the other end to as equal height, and the breadth of "dry" ground at the back of the houses on each side of the street was not more than one hundred feet. Fortunately, however the banks and most of the largest business houses are built upon this very spot - the crown of the hill. Another six feet, or ten at the most, would not have left an inch of ground in Windsor unwashed by the flood.

The expanse of flood is so great, that everybody is astonished at the tremendous accumulation of water, and it will seem incredible to all who have not actually seen it. Places which since the settlement of the colony, have never been known to be flooded are now lost to view. The plain on which Windsor is partly situated unites with South Creek and Eastern Creek to form a vast inland sea over the surface of which when the wind has been high the broken crested billows roll with as much force and volume as they do during moderately squally weather in Sydney Harbour. A boat may now be taken through deep water from Riverstone to the Blue Mountains - a distance of about 15 miles; and from Hall's at Pitt Town to the Kurrajong - some twenty miles. If the course of the Hawkesbury were taken, the area of flooded country would be considerably greater. Mulgrave railway station is buried, the tops of the laminated arches of the bridge there being under water and Rice's steaming-down establishment at South Creek is *'non est inventus'*, or at any rate *'invisus'*. The whole of this area was under cultivation, and crops of maize in many instances are ungarnered. The young wheat, the oaks and the lucerne crops must all be destroyed. In many parts the district was thickly peopled, but homesteads - houses, stacks and barns - are for the present covered by the flood or swept down with the current. Herds of cattle, pigs, numbers of horses and quantities of poultry are drowned, though perhaps some of the horse and horned stock - *rari nantes in gurgite vasto*[55] - may yet turn up in out of the way places when the owners can get a chance to look after them.

Senior-Sergeant Ferris, piloted by Mr. Ridge and Mr. Gasper, arrived at Windsor with four boats, manned by the Water police and Government boatmen at 3 o'clock pm on Wednesday, and they immediately set to work to remove settlers in the most dangerous places to positions which were supposed to be beyond the reach of the flood. I say "supposed" because it turned out afterwards that some of them had to be re-removed, or they would assuredly have perished. Besides the four boats sent up by Government there were a few private boats in the district, and they were manfully managed by Mr. R. Dick, Mr. R. Ridge, Mr. Johnson, Mr. J. Lane and other gentlemen whose names I did not learn. From Thursday afternoon until Saturday night they plied the oars with almost

[55] The Latin term 'Rare nantes in Gurgi vast', literally translated, means *rare survivors in the vast sea* (Virgil, Aeneid, I, 118). This is the final picture that Virgil presents after the description of the shipwreck of Aeneas and his companions. In a metaphorical sense, for example, it is said of those who, following a period of general crisis, managed to stay afloat and to overcome adversity. (Source: Wikipedia).

superhuman energy, and conveyed hundreds of people from Blacktown, Pitt Town, Wilberforce, Freeman's Reach, Mulgrave, McGraths's Hill, the Chain of Ponds, the Cornwallis, Clarendon (Richmond Road), South Creek and Eastern Creek to Windsor or the nearest points of safety. The waters rose so fast that rescue in many cases seemed perfectly hopeless, and I understand that when the boats touched at Windsor with their cargoes of precious freight the men were frantically besieged by excited throngs of people, clamorously beseeching them to go "such a place after such a person" and as may naturally be supposed, they carne in for a pretty fair share of remonstrance, not to say abuse from unreasoning friends who, in their despair; considered as lost their wives, husbands, mothers, fathers, sisters, brothers, or other friends as the case might be. The boatmen, private as well Government, kept tolerably calm and went on the with their work with resolution and vigour. The wind at times blew furiously, the rain carne down in torrents, and the waters rolled over the plain with tumultuous impetuosity. The boats had to be shot round chimneys or gable corners, rowed over fences and telegraph wires, or to be pushed through patches of forest, but despite every difficulty, the men worked cautiously as well as expeditiously. None of their boats were stove, hundreds of persons were transferred from one place to another, and I do not believe that you could find a man in Windsor who does not gratefully acknowledge his indebtedness to the brave fellows who timely arrived from Sydney, and to his fellow townsmen. I have not heard a single complaint of lack of diligence or duty, but all are ready to express admiration of the noble intrepidity exhibited at this trying time.

The people saved were mostly taken from the upper windows of their houses; many were taken off the ridge poles, and some were dragged out through holes cut in the roof. The great majority were overjoyed at their deliverance but many thought it impossible that the flood could reach them, and almost had to be forced to quit. There was generally speaking, no time to go down into the houses for wearing apparel, or indeed to shut doors or windows casements. There were some few unfortunate folk perched on the roofs of their houses who were loth *[sic]* to leave without their possessions. The boatsmen appear to have thought it uncommonly unaccountable that they should be accosted in this style: "Oh, my poor pig! arn't you going to take my poor pig?" by a man whom they were tearing from the grasp of death.

It would be impossible to give a narrative of a tithe even of the narrow escapes which different settlers and their families had from destruction, for those engaged in this perilous enterprise were too eagerly and incessantly occupied to remember much of what occurred. I may, however, relate a few incidents which have come to my knowledge, in order to give a general idea of the whole. At Cornwallis, a man named Alfred Norris, trying to escape from the flood, climbed up a willow tree and lashed his wife and two children to the branches. A third child he held in his arms. When discovered the flood had risen to where he was, and he was holding one of the children aloft in order to keep him out of the rising water. Had he not have been rescued by a boat he must soon have dropped from exhaustion or have been swept over by the rising stream. At the same place a man, name [Cupitt], was taken off the ridge-pole of his house, and soon afterwards the house was washed away. About twenty persons were lowered out of the windows of Mr. Baker's house, and ten or fifteen from Mrs. Dargin's. Mr. H. Bowman was taken out through the window of his house; and Mrs. Scarvill and family as well as some members of Mr. Want's family who were visiting at Clare House, Killarney, were rescued in a similar manner. The pilot boat took thirty-five persons out of Schofield's at McGrath's Hill. Most of the people at Pitt Town were removed to the church and schoolhouse, and some were taken to Clarendon and Clifton. On Friday night guns were being fired off in all directions and these signals of distress were answered by the boats' crews as speedily as possible. The residents at one place - I think McGrath's Hill - had a very narrow escape. One of the crew happened to see the flickering gleams of a light burning very faintly and hardly visible. It was about 3 o'clock in the morning when the boat pulled up and found nearly eighty men, women, and children crowded into a few places. Thirty were taken out of one loft, and there was just time for the return of the boats for the rest before the flood rose above the building in which they had taken refuge. The poor folks had given themselves up for lost.

Several families have fled to the ranges at the back of Mulgrave as well as to the hills at other places. A word or two about the condition of one family may suffice to indicate the lot of others similarly situated. Two of the boats sent up from Sydney were passing the "mainland" for so I may fitly describe it, when they saw a light and heard "cooeing" in the distance. For two hours before, the men had been groping their way in the darkness among the trees and snags. Most of them were thinly clad, and being exposed to a drenching rain and a biting westerly wind, the cold was beginning to benumb the limbs of those who were not pulling. When the men heard what they supposed were cries for help, the moody silence which had settled down on the company was instantly broken by responsive "cooeings", and all were energised by a new impulse. An "opening" happened to occur in front, and the boats were quickly at the shore. The people, however, were not in distress for on approaching the shore, we saw them rising from their crouching posture round the blazing log, and thus discovered that they were not in the slightest "danger". The men got out of the boats to "stretch their legs", and make inquiries as to their whereabouts. The watchers around, the fire consisted of a man with a wooden leg, his wife, and their children, five or six in number, all apparently under twelve years of age. All were poorly clad, in fact, half naked; but the mother and her little girls were worst off without shoes or stockings - a melancholy group. They stood around the fire ankle deep in mud. Their homestead and farm a few paces away, were under the flood; and they had been bereft of every earthly comfort. Their only prospect was to patiently endure the calamity which had overtaken them. They seemed resigned to their fate, and had been moodily listening to the moaning of the wind and surging of the water - a mournful cadence, which seemed to correspond with their dismal situation, and give utterance to their grief. The good woman at the head of this "social" gathering received us very hospitably and would have made tea had we have staid. The eldest of the girls was very pensive, and the men from the boats, though they spoke little, were deeply moved as they looked on the children whose fragile forms were exposed to the storm. How sadly did their lot contrast with that of hundreds snugly housed in Sydney! One of the boatmen discovered comfort in the fact that they had something yet for the fire was still left them. But they were not secure in the enjoyment of even that. The leaden expanse of water, a few yards away, was creeping upwards, and the rain had not then ceased. As I afterwards found, there are many in a worse plight than these poor people. They had saved about a barrowful of things; but others have saved nothing. Some lines in "Lear" forcibly describe the condition of these unhappy sufferers, and as they also put a query which must be now occupying the thoughts of many minds I will quote them:

> "Poor naked wretches, whereso'er you are,
> That bide the pelting of this pitiless storm,
> How shall your houseless heads and unfed sides,
> Your looped and windowed raggedness, defend you
> From seasons such as these?"

Few, if any, attempts could be made to save stock. I am told that there was a small steamer at Windsor which might have been made useful in this way, but "the owner was not at home, and the vessel was insured," therefore it was not used. Large numbers of animals were swimming. about, and some of the horses persistently tried to force themselves through the open doorways of the houses. A valuable imported horse, the property of Mr. Seeth, worth £500, was swimming for four hours when one of the police boats took him in tow to Windsor.

The people in Windsor are in a most desolate condition. Most of them have had no sleep for two or three nights; they have had but little food and that at irregular intervals, and they have gone through intense anxiety and fatigue. This is strongly marked on their faces. I have never seen a more disconsolate company than the small throng which the grey light of yesterday morning revealed gauging the height of the flood in George street.

What is left of the town is extremely wretched. Chimneys, crowned with dismal looking cats, crop up here and there, and there are few roofs which are not occupied as roosts by poultry. Quantities of flotsam and jetsam in the shape of furniture, bundles of straw, etc., are drifting about. Many of the houses have been washed down, and more must tumble as soon as the waters subside, especially if a westerly wind - the most prevalent at this season of the year - should spring up.

The weather yesterday was perfectly calm and fine, and the scenery between Windsor and Riverstone could not, now the waters are abroad, be surpassed for picturesqueness and beauty. But if anyone were disposed to contemplate the gorgeous hues of the Kurrajong, as it is bathed in the golden sunlight, or draped with clouds of snowy whiteness, he has only to look on the other hand to see one and another, hapless wretch shivering from cold and hunger, and he will be reminded that his boat is passing over orangeries, vineyards and fields; which a day or two ago gave promise of abundant harvests. At present, the railway line is submerged, and the ridgepoles of the station-houses, both at Windsor and Riverstone, are not more than two feet out of water.

At Riverstone two houses only have escaped the flood: and they are not more than a few feet from the outermost edge of the water. Mr. Bliss's elegant villa, with all the furniture in it, is under water; and two families had to be taken off the roofs of their houses by the boats which the Government sent up in charge of Mr. Owen, the traffic manager, from Sydney. One family consisted of seven persons: the other, of a widow woman and three or four children.

The railway engine cannot approach within half a mile of the station at Riverstone. The mails from Sydney to Windsor were taken up on Friday night by Mr. Thomas, engineer for existing lines of railway, and Mr. Owen: and on Saturday night the mail bags were taken by the last-named gentleman, who was despatched by the Government in charge of the boats designed for use at Richmond. The navigation through the bush at night is tedious, dangerous and difficult, and great credit is due to the gentlemen named for their pluck and perseverance in the matter. Mr. Owen reached Windsor at 9 o'clock on Saturday night, but could not find the station house, inasmuch as it was under water. On account of the accumulation of wood and debris, it took another hour to push the boats up George street to the post office. He then proceeded with the boats, which were manned principally by men from the railway station at Redfern, to Richmond, where as I understand, he was occupied during the remainder of the night and of yesterday morning in saving life.

Mr. Thomas was in charge of a special train on the line between Riverstone and Blacktown yesterday. Mr. Owen confirmed the report about the Eathers. He returned to Riverstone yesterday afternoon, came down by special train to Parramatta and then went back immediately with a ton of flour and bread which Mr. Byrnes had in readiness for an emergency. The people at Richmond are said to be starving. Mr. Byrnes, the Minister for Works, had four boats in readiness to send up to Windsor first thing yesterday morning: but on going up to Riverstone he found that the flood had begun to recede and therefore did not consider it necessary to send them. At Pitt Town the people are not in immediate want.

The line between Windsor and Riverstone cannot in all probability be opened for some time. The ballast is of an inferior description, and at present is of the consistency of mud. The railway lines at other places are uninjured.

I hear that the men in the railway department who manned the boats at Richmond acted with great tact and promptitude, and that a young fellow named Paul particularly distinguished himself by his heroism. Some of the officers and men of the railway department have shown great endurance and self-sacrifice in regard to the flooded out.

SMH, Monday 1st July 1867, p.3, 'Windsor'

INQUEST ON SIX BODIES OF THE EATHERS, LOST IN THE FLOOD - A coroner's inquiry was held yesterday (Wednesday) at the Commercial Hotel, before Mr. Laban White and a jury, on the bodies of Catherine Eather, Mary Ann Eather, Catherine Eather the younger, Charles Eather, Emma Eather, and Annie Eather, the wives and children of William and Thomas Eather, of Cornwallis, whose mournful fate will scarcely ever be forgotten in this district.

Thomas Eather having been duly sworn, deposed: I am a farmer, and resided in the Cornwallis, my family consisted of my wife Emma, aged thirty-six years, and four girls and two boys, of the several ages of sixteen, fourteen, twelve, ten, eight, and three years. The last time I saw six of them alive (the eldest son of Thomas Eather, the deponent, was fortunately from home, and not in the flood) was on Friday night, yesterday my oldest daughter Annie was brought into Windsor, the body having been seen floating near the place where she was drowned; today the body of my wife Emma, was found. On Friday afternoon the waters had risen, and continued to rise, very rapidly; we were all obliged to fly to the ridge pole of the house, hoping to be rescued by some boat; we remained some hours in awful suspense till the violence of the wind and waves swept the building and the whole of us into the water. I came up to the surface, and found myself in the branches of a cedar tree; I looked round after my wife and children but could see none of them; in about an hour after I was rescued by three men in a boat; I told them what had happened, they landed me at Mr. Arthur Dight's, Clarendon, there must have been twenty feet of water where my family were drowned.

William Eather being duly sworn deposed : I am a farmer, and resided at Cornwallis ; my family consisted of my wife, Catherine Eather, aged 37, and my children Mary Anne, Catherine, Charles, Clara, and William, of the respective ages of 11, 9, 6, 3, and 1 years ; on last Friday night I saw them alive ; they were then on the top of a house of my brother George Eather, having gone there for safety; I was with them; we were about 200 yards from my brother Thomas's; we had been there from Thursday night; on Friday night I was about taking by oldest boy into my arms, when I was washed away by the waves; I saw a tree close by me after I came to the surface, and managed to make for it. I heard the screams of my wife and children but could not see them; I fastened myself to the tree, and in a short time was rescued by a boat specially sent by Mr Arthur Dight; I believe my wife and three of my children have been brought to Windsor dead.

Philip Maguire deposed : I am a farmer, and live at Nelson, and a brother in-law of Mrs. William Eather; I went with Charles Eather, Thomas Eather, and Charles Westall, in search of bodies; yesterday (Tuesday), about two o'clock in the afternoon, we found Thomas Eather's eldest daughter Annie, floating about forty yards from where the family had been carried away; this morning we recovered four more bodies; the dead bodies of which the coroner and jury have had a view I recognise as the remains of Catherine Eather, wife of William Eather. and Mary Ann, Catherine, and Charles, the children of William Eather, also Emma, the wife of Thomas Eather and Annie, his eldest daughter.

The jury returned a verdict of accidental drowning. Boats have been out all day searching for the other bodies, but have returned unsuccessful.

SMH, Wednesday 28th August 1867, p.3, 'Windsor'

INQUEST - An inquest was held at Freeman's Reach, on Monday last, before Mr. Laban White, coroner, and a jury, on the body of Elizabeth Eather, daughter of Thomas Eather, one of the unfortunate persons who lost their lives in the late flood. Charles Clarke, a labourer, deposed:

About half past 6 o'clock this morning I went to the river for a bucket of water. I saw something on the sandbank near the river which I supposed to be a dead body-a dog was smelling at it, I went up and found that it was the body of a child, only the skull and left shoulder were exposed. I immediately gave information to the police at Windsor. It is about two months since the great flood, a strong current ran from Eather's house on the opposite side towards this place. The spot where the deceased is lying is no higher up the bank than high-water mark. Eather's house was about a mile from here on the other side of the river. George Eather deposed: I am the brother of William and Thomas Eather, whose wives and children were lost in the late flood, the bodies of six of them were discovered after the flood near the place where the deceased now lies, I can identify the body as that of Elizabeth Eather, daughter of my brother Thomas; she was ten or eleven years of age. The jury found "That the death of Elizabeth Eather was from accidental drowning in the late flood."

SMH, Friday 28th June 1867 p.5 'The weather at Windsor' by John Tebbutt

THE following résumé of the meteorological observations made here during the recent tempestuous weather will probably be interesting to your readers. The temperature during the months of May and June has been unusually high. There has been no frost up to this date, though it generally sets in by the middle of May. The lowest temperature yet reached, as indicated by the self-registering thermometer, is 32.9 on the 11th instant. In conjunction with the high temperature, the humidity of the atmosphere has been excessive, a combination which in winter is not an suspicious one. The month of May was most remarkably cloudy, whereas, as a rule, it is by far the clearest month in the year. From the 8th to the 17th instant the weather was fine, with light N.E. and S.E. winds; the character of the clouds during this period indicated the prevalence of tropical currents in the upper regions of the atmosphere. Lunar halos were frequent. The 17th was dull and cloudy. Rain set in on the morning of the 18th, and continued, with scarcely any intermission, till the night of the 22nd, when the weather began to clear. The wind continued steady from the S.E. and E.S.E. As was remarked in the case of the great flood of June, 1864, the rain clouds came up steadily throughout from the E. and E.S.E. Unfortunately the total amount of the rainfall could not be ascertained, as the gauge had to be removed from its position in the evening of the 21st, owing to the rapid rise of the flood, the water being then higher than the flood of June, 1864. The following are the amounts recorded while observations were practicable:

24h., ended 9 a.m. on 18th	0.050 inches
24h., ended 9 a.m. on 19th	0.923 inches
24h., ended 9 a.m. on 20th	4.229 inches
24h., ended 9 a.m. on 21st	2.944 inches
11h., ended 8 p.m. on 21st	1.220 inches
Total	9.366 inches

I should think the total rainfall up to the 23rd could not be less than 12 inches. The barometer fell steadily from 30.33 at 9 a.m. on the 12th, to 29.89 at 2 p.m. on the 21st, when the instrument was taken down. The greatest force of wind was experienced in the forenoon of the 21st from the S.E., but did not reach that of a gale. The flood reached its greatest height about 5 a.m. on the 23rd, being then about 14 ½ feet above the flood-mark of June, 1864, or about 62 feet above the mean tidal level of the South Creek, a tributary of the Hawkesbury.

The exact height will be determined at a favourable opportunity. The Observatory itself was so far submerged that the summit of the revolving roof was only about three feet above the water. I will here give, for comparison, the heights of the different floods that have occurred during the past ten years, as recorded by myself. The times given are those at which the floods attained their maxima, and the heights are given above the mean tidal level of the South Creek :- .

June 29th, 1857	32.1 ft
August 22nd, 1857	37.1 ft
February 12th, 1860	26.9 ft
April 29th-30th, 1860	36.8 ft
July 26th, 1860	34.3 ft
November 19th, 1860	35.4 ft
March 1st, 1864	22.4 ft
June 4th, 1864	22.1 ft
June 13th, 1864	47.4 ft
July 16th, 1864	35.6 ft
June 15th, 1866	26.0 ft (approx.)
July 13th, 1866	26.9 ft
April 15th-16th, 1867	20.6 ft
April 30th, 1867	25.9 ft
June 23rd, 1867	62.0 ft (approx.)

The above comparison will show how greatly the present disastrous flood has outstripped all its predecessors.

From the morning of the 23rd instant to the present date the weather has been beautifully fine, with light N.E. and N.W. winds. The barometer at 9 a.m. on the 25th stood at 30.066, corrected for temperature-the first observation obtained since the removal of the instruments, and is slowly rising. The height of the cistern above the mean tidal level is 53 feet.

JOHN TEBBUTT, JUN.

[Note that the above flood levels have been slightly revised – see WMA, 1996, Appendix D.A]

SMH, Tuesday 20th August 1867 p.4 Editorial

The large number of persons thus interested in trying to understand the science of rain-fall, will appreciate the effort now made to circulate with promptitude the observations taken by the Government Astronomer in Sydney. The observations for the flood month of June have just been published by Mr. SMALLEY in a neat pamphlet form, accompanied by a chart with the meteorological curves…

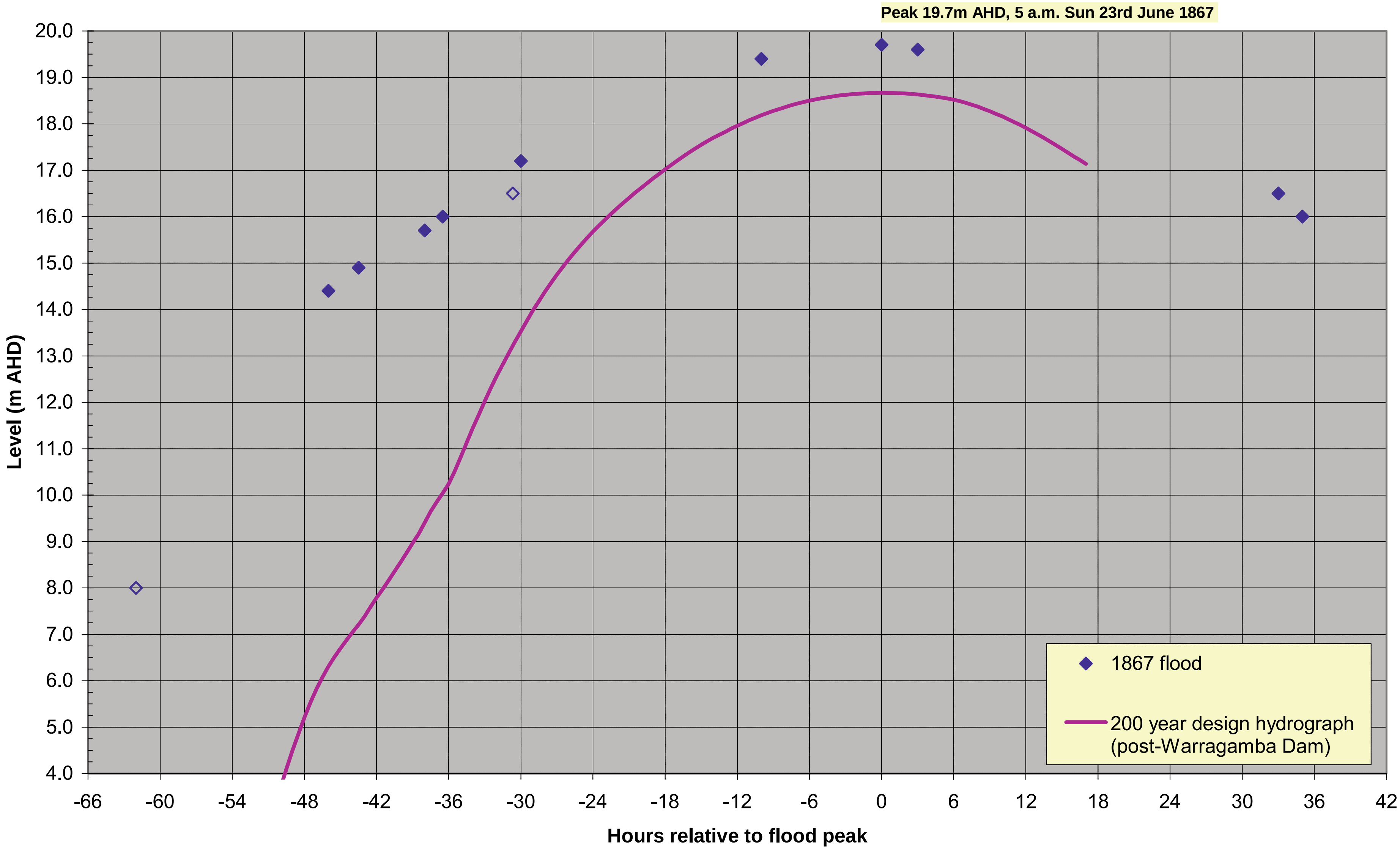
For the first sixteen days of [June] the wind was steadily west or west-north-west. On six of those days there had been rain, but very slight, not amounting to half-an-inch altogether. On the seventeenth, at the full of the moon–a point for those who believe in the moon's influence on the weather–the wind suddenly shifted to the south-east, but blew lightly, and with no rain. The next day it veered to the north-north-east. The velocity increased, and there was a little rain. On the next day the wind was a little more easterly, and more than an inch of rain fell, the violence of the wind still increasing. The storm therefore came up very gradually. If there had been any possibility of telling what was still behind, the warning was ample. It was not till the fourth day that the storm burst in its fury, and then the velocity of the wind and the fall of the rain was nearly quadruple that of the previous day, the direction of the wind being east-north-east. On the following day the wind scarcely abated, but the rainfall diminished by nearly one-half. The wind lulled still more on the next day, but with an increase in the rainfall. On the succeeding day both wind and rain diminished, and on the twenty-fourth the wind chopped round again to the west-north-west, and all was fine once more. Intercalated, therefore, in a month of prevailing westerly winds, there were seven days of wind from the eastward, and in six of those days rain fell, the heaviest rainfall being on the middle day of the seven. During the six days the recorded rainfall was 12.15, and on the stormiest day the rainfall was 4.12. We have records of a far heavier rainfall than this, although the flood on the Hawkesbury was so much higher than any ever previously known. The only explanation of this fact is to suppose that the rain last June must have fallen much more heavily inland than it did at Sydney. If we had had rain gauges at the various telegraph stations we should have been able to verify this conjecture.

It will be noticed that the storm wind set in from the south-east, and all the vessels trading between Sydney and New Zealand that week reported heavy weather. Yet the rain was comparatively a warm one, and so far would seem to indicate that it came from some more northern latitude. It will be interesting, if we can do it, to find the birth-place of the rainstorms that burst upon our coast, and track their pathway along the ocean till they reach us.

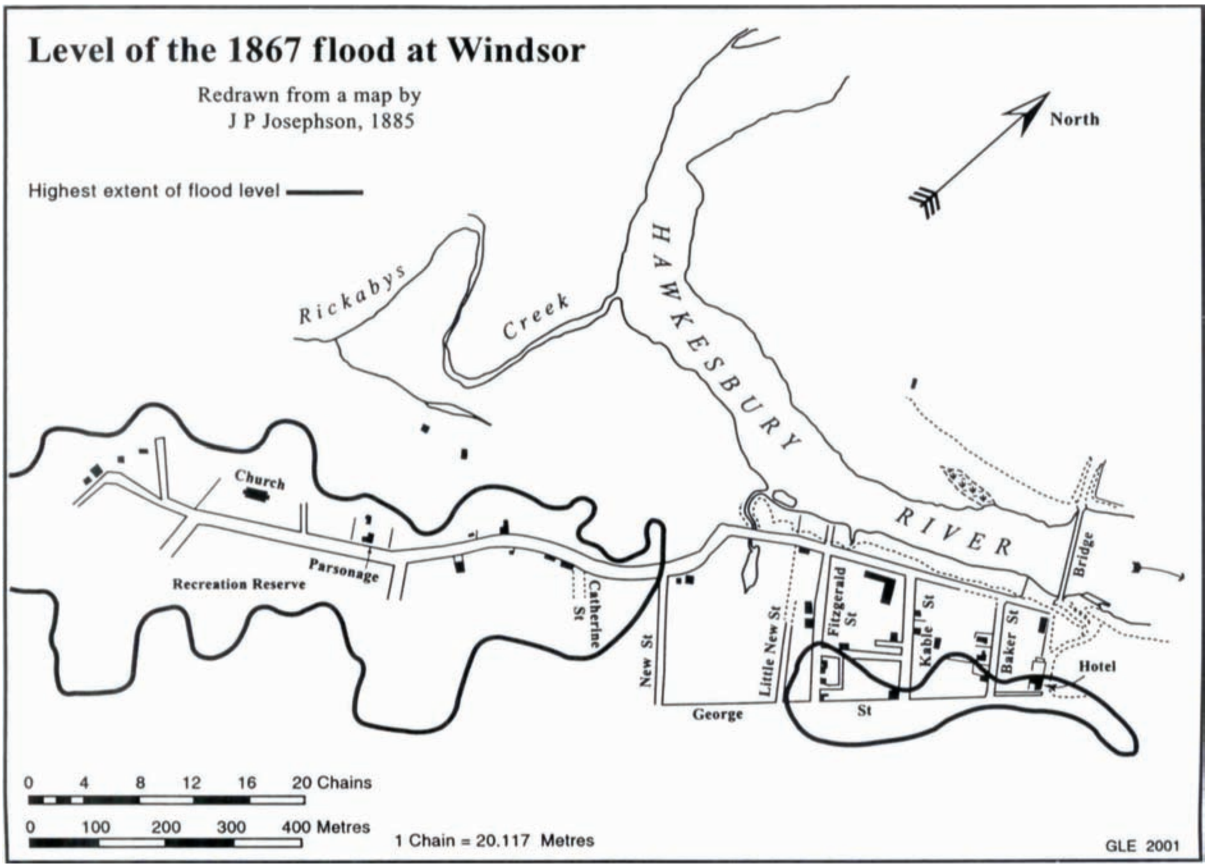
1867 Flood Hydrograph at Windsor, derived from reported flood heights

Notes: rates of rise/fall are shown in blue italics; stated peak heights above the 1864 flood are shown in pink

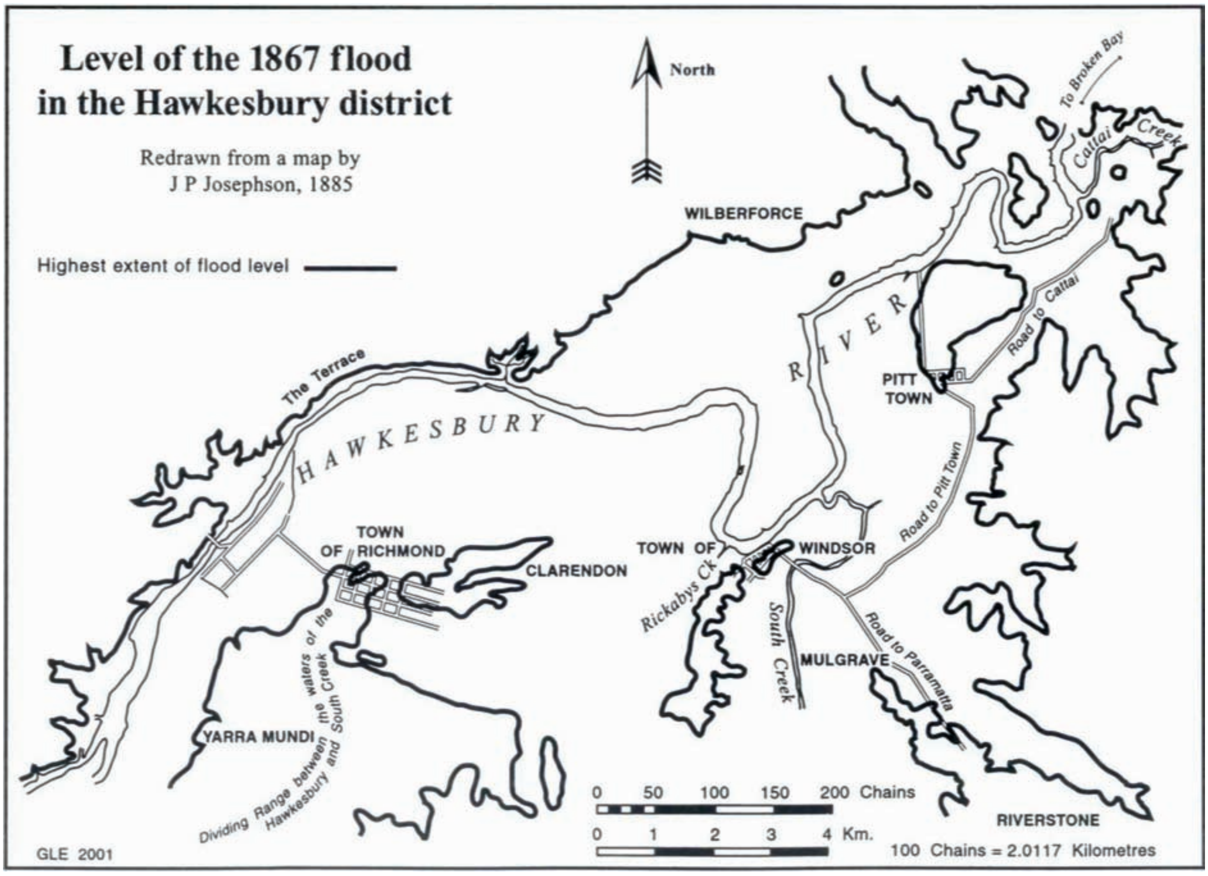
Date/time	Flood description	Source	Timing certainty	Level certainty	Comment	Hours to peak	Level (m AHD)
Thu 20 Jun 1867 9 am	By the morning the backwaters had then accumulated to a great extent, and the river was rising at the rate of *two and a half feet per hour.*	SMH, Tues 2nd Jul 1867, p.3	moderate	poor			
Thu 20 Jun 1867 3 pm	In the afternoon [the river] was bank high.	SMH, Tues 2nd Jul 1867, p.3	moderate	poor	Bankfull level at Windsor ~ 8m AHD (WMA, 1996, p.D11)	-62	8.0?
Fri 21 Jun 1867 7 am	When morning broke… waters had risen within a few feet of great flood of 1864 and were continuing to rise rapidly.	SMH, Tues 25th Jun, 1867, p.2	good	moderate		-46	14.4
Fri 21 Jun 1867 9:30 am	Flood nearly as high as 1864 and rising.	Illustrated Sydney News, Tues 16th Jul, 1867, p.7	good	moderate		-43.5	15.0
Fri 21 Jun 1867 3 pm	By [3 p.m.] the waters had risen amazingly – several feet higher than the 1864 flood.	SMH, Tues 25th Jun, 1867, p.2	good	moderate		-38	15.7
Fri 21 Jun 1867 4:30 pm	4.30 pm. Flood still rising water now three feet higher than great flood June 1864.	Telegram (Nichols 2001 p17)	good	good		-36.5	16.0
Fri 21 Jun 1867 10:20 pm	Water entered ground floor of Tebbutt residence (16.51m AHD) at gauge height of 52.2'.	WMA, 1996, p.D.A15	good	good	Clash with following entry – too low?	-30.66	16.5
Fri 21 Jun 1867 11 pm	11 pm. Water is still rising and a great portion of the town is flooded - now about 7 feet higher than the 1864 flood.	SMH, Tues 25th Jun, 1867, p.2	good	good	Clash with previous entry – too high?	-30	17.2
Sat 22 Jun 1867 12 pm	12 pm. The water has risen during the night and today at the rate of *seven inches per hour*, and still continuing to rise…	SMH, Tues 25th Jun, 1867, p.2	good	moderate			
Sat 22 Jun 1867 7 pm	The water only rose about a foot from Sat night to peak.	SMH, Tues 25th Jun, 1867, p.2	moderate	good		-10	19.4
Sun 23 Jun 1867 5 am	The flood reached its greatest height about 5 a.m. on the 23rd…	SMH, Fri 28th Jun, 1867, p.5 (John Tebbutt)	good				
Sun 23 Jun 1867 5 am	Flood peak 10.4' above floor of Tebbutt residence, 62.7' gauge height.	WMA, 1996, p.D.A15		good		0	19.7
Sun 23 Jun 1867 8 am	By 8 o'clock the water had gone down three or four inches.	SMH, Mon 24th Jun, 1867, p.5	good	good		3	19.6
Mon 24 Jun 1867 2 pm	2 pm. The water has fallen about 10 feet and continues to recede at the rate of *9 inches or so per hour.*	SMH, Tues 25th Jun, 1867, p.2	good	moderate	Say fallen 10½ ft to match rate	33	16.5
Mon 24 Jun 1867 4 pm	4 pm. Flood has now receded 12 feet from the highest flood line.	SMH, Tues 25th Jun, 1867, p.2	good	good		35	16.0


Peak 19.7m AHD, 5 a.m. Sun 23rd June 1867
Level (m AHD)
20.0
19.0
18.0
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
-66
-60
-54
-48
-42
-36
-30
-24
-18
-12
-6
0
6
12
18
24
30
36
42
Hours relative to flood peak
1867 flood
200 year design hydrograph (post-Warragamba Dam)

Extent of the 1867 flood at Windsor
Source: Nichols, 2001 after Josephson, 1885



Extent of the 1867 flood in the Hawkesbury District
Source: Nichols, 2001 after Josephson, 1885



APPENDIX B

FLOOD DAMAGES MATERIAL

– Inputs for Deriving Residential Sector Stage-Damage Data
– Outputs of Residential Sector Stage-Damage Data

SITE SPECIFIC INFORMATION FOR RESIDENTIAL DAMAGE CURVE DEVELOPMENT

Version 3.00 October 2007 — Queries to duncan.mcluckie@dnr.nsw.gov.au

PROJECT	DETAILS	DATE	JOB No.
xx	xx	13-Apr-11	J1921 Hawkesbury

BUILDINGS

Regional Cost Variation Factor	1.00	*From Rawlinsons*					
Post late 2001 adjustments	1.47	*Changes in AWE see AWE Stats Worksheet*					
Post Flood Inflation Factor	1.40	*1.0*	*to*	*1.5*			
Multiply overall structural costs by this factor		*Judgement to be used. Some suggestions below*					
	Regional City				*Regional Town*		
	Houses Affected			*Factor*	*Houses Affected*		*Factor*
Small scale impact	*<*	*50*		*1.00*	*<*	*10*	*1.00*
Medium scale impacts in Regional City		*100*		*1.20*		*30*	*1.30*
Large scale impacts in Regional City	*>*	*150*		*1.40*	*>*	*50*	*1.50*
Typical Duration of Immersion	24	hours					
Building Damage Repair Limitation Factor	1.00	*due to no insurance*	*short duration*				*long duration*
		Suggested range	*0.85*	*to*	*1.00*		
Typical House Size	240	m^2	*240 m^2 is Base*				
Building Size Adjustment	1.0						
Total Building Adjustment Factor	**2.06**						

CONTENTS

Average Contents Relevant to Site	$ 60,000	*Base for 240 m^2 house*	*$ 60,000*		
Post late 2001 adjustments	1.47	*From above*			
Contents Damage Repair Limitation Factor	0.90	*due to no insurance*	*short duration*		*long duration*
Sub-Total Adjustment Factor	1.32	*Suggested range*	*0.75*	*to*	*0.90*
Level of Flood Awareness	low	*low or high only. Low default unless otherwise justifiable.*			
Effective Warning Time	6	hour			
Interpolated DRF adjustment (Awareness/Time)	0.89	IDRF = Interpolated Damage Reduction Factor			
Typical Table/Bench Height (TTBH)	0.90	*0.9m is typical height. If typical is 2 storey house use 2.6m.*			
Total Contents Adjustment Factor AFD <= TTBH	**1.18**	AFD = Above Floor Depth			
Total Contents Adjustment Factor AFD > TTBH	**1.32**				

Most recent advice from Victorian Rapid Assessment Method

Low level of awareness is expected norm (long term average) any deviation needs to be justified.

Basic contents damages are based upon a DRF of	*0.9*				
Effective Warning time (hours)	***0***	***3***	***6***	***12***	***24***
RAM Average IDRF Inexperienced (Low awareness)	*0.90*	*0.80*	*0.80*	*0.80*	*0.70*
DRF (ARF/0.9)	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
RAM AIDF Experienced (High awareness)	*0.80*	*0.80*	*0.60*	*0.40*	*0.40*
DRF (ARF/0.9)	*0.89*	*0.89*	*0.67*	*0.44*	*0.44*
Site Specific DRF (DRF/0.9) for Awareness level for iteration	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
Effective Warning time (hours)	*6*	*12*	*6*		
Site Specific iterations	*0.89*	*0.89*	*0.89*		

ADDITIONAL FACTORS

Post late 2001 adjustments		1.47	*From above*
External Damage	$	6,700	*$6,700 recommended without justification*
Clean Up Costs	$	4,000	*$4,000 recommended without justification*
Likely Time in Alternate Accommodation		4	weeks
Additional accommodation costs /Loss of Rent	$	220	*$220 per week recommended without justification*

TWO STOREY HOUSE BUILDING & CONTENTS FACTORS

Up to Second Floor Level, less than	2.6	m	70%	Single Storey Slab on Ground
From Second Storey up, greater than	2.6	m	110%	Single Storey Slab on Ground

Base Curves

AFD = Above Floor Depth

Single Storey Slab/Low Set	13164	+	4871	x	AFD in metres
Structure with GST	AFD	greater than	0.0	m	
Validity Limits	AFD	less than or equal to		6	m
Single Storey High Set	16586	+	7454	x	AFD
Structure with GST	AFD	greater than	-1.50	m	
Validity Limits	AFD	less than or equal to		6	m
Contents	20000	+	20000	x	AFD
Contents with GST	AFD	greater than		0	
Validity Limits	AFD	less than or equal to		2	

Floodplain Specific Damage Curves for Individual Residences

Steps in Curve	0.1	m	
	Single Storey High Set	Single Storey Slab/Low Set	2 Storey Houses
Type	1	2	3
AFD from Modelling	Damage	Damage	Damage
-5.00	$0	$0	$0
-1.50	$9,849	$0	$0
-1.40	$22,507	$0	$0
-1.30	$24,041	$0	$0
-1.20	$25,575	$0	$0
-1.10	$27,109	$0	$0
-1.00	$28,643	$0	$0
-0.90	$30,177	$0	$0
-0.80	$31,711	$0	$0
-0.70	$33,245	$0	$0
-0.60	$34,779	$0	$0
-0.50	$36,313	$9,849	$9,849
-0.40	$37,847	$9,849	$9,849
-0.30	$39,381	$9,849	$9,849
-0.20	$40,915	$9,849	$9,849
-0.10	$42,449	$9,849	$9,849
0.00	$77,616	$36,940	$28,813
0.10	$81,796	$70,988	$52,646
0.20	$85,976	$74,342	$54,994
0.30	$90,156	$77,697	$57,342
0.40	$94,336	$81,051	$59,690
0.50	$98,516	$84,406	$62,039
0.60	$102,696	$87,760	$64,387
0.70	$106,876	$91,114	$66,735
0.80	$111,056	$94,469	$69,083
0.90	$115,236	$97,823	$71,431
1.00	$119,416	$107,058	$77,895
1.10	$123,596	$110,706	$80,449
1.20	$127,776	$114,354	$83,003
1.30	$131,956	$118,003	$85,557
1.40	$136,135	$121,651	$88,111
1.50	$140,315	$125,300	$90,664
1.60	$144,495	$128,948	$93,218
1.70	$148,675	$132,596	$95,772
1.80	$152,855	$136,245	$98,326
1.90	$157,035	$139,893	$100,880
2.00	$161,215	$143,542	$103,434
2.10	$162,749	$144,544	$104,136
2.20	$164,283	$145,547	$104,837
2.30	$165,817	$146,549	$105,539
2.40	$167,351	$147,551	$106,241
2.50	$168,885	$148,554	$106,942
2.60	$170,419	$149,556	$107,644
2.70	$171,953	$150,559	$164,630
2.80	$173,487	$151,561	$165,732
2.90	$175,021	$152,563	$166,835
3.00	$176,555	$153,566	$167,937
3.50	$184,224	$158,578	$173,451
4.00	$191,894	$163,590	$178,964
4.50	$199,564	$168,602	$184,477
5.00	$207,234	$173,614	$189,991

APPENDIX C

ADVICE FROM SES
ON EVACUATION PROCEDURES

Bewsher

25 May 2011
Ref: J1921L_4

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Bewsher Consulting Pty Ltd
ABN 24 312 540 210

Mr Peter Cinque
Region Controller
SES Sydney Western Region
Seven Hills NSW

By Email: peter.cinque@ses.nsw.gov.au

Dear Peter

HAWKESBURY FRMS&P
EVACUATION ISSUES

Thank you for the opportunity of meeting with you and Steven Molino yesterday to discuss the above project.

As you are aware, the project is drawing to a close and is at the critical stage of preparing its key findings which may influence future development options within the LGA. The meeting therefore was very useful for us in clarifying the SES's views. The draft FRMS report is in preparation and will shortly be forwarded to you for review and comment before the community consultation phase of the project begins.

The following provides a summary of matters that were discussed.

Release of Information Concerning the Impacts of Flooding on Utilities

1. The impacts on utilities have been most recently documented in "*Hawkesbury Nepean River Impacts of Flooding on Communities and Infrastructure Review*", Draft Report, April 2011 which has been prepared by Molino Stewart for the SES. This report compiles various datasets some of which are the subject of confidentiality agreements with the data suppliers. Consequently the report cannot be released without permission of the suppliers which would likely take some time to organise, and even then, might not be provided. Given the time frame of the Hawkesbury FRMS&P, the report cannot be made available to the FRMS consultants or the Council's Committee.

2. Nevertheless a comprehensive description of the impacts of flooding on utilities has been provided in Appendix H of the "*Proposed Warragamba Flood Mitigation Dam EIS*" (ERM Mitchell McCotter, 1995). In general, there have not been major changes in the utilities since that time and so the description in Appendix H could be utilised to inform the FRMS. The most significant utility changes which have occurred comprise:

   a. telecoms: – there has been a proliferation of mobile phone related infrastructure now in three utility companies compared with the single Telstra owned (fixed line based) systems that were present in the mid 1990s. In addition, newer telephone systems are more susceptible to indirect impacts due to failure of electricity supplies than those in the mid 1990s;

b. electricity: − Endeavour Energy (formerly Integral Energy) has lifted the levels of the feeder lines into the Hawkesbury Transmission substation. As a consequence power can be maintained for longer than was previously possible;

c. road network: − has been upgraded as noted in Molino Stewart's Evacuation Report.

Comments on the Molino Stewart Evacuation Report and Other Related Matters

1. The accuracy with which flood levels predictions can be made some time prior to a critical level occurring, is a key consideration in evacuation planning. Nine hours is typically the maximum time within which the Bureau of Meteorology can predict flood levels in the Windsor area using recorded rainfalls. Predictions in excess of nine hours require progressively greater use of forecast rainfalls which progressively increases the uncertainty in the flood level predictions.

2. Molino Stewart's modelling has assumed evacuations from Windsor, Richmond, McGraths Hill, Mulgrave, Bligh Park and Windsor Downs are triggered nine hours before a level of 14.1m is reached on the Windsor gauge. (This corresponds to about 14.3mAHD).

3. Molino Stewart's modelling has been based largely on the details provided in the SES's Hawkesbury Nepean Flood Emergency Sub Plan (2005) although the 14.1m trigger is not referred to in the Sub Plan. The SES prefers to use different triggers for each Sector as noted in Table 7 of the Sub Plan. These triggers relate to the level at which the evacuation route is cut.

4. The Sub Plan is in the process of revision. It does not include for the Jim Anderson Bridge (although Molino Stewart's modelling has included for the additional evacuation capacity provided by the Bridge). This bridge delays the time available for evacuation until the River level reaches 17.3mAHD. Molino Stewart's evacuation assessment will now need to use a different evacuation trigger. Whilst previously Molino Stewart had assumed that evacuation could commence nine hours before 14.1m, they will now need to assume evacuation commences nine hours before 17.3mAHD. This means their revised analysis will show less evacuation capacity exists than previously calculated.

5. In an actual flood emergency the SES will ensure evacuation from Windsor and other sectors occurs in sufficient time to enable full evacuation prior to the evacuation route being cut. A common evacuation trigger will not be used but will be determined on the circumstances and characteristics of each sector. In some sectors (including Windsor), the evacuation will have to occur more than nine hours before the route is forecast to be cut. As discussed above, predictions of flood levels in excess of nine hours ahead have increased levels of uncertainties. The calling of an unnecessary evacuation is to be avoided given the costs to the community and the potential adverse public reaction. It may also make it more difficult to get the community to respond to future evacuation calls.

6. Molino Stewart will review their draft report and where necessary revise their documentation to:

a. clarify references to the 14.1m trigger level;

b. references to "vehicles unable to evacuate" should also indicate the corresponding time deficit; and

c. where such a time deficit exists, explain that the SES will manage the evacuation in order to make it possible for all vehicles to evacuate, however this necessitates a reduction in confidence in calling an evacuation (expressed by the time deficit).

7. The SES is firmly of the view that evacuation from Windsor is severely constrained at present and the calling of an evacuation must occur early, considerably more than nine hours before the Jim Anderson Bridge is cut, when there is an unacceptably high risk of calling an evacuation unnecessarily. Consequently it is their opinion that:

a. infrastructure upgrades should be pursued to reduce the evacuation times and increase confidence in the calling of an evacuation; and

b. until the evacuation time can be reduced somewhat below nine hours, no further development (which increases the number of potential evacuees) should occur. This development includes not only:

i) the release of new development areas (e.g. rezoning of land for residential purposes); but also

ii) any new residential redevelopment on existing vacant zoned land; and

iii) intensification of existing development (e.g. dual occupancies, redevelopment of residential development which increases density).

8. The SES' views on further development within Windsor have been conveyed in writing to Council on previous occasions. Although the SES has a role in providing emergency management advice, the land use planning decisions rest with the consent authority being Council, and in some cases, the State Government.

9. Should additional infrastructure be provided in the future to increase evacuation capacity, this should not be viewed as justification for allowing further development. The current deficit in evacuation capacity is so large that even with significant improvements in infrastructure, evacuation will still likely require more than the maximum of nine hours required for more confident evacuation calls to be made.

10. The SES believes that the current deficit in evacuation capacity is likely to be larger than the deficit that existed at the time of the preparation of the Hawkesbury Nepean Flood Management Strategy in 1997 (prior to the construction of the Jim Anderson Bridge). This reduction in capacity has apparently occurred as a result of ongoing development within the evacuation constrained area.

11. The change from using an evacuation trigger based on anticipation of 14.1m at the Windsor gauge, to a trigger based on anticipation of losing the access route for a sector, also has implications for the Richmond evacuation modelling carried out by Molino Stewart. Based on the 14.1m trigger, the previous analyses carried out by Molino Stewart indicated there was ample time for Richmond to evacuate. However if the analyses assume evacuations are commenced nine hours before 20.1mAHD rather than nine hours before 14.1m (on the gauge), then there will be insufficient

time to get everyone out. Consequently the SES will have to commence evacuations earlier than nine hours before 20.1m which the SES have indicated is not satisfactory due to an unacceptable risk that evacuations will be called unnecessarily. As a result, the previous conclusion that there was sufficient evacuation capacity from Richmond is no longer correct.

Yours sincerely

Drew Bewsher
Director

cc: Mr Steven Molino, Molino Stewart, (smolino@molinostewart.com.au)

APPENDIX D

ADVICE FROM BUREAU OF METEOROLOGY CONCERNING CONFIDENCE IN FLOOD WARNING PREDICTIONS AT WINDSOR

Bewsher

31 May 2011
Ref: J1921L_6.doc

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Dear Gordon

HAWKESBURY FLOODPLAIN RISK MANAGEMENT STUDY & PLAN
FLOOD WARNING ISSUES

Thank you for the opportunity of meeting with you last Friday to discuss the above project.

As you are aware, evacuation of many parts of the Hawkesbury LGA is constrained because at certain flood levels, access routes are cut leaving 'islands' which in major flood situations, may eventually be overwhelmed by flood waters. The principal strategy for emergency managers is therefore to commence evacuations in sufficient time to ensure all floodplain occupants can leave the floodplain in their own motor vehicles before egress routes are cut.

Calling an evacuation within the Hawkesbury-Nepean Valley is a significant decision as it may involve evacuation of many tens of thousands of people. If called unnecessarily, it would impose a very significant social and economic cost on the community and could potentially dissuade the community from responding to evacuation requests in future flood events.

In Attachment A, a copy of the SES' evacuation triggers for the Hawkesbury LGA is provided. This is an extract from *Hawkesbury Nepean Flood Emergency Sub Plan* prepared in 2006. Note that this plan is under review and therefore the information may change particularly in relation to the 2007 construction of the Jim Anderson Bridge over South Creek. This allows evacuation from the Windsor 'island' to occur up until about 17.3mAHD (approx 17.1m on the Windsor gauge) when this access is cut by flood waters.

The Hawkesbury LGA is continuing to grow through release of new development areas such as Pitt Town, and importantly due to infill development on existing zoned land. The increased population in the area increases the time necessary for evacuation. As a result, evacuation has to commence earlier than would otherwise have had to occur without the growth in population. A key consequence of this earlier evacuation is that confidence in flood warning predictions reduces.

In relation to this issue of confidence in flood warning predictions, the following summarises your comments at our meeting last week:

Floodplain Management • Water Resources and Hydrology • Flood Risk Assessment

Confidence in Providing Flood Level Predictions for the Hawkesbury LGA

1. The catchment response time for the River at Windsor is about nine hours. That is, the effects of rainfall at a point in time when the catchment area between Wallacia and Windsor becomes saturated will typically be seen in the river levels at Windsor about nine hours later. Runoff from the Nepean and Warragamba River catchments will take longer to arrive.

2. Water level prediction in excess of nine hours for the effect of the local catchment to Windsor which may cause initial road closures, may require the use of predicted rainfalls. Using predicted rainfalls to prepare Flood Watches and flood level predictions is common practice for NSW within the Bureau. Rainfall predictions are based on weather models and the interpretation of real time information, such as weather radar and rainfall measurements, by the meteorologist.

3. Every flood event is different and depending on the temporal and spatial distribution of the rainfall, differing river level behaviour can be expected for any given total catchment rainfall. Nevertheless the comments presented here are indicative of what might be expected based on the observed meteorological and hydrological behaviour of major historical floods including those in 1961, 1964, 1978 and 1990.

4. The largest of the recent historical floods for which the Bureau has records was the November 1961 event which reached a height of 15.0mAHD at Windsor and had an estimated average recurrence interval (ARI) of about 35 years. The other historical events listed above all had ARI of 20–30 years. These events were associated with about 3–5 days of rainfall often with variable rainfall totals on each day.

5. The largest historical flood occurred in June 1867. If this rainfall event was to occur today, the river at Windsor would rise to about 19.3mAHD which is about a 200 year ARI event. Care must be used when extrapolating meteorological and hydrological behaviour observed in the various 20–35 year ARI floods which have occurred in the 20th century to that which might occur in an extreme event such as another 1867 event or a probable maximum flood (PMF). Nevertheless the Bureau anticipates that these extreme weather systems will be broadly similar in duration although with higher intensities and persistence.

6. The provision of the Bureau's flood warning services to the Hawkesbury-Nepean Valley are summarised in the *State Flood Sub Plan*. Attachment B reproduces pages C-7 and C-8 which detail the requirements for the Hawkesbury LGA. In particular under the current arrangements, if the peak height of the river is expected to exceed 16.0m, the Bureau is required to provide:

   (a) 6 hours notice of a river height of 9.6m at the Windsor gauge; and

   (b) 15 hours notice of a river height of 13.7m at the Windsor gauge.

7. In relation to the Bureau's ability to provide predictions of a Windsor flood height of 17.1m on the gauge (i.e. 17.3mAHD):

   (a) analyses undertaken by the Bureau indicate the nominated flood warning predictions in coastal NSW are generally accurate within 0.3m, 70% of the time (refer *Flood Warning, Manual 21, Aust Emergency Manual Series, 2009*). Whilst peak predictions for Windsor will generally have this accuracy, forecasts for levels along the rising stages of the flood may be less accurate, particularly if greater periods of forecast rain are required for modelling;

(b) there is evidence that flood warning prediction accuracy has improved over the past two decades. With increased improvements of weather models, a continued marginal improvement in warning predictions is anticipated in the future;

(c) sensitivity analyses of flood models used by the Bureau for flood exercises in the Valley indicate extending the time of flood level predictions from 15 hours to 18 hours will generally not alter the predicted peak levels to any significant extent. However the Bureau may need to use longer periods of forecast rainfall in its flood level predictions for road closures in order to provide longer warning times for the SES to arrange the evacuation of additional people off the floodplain;

(d) based on the information currently available to the Bureau, it is likely that predictions for the river level at Windsor exceeding 17.3m AHD can be made either 15 or 18 hours prior with similar levels of accuracy expected due to uncertainty in future rainfall and the impact of upstream flows.

Thank you for your assistance. This information will be used in assessing evacuation constraints in the Hawkesbury floodplains and providing advice to the Council concerning the flood risks associated with future development in the LGA.

Yours sincerely

Drew Bewsher
Director

APPENDIX E

EVACUATION CAPABILITY ASSESSMENT PREPARED ON SES EVACUATION SECTOR BASIS

(Note that whilst the overall assessment will remain similar, different time assessments may result when the calculations are carried out on a Sub-Sector basis. For an example of a Sub-Sector assessment, see Appendix F).

Table E.1 − Evacuation Timeline Assessments for Key Evacuation Constrained Sectors
(2010 Population Conditions) (Limit of Confident Flood Prediction LCFP = 9 hours)

			Richmond & Richmond Lowlands	Bligh Park & Windsor Downs	Windsor	Windsor (Upgraded)	Windsor (Upgraded) with Bligh Pk Stage 2	North Richmond	Comments
a	Epoch		2010	2010	2010	2010	2010	2010	
b	Vehicles needing to evacuate		5127	4543	6278	6278	7614	1830	See Note 1
c	Assumed vehicle egress capacity	(per hour)	600	600	600	1200	1200	600	See Note 2
d	Warning acceptance factor (WAF)	(hours)	1.0	1.0	1.0	1.0	1.0	1.0	See Section 5.3.3
e	Warning lag factor (WLF)	(hours)	1.0	1.0	1.0	1.0	1.0	1.0	See Section 5.3.3
f	Unrestricted travel time	(hours)	8.5	7.6	10.5	5.2	6.3	3.1	=b/c
g	Traffic safety factor (TSF)	(hours)	2.0	2.0	2.5	1.5	1.5	1.0	See Section 5.3.3
h	Total travel time	(hours)	10.5	9.6	13.0	6.7	7.8	4.1	=f+g
i	Total evacuation time after mobilisation	(hours)	12.5	11.6	15.0	8.7	9.8	6.1	=f+g+d+e
j	Limit of confident flood prediction (LCFP)	(hours)	9.0	9.0	9.0	9.0	9.0	9.0	See Section 5.3.7
k	Evacuation time beyond LCFP	(hours)	3.5	2.6	6.0	0.0	0.8	0.0	=i-j
m	Windsor gauge level at which egress is cut	(m)	19.8	18.3	17.1	17.1	17.1	17.3	See Table 5.5
n	Estimated Windsor gauge level at which evacuation must commence	(m)	13.5	12.5	9.6	12.7	12.2	14.3	=m-i*0.5 (See Note 3)
p	Estimated Windsor gauge level at LCFP	(m)	15.3	13.8	12.6	12.6	12.6	12.8	=m-j*0.5 (See Note 3)
q	Vehicles assumed to evacuate prior to the LCFP		751	271	1919	0	0	0	=b*(i-j-d-e)/(i-d-e)
r	Vehicles assumed to evacuate within the LCFP		4376	4272	4359	6278	7614	1830	=b*j/(i-d-e)
s	Proportion of vehicles assumed to evacuate prior to the LCFP	(%)	15%	6%	31%	0%	0%	0%	=q/b
t	Proportion of vehicles assumed to evacuate within the LCFP	(%)	85%	94%	69%	100%	100%	100%	=r/b

Note 1:	All 2010 and 2031estimates from **Volume 2** except for Richmond which is from Molino Stewart (2011b) . Changes in regional evacuation traffic beyond the LGA assumed to have no influence on evacuation of key constrained areas listed in this table.
Note 2:	Windsor (Upgraded) includes for second outbound lane on Jim Anderson Bridge and other measures recommended in (Molino Stewart, 2007b) which doubles egress capacity to 1200 vehicles per hour.
Note 3:	A constant rate of rise of water levels on the Windsor gauge of 0.5m per hour has been assumed throughout the rising limb of the flood.

Table E.2 − Evacuation Timeline Assessments for Key Evacuation Constrained Sectors

(2031 Population Conditions) (Limit of Confident Flood Prediction LCFP = 9 hours)

			Richmond & Richmond Lowlands	Bligh Park & Windsor Downs	Windsor	Windsor (Upgraded)	Windsor (Upgraded) with Bligh Pk Stage 2	North Richmond	Comments
a	Epoch		2031	2031	2031	2031	2031	2031	
b	Vehicles needing to evacuate		6323	5660	7702	7702	9037	2259	See Note 1
c	Assumed vehicle egress capacity	(per hour)	600	600	600	1200	1200	600	See Note 2
d	Warning acceptance factor (WAF)	(hours)	1.0	1.0	1.0	1.0	1.0	1.0	See Section 5.3.3
e	Warning lag factor (WLF)	(hours)	1.0	1.0	1.0	1.0	1.0	1.0	See Section 5.3.3
f	Unrestricted travel time	(hours)	10.5	9.4	12.8	6.4	7.5	3.8	=b/c
g	Traffic safety factor (TSF)	(hours)	2.5	2.0	2.5	1.5	2.0	1.0	See Section 5.3.3
h	Total travel time	(hours)	13.0	11.4	15.3	7.9	9.5	4.8	=f+g
i	Total evacuation time after mobilisation	(hours)	15.0	13.4	17.3	9.9	11.5	6.8	=f+g+d+e
j	Limit of confident flood prediction (LCFP)	(hours)	9.0	9.0	9.0	9.0	9.0	9.0	See Section 5.3.7
k	Evacuation time beyond LCFP	(hours)	6.0	4.4	8.3	0.9	2.5	0.0	=i-j
m	Windsor gauge level at which egress is cut	(m)	19.8	18.3	17.1	17.1	17.1	17.3	See Table 5.5
n	Estimated Windsor gauge level at which evacuation must commence	(m)	12.3	11.6	8.4	12.1	11.3	13.9	=m-i*0.5 (See Note 3)
p	Estimated Windsor gauge level at LCFP	(m)	15.3	13.8	12.6	12.6	12.6	12.8	=m-j*0.5 (See Note 3)
q	Vehicles assumed to evacuate prior to the LCFP		1958	1204	3182	0	504	0	=b*(i-j-d-e)/(i-d-e)
r	Vehicles assumed to evacuate within the LCFP		4365	4455	4520	7702	8534	2259	=b*j/(i-d-e)
s	Proportion of vehicles assumed to evacuate prior to the LCFP	(%)	31%	21%	41%	0%	6%	0%	=q/b
t	Proportion of vehicles assumed to evacuate within the LCFP	(%)	69%	79%	59%	100%	94%	100%	=r/b

Note 1:	All 2010 and 2031estimates from **Volume 2** except for Richmond which is from Molino Stewart (2011b) . Changes in regional evacuation traffic beyond the LGA assumed to have no influence on evacuation of key constrained areas listed in this table.
Note 2:	Windsor (Upgraded) includes for second outbound lane on Jim Anderson Bridge and other measures recommended in (Molino Stewart, 2007b) which doubles egress capacity to 1200 vehicles per hour.
Note 3:	A constant rate of rise of water levels on the Windsor gauge of 0.5m per hour has been assumed throughout the rising limb of the flood.

Table E.3 − Evacuation Timeline Assessments for Key Evacuation Constrained Sectors

(2010 Population Conditions) (Limit of Confident Flood Prediction LCFP = 15 hours)

			Richmond & Richmond Lowlands	Bligh Park & Windsor Downs	Windsor	Windsor (Upgraded)	Windsor (Upgraded) with Bligh Pk Stage 2	North Richmond	Comments
a	Epoch		2010	2010	2010	2010	2010	2010	
b	Vehicles needing to evacuate		5127	4543	6278	6278	7614	1830	See Note 1
c	Assumed vehicle egress capacity	(per hour)	600	600	600	1200	1200	600	See Note 2
d	Warning acceptance factor (WAF)	(hours)	1.0	1.0	1.0	1.0	1.0	1.0	See Section 5.3.3
e	Warning lag factor (WLF)	(hours)	1.0	1.0	1.0	1.0	1.0	1.0	See Section 5.3.3
f	Unrestricted travel time	(hours)	8.5	7.6	10.5	5.2	6.3	3.1	=b/c
g	Traffic safety factor (TSF)	(hours)	2.0	2.0	2.5	1.5	1.5	1.0	See Section 5.3.3
h	Total travel time	(hours)	10.5	9.6	13.0	6.7	7.8	4.1	=f+g
i	Total evacuation time after mobilisation	(hours)	12.5	11.6	15.0	8.7	9.8	6.1	=f+g+d+e
j	Limit of confident flood prediction (LCFP)	(hours)	15.0	15.0	15.0	15.0	15.0	15.0	See Section 5.3.7
k	Evacuation time beyond LCFP	(hours)	0.0	0.0	0.0	0.0	0.0	0.0	=i-j
m	Windsor gauge level at which egress is cut	(m)	19.8	18.3	17.1	17.1	17.1	17.3	See Table 5.5
n	Estimated Windsor gauge level at which evacuation must commence	(m)	13.5	12.5	9.6	12.7	12.2	14.3	=m-i*0.5 (See Note 3)
p	Estimated Windsor gauge level at LCFP	(m)	15.3	13.8	12.6	12.6	12.6	12.8	=m-j*0.5 (See Note 3)
q	Vehicles assumed to evacuate prior to the LCFP		0	0	0	0	0	0	=b*(i-j-d-e)/(i-d-e)
r	Vehicles assumed to evacuate within the LCFP		5127	4543	6278	6278	7614	1830	=b*j/(i-d-e)
s	Proportion of vehicles assumed to evacuate prior to the LCFP	(%)	0%	0%	0%	0%	0%	0%	=q/b
t	Proportion of vehicles assumed to evacuate within the LCFP	(%)	100%	100%	100%	100%	100%	100%	=r/b

Note 1:	All 2010 and 2031estimates from **Volume 2** except for Richmond which is from Molino Stewart (2011b) . Changes in regional evacuation traffic beyond the LGA assumed to have no influence on evacuation of key constrained areas listed in this table.
Note 2:	Windsor (Upgraded) includes for second outbound lane on Jim Anderson Bridge and other measures recommended in (Molino Stewart, 2007b) which doubles egress capacity to 1200 vehicles per hour.
Note 3:	A constant rate of rise of water levels on the Windsor gauge of 0.5m per hour has been assumed throughout the rising limb of the flood.

Table E.4 − Evacuation Timeline Assessments for Key Evacuation Constrained Sectors

(2031 Population Conditions) (Limit of Confident Flood Prediction LCFP = 15 hours)

			Richmond & Richmond Lowlands	Bligh Park & Windsor Downs	Windsor	Windsor (Upgraded)	Windsor (Upgraded) with Bligh Pk Stage 2	North Richmond	Comments
a	Epoch		2031	2031	2031	2031	2031	2031	
b	Vehicles needing to evacuate		6323	5660	7702	7702	9037	2259	See Note 1
c	Assumed vehicle egress capacity	(per hour)	600	600	600	1200	1200	600	See Note 2
d	Warning acceptance factor (WAF)	(hours)	1.0	1.0	1.0	1.0	1.0	1.0	See Section 5.3.3
e	Warning lag factor (WLF)	(hours)	1.0	1.0	1.0	1.0	1.0	1.0	See Section 5.3.3
f	Unrestricted travel time	(hours)	10.5	9.4	12.8	6.4	7.5	3.8	=b/c
g	Traffic safety factor (TSF)	(hours)	2.5	2.0	2.5	1.5	2.0	1.0	See Section 5.3.3
h	Total travel time	(hours)	13.0	11.4	15.3	7.9	9.5	4.8	=f+g
i	Total evacuation time after mobilisation	(hours)	15.0	13.4	17.3	9.9	11.5	6.8	=f+g+d+e
j	Limit of confident flood prediction (LCFP)	(hours)	15.0	15.0	15.0	15.0	15.0	15.0	See Section 5.3.7
k	Evacuation time beyond LCFP	(hours)	0.0	0.0	2.3	0.0	0.0	0.0	=i-j
m	Windsor gauge level at which egress is cut	(m)	19.8	18.3	17.1	17.1	17.1	17.3	See Table 5.5
n	Estimated Windsor gauge level at which evacuation must commence	(m)	12.3	11.6	8.4	12.1	11.3	13.9	=m-i*0.5 (See Note 3)
p	Estimated Windsor gauge level at LCFP	(m)	15.3	13.8	12.6	12.6	12.6	12.8	=m-j*0.5 (See Note 3)
q	Vehicles assumed to evacuate prior to the LCFP		0	0	169	0	0	0	=b*(i-j-d-e)/(i-d-e)
r	Vehicles assumed to evacuate within the LCFP		6323	5660	7533	7702	9037	2259	=b*j/(i-d-e)
s	Proportion of vehicles assumed to evacuate prior to the LCFP	(%)	0%	0%	2%	0%	0%	0%	=q/b
t	Proportion of vehicles assumed to evacuate within the LCFP	(%)	100%	100%	98%	100%	100%	100%	=r/b

Note 1:	All 2010 and 2031estimates from **Volume 2** except for Richmond which is from Molino Stewart (2011b) . Changes in regional evacuation traffic beyond the LGA assumed to have no influence on evacuation of key constrained areas listed in this table.
Note 2:	Windsor (Upgraded) includes for second outbound lane on Jim Anderson Bridge and other measures recommended in (Molino Stewart, 2007b) which doubles egress capacity to 1200 vehicles per hour.
Note 3:	A constant rate of rise of water levels on the Windsor gauge of 0.5m per hour has been assumed throughout the rising limb of the flood.

APPENDIX F

EXAMPLE OF EVACUATION CAPABILITY ASSESSMENT PREPARED ON A SUB-SECTOR BASIS

(This has been prepared for Bligh Park and Windsor Downs. The assessment presented here updates that presented in Appendix E for Bligh Park and Windsor Downs. Note that further consideration of topography and road low points in each of the sub-sectors might allow yet further refinement and might yield slightly different results).

Table F.1 – Evacuation Timeline Assessments for Sub-Sectors in Bligh Park and Windsor Downs

(2010 Population Conditions) (Limit of Confident Flood Prediction LCFP = 9 hours)

			Windsor Downs	Bligh Park East	Bligh Park East & West	Comments
a	Epoch		2010	2010	2010	
b	Vehicles needing to evacuate		628	1674	2242	See Note 1
c	Assumed vehicle egress capacity	(per hour)	600	600	600	See Note 2
d	Warning acceptance factor (WAF)	(hours)	1.0	1.0	1.0	See Section 5.3.3
e	Warning lag factor (WLF)	(hours)	1.0	1.0	1.0	See Section 5.3.3
f	Unrestricted travel time	(hours)	1.0	2.8	3.7	=b/c
g	Traffic safety factor (TSF)	(hours)	1.0	1.0	1.0	See Section 5.3.3
h	Total travel time	(hours)	2.0	3.8	4.7	=f+g
i	Total evacuation time after mobilisation	(hours)	4.0	5.8	6.7	=f+g+d+e
j	Limit of confident flood prediction (LCFP)	(hours)	9.0	9.0	9.0	See Section 5.3.7
k	Evacuation time beyond LCFP	(hours)	0.0	0.0	0.0	=i-j
m	Windsor gauge level at which egress is cut	(m)	18.9	17.0	18.3	See Table 5.5
n	Estimated Windsor gauge level at which evacuation must commence	(m)	16.9	14.1	14.9	=m-i*0.5 (See Note 3)
p	Estimated Windsor gauge level at LCFP	(m)	14.4	12.5	13.8	=m-j*0.5 (See Note 3)
q	Vehicles assumed to evacuate prior to the LCFP		0	0	0	=b*(i-j-d-e)/(i-d-e)
r	Vehicles assumed to evacuate within the LCFP		628	1674	2242	=b*j/(i-d-e)
s	Proportion of vehicles assumed to evacuate prior to the LCFP	(%)	0%	0%	0%	=q/b
t	Proportion of vehicles assumed to evacuate within the LCFP	(%)	100%	100%	100%	=r/b

Note 1:	Derived using 2010 and 2031estimates from **Volume 2** for all of Bligh Park and Windsor Downs, then distributed to sub-sectors based on dwelling counts. Changes in regional evacuation traffic beyond the LGA assumed to have no influence on evacuation of key constrained areas listed in this table.
Note 2:	600 vehicles per hour.
Note 3:	A constant rate of rise of water levels on the Windsor gauge of 0.5m per hour has been assumed throughout the rising limb of the flood.

Table F.2 – Evacuation Timeline Assessments for Sub-Sectors in Bligh Park and Windsor Downs

(2031 Population Conditions) (Limit of Confident Flood Prediction LCFP = 9 hours)

			Windsor Downs	Bligh Park East	Bligh Park East & West	Comments
a	Epoch		2031	2031	2031	
b	Vehicles needing to evacuate		782	2085	2792	See Note 1
c	Assumed vehicle egress capacity	(per hour)	600	600	600	See Note 2
d	Warning acceptance factor (WAF)	(hours)	1.0	1.0	1.0	See Section 5.3.3
e	Warning lag factor (WLF)	(hours)	1.0	1.0	1.0	See Section 5.3.3
f	Unrestricted travel time	(hours)	1.3	3.5	4.7	=b/c
g	Traffic safety factor (TSF)	(hours)	1.0	1.0	1.5	See Section 5.3.3
h	Total travel time	(hours)	2.3	4.5	6.2	=f+g
i	Total evacuation time after mobilisation	(hours)	4.3	6.5	8.2	=f+g+d+e
j	Limit of confident flood prediction (LCFP)	(hours)	9.0	9.0	9.0	See Section 5.3.7
k	Evacuation time beyond LCFP	(hours)	0.0	0.0	0.0	=i-j
m	Windsor gauge level at which egress is cut	(m)	18.9	17.0	18.3	See Table 5.5
n	Estimated Windsor gauge level at which evacuation must commence	(m)	16.7	13.8	14.2	=m-i*0.5 (See Note 3)
p	Estimated Windsor gauge level at LCFP	(m)	14.4	12.5	13.8	=m-j*0.5 (See Note 3)
q	Vehicles assumed to evacuate prior to the LCFP		0	0	0	=b*(i-j-d-e)/(i-d-e)
r	Vehicles assumed to evacuate within the LCFP		782	2085	2792	=b*j/(i-d-e)
s	Proportion of vehicles assumed to evacuate prior to the LCFP	(%)	0%	0%	0%	=q/b
t	Proportion of vehicles assumed to evacuate within the LCFP	(%)	100%	100%	100%	=r/b

Note 1:	Derived using 2010 and 2031estimates from **Volume 2** for all of Bligh Park and Windsor Downs, then distributed to sub-sectors based on dwelling counts. Changes in regional evacuation traffic beyond the LGA assumed to have no influence on evacuation of key constrained areas listed in this table.
Note 2:	600 vehicles per hour.
Note 3:	A constant rate of rise of water levels on the Windsor gauge of 0.5m per hour has been assumed throughout the rising limb of the flood.

Table F.3 – Evacuation Timeline Assessments for Sub-Sectors in Bligh Park and Windsor Downs

(2010 Population Conditions) (Limit of Confident Flood Prediction LCFP = 15 hours)

			Windsor Downs	Bligh Park East	Bligh Park East & West	Comments
a	Epoch		2010	2010	2010	
b	Vehicles needing to evacuate		628	1674	2242	See Note 1
c	Assumed vehicle egress capacity	(per hour)	600	600	600	See Note 2
d	Warning acceptance factor (WAF)	(hours)	1.0	1.0	1.0	See Section 5.3.3
e	Warning lag factor (WLF)	(hours)	1.0	1.0	1.0	See Section 5.3.3
f	Unrestricted travel time	(hours)	1.0	2.8	3.7	=b/c
g	Traffic safety factor (TSF)	(hours)	1.0	1.0	1.0	See Section 5.3.3
h	Total travel time	(hours)	2.0	3.8	4.7	=f+g
i	Total evacuation time after mobilisation	(hours)	4.0	5.8	6.7	=f+g+d+e
j	Limit of confident flood prediction (LCFP)	(hours)	15.0	15.0	15.0	See Section 5.3.7
k	Evacuation time beyond LCFP	(hours)	0.0	0.0	0.0	=i-j
m	Windsor gauge level at which egress is cut	(m)	18.9	17.0	18.3	See Table 5.5
n	Estimated Windsor gauge level at which evacuation must commence	(m)	16.9	14.1	14.9	=m-i*0.5 (See Note 3)
p	Estimated Windsor gauge level at LCFP	(m)	14.4	12.5	13.8	=m-j*0.5 (See Note 3)
q	Vehicles assumed to evacuate prior to the LCFP		0	0	0	=b*(i-j-d-e)/(i-d-e)
r	Vehicles assumed to evacuate within the LCFP		628	1674	2242	=b*j/(i-d-e)
s	Proportion of vehicles assumed to evacuate prior to the LCFP	(%)	0%	0%	0%	=q/b
t	Proportion of vehicles assumed to evacuate within the LCFP	(%)	100%	100%	100%	=r/b

Note 1:	Derived using 2010 and 2031estimates from **Volume 2** for all of Bligh Park and Windsor Downs, then distributed to sub-sectors based on dwelling counts. Changes in regional evacuation traffic beyond the LGA assumed to have no influence on evacuation of key constrained areas listed in this table.
Note 2:	600 vehicles per hour.
Note 3:	A constant rate of rise of water levels on the Windsor gauge of 0.5m per hour has been assumed throughout the rising limb of the flood.

Table F.4 − Evacuation Timeline Assessments for Sub-Sectors in Bligh Park and Windsor Downs

(2031 Population Conditions) (Limit of Confident Flood Prediction LCFP = 15 hours)

			Windsor Downs	Bligh Park East	Bligh Park East & West	Comments
a	Epoch		2031	2031	2031	
b	Vehicles needing to evacuate		782	2085	2792	See Note 1
c	Assumed vehicle egress capacity	(per hour)	600	600	600	See Note 2
d	Warning acceptance factor (WAF)	(hours)	1.0	1.0	1.0	See Section 5.3.3
e	Warning lag factor (WLF)	(hours)	1.0	1.0	1.0	See Section 5.3.3
f	Unrestricted travel time	(hours)	1.3	3.5	4.7	=b/c
g	Traffic safety factor (TSF)	(hours)	1.0	1.0	1.5	See Section 5.3.3
h	Total travel time	(hours)	2.3	4.5	6.2	=f+g
i	Total evacuation time after mobilisation	(hours)	4.3	6.5	8.2	=f+g+d+e
j	Limit of confident flood prediction (LCFP)	(hours)	15.0	15.0	15.0	See Section 5.3.7
k	Evacuation time beyond LCFP	(hours)	0.0	0.0	0.0	=i-j
m	Windsor gauge level at which egress is cut	(m)	18.9	17.0	18.3	See Table 5.5
n	Estimated Windsor gauge level at which evacuation must commence	(m)	16.7	13.8	14.2	=m-i*0.5 (See Note 3)
p	Estimated Windsor gauge level at LCFP	(m)	14.4	12.5	13.8	=m-j*0.5 (See Note 3)
q	Vehicles assumed to evacuate prior to the LCFP		0	0	0	=b*(i-j-d-e)/(i-d-e)
r	Vehicles assumed to evacuate within the LCFP		782	2085	2792	=b*j/(i-d-e)
s	Proportion of vehicles assumed to evacuate prior to the LCFP	(%)	0%	0%	0%	=q/b
t	Proportion of vehicles assumed to evacuate within the LCFP	(%)	100%	100%	100%	=r/b

Note 1:	Derived using 2010 and 2031estimates from **Volume 2** for all of Bligh Park and Windsor Downs, then distributed to sub-sectors based on dwelling counts. Changes in regional evacuation traffic beyond the LGA assumed to have no influence on evacuation of key constrained areas listed in this table.
Note 2:	600 vehicles per hour.
Note 3:	A constant rate of rise of water levels on the Windsor gauge of 0.5m per hour has been assumed throughout the rising limb of the flood.

APPENDIX G

ADVICE FROM HALCROW (TRAFFIC ENGINEERS) CONCERNING THE CAPACITY OF THE JIM ANDERSON BRIDGE DURING FLOOD EVACUATIONS

Halcrow
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Tel +61 2 9410 4100 Fax +61 2 9410 4199
www.halcrow.com/australasia

Halcrow

Mr Drew Bewsher
Bewsher Consulting Pty Ltd
P.O. Box 352
Epping NSW 2121

21 June 2011

Dear Drew

Re: Jim Anderson Bridge, Mulgrave
Review of Traffic Capacity During Flood Evacuation Event

In response to your request Halcrow have undertaken a review of the traffic flow capacity of the Jim Anderson Bridge along the Hawkesbury Valley Way during flood evacuation events.

The review has included:

- Review of design plans;
- A site inspection;
- Review of bridge traffic capacity assumptions; and
- Ability of bridge to carry dual outbound lanes during an evacuation.

Our findings from the review are outlined in this letter.

Existing Conditions

The Jim Anderson Bridge was constructed as part of the Windsor flood evacuation route along the Hawkesbury Valley Way.

Hawkesbury Valley Way has become an important road within the urban road network, providing a bypass of the Windsor township.

For normal operation the bridge provides two travel lanes (one in each direction) with a sealed road shoulder on both sides of the road which is reserved for a breakdown lane/ bike path. The bridge has a posted speed limit of 70km/hr.

Along the bridge a sealed road with of 11.6 metres, comprising:

- Travel lanes = 2 x 3.3 metres
- Shoulder lanes = 2 x 2.5 metres

Traffic counts undertaken by Halcrow (then Halcrow MWT) in May 2009 indicated that the Hawkesbury River Way carries in the order of 19,000 vehicles per day.

During peak hour periods the bridge was surveyed to carry:

- AM Peak
  - Northbound = 544 vehicles / hour
  - Southbound = 916 vehicles / hour
- PM Peak
  - Northbound = 976 vehicles / hour
  - Southbound = 790 vehicles / hour

Traffic Lane Capacity During Flood Events

The emergency planning for vehicle movement during a flood event is based on a flow rate of 600 vehicles / hour / lane. It is understood from our review of State Emergency Service documentation[1] that this number has been derived from "a typical rural road flow rate of 1,200 vehicles / hour / lane" and applying a reduction factor of 50% (divide by 2) to account for adverse driving conditions such as heavy rain, darkness and driver unfamiliarity.

Debate could be given to whether Hawkesbury Valley Way at the bridge is a rural or urban road given the road's current function in the urban road network. Urban roads typically have a higher capacity per lane than rural roads (1,400 vehicles / hour / lane versus 1,200 vehicles / hour / lane).

A traffic capacity of 600 vehicles per hour per lane represents a flow rate of 1 vehicle every 6 seconds. Under current peak hour traffic flows a flow rate of 1 vehicle every 3.6 seconds is being achieved and it could be argued that the current conditions are not at operational capacity.

Notwithstanding the above, the implications of adverse weather and unfamiliar driving conditions should not be underestimated. Driver uncertainty will play a key role in the ability to get vehicles across the bridge in a timing and efficient manner.

Thus while a flow rate of 600 vehicles / lane / hour is conservative, it is considered to be an appropriate flow for emergency planning purposes.

[1] Emergency Risk Management for Hawkesbury-Nepean Flooding, NSW State Emergency Service (June 2002)

Dual Outbound Lanes on the Bridge (Geometric Conditions)

Obviously the provision of additional lanes in the outbound direction will significantly increase the capacity of the bridge.

As part of this review we have considered if the geometric conditions of the bridge would facilitate the provision of dual (2) outbound lanes and one inbound lane across the bridge.

As stated above, the bridge has a sealed road width of 11.6 metres. This width could accommodate the following lane widths:

• Outbound kerb lane =	3.7 metres
• Outbound centre lane =	3.5 metres
• Median (ie. witches hats) =	0.4 metres
• Inbound lane =	4.0 metres
	11.6 metres

It is considered that these lane widths can be safely provided along the bridge which generally has a straight to gentle curved alignment. Notwithstanding it is suggested that a speed limit of 40 – 50 km/hr be applied during dual lane operating modes.

This allows for the protection of traffic control staff and road safety as there is no break down lane and narrow lane widths. Repeat signage should be used to reinforce the speed limit as the road alignment is straight and speed limits likely to be violated.

It is noted that lane widths of 3 metres are provided across the Sydney Harbour Bridge with a posted speed limit of 80km / hour.

Dual Outbound Lanes on the Bridge (Management Measures / Constraints)

It is noted that the SES[2] has indicated that dual outbound lanes may be used as a last resort if factors have reduced the expected time frame for evacuation.

However, the SES has also noted that they do not consider dual outbound lanes as a viable primary traffic flow enhancement strategy.

While it is considered geometrically possible to provide dual outbound lanes, the practicalities of operating dual lanes will require a set up period and on going maintenance and management (ie. traffic controllers) to minimise the possibility of incidences.

For example set up would require:

- the placement of barriers and / or witches hats to delineate the new lanes; and
- erection of VMS signage to advise of changed traffic conditions.

To install these safely would require temporary closure of the road.

[2] Emergency Risk Management for Hawkesbury-Nepean Flooding, NSW State Emergency Service (June 2002)

Upstream and Downstream Traffic Flow Constraints

The implementation of a dual outbound lane arrangement is only considered practical if there are no upstream or downstream constraints to providing two outbound lanes. For example, if a merge from two lanes to one lane is required when vehicles drive off the bridge then the effective dual lane capacity of the bridge is negated and may even be reduced given the friction associated with merge areas.

A preliminary review of the bridge entry and exit ramps / lanes indicated that a dual outbound lane could be provided within the existing sealed road area with appropriate lane delineation (ie. witches hats, barriers). Detailed analysis will be required to determine heavy vehicle turning path requirements around bends under a dual outbound lane scenario (particularly at the southern or Mulgrave end of the bridge).

Turning paths for heavy vehicles should be checked at intersections for help with designing the emergency layout.

Conclusion

This review has concluded the following:

- The assumed traffic flow rate of 600 vehicles / hour / lane is appropriate for planning purposes. It is noted that the rate is conservative and higher single lane flows may be achieved.

- The road geometry of the bridge would allow for the safe provision of three separated traffic lanes which would include two outbound lanes and one inbound lane.

- Provision of dual outbound lanes would significantly increase evacuation capacity.

- Implementation of dual outbound lanes will require significant set up and operational personnel. Guidance as to the practicalities of such management arrangements should be sought from the SES.

We trust that the above satisfactorily addresses your queries. If you require any further information please do not hesitate to contact the undersigned.

Yours Sincerely

Jason Rudd

Jason Rudd
Associate Director

APPENDIX H

ADVICE RECEIVED FROM BUREAU OF METEOROLOGY AND NSW ROADS AND MARITIME SERVICES IN RESPONSE TO REQUEST FROM COUNCIL'S FLOOD MANAGEMENT ADVISORY COMMITTEE

Australian Government

Bureau of Meteorology

NEW SOUTH WALES REGIONAL OFFICE
Bureau of Meteorology
PO Box 413 Darlinghurst NSW 1300 Australia

In reply please quote

2 September 2011

Mr Matthew Owens
Director City Planning
Hawkesbury City Council
PO Box 146
WINDSOR NSW 2756

Dear Mr Owens

HAWKESBURY FLODPLAIN RISK MANAGEMENT STUDY – FLOOD WARNING ISSUES

I refer to your letter of 30 August concerning flood predictions for the Hawkesbury River.

I agree with the Drew Bewsher's summary attached to your letter, noting the comments about the confidence of 15 hour verses 18 hour flood predictions, both of which may need to be based upon similarly correct, or incorrect, assumptions of forecast rainfall.

It is not possible to provide the level of confidence in accuracy of a range of flood predictions you requested. It depends on lead times provided and the accuracy of inputs, including rainfall predictions as well as recorded rainfall and river levels, into the modelling process. Due to the lack of recent major floods in the Nepean Hawkesbury Valley and the changes in modelling and rainfall forecasting technology since the last major flood in August 1990, and minor to moderate flood of August 1998, it is not possible to provide meaningful statistics of flood warning performance for this valley which are relevant to present practice. The accuracy of recent flood predictions for coastal NSW in the June 2011 event was that 76% of predictions were within 0.3 metres, which indicates an improvement from the 70% figure that has been quoted in Drew's report. However, I cannot guarantee that this improvement is sustainable or will be achieved in the Hawkesbury Valley.

The Bureau does model flows from the Grose and MacDonald River catchments to predict river heights along the Hawkesbury River to North Richmond and downstream. However, the rain and river networks for these catchments would need to be upgraded if they were to underpin quantitative flood warning services for Grose Wold or St Albans.

Also, the Bureau provides Probable Maximum Precipitation (PMP) values that are used, usually by consultants, in hydrological and hydraulic models to develop Probable Maximum Flood (PMF) flows and flood levels respectively. The Bureau does not undertake PMF studies.

I, or one of my staff, will be happy to address a future committee meeting on the above issues.

Yours sincerely

Gordon McKay
Regional Hydrology Manager
NSW Flood Warning Centre

Australia's National Meteorological Service

Level 16 300 Elizabeth Street Sydney New South Wales. Tel: (02) 9296 1555 Fax: (02) 9296 1506 www.bom.gov.au ABN 92 637 533 532

Transport
Roads & Maritime
Services

GM12/2398

Mr Matthew Owens
Director City Planning
Hawkesbury City Council
366 George Street
WINDSOR NSW 2756

Dear Mr Owens

Thank you for your letter to Roads and Maritime Services (RMS) about the Hawkesbury Floodplain Risk Management Study.

The event management plan of which the operation of Hawkesbury Valley Way is of significance is due to be reviewed this year. The council will be invited to participate in this review and the suggestion of running three lanes of traffic on the bridge can be considered as part of the review.

The bridge was designed to accommodate two lanes outbound and one emergency lane inbound during evacuation events, should this be required.

I hope this has been of assistance. For more information please contact Mr Michael Kayello, Traffic Engineering Officer, at RMS on (02) 8849 2172.

Yours sincerely

Julie Fell
Manager, Customer and Ministerial Enquiries

Roads & Maritime Services

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