

HAWKESBURY-NEPEAN VALLEY FLOOD MANAGEMENT REVIEW — DEVELOPING A STRATEGY WHERE FLOOD DEPTH CAN BE NINE METRES ABOVE FLOOD PLANNING LEVEL

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Sue is the Specialist Technical Manager for the NSW Government's Hawkesbury-Nepean Valley Flood Management Taskforce. Sue has many years of experience across all facets of flood risk management. Before Sue's current role, Sue was Sydney Regional Manager for the NSW Office of Environment and Heritage, managing technical issues and grant funding assistance for flood, coast and estuaries for the 41 local government areas across the Sydney Region. Prior to these roles in state government, Sue worked for six years in local government and 15 years in consulting in floodplain risk management and water resource management. In recent years, Sue has also lectured at the UTS Flood Management Course on the topic of land use planning and held the position of Director Land Use Planning with the Floodplain Management Association for two years between 2010 and 2012.

Abstract

The Hawkesbury-Nepean Valley floodplain is located in Western Sydney with preliminary estimates indicating that more than 70,000 people are currently living in areas prone to flooding from the Hawkesbury-Nepean River. *A Plan for Growing Sydney* (2014) identifies the region as an area of significant urban growth, with a projected population of nearly 90,000 people by 2031, including 39,000 new homes and 37,000 new jobs.

The unique natural characteristics of the Hawkesbury-Nepean Valley make it susceptible to significant flood risk. The combination of the large upstream catchments and narrow downstream gorges cause floodwaters to back up behind natural 'choke points' like a 'bath tub'. This combined with many evacuation routes being cut by floodwaters long before the higher inhabited areas are inundated, thereby isolating communities, potentially places many lives at risk.

The 1 in 100 chance per year flood is generally the flood used to set residential floor levels (known as the flood planning level). However, at the town of Windsor, the flood of record in 1867 would have been two metres higher than the 1 in 100 chance per year flood, while the worst possible flood would be nearly nine metres higher than this flood planning level.

The Hawkesbury-Nepean Valley Flood Management Review began in early 2013 in response to the NSW Government's adoption of the State Infrastructure Strategy 2012-2032 and on-going community concerns about flood risk. This paper presents the key findings for the first stage of the Review. The second phase of the Review is currently being undertaken by the multi-agency Hawkesbury-Nepean Valley Flood Management Taskforce, with a report to the NSW State Government due later in 2015.

The Hawkesbury-Nepean flood problem

The Hawkesbury-Nepean River catchment

The Hawkesbury-Nepean river system (**Figure 1**) is one of New South Wales' (NSW) most important natural assets and is one of the largest coastal river catchment along the NSW coastline. Its catchment covers 2.2 million hectares (22,000 square kilometres), framing the northern and western edges of the Sydney Basin. It is the main source of drinking water for over four million people, or 70 percent of the NSW population. Its waters also support agricultural and horticultural industries that generate more than \$1 billion annually, including \$259 million of irrigated agriculture which supplies much of Sydney's fresh food. Each year more than 10 million people visit the Hawkesbury-Nepean catchment to experience its natural assets including World Heritage listed wilderness, rainforests, open woodlands, wetlands and heath lands, and the spectacular Hawkesbury estuary. (NSW Government, 2013).

As shown on **Figure 1**, more than 40 percent of the Hawkesbury-Nepean catchment (9,000 square kilometres) is upstream of Warragamba Dam. Warragamba Dam was constructed between 1948 and 1960 with the sole purpose of supplying water to the Sydney metropolitan area.

History of flooding

The largest flood on record in the Hawkesbury-Nepean Valley occurred in 1867 when the river level reached 19.7 metres Australian Height Datum (AHD) at Windsor. Taking into account the construction of Warragamba Dam, a repeat of the 1867 flood would be equivalent to a level of 19.3 metres AHD at Windsor. This means that the water level would have been 19.2 metres above the normal river level at Windsor. The normal river level at Windsor is less than 0.5 metre above sea level, although it is more than 100 kilometres from the coast. Recent analysis suggests that the 1867 flood represent a flood around a 1 in 500 chance per year flood (this estimate is currently being verified).

Analysis of sediment within the Nepean gorge shows that prior to European settlement, but under current climatic conditions, at least one flood would have reached or exceeded level equivalent to about 20 metres AHD at Windsor (Molino Stewart Pty Ltd, 2012), equivalent to about a 1 in 1,000 chance per year flood.

Table 1 lists flood levels at Penrith and Windsor for a number of historical floods in the Hawkesbury-Nepean Valley and compares them with design flood levels. **Table 1** shows that the most recent flood greater than a 1 in 20 chance per year flood occurred in 1978, nearly 40 years ago.

Each flood event is unique due to the timing of rainfall across the Hawkesbury-Nepean Valley catchment. While 40 per cent of the catchment flows through Warragamba Dam, 60 per cent does not flow through the dam. **Figure 2** shows how the contributions of the different subcatchments have varied considerably during flood events since the construction of Warragamba Dam in 1960. For instance, in the August 1990 flood, 73 percent of the flood at Windsor came from the Warragamba catchment, while in the August 1986 flood, the Warragamba subcatchment only contributed 42 percent of floodwaters at Windsor.

Figure 1: Locality plan and subcatchments of the Hawkesbury-Nepean Valley



Source: (NSW Office of Water, 2014b)

Table 1: Comparison of historical and design flood levels, including estimates of number of people needing evacuation

Flood size (chance per year and date of historical flood)	Design flood levels (metres AHD)		Estimate of total number of people needing evacuation planning (2011)
	Penrith	Windsor	
once per year	15.4*	3.5*	
March 2012	18.4	6.0	
1 in 2	16.0*	7.4**	
November 1969	19.2	10.2	
1 in 5	20.4	10.4	30
May 1974	19.3	10.4	
July 1988	20.3	10.9	
June 1975	21.5	11.2	
August 1986	20.0	11.4	
1 in 10	21.9	12.2	200
May 1988	22.6	12.8	
August 1990	23.4	13.5	
1 in 20	23.5	13.7	2,400
March 1978	23.4	14.5	
June 1964	23.7	14.6	
November 1961	23.9	15.0	
1 in 50	24.8	15.8	7,500
1 in 100	25.9	17.3	28,000
1 in 200	26.5	18.3	42,000
June 1867**	26.9	19.3	
1 in 500	27.1	19.6	48,000
1 in 1,000***	27.6	20.4	52,000
1 in 2,000	28.7	22.1	57,000
1 in 5,000	30.3	23.8	63,000
Probable Maximum Flood	31.5	26.2	73,000

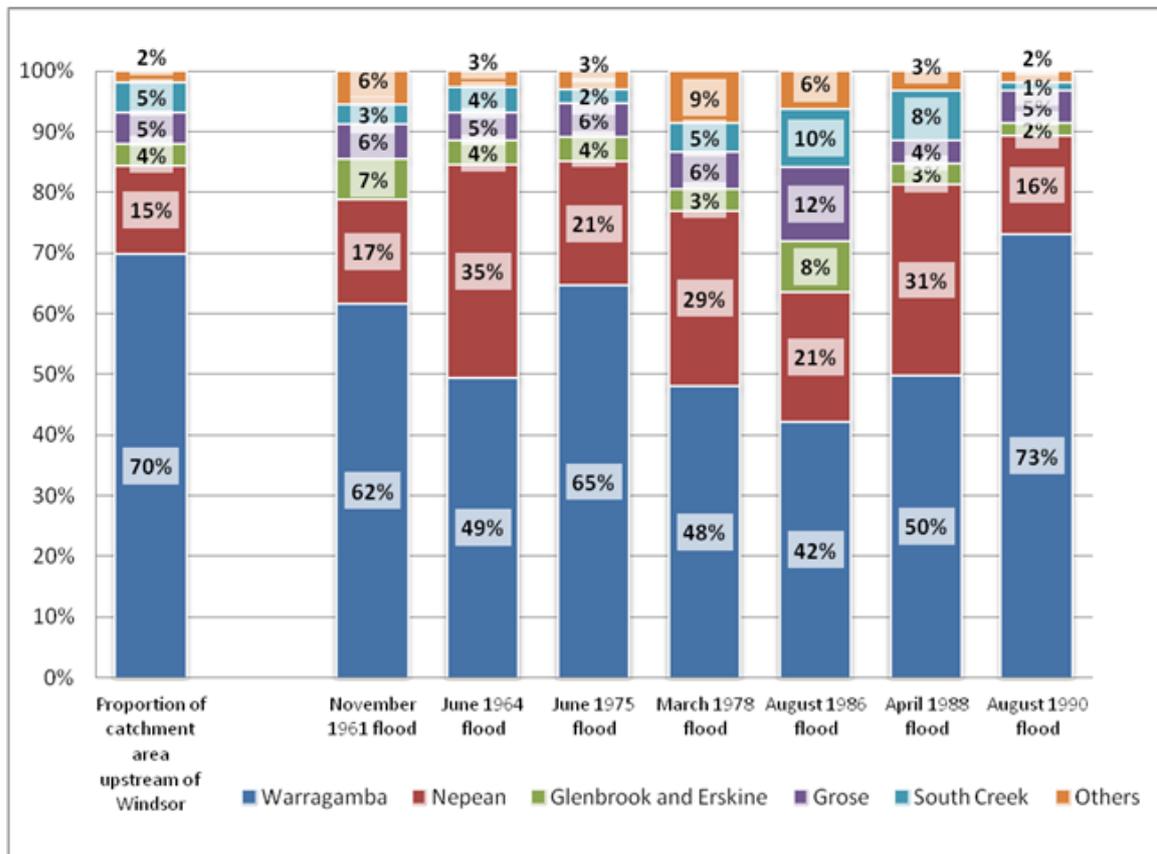
* assumes drawdown of Warragamba Dam

** adjusted for Warragamba Dam

*** there is evidence that a flood of this size has occurred at least once before European settlement under current climate conditions

Source: (NSW Office of Water, 2014b)

Figure 2: Subcatchment contributions to flooding at Windsor since 1960



Source: (NSW Office of Water, 2014b)

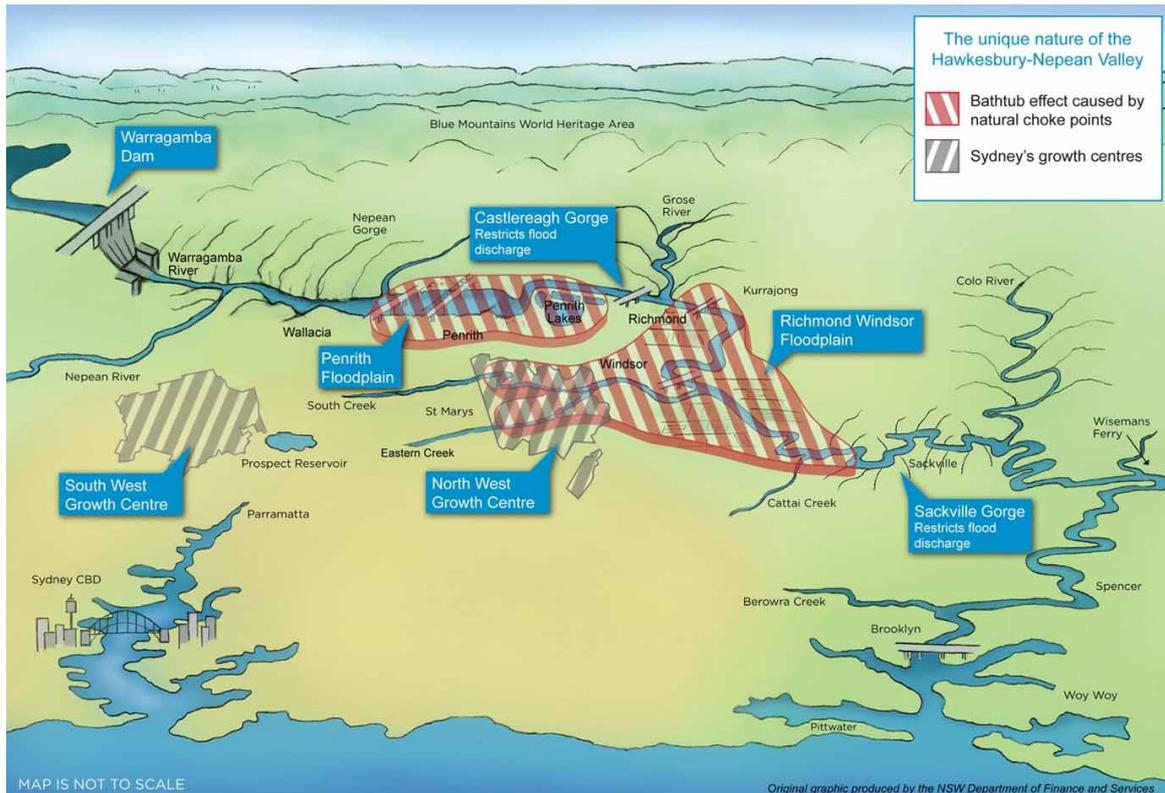
Why is flooding in the Hawkesbury-Nepean Valley so different from other floodplains?

The natural characteristics of the Hawkesbury-Nepean Valley make it susceptible to significant flood risk. The Hawkesbury-Nepean Valley consists of a sequence of floodplains linked by gorges. As shown on **Figure 3** the combination of large upstream catchments and the narrow downstream gorges results in floodwaters backing up behind the natural ‘choke points’. This ‘bathtub effect’ causes significant flooding in the Penrith and the Richmond-Windsor floodplains.

The worst flood that could conceivably occur is referred to as the Probable Maximum Flood (PMF). It is the PMF that defines the extent of the floodplain and the area that requires planning for possible evacuation. Management of risks from flooding, including danger to personal safety, needs to consider all floods up to the PMF, even though such an event is extremely rare.

A key impact of the ‘bathtub effect’ for flooding in the Hawkesbury-Nepean Valley is the large range of flood depths. In most NSW rivers, the difference in the flood depth between the 1 in 100 chance per year flood level and the PMF is usually less than two metres. In the Richmond-Windsor region, the PMF is up to nine metres above the 1 in 100 chance per year flood level and would be about 26 metres above normal river level. Even the 1 in 100 chance per year flood would be around 17 metres above the normal river at Windsor.

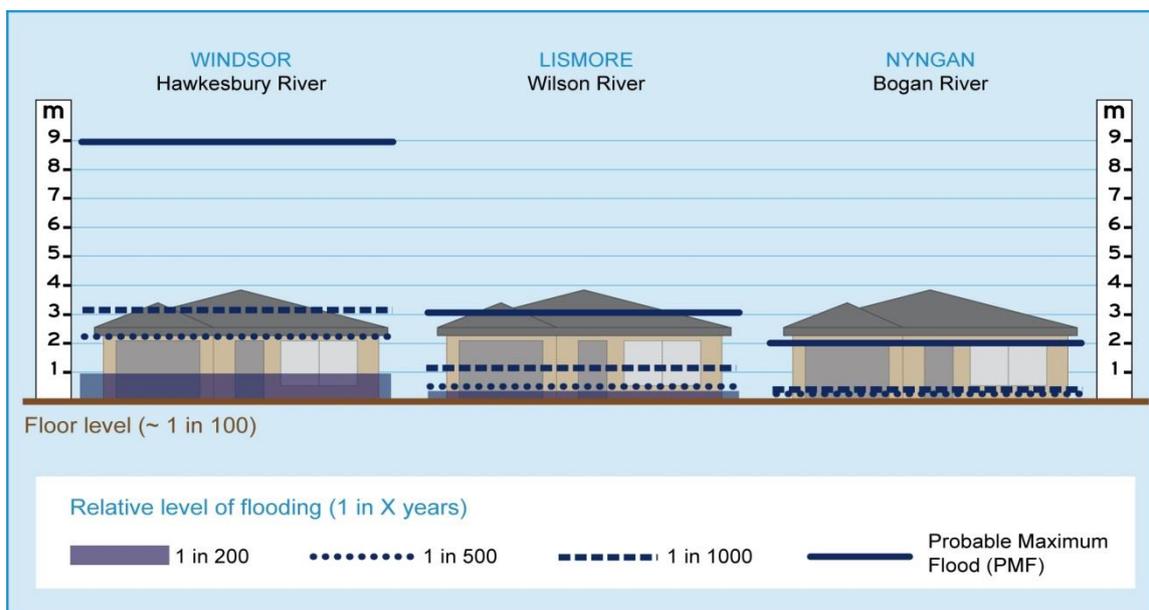
Figure 3: The 'bathtub' effect of flooding in the Hawkesbury-Nepean Valley



Source: (NSW Office of Water, 2014b)

Figure 4 shows the difference between the levels of a 1 in 200, 1 in 500, 1 in 1,000 chance per year and a PMF for the Hawkesbury River at Windsor, compared with the Wilson River at Lismore on NSW's northern rivers and the Bogan River at Nyngan in NSW's central west, assuming the floor level of the house is built at the level of the 1 in 100 chance per year flood.

Figure 4: Comparison of flood levels at three NSW floodplains



Source: adapted from (ERM Mitchell McCotter Pty Ltd, 1995)

Population at risk and impacts of flooding

The main Hawkesbury-Nepean floodplain from Warragamba Dam to Brooklyn is home to around one million people. *A Plan for Growing Sydney* (NSW Planning and Environment, 2014) sets out the framework for Sydney's growth to 2031. *A Plan for Growing Sydney* indicates a projected population increase in the Metropolitan West subregion (most of which is located within the Hawkesbury-Nepean Valley) of nearly 90,000 people by 2031, with a target of at least 39,000 new homes and 37,000 additional jobs. The North West Growth Centre will accommodate a large proportion of these homes and jobs. Many new homes and jobs across the region will be located in the Hawkesbury-Nepean floodplain.

Figure 5 shows the extent of the Hawkesbury-Nepean Valley floodplain and displays the extent of the 1 in 100 chance per year flood (typically used as the basis for flood planning in NSW) together with the extent of the PMF. This highlights the significant scale of inundation around Richmond, Windsor, Bligh Park, Penrith, McGraths Hill and Marsden Park.

Preliminary estimates indicate that around 70,000 people are currently living within the Hawkesbury-Nepean floodplain. Evacuation planning needs to include all people living in the floodplain. **Table 1** provides an estimate of the number of people needing evacuation planning for various sized flood events. In a 1 in 200 chance per year flood, more than 13,000 people have been estimated to live in houses where there would be flood waters more than two metres above their home's floor level. (NSW Office of Water, 2014b).

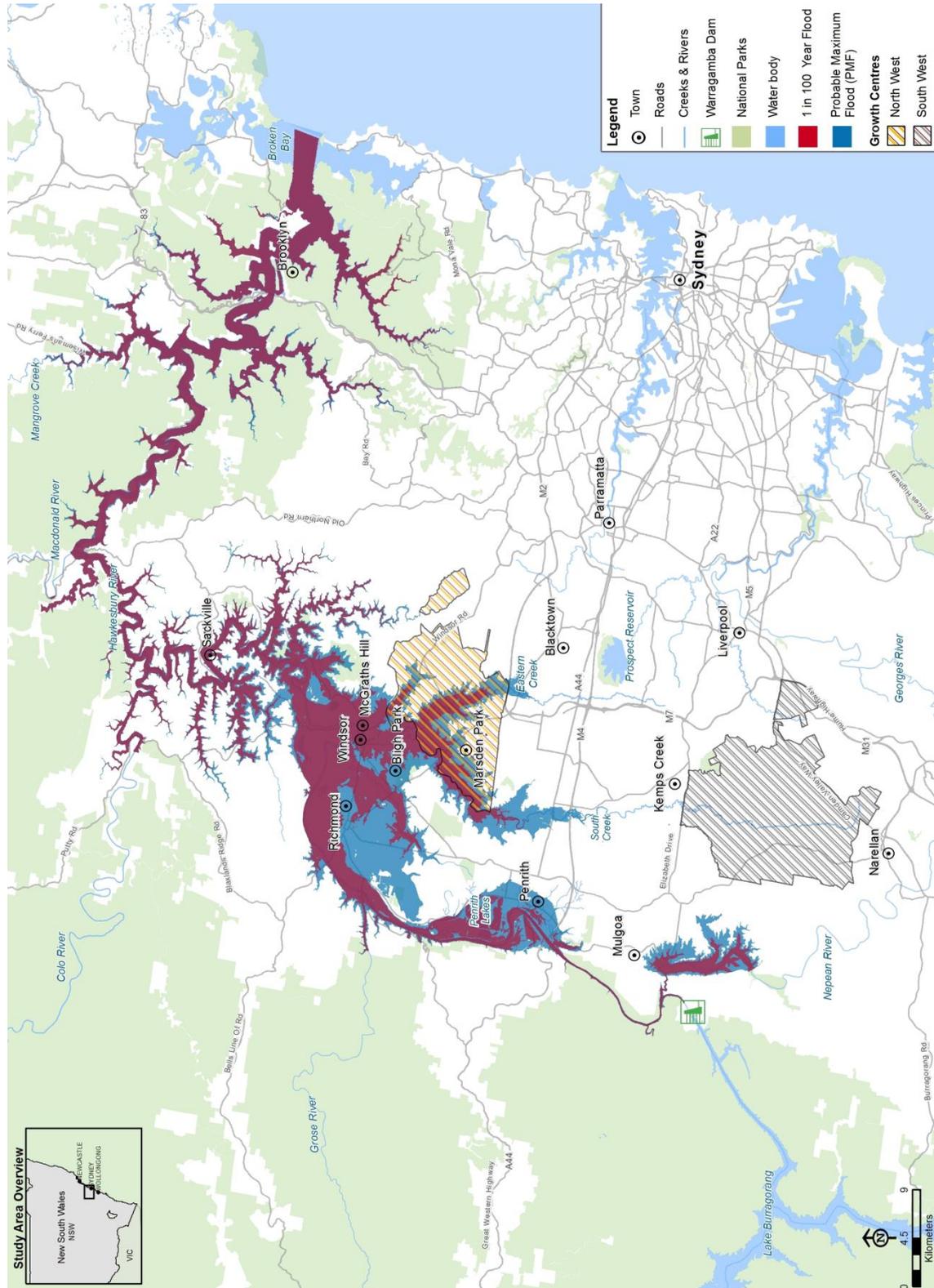
In a repeat of a flood the size of the 1867 flood, flood damages have been estimated to be in the order of \$2-\$5 billion. The long-term averaged costs of damages are mainly attributed to flood between the 1 in 100 and 1 in 500 chance per year floods (rather than to larger, rarer floods), with these floods contributing nearly half of the average annual damage (Molino Stewart Pty Ltd, 2012).

Flood evacuation

The shape of the landform (that is, its topography), has a significant influence on how floodwaters inundate the landscape and the ability of its occupants to evacuate. In the Hawkesbury-Nepean floodplain, many evacuation routes have low points that are flooded and are cut off by floodwaters before the higher inhabited areas are inundated. This leads to isolated flood islands where access is restricted to and from different areas of the floodplain during a flood. **Figure 6** illustrates the implications of flood islands for flood evacuation planning.

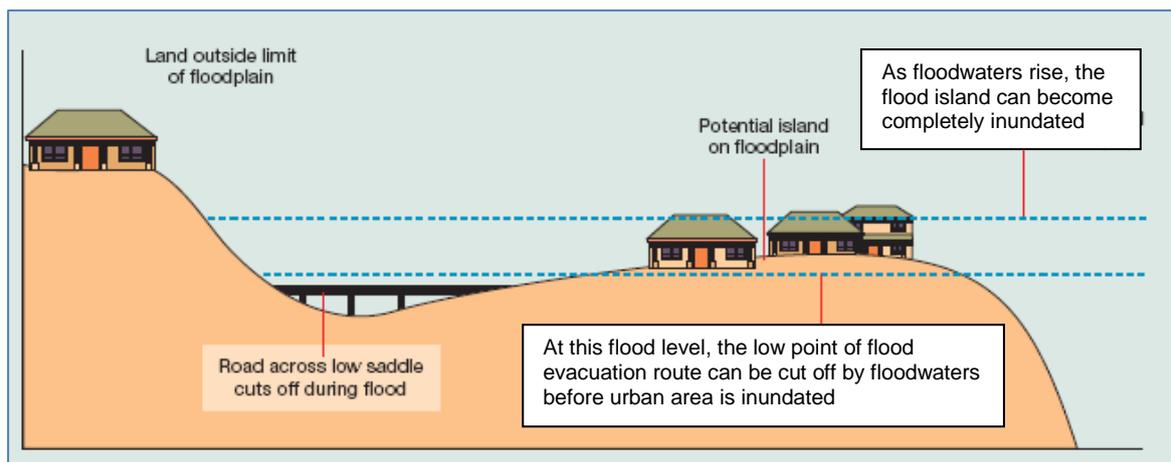
Some of these isolated flood islands can become totally inundated as flood waters rise. The townships of Richmond, Windsor, South Windsor, Bligh Park, Pitt Town and McGraths Hill will all become inundated flood islands during large floods of various sizes. For example, McGraths Hill will be completely inundated in a 1 in 100 chance per year flood, while the area's only flood evacuation route is more than 3.5 metres below this flood level.

Figure 5: Flood extents and future growth centres in Hawkesbury-Nepean Valley



Source: (NSW Office of Water, 2014b)

Figure 6: Implications of flood islands for flood evacuation planning



Source: adapted from (Hawkesbury-Nepean Floodplain Management Steering Committee, 2006)

With the low points of flood evacuation routes often lower than the higher urban area, evacuations need to commence well before the urban area is inundated. The time to complete an evacuation includes the time to receive the flood warning, the time to mobilise NSW State Emergency Service (SES) personnel, the time to start the evacuation, the time for the community to accept and act on the warning, and the time taken for traffic to drive the evacuation route to outside the level of potential flooding.

As a result of the estimated time required to complete an evacuation, the SES is forced to make the decision to evacuate based on forecast rainfall (that is, before the rain has actually fallen). This forecast rainfall has varying uncertainty and accuracy. It is estimated that the decision to evacuate would need to be made around six hours ahead of rain actually falling and at a time when river levels are in bank or near normal river levels. The risks of this evacuation decision include:

- an evacuation decision being made with forecast rainfall not eventuating, leading to a mass evacuation being found to be unnecessary with significant disruption to the community
- difficulty convincing the community to leave at the commencement of evacuation without significant visual clues due to river levels being in bank or near normal levels.

Conversely if the forecast rainfall initially shows that the evacuation route is not forecast to be cut and the evacuation call is not made, the risks include:

- insufficient time to fully evacuate the area if forecast or actual rainfall increases and possibly cuts the evacuation route ahead of complete evacuation
- a large flood rescue problem for remaining trapped population.

The long evacuation times and use of uncertain rain forecasts results in complicated and risky evacuation decisions. It has been identified that the capacities of flood evacuation routes across the valley need to be increased.

The Hawkesbury-Nepean Valley Flood Management Review

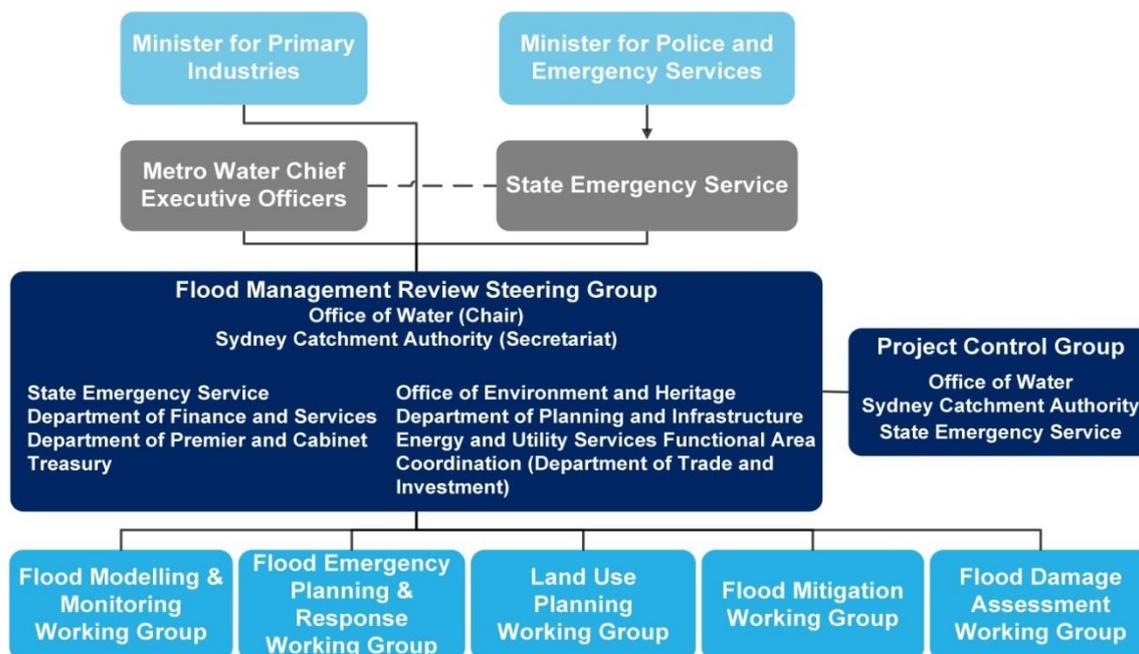
In its 'First Things First – The State Infrastructure Strategy 2012-2032' report released in 2012, Infrastructure NSW (INSW) proposed a range of specific infrastructure investments and reforms over a 20-year period. INSW recommended the need for a review of flood mitigation options for the Hawkesbury-Nepean Valley as a high priority for NSW Government consideration (Infrastructure NSW, 2012).

At the same time, community awareness of flooding issues, and the potential role of dams in mitigating the effects of floods was heightened by significant flood events in south-east Queensland, Victoria as well as at various locations along the NSW coast.

Following its review of the INSW recommendations, the NSW Government released its State Infrastructure Strategy in December 2012 and identified the State's infrastructure delivery and reform priorities over the next five years. One of the key projects in the strategy was a review of major flood mitigation options available in the Hawkesbury-Nepean Valley, including options for raising the crest of the Warragamba Dam wall and evacuation route upgrades (NSW Department of Premier and Cabinet, 2012).

In response to these issues, the NSW Government commissioned the *Hawkesbury-Nepean Valley Flood Management Review* (the Review) in early January 2013. This included the formation of the inter-agency *Hawkesbury-Nepean Valley Flood Management Review Inter-agency Steering Group* (the Steering Group). Five technical working groups were established to report on key elements of the Review. The governance arrangements are shown in **Figure 7**.

Figure 7: Governance structure of the Hawkesbury-Nepean Valley Flood Management Review



Source: (NSW Office of Water, 2014b)

Note: Names of agencies reflect those current at the time of completion of the Review (March 2014). Some agency names have changed since that time.

The purpose of the Review was to examine current flood management, land use planning and emergency procedures in the Hawkesbury-Nepean Valley and identify any opportunities to improve the ways in which future floods are managed.

The scope of the Review was defined by the following Terms of Reference:

- describe current management arrangements in relation to flood mitigation in the Hawkesbury-Nepean Valley and evaluate their adequacy and effectiveness. Flood mitigation includes flood emergency planning and response, land use planning and structural measures for Warragamba Dam and downstream of Warragamba Dam
- consider what factors have changed since the current management arrangements were put in place and, in particular, to consider the influence of the North West Growth Centre on the changing risk profile within the valley
- collate current information and modelling to assist the Review, and scope any additional modelling required
- describe the management options that have previously been examined to further mitigate the impacts of flooding in the valley, and review whether any of these options need re-assessment
- explore all options to improve flood mitigation strategies and processes in the valley, including but not limited to:
 - current evacuation routes and whether upgrades are required
 - assessment of the appropriateness of current urban planning policies
 - consideration of current governance arrangements for flood planning and response and whether it is feasible that planning and response arrangements be overseen by a single agency
 - assessment of whether changes to the operation and configuration of key processes of water infrastructure, such as Warragamba Dam, are required.

The study area for the Review was defined as the riverine floodplain of the Hawkesbury-Nepean River from Warragamba Dam to Brooklyn Bridge (refer **Figure 5**). The Review did not examine flooding upstream of Warragamba Dam and in the Nepean River upstream of Wallacia, nor did it examine localised flash flooding from smaller intense storm events.

Guiding principles, aims and desired outcomes of the Review

The overall aim of the Hawkesbury-Nepean Valley Flood Management Review was:

“The Hawkesbury-Nepean Valley is strategically managed so the community is more resilient to flood risk”

The desired outcomes of this Review can be described under the following three broad objectives:

- **keeping the community safe** — the risk to life, property and infrastructure within existing development in the Hawkesbury-Nepean Valley is managed strategically
- **community awareness** — an informed community the benefits, costs and risks of living with floods in the Hawkesbury-Nepean Valley
- **sustainable future growth** — future growth and development in the Hawkesbury-Nepean Valley is strategically managed considering the flood risk.

The overall aim and desired outcomes of the Review were developed for the Review using the following guiding principles and key inputs:

- *National Strategy for Disaster Resilience* and in particular the role of government has in strengthening resilience to disasters (Attorney-General's Department, 2011)
- *Australian Emergency Management Handbook No.7 — Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (Australian Emergency Management Institute, 2014)
- *NSW Government Flood Prone Land Policy and accompanying Floodplain Development Manual — The Management of Flood Liable Land* (NSW Government, 2005)
- *NSW 2021 — A Plan to Make NSW Number One* (NSW Government, 2011).

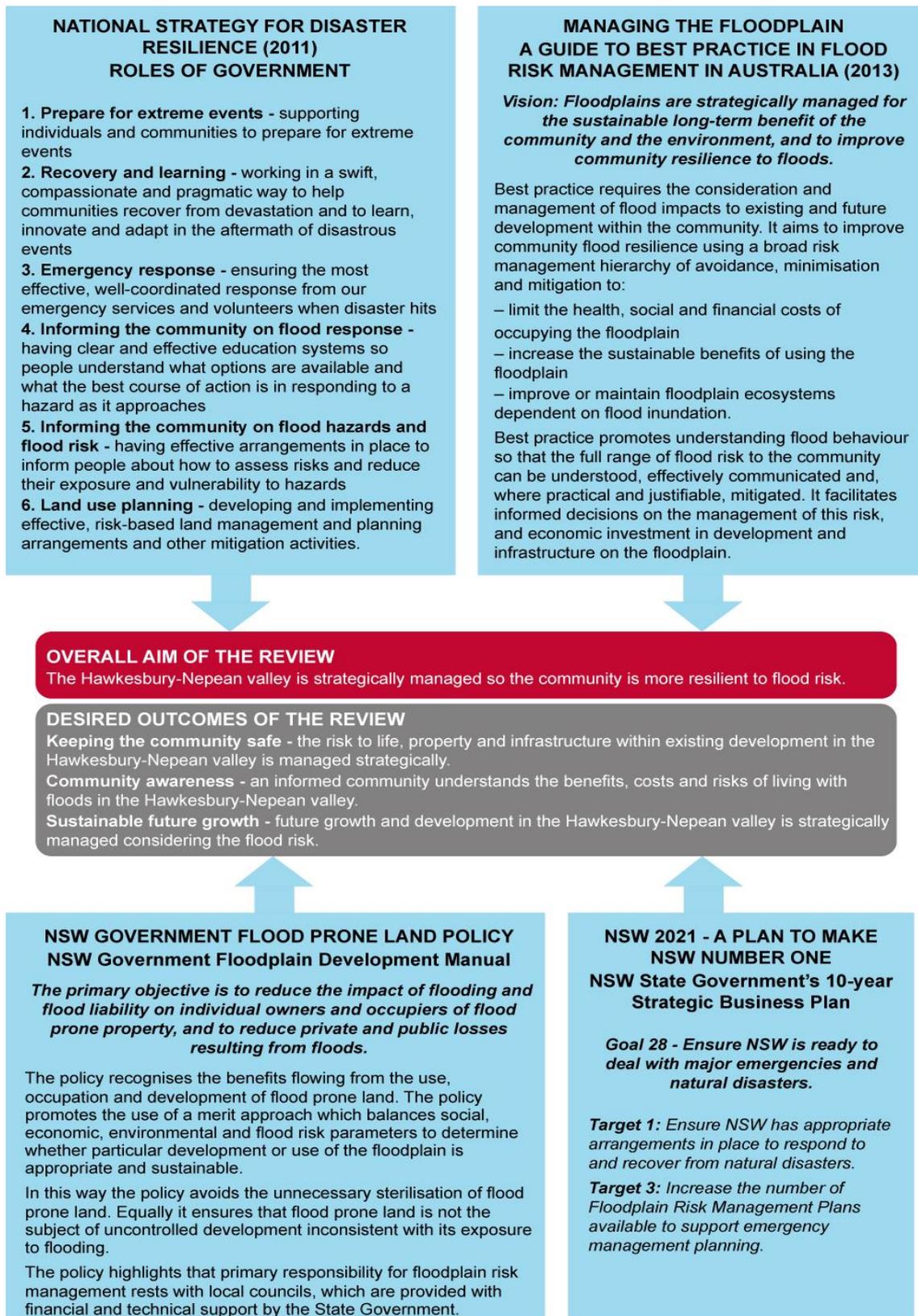
Figure 8 illustrates the guiding principles and key inputs to the aims and desired outcomes of the Hawkesbury-Nepean Valley Flood Management Review.

Flood risk management options considered by the Review

The suite of flood risk management options considered by the Review were identified and developed considering the following key objectives:

- describe the management options that have been previously examined to reduce the impacts of flooding in the valley and review whether any of these options needed reassessment
- explore all other options to improve flood mitigation strategies and processes in the valley
- develop high level contemporary costs and benefits for a range of flood risk management options.

Figure 8: Guiding principles and key inputs to aims and desired outcomes of the Review



Source: (NSW Office of Water, 2014b)

Note: Australian Emergency Management Handbook No.7 — Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (Australian Emergency Management Institute, 2014) was in draft form during the time of the Review. The final version was released in February 2014. The Vision Statement the final version is the same as that in the 2013 draft.

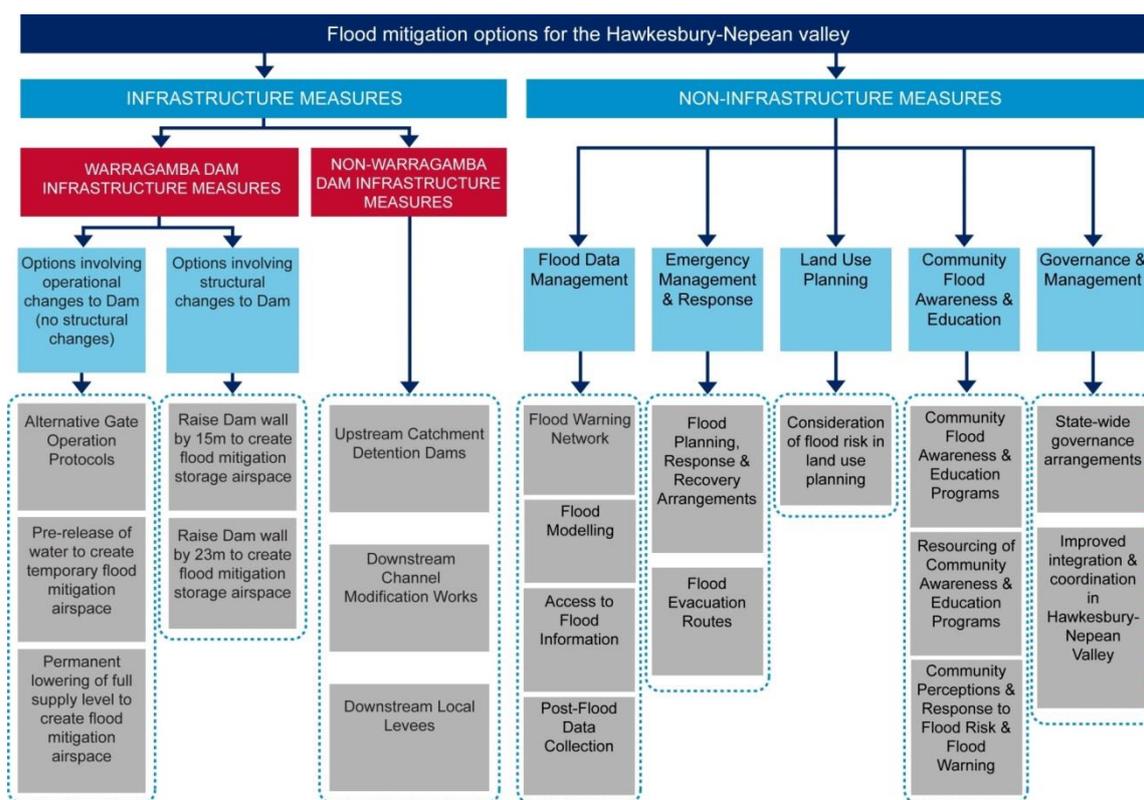
A suite of possible floodplain risk management treatment options was developed as part of the Review taking into account the following key background and input information:

- *Interim Report on Short Term Flood Mitigation Works & Measures in the Nepean- Hawkesbury Valley* (Inter-departmental Committee of Inquiry into Nepean-Hawkesbury Flood Problems, 1968)
- *Hawkesbury-Nepean Valley Flood Plain Management Strategy Report* (Gutteridge, Haskins and Davey, 1981) which was prepared as part of the Joint Commonwealth/State/Local Government Steering Committee Flood Plain Management Studies)
- *Proposed Warragamba Flood Mitigation Dam — Environmental Impact Statement* (ERM Mitchell McCotter Pty Ltd, 1995)
- *Achieving a Hawkesbury-Nepean Floodplain Management Strategy* (Hawkesbury-Nepean Flood Management Advisory Committee, 1997) — the Review included an audit of all the recommendations made as part of the 1997 Strategy
- *Hawkesbury-Nepean Flood Management Strategy — Engineering Studies to Modify Flood Behaviour* (Webb, McKeown & Associates Pty Ltd, 1997)
- *Hawkesbury Floodplain Risk Management Study and Plan* (Bewsher Consulting Pty Ltd, 2012)
- *Hawkesbury-Nepean Flood Damages Assessment* (Molino Stewart Pty Ltd, 2012).

Figure 9 provides an overview of the suite of flood risk management options considered as part of the Review, which were divided into the following categories:

- **infrastructure measures** — these are measures that modify flood behaviour. They are also referred to as ‘structural measures’ or flood mitigation measures. Infrastructure measures considered as part of the Review have been further divided into the following categories:
 - **Warragamba Dam infrastructure measures** — these measures relate specifically to potential changes to Warragamba Dam, both structurally and operationally
 - **Non-Warragamba Dam infrastructure measures** — these measures relate to structural flood mitigation options that do not involve changes to Warragamba Dam
- **non-infrastructure measures** — these are measures that modify property and the community’s response to flooding. They are also referred to as ‘non-structural measures’. Non-infrastructure measures considered as part of this review are as follows:
 - flood data management
 - emergency management and response
 - land use planning
 - community flood awareness and education
 - governance and management.

Figure 9: Suite of flood risk management options considered for the Hawkesbury-Nepean Valley



Source: (NSW Office of Water, 2014a)

Proposed strategies and recommendations

The outcome of the Hawkesbury-Nepean Valley Flood Management Review comprised ten proposed strategies involving 20 recommendations, grouped into three major categories:

- **infrastructure** — includes works that can be built to mitigate flood risk
- **governance** — includes changes in governance that can be reduce the impact of floods through improved preparation and management
- **non-infrastructure** — includes measures for better flood emergency planning, response and recovery, land use planning and flood modelling.

Table 2 presents the proposed strategies and recommendations, while **Figure 10** shows how these have been linked back to the overall aim and desired outcomes of the Review, as well as with the roles of government as outlined in the *National Strategy for Disaster Resilience*.

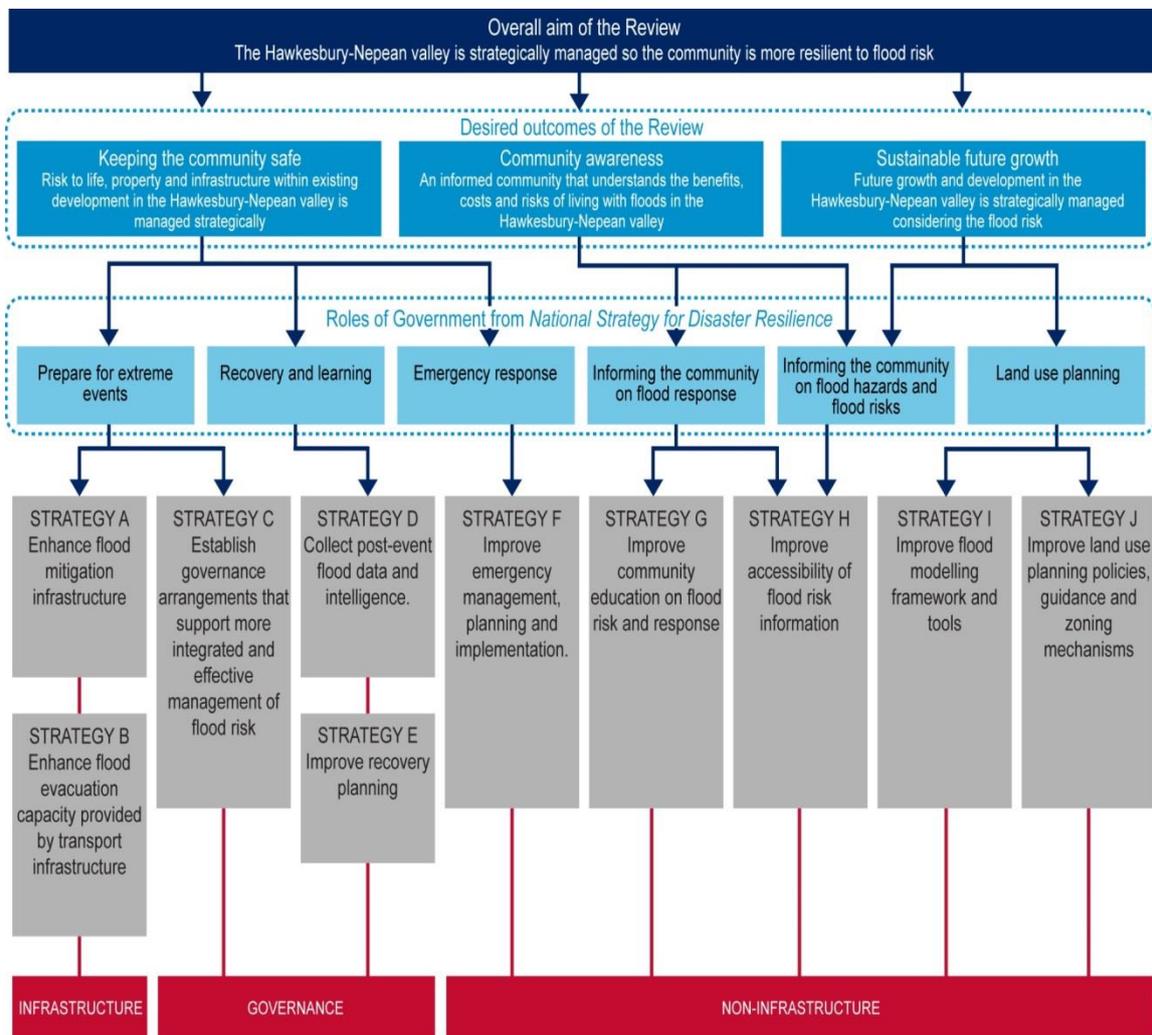
Table 2: Summary of proposed strategies and recommendations for the Hawkesbury-Nepean Valley Flood Management Review

Strategy	Issue	Recommendation
Infrastructure		
STRATEGY A Enhance flood mitigation infrastructure	Current infrastructure provides no protection from major flood events	Recommendation 1: Determine the appropriateness and the steps required to allow the reduction of full supply level by up to five metres and/or the implementation of alternative gate operation at Warragamba Dam for the mitigation of minor flood events in the short term.
		Recommendation 2: Optimise the configuration of a raised Warragamba Dam for flood mitigation for the full range of flood events and water supply, with due consideration of upstream impacts
STRATEGY B Enhance flood evacuation capacity of transport infrastructure	Current infrastructure provides no protection from major flood events	Recommendation 3: Develop and implement a program of cost-effective road improvement works that can enhance flood evacuation capacity in the short to medium term.
		Recommendation 4: Improve regional transport infrastructure to address current and projected flood evacuation capacity constraints and timelines
Governance		
STRATEGY C Establish governance arrangements that support more integrated and effective management of flood risk.	Current governance arrangements within the Hawkesbury-Nepean Valley do not support a regional approach that integrates land use, flood mitigation, infrastructure and flood evacuation planning and flood modelling	Recommendation 5: Establish a dedicated group or body within an existing agency to provide a more integrated, coordinated and regional approach to land use, infrastructure and evacuation planning and flood modelling in the Hawkesbury-Nepean Valley
	Current NSW state-wide governance arrangements for flood risk management do not support 'best practice' flood planning, prevention, preparedness and response	Recommendation 6: Review the NSW state-wide governance arrangements for flood risk management so that broader issues identified by this Review can be most effectively addressed
	Capacity of existing flood gauging network to provide flood warnings into the future is unclear	Recommendation 7: Ensure effective flood gauging arrangements in the Hawkesbury-Nepean Valley

Strategy	Issue	Recommendation
STRATEGY D Collection of post-event flood data and intelligence	No strategic governance framework or funding for collecting of post-event data and intelligence, as required to provide quantitative inputs to flood plan reviews	Recommendation 8: Clarify roles, responsibilities and consider funding options for post-event collection of data and flood intelligence.
STRATEGY E Improve recovery planning	Flood recovery strategies and arrangements may not reflect the impacts of major flood events in the Hawkesbury-Nepean Valley	Recommendation 9: Develop a Hawkesbury-Nepean Flood Recovery Plan, which identifies strategies and arrangement for recovery from severe floods in the Hawkesbury-Nepean Valley
	Planning and funding of infrastructure reconstruction following a major flood in the Hawkesbury-Nepean Valley	Recommendation 10: Review the adequacy of current arrangements for infrastructure reconstruction following a major flood event in the Hawkesbury-Nepean Valley
Non-infrastructure options		
STRATEGY F Improve emergency management, planning and implementation	Inadequate tools and information available to develop, test and improve evacuation planning for major flood events	Recommendation 11: Develop a comprehensive road evacuation network model for floods in the Hawkesbury-Nepean floodplain to inform evacuation capacity assessments and strategic transport planning, and to assist with the real-time operational management of evacuation during floods.
	Appropriate consideration of flood evacuation capacity in the planning of new road infrastructure in the Hawkesbury-Nepean Valley	Recommendation 12: Ensure future road infrastructure planning considers flood evacuation requirements throughout the Hawkesbury-Nepean floodplain.
	NSW State Emergency Service capacity to manage the flood threat.	Recommendation 13: Ensure the NSW State Emergency Service has the long-term capacity to plan and exercise for the full range of flood events in the Hawkesbury-Nepean Valley.
STRATEGY G Improve community education on flood risk and response	Low community awareness of flood risk and recommended response measures	Recommendation 14: Undertake, coordinate and evaluate community education programs on flood risk and response.
	Reported intention of a portion of the community not to respond to flood evacuation warnings	Recommendation 15: Monitor, investigate and address community response to flood warnings
STRATEGY H Improve accessibility of flood risk information	Poor access to flood risk information	Recommendation 16: Develop mechanisms and arrangements to promote and provide greater access to flood risk information
STRATEGY I Improve flood modelling framework and tools.	Planning of land use, urban development, infrastructure and flood evacuation is not supported by a comprehensive and integrated flood modelling framework	Recommendation 17: Develop and maintain a comprehensive flood model and flood modelling framework for the Hawkesbury-Nepean Valley

Strategy	Issue	Recommendation
STRATEGY J Improve consideration of flood risk in land use planning	Inadequate land use planning policy and guidance leads to inconsistent and ineffective planning practices on flood-prone land	Recommendation 18: Develop a NSW Planning Policy and Guideline to improve land use planning practices on flood-prone land
	Inadequate land use planning tools for managing flood-prone land	Recommendation 19: Provide improved land use planning tools for managing flood-prone land
	Inadequate detailed consideration of flood risk and evacuation capacity in regional and subregional plans	Recommendation 20: Ensure appropriate consideration of flood risk in metropolitan, regional and subregional planning

Figure 10: Structure of Review findings including links between proposed strategies and overall aim and desired outcomes



Source: (NSW Office of Water, 2014a)

Conclusions of the Review and formation of Hawkesbury-Nepean Valley Flood Management Taskforce

Overall, the Hawkesbury-Nepean Valley Flood Management Review found that:

- there is no simple solution or single infrastructure option to deal with the complexity of the flood issues in the valley — the risk of flooding in the Valley cannot be eliminated
- infrastructure options, such as raising Warragamba Dam can reduce, but not eliminate, the risk of flooding in the valley
- evacuation during flood events is critical issue for the Hawkesbury-Nepean Valley — evacuation by road is the most effective measure to reduce the risk to life from flooding
- it is possible to reduce and manage the risk to life and property through a combination of flood prevention, preparedness, response and recovery.

The outcomes, strategies and conclusions from the Hawkesbury-Nepean Valley Flood Management Review were presented to the NSW Government in March 2014. This included the identification of a suite of more detailed investigations and cost benefit analyses to be addressed in the subsequent stage of the Review, as follows:

- focus on community awareness and emergency preparedness:
 - review of the Hawkesbury-Nepean Flood Emergency Sub Plan and other relevant emergency plans to ensure they include the most up-to-date information and data (from *Strategy F*)
 - enhance community education programs and further investigate community attitudes and responses to flood risk (from *Strategy G*)
 - develop an effective evacuation modelling tool to enable completion of an integrated traffic evacuation plan for the floodplain (from *Strategy B*)
 - identify any minor road and intersection improvements that could assist in flood evacuation in the short term (from *Strategy B*)
 - review key local and state government planning instruments and guidance to minimise the risks associated with ongoing infill and greenfield development (from *Strategy J*)
 - investigate alternative gate operation procedures and reduction of the full supply level by up to five metres for Warragamba Dam. This could help reduce the frequency and impact of small floods. Water supply impacts would need to be fully considered (from *Strategy A*).
- focus on detailed assessment of infrastructure flood mitigation options including estimated costs, economic impacts, social impacts and time frames:
 - identify major regional road and intersection improvements that would assist with evacuation and undertaking cost benefit analysis of the selected options (from *Strategy B*)

- revise the regional emergency management plan to include consideration of the implications of the scenario of more widespread flooding in the Greater Sydney region (from *Strategy F*)
- commence development of a state-wide planning policy addressing floods and other natural hazards (from *Strategy J*)
- develop a flood recovery plan which includes consideration of reconstruction of essential infrastructure following a major flood (from *Strategy E*)
- undertake a detailed cost benefit analysis of optimising Warragamba Dam for flood mitigation and water supply through changes to operational arrangements and/or raising of the dam wall, including consideration of upstream and downstream impacts (from *Strategy A*)
- seek an agreed approach and consistent use of flood modelling and monitoring data for the region (from *Strategy H and I*)
- develop governance reforms to create an enduring and effective whole of government response to flood risks (from *Strategies C and D*).

To progress this next stage of the Review through the undertaking of the above suite of actions, the NSW Government established a dedicated Taskforce, headed by an independent Chairperson in April 2014. The multi-agency Hawkesbury-Nepean Valley Flood Management Taskforce is currently undertaking the second phase of the Review, with a report to the NSW Government due later 2015.

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