Hawkesbury City Council

attachment 5
to
item 2

Infrastructure NSW - Resilient Valley
Resilient Valley Communities Strategy
2017

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Resilient Valley, Resilient Communities

Hawkesbury-Nepean Valley
Flood Risk Management Strategy
January 2017

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For enquiries please contact info@insw.com.au

Executive summary

Resilient Valley, Resilient Communities – the Hawkesbury-Nepean Valley Flood Risk Management Strategy (the Flood Strategy) is a comprehensive long-term framework for the NSW Government, local councils, businesses and the community to work together to reduce and manage the flood risk in the Hawkesbury-Nepean Valley.

This Flood Strategy addresses flooding from the Hawkesbury-Nepean River between Bents Basin, near Wallacia, and the Brooklyn Bridge. This area – referred to as the Hawkesbury-Nepean Valley (the Valley) – covers 425 square kilometres of floodplain and falls mainly within four fast-growing Local Government Areas in Western Sydney: Penrith City, Hawkesbury City, The Hills Shire and Blacktown City. It includes the population centres of Penrith, Richmond and Windsor and many surrounding suburbs.

The Valley has a high flood hazard, with both historical and geological evidence of widespread flooding across the Valley. Climate change may further increase the severity and frequency of the flood hazard in the future.

There is also a high level of flood exposure as the floodplain is located in an area with a large and growing population, and one of Australia's most significant and diverse economies. Expanding urban development across the Valley means that flood exposure will increase in the future. Up to 134,000 people live and work on the floodplain and could require evacuation. This number is forecast to double over the next 30 years. Over 25,000 residential properties and two million square metres of commercial space are currently subject to flood risk, and this will increase significantly in the coming years.

Strategy objectives and vision

The objective of the Flood Strategy is to reduce flood risk to life, property and social amenity from regional floods in the Hawkesbury-Nepean Valley now and in the future.

The Flood Strategy's vision is for Hawkesbury-Nepean Valley communities and all levels of government to adapt to flooding by working together to:

- **understand** and be **fully aware** of flood risk
- **act** to reduce flood risk and manage growth
- be **ready** to respond and recover from flooding.

The flood risk is heightened by a number of factors:

- insufficient road capacity to safely evacuate the whole population in a timely fashion
- a fragmented approach to managing flood risk
- low community awareness about the flood risk.

The Insurance Council of Australia considers this Valley to have the highest single flood exposure in New South Wales, if not Australia.

The Hawkesbury-Nepean Valley Flood Management Taskforce (the Taskforce), an independently chaired inter-agency group, investigated feasible infrastructure and non-infrastructure options to reduce overall flood risk in the Valley. This was based on previous work completed in response to the *State Infrastructure Strategy 2012-2032* by the 2013 Hawkesbury-Nepean Valley Flood Management Review.

The Flood Strategy is the result of the Taskforce's investigation and was adopted by the NSW Government in June 2016.

The Taskforce found that raising the Warragamba Dam wall by around 14 metres is the infrastructure option with the highest benefit. This would reduce flood risk by creating airspace in the dam to temporarily hold back and slowly release flood waters coming from the Warragamba River catchment.

Raising the Warragamba Dam wall would reduce flood damages by 75% on average. It would reduce the flood damages for a 1 in 500 chance per year flood[1] for current levels of urban development from $5 billion to $2 billion. In 2041, it would reduce flood damages for a 1 in 500 chance per year flood from $7 billion to $2 billion.

While raising the Warragamba Dam wall will make a significant difference to flood risk in the Valley, no combination of infrastructure options can eliminate the risk. Regardless of any infrastructure option, non-infrastructure options must be part of the solution for managing ongoing flood risk.

Notes

1. Flood size is described in terms of the chance of that flood occurring in any one year, see Flood Size box page 11.

The Flood Strategy includes a range of targeted actions designed to deliver nine outcomes:

Outcome 1: Coordinated flood risk management across the Valley now and in the future – including a new Hawkesbury-Nepean Valley Flood Risk Management Directorate, based initially within Infrastructure NSW, to oversee implementation of the Flood Strategy

Outcome 2: Reduce flood risk in the Valley by raising Warragamba Dam wall – raising the dam wall by around 14 metres, subject to completion of an Environmental Impact Statement (including community consultation) and a full business case

Outcome 3: Strategic and integrated land use and road planning – including preparation of a Regional Evacuation Road Master Plan and a Regional Land Use Planning Framework to better manage flood risk in the Valley

Outcome 4: Accessible contemporary flood risk information – improving mapping of flood risk and making this information widely available

Outcome 5: An aware, prepared and responsive community – including a coordinated focus on raising community understanding of flood risk and flood evacuation routes

Outcome 6: Improved weather and flood predictions – updating the Bureau of Meteorology's Hawkesbury-Nepean weather prediction and flood forecasting model

Outcome 7: Best practice emergency response and recovery – providing for periodic reviews and updates of emergency and recovery plans maintained by the NSW State Emergency Service and the NSW Office for Emergency Management

Outcome 8: Adequate local roads for evacuation – undertaking around 40 high priority local evacuation road upgrades, subject to business cases

Outcome 9: Ongoing monitoring, evaluation, reporting and improvement of the Flood Strategy – establishing a monitoring, evaluation, reporting and improvement framework.

Short-term milestones for the implementation of the Flood Strategy include:

- **2017** Community engagement activities commence
- **2017** Evacuation route signage installed
- **2018** Improved weather predictions and flood forecasting
- **2018** Local road upgrades construction
- **2019** Regional land use and road planning framework implemented
- **2020** Full business case decision for raising Warragamba Dam wall

Contents

1 Background

The Hawkesbury–Nepean Valley

The Flood Strategy addresses flooding from the Hawkesbury-Nepean River between Bents Basin, near Wallacia, to the Brooklyn Bridge. This is the area referred to in the Flood Strategy as the Hawkesbury-Nepean Valley (the Valley).

The Valley covers 425 square kilometres of floodplain (Figure 1). The extent of the floodplain is based on the largest possible flood event (probable maximum flood or PMF). The key areas of the Valley floodplain are at Wallacia, around Penrith, Richmond-Windsor and small pockets downstream of Sackville.
The Valley floodplain also includes the backwater effects (the river backing up) of flooding from the Hawkesbury-Nepean River, such as South Creek and Eastern Creek. The Flood Strategy does not address localised tributary flooding that occurs independently of flooding in the Hawkesbury-Nepean River.

The Valley floodplain falls mainly within four Local Government Areas – Penrith City, Hawkesbury City, The Hills Shire, and Blacktown City – and includes the key population centres of Penrith, Richmond and Windsor, and many surrounding suburbs.

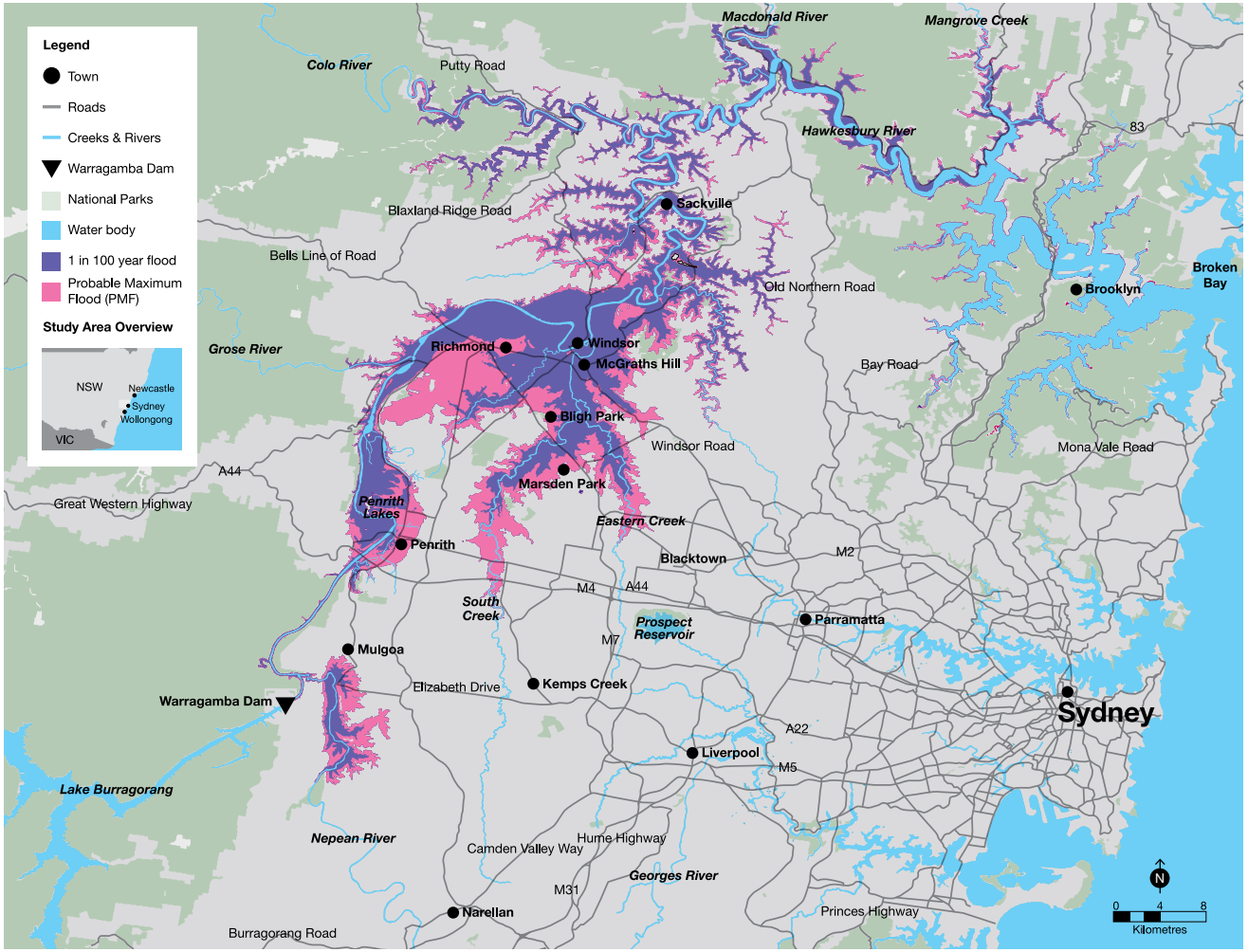

Figure 1 The Hawkesbury-Nepean Valley Floodplain
Base data courtesy of NSW State Emergency Service

The Flood Strategy is a comprehensive long-term framework for the NSW Government, local councils, businesses and the community to work together to reduce and manage the flood risk in the Hawkesbury-Nepean Valley.

The Flood Strategy has been developed by the Hawkesbury-Nepean Valley Flood Management Taskforce in response to the *State Infrastructure Strategy 2012–2032* and the 2013 Hawkesbury-Nepean Valley Flood Management Review.

State Infrastructure Strategy 2012–2032

The *2012 State Infrastructure Strategy 2012–2032* highlighted that improved flood mitigation infrastructure is critical to protecting people, buildings, public assets and the NSW economy. Infrastructure NSW commissioned a study to update data on flood impacts in the Valley. It found that a major flood event would cause billions of dollars of damage and place tens of thousands of homes and people at risk. The impact would extend beyond the Valley and be felt across the NSW and Australian economies.

Infrastructure NSW recommended that the NSW Government review all major flood mitigation options available to significantly reduce the potential economic and social impact of flooding in the Valley.

The NSW Government accepted this recommendation and commenced the Hawkesbury-Nepean Valley Flood Management Review in early 2013.

Hawkesbury-Nepean Valley Flood Management Review

The 2013 Review explored all plausible flood mitigation options and measures with the potential to reduce flood risk to life and property in the Valley, including governance arrangements, policy settings, planning tools, community education, and infrastructure.[2]

The 2013 Review found that there is no simple solution or single infrastructure option that could address all of the flood risk in the Valley. This risk would continue to increase with projected population growth unless an integrated strategy incorporating both flood mitigation infrastructure, non-infrastructure and policy options was adopted.

Recommendations for more detailed investigation of 10 infrastructure and non-infrastructure initiatives to reduce overall flood risk in the Valley were referred to the Hawkesbury-Nepean Valley Flood Management Taskforce, for a detailed cost benefit analysis of the preferred options.

Hawkesbury-Nepean Valley Flood Management Taskforce

The NSW Government established the Hawkesbury-Nepean Valley Flood Management Taskforce (the Taskforce) in early 2014 to advance the work carried out by Infrastructure NSW and the 2013 Review. This Flood Strategy is the result of the Taskforce's comprehensive assessment of flood mitigation options and was adopted by the NSW Government in June 2016.

The Taskforce was independently chaired by Mark Bethwaite AM and included senior representatives from:

- Infrastructure NSW
- Department of Premier & Cabinet
- Department of Primary Industries (Water)
- WaterNSW (previously Sydney Catchment Authority)
- NSW State Emergency Service
- Office of Emergency Management
- Department of Planning and Environment
- Office of Environment and Heritage
- NSW Treasury
- NSW Public Works Advisory (part of Department of Finance, Services and Innovation)
- Roads and Maritime Services.

A Stakeholder Reference Panel was established to enable collaboration with local councils on the Penrith and Richmond-Windsor floodplains (Penrith City Council, Hawkesbury City Council, The Hills Shire Council and Blacktown City Council), Western Sydney Regional Organisation of Councils (WSROC), Sydney Water Corporation, Floodplain Management Australia and the Insurance Council of Australia.

The Taskforce developed a methodology to select the best mix of infrastructure and non-infrastructure measures to reduce flood risk in the Valley for inclusion in the Flood Strategy. This approach is outlined in the following box.

The results of the Taskforce's investigation of current and future conditions and flood risk are provided in section 2. The shortlisting, evaluation and selection of options are described in section 3.

The Flood Strategy is aligned with the 2011 National Strategy for Disaster Resilience and the broader emergency management framework set out in the *State Emergency and Rescue Management Act 1989*. These aspects of the Taskforce's work are presented in section 4.

Notes

2. Further information on the 2013 Review Reports is available at <http://www.water.nsw.gov.au/water-management/water-availability/flood-management/hawkesbury-nepean-valley-flood-management-review>.

The Taskforce's approach

The Taskforce developed the following methodology to select the best mix of infrastructure and non-infrastructure measures to reduce flood risk for inclusion in the Flood Strategy:

1. **Establishing the different levels of urban development (population) that could occur in the Valley by 2041**
2. **Assessing current and future flood risk in terms of flood damages and risk to life, including consideration of climate change**
3. **Further investigating infrastructure options identified in the 2013 Review to create a shortlist for final evaluation**
4. **Evaluating infrastructure options for the development of the Flood Strategy.**

1. Establishing levels of urban development to 2041

An urban forecasting methodology and spatial database of current forecast urban development were developed for the Valley. These were based on information from the NSW Department of Planning and Environment, Bureau of Transport Statistics (BTS, part of Transport for NSW), local councils, NSW Land and Property Information and the Australian Bureau of Statistics. They provided the information for assessing flood risk to life and damage.

The Taskforce assumed that the identified potential urban development would largely occur by 2041. This 25 year time horizon was considered reasonable for strategic planning and as a baseline to assess the impact of different measures to reduce flood risk.

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Urban development was divided into four categories:

- Residential dwellings, population and vehicles – this included existing development and future development including large urban release areas and urban renewal
- Employment lands – this included commercial and industrial buildings, businesses, employees and vehicles
- Utilities, infrastructure and other public assets – this included schools, hospitals, water and sewerage infrastructure
- Road infrastructure.

2. Assessing current and future flood risk

Current and future flood risk was assessed in the following ways.

Understanding community resilience – Social research and community network analysis were conducted to better understand current levels of community awareness of and resilience to flood risk in the Valley. Community attitudes were measured through surveys and interviews designed to assess the levels of preparedness for and attitudes to flood risk.

Understanding flood behaviour – A new flood model was developed for the Valley by WMAwater Pty Ltd. This was based on the latest techniques from Australian Rainfall and Runoff, the national guideline for estimating flood characteristics in Australia. The computer-based flood model was used to assess the impact of various flood mitigation infrastructure options on flood likelihood and behaviour in the Valley. Results of the modelling were also inputs to the evacuation modelling and flood damages assessment.

Given the variability of floods in the Valley, the flood model employed a technique that considered more than 20,000 possible flood scenarios. This allowed for the fact that floods that reach the same level can have different durations, for the various speeds with which floodwaters rise and for different volumes from contributing river or creeks.

Estimating risk to life: evacuation modelling – A flood evacuation model was specifically developed for the Taskforce by Data61 (CSIRO) to estimate the extent of potential danger to personal safety or risk to life. It was also used to assess the impact of flood mitigation infrastructure options on risk to life.

The evacuation model assumed that all of the evacuating population (residents and workers) would comply with the order to evacuate and follow the orders of NSW State Emergency Service. The risk to life model also reflected the evacuation plan for the Valley in the NSW State Emergency Service Hawkesbury Nepean Emergency Sub Plan.

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The model assumed that the Bureau of Meteorology was able to predict flood levels up to 15 hours ahead based on forecast rainfall. It modelled evacuations for 46 representative flood events with between a 1 in 50 and 1 in 5,000 chance per year of occurring (see *Flood Size* box in section 2). Approximately 12,000 model runs were generated based on various combinations of flood mitigation infrastructure and evacuation road upgrades for different levels of urban development.

The number of vehicles unable to evacuate in floods was used to estimate the risk to life (danger to personal safety) as it was assumed that the extent of loss of life and injury would be directly linked to the number of vehicles unable to evacuate.

Estimating economic impacts: flood damages assessment – A flood damages assessment methodology was developed with the Centre for International Economics (CIE) to quantify the benefits of implementing the infrastructure measures in avoided economic damages compared to no options being implemented.

Flood damages were calculated on an annual average basis to enable comparison between the options. The assessment of the change in projected annual average economic damages from floods was based on direct and indirect damage to residential, commercial, utility and infrastructure assets in the Valley as well as the cost from loss of life, injury and reduced social amenity.

3. Further investigation of infrastructure options identified in the 2013 Review to create a shortlist for final evaluation

The Taskforce undertook a preliminary assessment of all feasible infrastructure options identified in the 2013 Review. Following this assessment, a shortlist of options was taken forward for further investigation and cost benefit analysis (see section 3).

4. Evaluation of options for the development of the Flood Strategy

The Taskforce's final detailed evaluation of the shortlisted infrastructure options was informed by:

- A cost benefit analysis (CBA), which included an economic assessment of flood mitigation benefits and quantification of the costs of each infrastructure option
- An environmental, cultural and social impact assessment.

Details of the methodology adopted in relation to the CBA and impact assessment are provided in the *Evaluation methodologies* box in section 3.

Non-infrastructure measures considered by the Taskforce for inclusion in the Flood Strategy were based on recommendations of the 2013 Review and the identified roles for government in disaster resilience recommended in the 2011 National Strategy for Disaster Resilience.

2 The Risk

The Hawkesbury-Nepean Valley – highest flood risk in NSW

The highest flood risk in NSW

Floods are a natural part of the Australian landscape, and Australian floodplains are valued for their biodiversity and agricultural productivity.

Flood risk, that is the risk to human life and property, occurs when development within floodplains is exposed to flood hazard. Flood risk is a result of the extent of the flood hazard and the level of exposure to that hazard.

Figure 2 **Elements of flood risk**

The Hawkesbury-Nepean Valley has a high flood hazard, with both historical and geological evidence of rapid widespread flooding across the Valley.

There is also a high level of flood exposure as the floodplain is located in the Western Sydney region, an area with a large and growing population. It is one of Australia's most significant and diverse economies, with an annual gross regional product of about $104 billion in 2013/14.[3]

Expanding urban development across the Valley means that flood exposure will increase in the future. Climate change may further increase this flood risk as it has the potential to increase the severity and frequency of the flood hazard in the Valley.

The Insurance Council of Australia considers this Valley to have the highest single flood exposure in New South Wales, if not Australia.

Flood size

Flood size is described in terms of the chance of that flood occurring in any one year.

Small floods occur more regularly and generally have lower economic and social impacts, compared to less common larger floods that often have higher impacts.

Floods occur randomly, so one flood event does not change the chance of a subsequent flood occurring.

A 1 in 100 chance per year flood could occur several years in a row, or it could be more than 100 years before a flood of that size occurs again. For example, the flood that occurred in Brisbane in 2011 was about a 1 in 100 year event. A person living in the Valley to 70 years of age has a 50% chance of experiencing this size flood during their lifetime, and a 10% chance of experiencing it twice.

The largest flood that could occur is called the probable maximum flood (PMF). Being the largest possible flood, it has the lowest probability of all possible floods. This flood defines the extent of the floodplain.

A high flood hazard

A history of flooding

The Hawkesbury-Nepean Valley has a long history of flooding. The largest flood on record in the Valley occurred in 1867 when the river level reached 19.7 metres above mean sea level at Windsor (considered to be equivalent to about a 1 in 500 year flood). Analysis of sediments within the Nepean Gorge shows that prior to European settlement, at least one flood reached or exceeded the level of a flood with about a 1 in 1000 chance per year. Such a flood would reach around 20 metres above mean sea level at Windsor.[4]

If these floods happened today (2016)

In a flood similar to the Brisbane 2011 floods (1 in 100 chance per year):

5,000
residential properties impacted

$2 bn
in damages

64,000
people need to evacuate

In a flood similar to the largest flood in European history (1867 flood):

12,000
residential properties impacted

$5 bn
in damages

90,000
people need to evacuate

Or by 2041

By 2041, impacts of an 1867-like flood are estimated to increase dramatically, even under conservative assumptions

$7 billion
in damages

158,000–171,000
people need to evacuate

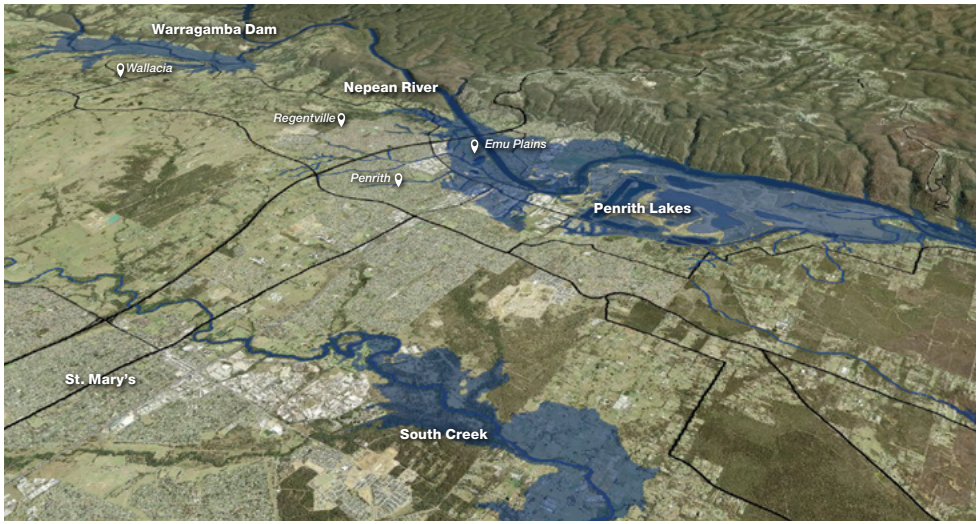

Image 1 Impact of a 1 in 500 chance per year flood at Penrith (similar in size to the largest flood on record – the 1867 flood).

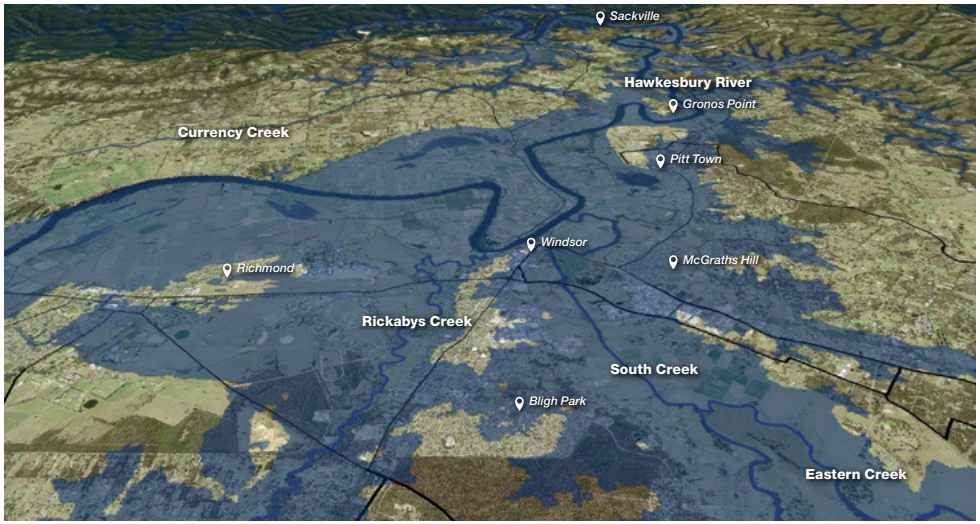

Image 2 Impact of a 1 in 500 chance per year flood at Windsor (similar in size to the largest flood on record – the 1867 flood).

Image 3 The corner of Macquarie Street and Windsor Road, Windsor today (2014) and the extent of flooding in 1961 (between a 1 in 20 to 1 in 50 chance per year flood).

Source (L): Barry Gibbons Collection, Courtesy of Hawkesbury Regional Museum

Source (R): Hawkesbury Camera Club, Courtesy of Hawkesbury Regional Museum

Image 4 George Street, Windsor today (2014) and during the 1961 flood (between a 1 in 20 to 1 in 50 chance per year flood).

Source (L): Barry Gibbons Collection, Courtesy of Hawkesbury Regional Museum

Source (R): Hawkesbury Camera Club, Courtesy of Hawkesbury Regional Museum

The Valley's 'bathtub' effect

The combination of large upstream catchments and narrow downstream sandstone gorges results in floodwaters backing up behind natural choke points in the Valley.

The Valley has been described as a bathtub, with five main taps (being the main tributaries) but only one plug hole, Sackville Gorge (Figure 3). As a result, floodwaters back up and rise rapidly, causing significant flooding both in terms of areas and depth. This bathtub effect is unusual as most river valleys tend to widen as they approach their mouths, which is not the case in the Valley.

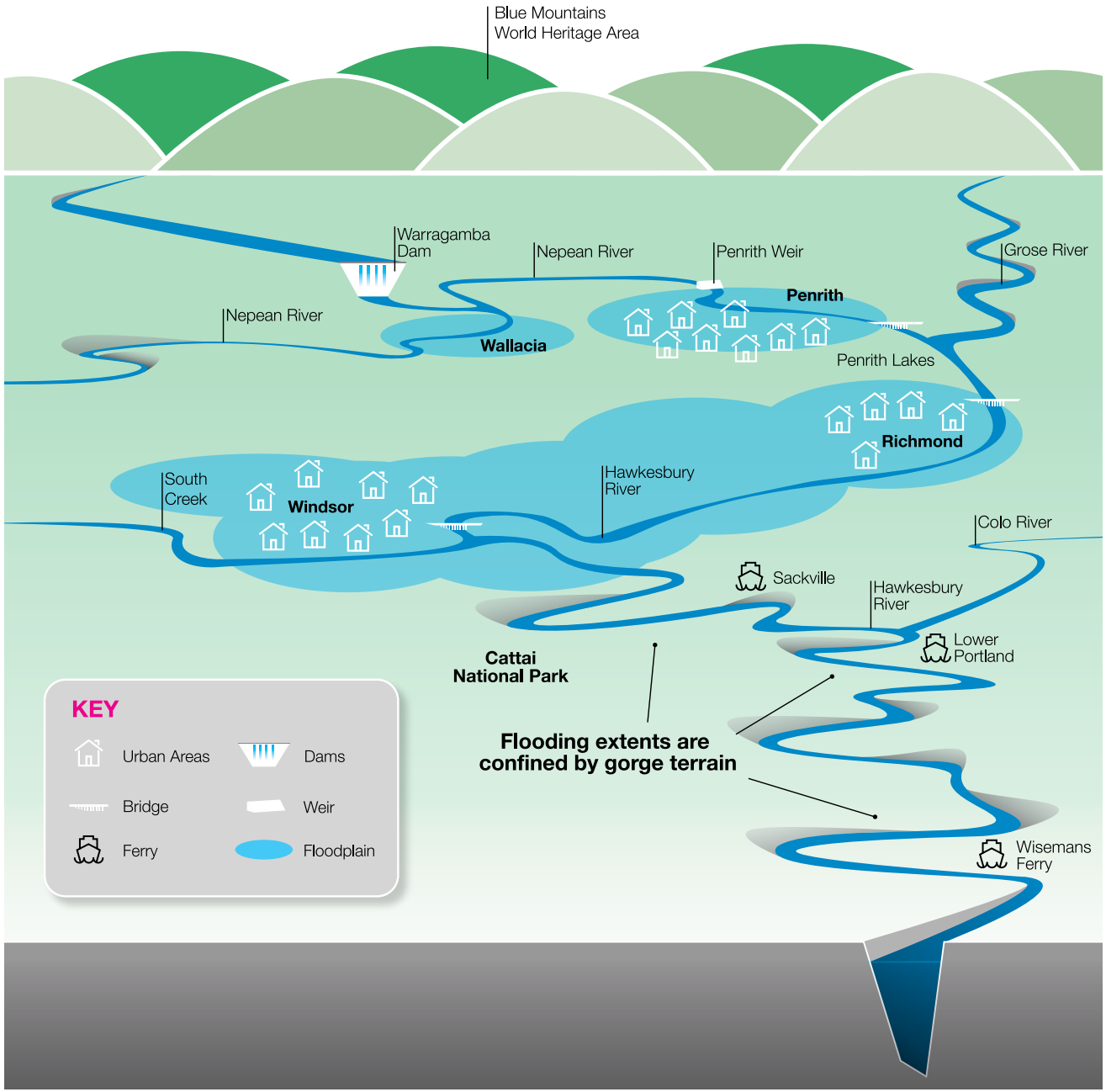

Figure 3 The 'bathtub' effect in the Hawkesbury-Nepean Valley

The floodwaters flowing into the Valley come from several different river catchments. The largest of these, representing 80% of the catchment at Penrith, is the Warragamba River catchment: the area that drains into Warragamba Dam (Figure 3). Warragamba Dam is located about 65 kilometres west of Sydney in a narrow gorge on the lower section of the Warragamba River, 3.3 kilometres before it joins the Nepean River. The Nepean River then becomes the Hawkesbury River at the junction of the Grose River at Yarramundi. This entire river is referred to as the Hawkesbury-Nepean River.

Further inflows can come from the Nepean River, the Grose River, South Creek and others. While floods can occur without contribution from the Warragamba catchment, most significant floods (above the 1 in 100 chance per year flood) will include significant floodwater inflows from the Warragamba River catchment. However, each flood event is unique due to the timing of rainfall across the Valley catchment. Figure 4 shows how the contributions from various river catchments have varied for previous floods in the Valley.

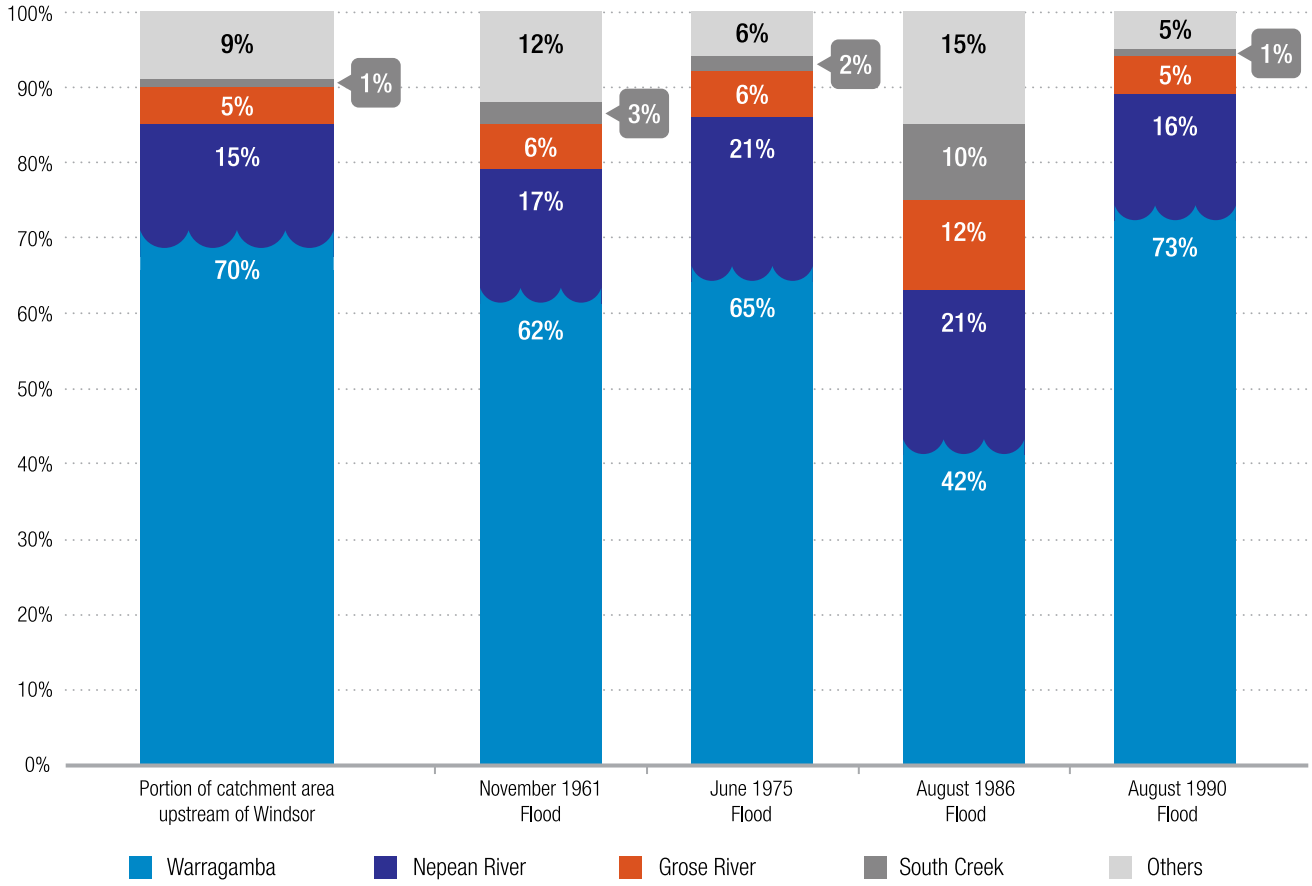

Figure 4 Relative contribution of different river catchments in previous floods in the Hawkesbury-Nepean Valley

As a result of its ‘bathtub’ topography, floodwaters in the Valley can be much deeper than on most other floodplains in NSW and Australia. Figure 5 shows the differences in flood levels and flood risk between the Hawkesbury River at Windsor and two other floodplains in NSW. On floodplains such as those in Lismore (on the NSW north coast) and Nyngan (in inland NSW), the difference between a 1 in 100 chance per year flood and the probable maximum flood is about two to three metres. At Windsor, this difference is about nine metres.

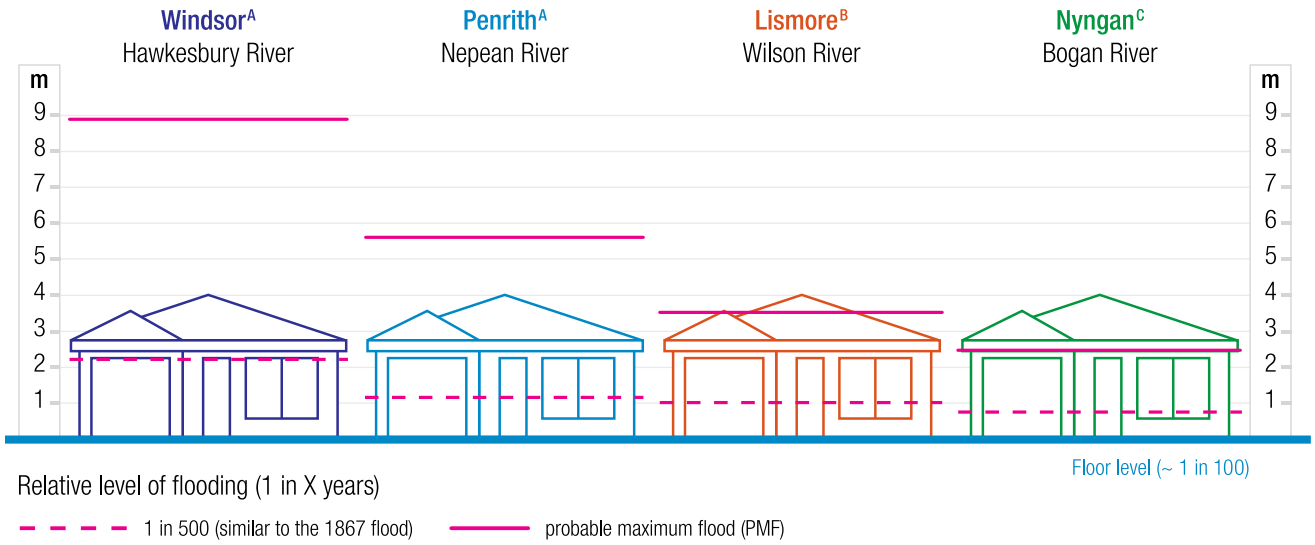

Figure 5 Comparison of the differences in flood levels and flood risk between the Hawkesbury-Nepean River at Windsor and other floodplains

Source: adapted from ERM Mitchell McCotter Pty Ltd (1995). Proposed Warragamba Flood Mitigation Dam – Environmental Impact Statement (Volumes 1, 2 & 3).
A. Hawkesbury-Nepean Flood Study – Stage 3. Final Report (WMAwater Pty Ltd, March 2016)
B. Lismore Floodplain Risk Management Plan – Glossary and Appendices (Lismore City Council, 2014)
C. Nyngan April 1990 Flood Investigation. (NSW Department of Water Resources, 1990)

Climate change may increase the Valley's flood hazard

The Valley's high flood hazard may increase in the future as a result of climate change. Climate change has the potential to alter the frequency and severity of rainfall extremes, change rainfall patterns and increase the likelihood of flooding in the Valley.

In 2016, the Australian Government updated Australian Rainfall and Runoff (AR&R)[5] – the national guideline for estimating flood characteristics in Australia. AR&R indicates that there is likely to be increased rainfall intensity with an associated increase in flooding in Australia generally and in the Valley as a result of climate change.[6] For example, a 2°C increase in temperature would result in a 10% increase in rainfall intensity.[7]

In coastal NSW, including the Valley, flash flooding, river flooding, hail, wind and coastal erosion due to very rough seas, are often associated with low-pressure systems off the Australian east coast. These weather systems are referred to as East Coast Lows (ECLs) and occur on average 10 times each year. Floods in the Valley are usually associated with ECLs, as are most floods in coastal south-eastern Australia.[8]

The Eastern Seaboard Climate Change Initiative – East Coast Lows (ESCCI-ECL) program is a research cooperative led by the NSW Office of Environment and Heritage that provides information on future possible changes in the frequency and intensity of ECLs as a result of climate change. It has found that while there may be a decrease in the number of small to moderate ECLs in the cool season with little change in these storms during the warm season, extreme ECLs in the warmer months may increase in number, further increasing the flood risk.[9]

Patterns of the El Niño–Southern Oscillation (ENSO) cycle and other climatic influences may also be affected by climate change, leading to increased flooding. Although large uncertainties exist about the future pattern, El Niño years experienced in NSW are likely to continue to result in lower than average rainfall and become hotter.[10] By comparison, La Niña years are expected to continue to result in higher than average rainfall and become warmer, with storms producing heavy downpours likely to become more frequent, with flooding increasing during these years.[11]

A high flood risk

A large and growing urban population

Although large flood events are infrequent, they have high economic and social consequences that will increase with population growth, residential and commercial development.

The Hawkesbury-Nepean Valley is changing from a semi-rural landscape to an urbanised floodplain, and includes parts of Greater Sydney's rapidly growing North West Growth sector. Up to 134,000 people live and work on the floodplain and could require evacuation. This number is forecast to double over the next 30 years.

Over 25,000 residential properties and two million square metres of commercial space are currently subject to flood risk, and this will significantly increase in the coming years.

Limited application of land use planning controls

The NSW Floodplain Development Manual[12] defines a floodplain as including all sized floods up to the largest possible flood (probable maximum flood or PMF). However, the 'Guideline for Residential Development on Low Flood Risk Land' (an addendum to the NSW Floodplain Development Manual issued in 2007 and given effect under the *Environment and Planning Assessment Act 1979*) recommends the application of flood related controls for residential development to land roughly at or below the 1 in 100 chance per year flood level.

The application of the guideline has resulted in a focus on the 1 in 100 chance per year flood for land use planning, rather than a risk based approach that considers the full range of flood sizes. Given the large flood depths between the 1 in 100 chance per year flood and the probable maximum flood in the Valley, the focus on the area below the 1 in 100 chance per year flood level does not adequately address flood risk (Figure 6). This increases the scale of emergency evacuations and does not provide for flood compatible buildings for all levels of risk.

The guideline includes a provision for local councils to apply to the NSW Government for 'exceptional circumstances' to apply controls above the 1 in 100 chance per year flood level. No councils in the Valley have applied despite the exceptional flood risk.

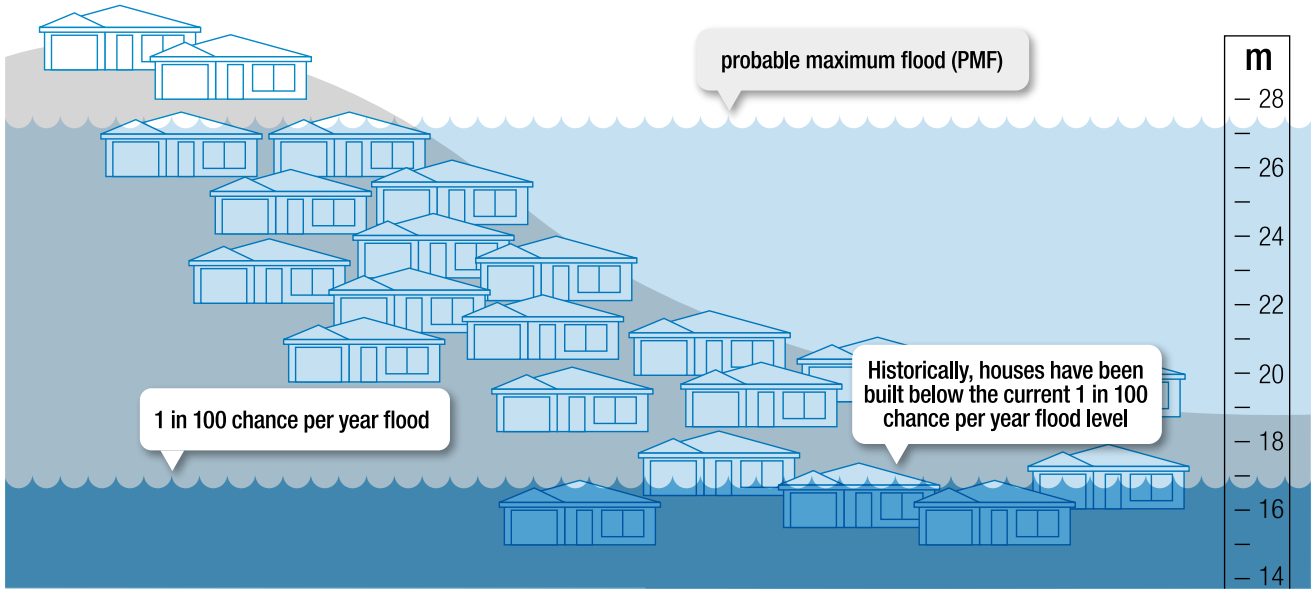

Figure 6 Current urban development in the Richmond-Windsor has different levels of flood risk within the floodplain, with development located from below the 1 in 100 chance per year flood level to above the level of the probable maximum flood

Evacuation constraints and complexity

Evacuating people away from flood affected areas is the primary method of reducing the risk to life during a flood. In the Valley, the NSW State Emergency Service identifies mass self-evacuation by private motor vehicles as the primary method for evacuation, as other transport options are highly vulnerable to floods or have limited capacity. The major regional evacuation road routes are shown in Figure 7.

Legend

- Castlereagh Road route
- Great Western Highway
- Hawkesbury Valley Way
- Llandilo Road route
- Londonderry Road route
- M4 Motorway
- Old Northern Road route
- Park Road route
- Pitt Town route
- Richmond Road route
- The Northern Road route
- Wallacia alternate route
- Windsor Road route
- Westlink M7

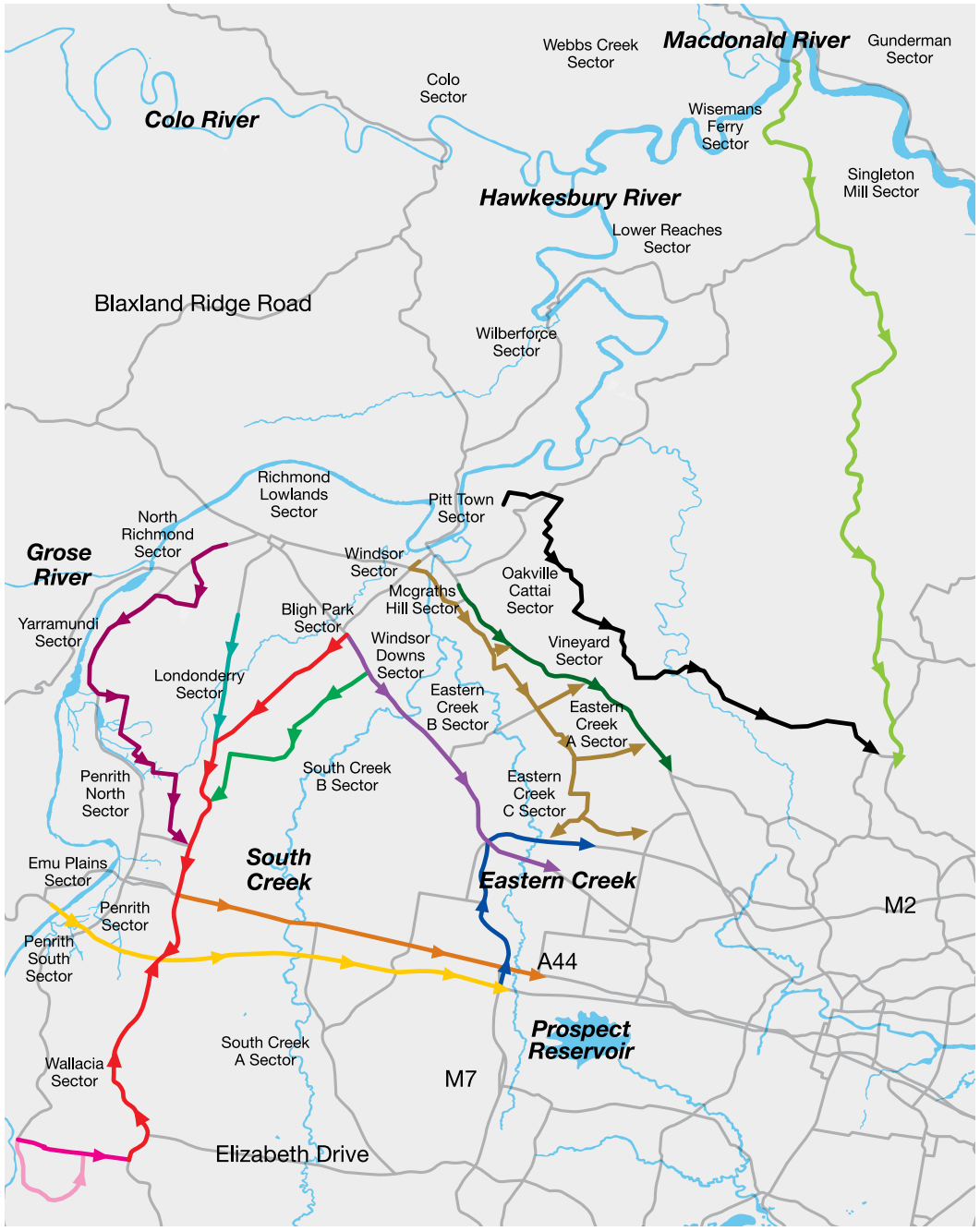

Figure 7 Major regional evacuation road routes out of the Valley

Currently, there is not enough road capacity to safely evacuate the whole population on time, with multiple communities relying on common, constrained and congested road links as their means of evacuation.

The undulating topography of the Valley results in many key evacuation routes becoming flooded at low points long before population centres are inundated, creating flood islands. Many of the significant urban centres such as McGraths Hill, Windsor, Richmond and Bligh Park are located on flood islands which can become fully submerged in large flood events (Figure 8).

Reliable and timely flood forecasts and warnings are critical for evacuation. Currently the Bureau of Meteorology has advised that it can provide up to 15-hour flood level predictions for large flood events. However, the NSW State Emergency Service requires more than 15 hours to evacuate some flood islands in the Valley during large flood events. This could force the NSW State Emergency Service to make evacuation orders based on uncertain flood prediction. If the flood exceeds the prediction, lives could be at risk. Alternatively, if the flood does not reach the predicted level, large numbers of people could be evacuated unnecessarily, which could mean people may be reluctant to follow future evacuation orders.

If a 1 in 100 chance per year flood occurred today, more than 64,000 people would need to evacuate. This could rise to 90,000 people for a 1 in 500 chance per year flood.

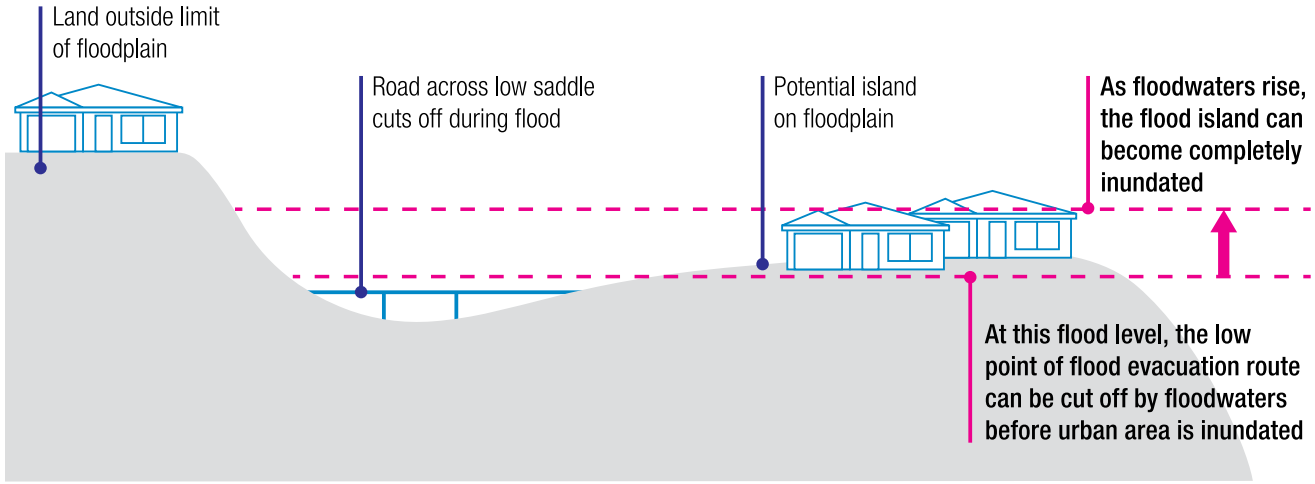

Figure 8 How a flood island can be isolated then fully submerged

Fragmented approach to managing flood risk

The current responsibilities for flood risk management in NSW do not adequately support a regional integrated approach to land use, road and emergency planning.

In NSW, individual local councils have primary responsibility for managing flood prone land. State government responsibilities include strategic land use, regional roads and emergency planning. The Australian Government is responsible for weather predictions and flood forecasting.

The Valley's flood risk problem extends beyond local council boundaries and requires a regional strategic approach.

Integrating these responsibilities is essential for managing the cumulative regional impacts of urban development on flood risk across the Valley.

Low community flood awareness

Many Valley residents have no experience of a past flood in the region. Australian Bureau of Statistics data indicates that 27% of the community was not living in the Valley five years prior to the 2011 census, and almost 1 in 10 were not living in the area 12 months prior.

This influx of new residents, the lack of significant flood events during the prolonged drought up to 2012, and the fact that the floodwaters may reach areas far from the Hawkesbury-Nepean River, may help explain why current levels of flood risk awareness in the Valley are low. Social research conducted by the Taskforce found that only a third of Valley residents consider flood to be a risk.

Local councils are primarily responsible for providing property-based flood information to residents. Local councils provide information on flood development controls. As local councils are only required to apply flood controls below the 1 in 100 chance per year flood levels there is a perception in the community that there is no flood risk above the 1 in 100 chance per year flood level. However, as described earlier, there is significant flood risk above this level in this Valley (Figure 6).

The NSW State Emergency Service is responsible for providing flood preparedness and response information.

Social research has shown that there are low levels of community awareness and acceptance of flood risk. This can:

- increase the risk to life during floods as people may delay or refuse to evacuate, drive through floodwaters or sightsee in flooded areas
- increase property damage by members of the community:
  - not building with flood-compatible materials
  - not having flood insurance
  - not raising movable items above the floodwaters ahead of floods
  - not being psychologically prepared to cope with flood events.

Notes

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3 Methodology

Getting it right: selecting the best options to reduce flood risk in the Valley

Selecting the best options to reduce flood risk

To develop the Flood Strategy, the Taskforce conducted a comprehensive evaluation of plausible infrastructure and non-infrastructure options to reduce flood risk in the Valley and protect people, buildings, assets and the economy. The Taskforce analysed available data, information and modelling of population growth, urban development and flood risk in the Valley (see 'The Taskforce's approach' box in Section 1). This analysis was applied to shortlist feasible options, evaluate these options and select final preferred solutions for inclusion in the Flood Strategy.

No simple, single solution

The Taskforce confirmed the findings of the 2013 Review that there is no simple solution or single infrastructure option that can eliminate the high flood risk in the Valley. A combination of infrastructure and policy or other initiatives will be required to reduce flood risk by:

- changing the probability of different sized flood events
- reducing the exposure of the population to flood risk
- reducing the exposure of property and other assets to floods
- increasing the resilience of communities, property and public assets exposed to floods.

Flood mitigation infrastructure (for example, flood mitigation dams) can mitigate the risk by changing the probability of flood events of different sizes. This reduces the exposure of the population to flood risk as well as reducing the exposure of property and other assets to floods. Other infrastructure solutions (such as upgrading evacuation roads) can reduce the exposure of the population to flood risk, but will not change the probability or extent of flood events.

Non-infrastructure measures are essential to managing ongoing flood risk. These solutions include strategic and integrated land use and road planning to reduce the exposure of the population to flood risk and increase community resilience.

Infrastructure options

The Taskforce undertook a preliminary assessment of all feasible infrastructure options identified in the 2013 Review, which explored all previously identified options. Five shortlisted options were taken forward for further investigation and cost benefit analysis:

- Warragamba Dam wall raising
- major regional evacuation road upgrades
- lowering the storage level of Warragamba Dam
- Currency Creek diversion channel
- dredging of the Hawkesbury-Nepean River.

Local evacuation road upgrades were identified as essential to ensure optimal efficiency of the current road evacuation routes and were assumed in the cost benefit analysis.

Options that did not warrant being taken forward for further consideration are discussed in the *Infrastructure options not included in final evaluation* box.

Evaluation methodologies

Cost benefit analysis

Cost benefit analysis (CBA) compares the benefits and costs of various options. In general, if the benefits outweigh the costs, the option is considered to be favourable. The extent to which the benefits outweigh the costs is called the net benefit. A larger net benefit indicates a more favourable option.

An economic assessment determined the benefits based on each option's ability to reduce flood risk. The quantified benefits included:

- the extent that the potential danger to personal safety or risk to life is reduced, estimated using flood evacuation modelling
- the extent that potential impacts on the economy and social amenity are reduced, estimated using flood damages assessment.

The quantified costs included:

- construction costs of the infrastructure options
- modelling, analysis and quantification of the water security impacts
- implementation costs of non-infrastructure options.

Key assumptions of the CBA included:

- conservative projections of future development in the Valley
- full compliance with an order to evacuate from the NSW State Emergency Service
- conservative assumptions associated with quantifying risk to life.

Impact assessments

Environmental, cultural and social impacts are associated with building and operating flood mitigation infrastructure. In addition, while flood mitigation infrastructure provides regional benefits, there can be local impacts.

An environmental, cultural and social impact assessment was undertaken for the shortlisted flood mitigation infrastructure options investigated by the Taskforce. The assessment was to a standard that is suitable for a detailed feasibility investigation.

An environmental assessment of evacuation road upgrades will be undertaken as part of any future implementation.

Warragamba Dam wall raising

The option

Warragamba Dam is a water supply dam and provides around 80% of Sydney's water supply. It is not designed or operated for flood mitigation.

Options were investigated to raise the height of the existing Warragamba Dam wall to provide airspace to temporarily store floodwaters upstream of the dam wall. This would reduce flood risk by temporarily holding back and slowly releasing floodwaters coming from the Warragamba River catchment, decreasing the depth and extent of the flood downstream.

The 2013 Review investigated two options to raise the Warragamba Dam wall: by 15 metres and 23 metres. The Taskforce considered a wider range of options from 12 to 30 metres to confirm the two options that would be included in detailed investigation. The two heights selected were 14 and 20 metres as these represent the cost and engineering feasibility upper and lower bounds of the option.

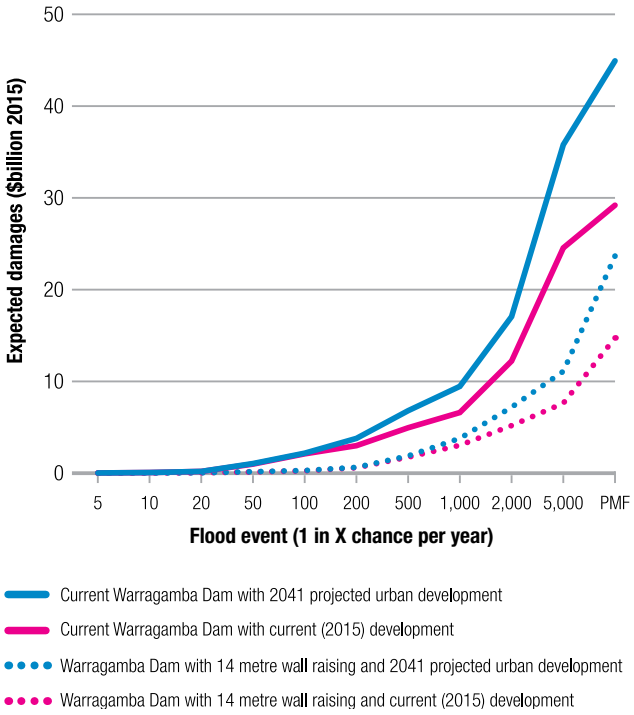

Figure 9 Current (2015) and future (2041) reduction in flood damages provided by the 14 metre Warragamba Dam wall raising ($billion, 2015)

The evaluation

Effect of raising Warragamba Dam wall by 14 metres on the number of residential properties affected (2015)

In a flood similar to the Brisbane 2011 floods (1 in 100 chance per year):

1,000 residential properties impacted – down from 5,000

In a flood similar to the largest flood since European colonisation (1867 flood):

5,000 residential properties impacted – down from 12,000

Figure 9 shows the current (2015) and future (2041) benefits provided by raising Warragamba Dam wall by 14 metres for different sized flood events, compared to the existing dam.

Raising the dam wall by 14 metres will reduce the overall flood damage by 75%. For a 1 in 500 chance per year flood, similar to the 1867 flood, the 14 metre dam wall raising would reduce the flood damages for urban development from $5 billion to $2 billion.

For urban development in 2041, raising Warragamba Dam wall by 14 metres would reduce flood damages for a 1 in 500 chance per year flood from $7 billion to $2 billion.

The flood risk is significantly reduced but not eliminated by the Warragamba Dam wall raising as floods can come from other unmitigated catchments that are without dams.

Lowering the permanent water supply level of Warragamba Dam

The option

Lowering the permanent water supply level of Warragamba Dam is another option to create airspace to temporarily store floodwaters. This would reduce the volume available in Warragamba Dam for water supply.

Two options for lowering the permanent water supply level of Warragamba Dam were included in the detailed cost benefit analysis: a reduction of the level by five metres and 12 metres (the maximum possible lowering of the water supply level as this is the height of the existing gates).

The evaluation

Lowering Warragamba Dam's permanent water supply level by 12 metres would be equivalent to reducing the dam water storage by nearly 40% – or one and a half years of water supply to Sydney. This option was not selected as it has negative net benefits: to maintain water supply security to Sydney, new sources of water supply would need to be built in addition to the continuous operation of the existing Sydney desalination plant.

Lowering the dam's permanent water supply level by five metres was not selected because of its limited potential benefits for managing flood sizes that result in the greatest risk – those larger than the 1 in 100 chance per year flood. Figure 10 shows that permanently lowering the water supply level by five metres has limited effectiveness for floods greater than the 1 in 100 chance per year. By comparison, as shown in Figure 9, raising the Warragamba Dam wall by 14 metres reduces damages across all flood events.

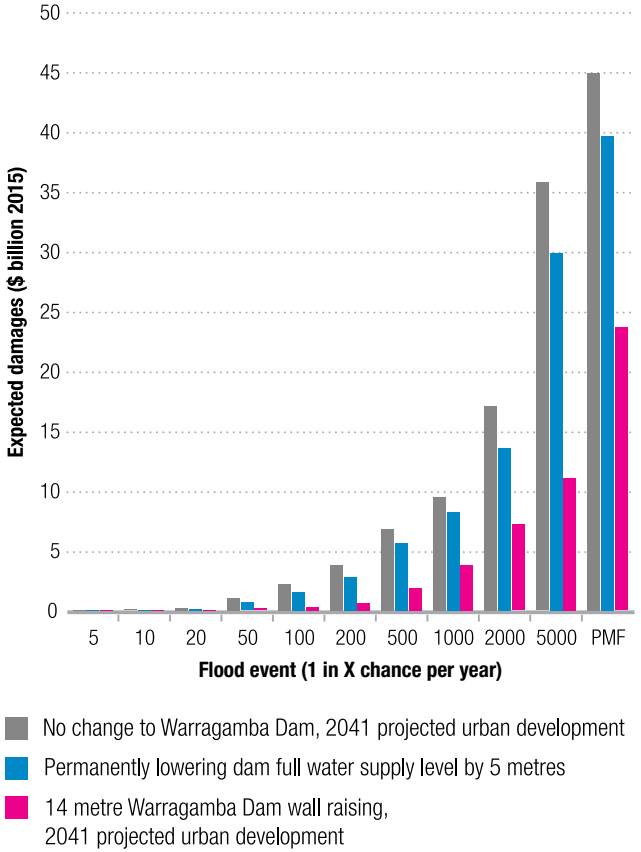

Figure 10 Projected flood damages by event in 2041 with no change to Warragamba Dam, permanent lowering of the water supply level by 5 metres, and permanent raising of the supply level by 14 metres ($billion, 2015)

Dredging of the Hawkesbury-Nepean River, and Currency Creek diversion channel

The options

The option to dredge the Hawkesbury-Nepean River for flood mitigation would involve continuously removing sediment to reach 10 metres below the current bed level for a distance of 66 kilometres from Windsor to Wisemans Ferry.

The Taskforce also completed detail investigation in an option to cut a bypass channel to the Hawkesbury-Nepean River between Wilberforce and Currency Creek (re-joining the Hawkesbury River near the Sackville Ferry) to improve the flow of floodwaters out of the floodplain.

The evaluation

The dredging of the Hawkesbury-Nepean River (even by 10 metres for 66 kilometres) and the Currency Creek diversion channel were not selected as they have construction costs similar to those of raising Warragamba Dam wall without the comparable regional flood risk mitigation benefits.

They also have significant environmental impacts. As shown in Figure 11, both options would have negative net benefits.

Major regional evacuation road options

The option

Upgrades to increase the capacity of major regional evacuation roads would reduce exposure to flood risk by increasing the number of people that are able to evacuate, reducing risk to life. However, it should be noted that investment in road evacuation infrastructure does not change flood behaviour. It does not have an effect on the likelihood that certain flood levels in the Valley will be reached and so does not decrease flood damages.

A number of major regional evacuation road options were selected for evaluation based on their ability to increase evacuation capacity. The options were developed by an expert working group of Roads and Maritime Services, NSW State Emergency Service and Infrastructure NSW.

Nine major regional road options were considered in the detailed investigation. These included various combinations of:

- raising selected existing low points on roads to the current 1 in 100 and 1 in 200 chance per year flood levels
- adjusting the use of existing roads to add lane capacity during flood emergency evacuation
- bringing forward the construction of the Castlereagh Freeway constructed to various road heights.

The evaluation

Major regional evacuation road options would not have positive net benefits as they have high construction costs relative to their benefits by 2041 in terms of reducing risk to life. In addition, these options do not reduce potential economic damages. Therefore, no major regional evacuation road options were selected for the Flood Strategy. However, the strategy includes actions to consider flood risk on regional road planning for growth in this Valley.

Local evacuation road upgrades

Local roads are generally those roads, managed by local council, that connect the population to major regional evacuation roads. In the Taskforce's evaluation of infrastructure options, around 40 high priority local evacuation road upgrades were identified as essential to maintain access to major regional evacuation routes. These have been included as a short-term measure in the Flood Strategy and will be subject to a future business case.

The upgrades were identified by a working group led by Roads and Maritime Services in consultation with local councils in the Valley, the NSW State Emergency Service and other stakeholders. These upgrades were selected from a list of 177 potential projects as the options that would best prevent premature closure due to flash floods or provide additional capacity to allow evacuating communities to access major regional evacuation routes.

Each upgrade project was selected based on the:

- number of potential evacuees benefitting from the project
- project's ability to improve evacuation during more frequent smaller floods that will still occur with local rainfall even if the Warragamba Dam wall is raised
- relative cost of the project
- potential environmental and social impact of the project.

Results of the cost benefit analysis of infrastructure options

Each infrastructure option was evaluated in terms of its net benefits, defined as its discounted benefits less its discounted costs.

Discounting reduced the projected costs and benefits of an option to a current value for 2015 to allow for comparison. These costs and benefits have been discounted by 7% per year as per NSW Treasury Policy.

Based on the results of the evaluation, raising Warragamba Dam by 14 metres was selected as the preferred infrastructure option as it provided the largest net benefits of around $200 million (Figure 11).

While raising Warragamba Dam wall is the infrastructure option with the highest net benefit, no combination of infrastructure options can eliminate the risk. Regardless of any infrastructure option, non-infrastructure options must be part of the solution for managing ongoing flood risk.

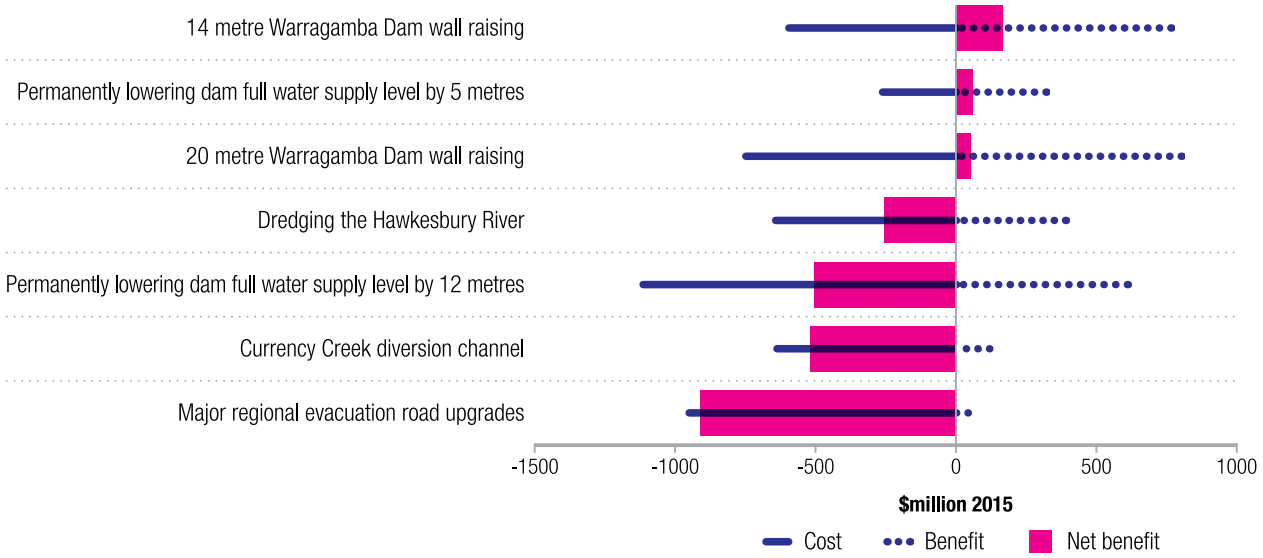

Figure 11 **Net benefits, costs and benefits of infrastructure options in order of decreasing net benefits ($millions)**

Non-infrastructure options

A range of non-infrastructure measures were identified as essential to mitigate and manage the residual flood risk in the Valley.

It is difficult to quantify the benefits of non-infrastructure measures in monetary terms, but they are important to reducing ongoing risk. The measures included in the Flood Strategy were developed by the Taskforce based on recommendations of the 2013 Review, the 2011 National Strategy for Disaster Resilience and the national flood risk management framework.

The non-infrastructure measures incorporated into the Flood Strategy broadly fit within the following categories:

- coordinated flood risk management
- strategic and integrated land use and road planning
- access to contemporary flood risk information
- community awareness, preparedness and response
- improved weather and flood predictions
- best practice emergency response and recovery.

House repurchase was also considered but not taken forward for further consideration (see the box *House repurchase in flood risk areas*).

Infrastructure options not included in final evaluation

Construction of new dams

Reviews carried out from 1987 to 1995 considered a number of site alternatives to those on the Warragamba River for new flood mitigation dams. These were rejected due to their low cost-effectiveness for flood mitigation and significant environmental impacts, with most sites located within National Parks. As Warragamba Dam captures approximately 80% of the catchment upstream of Penrith, other flood mitigation dams on alternative rivers cannot be as effective. Alternative dam sites were reconsidered as part of the Taskforce work but no new information was found that would justify further consideration of new dam sites for flood mitigation.

Options to build another dam on the Warragamba River, downstream of Warragamba Dam were also assessed. However, based on the construction costs, environmental and operational impact, options that raise the existing Warragamba Dam wall were found to be more cost effective to reduce flood risk than new dams on the Warragamba River. New dam construction was up to three times more costly than raising the wall of the existing Warragamba Dam to provide similar flood mitigation benefits.

Changing operation of the existing Warragamba Dam gates (pre-release and surcharge)

The Taskforce investigated flood mitigation options for operating the current Warragamba Dam differently. The options included:

- **pre-releasing water ahead of a predicted flood inflow**
- **changing the operation of the gates to temporarily hold back floodwater (this is called surcharging).**

These options have limited flood mitigation effectiveness for those larger floods that pose a significant risk to lives or property.

Levees

Levees at McGraths Hill and Peachtree Creek were identified as cost effective options for providing local flood protection only. As these levees provide only limited and localised benefits, they were not included in the Strategy. However, Peachtree Creek levee was considered to be worthy of more detailed consideration as a local measure.

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Diversion channels other than at Currency Creek

Two diversion channels in addition to Currency Creek were investigated. The Sackville Gorge was investigated as an option that increases the rate at which floodwaters could drain away from the floodplain. The options assessed were:

- a diversion channel on the Hawkesbury River from Sackville to the Cumberland Reach
- a diversion channel on the Hawkesbury River from Sackville to Leets Vale.

The diversion channel from Sackville to Leets Vale was calculated by the 2013 Review to have a construction cost of more than $5 billion and would not deliver net regional flood mitigation benefits. The 2013 Review also found that the Sackville to Cumberland Reach diversion channel would provide minimal flood mitigation benefits, although it would be considerably cheaper. Because Sackville Gorge is in a tidal zone and is almost at sea level, these options had limited capacity to increase the rate at which floodwaters drain away from the floodplain. As a result, these two options were not taken forward for further investigation.

House repurchase in flood risk areas

The large and growing urban development in the Valley precludes house purchase as a flood mitigation option. For example, there are currently about 6,200 houses located between the 1 in 100 and 1 in 500 (similar to the 1867 flood) chance per year flood levels – the areas that contribute most to flood risk. These houses could cost around $3.3 billion to purchase, assuming a median house price for the four key councils of $523,000 (NSW Department of Family and Community Services (DFCS) Rent and Sales Report 115, dwelling prices as at December 2015).

4 Strategy

The Hawkesbury-Nepean Valley Flood Risk Management Strategy

Flood Strategy

The Flood Strategy sets out a clear path for the NSW Government, local councils, businesses and the community to work together to understand, reduce and manage the flood risk in the Hawkesbury-Nepean Valley.

Alignment of the Flood Strategy

The 2013 Hawkesbury-Nepean Flood Risk Management Review and the 2011 National Strategy for Disaster Resilience shaped the overarching vision, objective, guiding principles and outcomes adopted for the Flood Strategy. The 2011 National Strategy for Disaster Resilience emphasises that resilience is a shared responsibility between all levels of government, business, the non-government sector, communities and individuals. The Flood Strategy is aligned with the broader emergency management framework set out the *State Emergency and Rescue Management Act 1989*.

Strategy vision

Hawkesbury-Nepean Valley communities and all levels of government will **adapt** to flooding by working together to:

- **understand** and be **fully aware** of flood risk
- **act** to reduce flood risk and manage growth
- be **ready** to respond and recover from flooding.

Strategy objective

To reduce flood risk to life, property and social amenity from regional floods in the Hawkesbury-Nepean Valley now and in the future.

Guiding principles

The guiding principles of the Flood Strategy are:

1. Protecting people's lives, assets and social amenity as a priority.
2. Sharing responsibility for flood risk management between all levels of government, communities, individuals and business.
3. Fulfilling the National Strategy for Disaster Resilience roles for government to:
   - prepare for extreme events – support individuals and communities to prepare for extreme events
   - recover and learn from events – to help communities recover from devastation and to learn, innovate and adapt in the aftermath of disastrous events
   - respond to the emergency – ensure the most effective, well-coordinated response from our emergency services and volunteers when disaster hits
   - inform the community about flooding – have effective arrangements in place to inform people about how to assess risks and reduce their exposure and vulnerability to hazards
   - inform the community about flood response – have clear flood risk information so people know what the best course of action is when called to respond
   - strategically manage the flood risk – develop and implement effective, risk-based land management and planning arrangements and other mitigation activities.

Delivering results

The Flood Strategy is designed to deliver nine key outcomes:

Outcome 1
Coordinated flood risk management across the Valley now and in the future

Outcome 2
Reduced flood risk in the Valley by raising Warragamba Dam wall

Outcome 3
Strategic and integrated land use and road planning

Outcome 4
Accessible contemporary flood risk information

Outcome 5
An aware, prepared and responsive community

Outcome 6
Improved weather and flood predictions

Outcome 7
Best practice emergency response and recovery

Outcome 8
Adequate local roads for evacuation

Outcome 9
Ongoing monitoring and evaluation, reporting and improvement of the Flood Strategy

1

Coordinated flood risk management across the Valley now and in the future

Clear responsibilities and accountabilities that result in a regional risk-based integrated approach to ongoing flood risk management.

Responsibility is about ownership of a task. Accountability means being answerable for the desired outcome. Responsibility can be shared – accountability cannot. This strategy aims to share responsibility for flood risk management while clarifying accountability.

Actions to be taken:

- coordinate implementation of the Flood Strategy actions across all levels of government and the community through the Hawkesbury-Nepean Valley Flood Risk Management Directorate (the Directorate), based initially within Infrastructure NSW
- coordinate regional flood risk management responsibilities in the Valley (the Directorate)
- review ongoing responsibilities and accountabilities following the initial term of the Directorate at Infrastructure NSW (the Directorate).

2

Reduced flood risk in the Valley by raising Warragamba Dam wall

Final design will be completed and approvals obtained for raising Warragamba Dam wall by around 14 metres to significantly reduce and mitigate flood risk.

In developing the Flood Strategy, the Taskforce found that raising the Warragamba Dam wall by around 14 metres was a cost effective measure for reducing flood damages and risk to life. This measure will result in around 75% reduction in the damages expected from floods on average each year and significantly reduce the risk to life from flood events. Proceeding to construction is subject to environmental and planning approvals.

Actions to be taken:

- complete detailed design and costing for the raising of Warragamba Dam wall by around 14 metres for flood mitigation (WaterNSW)
- prepare an Environmental Impact Statement – this will include community consultation and detailed assessment of the potential environmental impacts from construction and ongoing operation (WaterNSW)
- submit environmental and planning approvals – the environmental and planning approval for raising the dam wall will also be referred to the Australian Government under the *Environment Protection and Biodiversity Conservation Act 1999* (WaterNSW)
- submit a final business case for raising the dam wall to the NSW Government by 2020 (the Directorate).

3

Strategic and integrated land use and road planning

A regional planning framework will be prepared and implemented that integrates land use and road planning to better adapt to and manage flood risk in the Valley.

The Warragamba Dam wall raising is designed to reduce flood risk for the current and future population based on development that is currently permissible. As it will not eliminate flood risk entirely, growth will need to be carefully managed in the Valley.

While development will still occur in the Valley, the benefits of the dam wall raising in reducing the risk to life and flood damage will be lost if development is not managed in flood-prone areas. This means that areas subject to current flood-related development controls based on the 1 in 100 chance per year flood level (that is, below 17.3 metres above river level at Windsor and 25.9 metres at Penrith) will continue to be subject to controls following the Warragamba Dam wall raising.

New development restrictions may also apply – particularly around areas with existing higher flood risk. It is important to ensure that population growth in the Valley is carefully managed, both in terms of absolute numbers of people and the distribution of the population within the Valley. This means that land use and road planning will need to account for the cumulative impact of growth on road evacuation capacity.

Actions to be taken:

- improve and maintain regional flood risk information to support land use, road and emergency planning:
  - undertake a regional flood study to identify the current flood hazards from riverine flooding based on a new fit for purpose and accessible regional flood model (Hawkesbury-Nepean Valley Flood Risk Management Directorate – the Directorate)
  - develop a fit for purpose regional evacuation model that identifies evacuation capacity constraints for different areas in the Valley (Roads and Maritime Services)
  - determine asset damages assessment information across the Valley (the Directorate).
- integrate land use and road planning to shape long-term growth by managing the cumulative impact of growth on road evacuation capacity and flood damages based on regional flood risk information:
  - develop a Regional Evacuation Road Master Plan that identifies a coherent evacuation road network for the Valley and suitable flood design standards (Roads and Maritime Services)
  - develop a Regional Land Use Planning Framework that gives effect to these policies (Department of Planning and Environment)
  - develop a land use planning response to maintain the benefits of the Warragamba Dam wall raising (Department of Planning and Environment).

4 Accessible contemporary flood risk information

Communities and all levels of government accessing and using consistent flood risk information.

Flood risk information for all possible flood events needs to be accessible to allow communities, decision makers from all level of government and the insurance industry to understand and be fully aware of floods.

Actions to be taken:

- map flood risk – the physical flood hazard and the risk to life for all flood events (Hawkesbury-Nepean Valley Flood Risk Management Directorate – the Directorate)
- make flood risk information for all events available on the web (the Directorate).

5 An aware, prepared and responsive community

Across the Valley, prepared communities will be better able to respond to flood risk, reducing risk to life and the impact on the community.

Improving the awareness and preparedness of the community is critical to reducing flood risk.

By providing information and increasing awareness of flood risk, individuals and households will be able to improve their own preparations for and resilience to floods, minimising the impact on their families and property during an emergency. This will also accelerate recovery once the flood has passed.

Actions to be taken:

- coordinate flood community engagement activities across government agencies (the Directorate)
- upgrade evacuation route signage and implement a supporting communications program to raise awareness and understanding of the flood evacuation routes (Roads and Maritime Services)
- develop and implement a community engagement program around the release of flood risk mapping (the Directorate)
- develop and implement a community consultation program for the Warragamba Dam wall raising Environmental Impact Statement (WaterNSW)
- track levels of community flood risk awareness in the Valley. (the Directorate).

6

Improved weather and flood predictions

Improved weather predictions will allow for greater certainty about the timing and maximum heights of floods for improved emergency response. Arrangements will be in place to support the availability of rainfall monitoring information for weather and flood predictions.

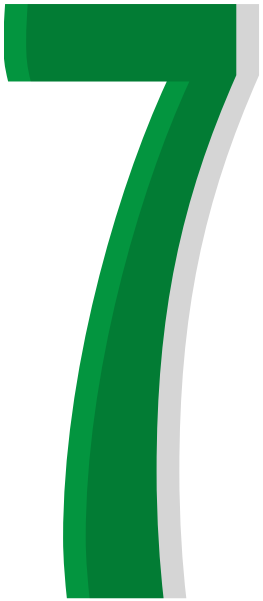
The Bureau of Meteorology's Hawkesbury-Nepean Forecasting model needs to be updated to improve accuracy and timeliness to assist with emergency response and evacuation planning.

To safely evacuate everyone in the Valley in a major flood the NSW State Emergency Services require early and accurate forecasts. Without accurate forecasting from the Bureau of Meteorology, the NSW State Emergency Service runs the risk of asking people to evacuate when it is later proved unnecessary.

The Taskforce's Hawkesbury-Nepean Valley Flood Monitoring Working Group will continue to operate. It will maintain information exchange and coordination between the agencies that own the rainfall and river level monitoring sites used for weather and flood predictions. The group will help to ensure that the sites are maintained for flood predictions. The working group will report to the Bureau of Meteorology's NSW Flood Warning Consultative Committee. This committee coordinates flood predictions and warnings for the state.

Actions to be taken:

- update weather forecasting techniques for the Hawkesbury-Nepean Valley (Bureau of Meteorology)
- update the regional flood prediction tool for the Hawkesbury-Nepean Valley (Bureau of Meteorology)
- continue the Hawkesbury-Nepean Valley Flood Monitoring Working Group.



Best practice emergency response and recovery

There will be continuous improvement of emergency response and recovery planning.

The NSW State Emergency Service and the NSW Office for Emergency Management each maintain flood risk response and recovery plans for the Hawkesbury-Nepean Valley. Testing of the plans and ensuring that the necessary capabilities are maintained is critical for continuous improvement. Ensuring these arrangements are adequate, understood and well-rehearsed is important given the likely prolonged and highly complex nature of response and recovery in the Valley.

Actions to be taken:

- periodically review and update the emergency response plan (Hawkesbury-Nepean Flood Plan) to account for the latest flood risk information and integrate with recovery arrangements (NSW State Emergency Service)
- periodically review and update the Valley recovery strategy (Hawkesbury-Nepean Valley Flood Recovery Strategy) (NSW Office of Emergency Management)
- plan for recovery from catastrophic events by developing NSW recovery arrangements for catastrophic disasters using the Valley as a case study (NSW Office of Emergency Management)
- test and rehearse emergency response and recovery plans and arrangements with regular exercises (NSW State Emergency Service and NSW Office of Emergency Management)
- improve and maintain rescue capability (NSW State Emergency Service).

8 Adequate local roads for evacuation

Local evacuation roads will be upgraded to support flood evacuation.

Around 40 high priority local evacuation road upgrades have been identified for investment to maintain access to major regional evacuation roads.

Actions to be taken:

- upgrade priority local evacuation roads to maintain access to major regional evacuation routes, subject to approval of business cases (Roads and Maritime Services).

9 Ongoing monitoring and evaluation, reporting and improvement of the Flood Strategy

Ongoing monitoring and evaluation, reporting and improvement of the Flood Strategy will be undertaken to accommodate changes over time and to ensure that the strategy's actions continue to meet the vision and objective.

The outcomes of the Flood Strategy will be periodically reviewed under an adaptive management framework which involves continuous monitoring, evaluation, reporting and improvement (MERI) as illustrated in Figure 12.

The purpose of regular reviews is to evaluate the effectiveness of the Flood Strategy in achieving its objective and to ensure the expected benefits are realised. This involves continuous monitoring of flood risk, including monitoring of urban growth, changes to road evacuation capacity and climate change. This will ensure that potential future investment or policy development is informed by the best available information.

Actions to be taken:

- develop and implement a monitoring, evaluation, reporting and improvement (MERI) framework for the Flood Strategy (Hawkesbury-Nepean Valley Flood Risk Management Directorate).

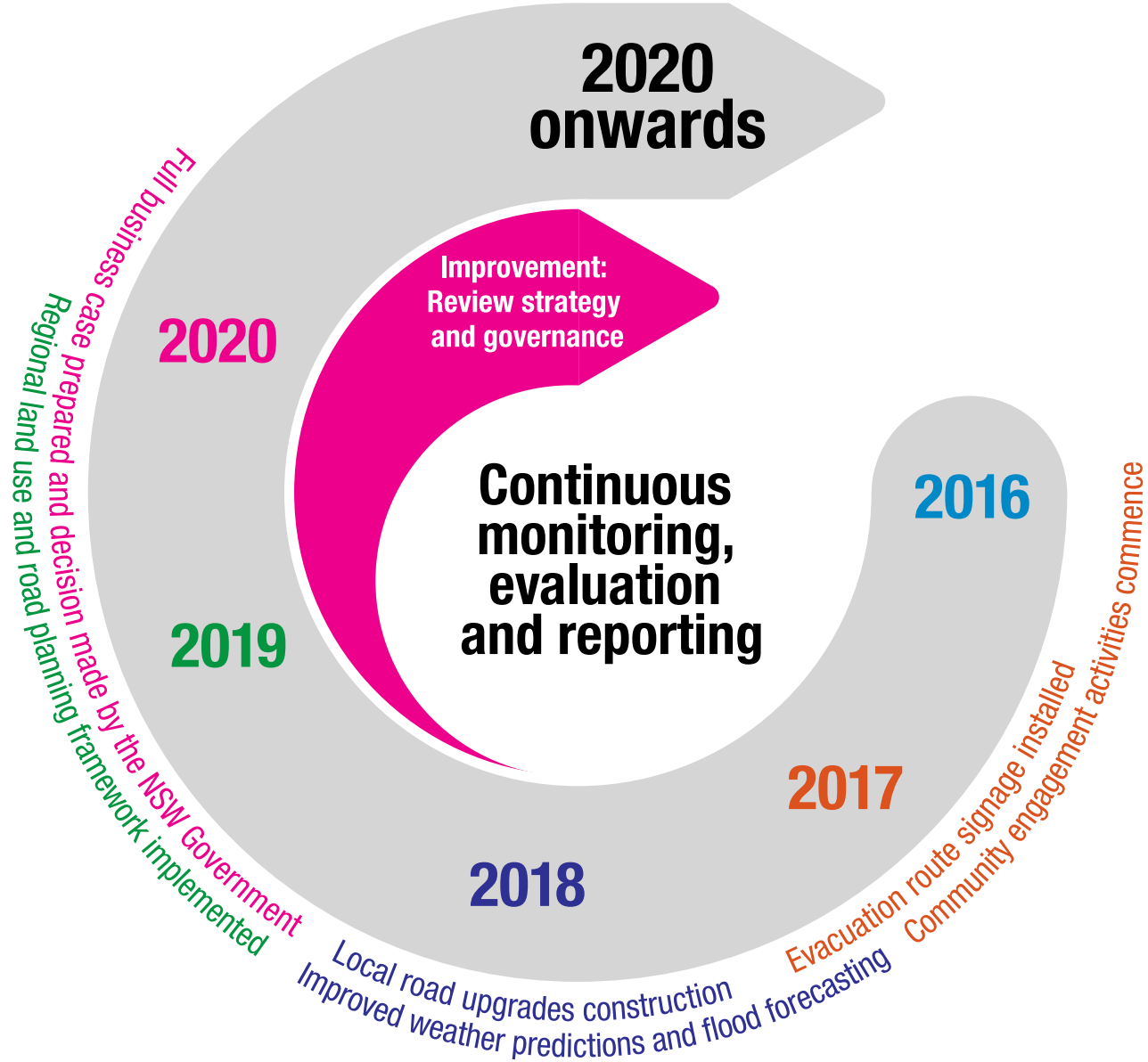


Figure 12 **Monitoring, evaluation, reporting and improvement (MERI) framework for the Flood Strategy and key milestones**

Further information

For further information and updates go to insw.com

5 Appendix

Accessible longform charts and graphics

Accessible longform charts and graphics

Figure 1 The Hawkesbury-Nepean Valley Floodplain

Map of the Greater Sydney Region showing the extents of the 1 in 100 chance per year flood and probable maximum flood in the Hawkesbury-Nepean Valley.

Figure 2 Elements of flood risk

Schematic diagram showing ‘flood hazard’ plus ‘exposure’ results in ‘flood risk’.

Figure 3 The ‘bathtub’ effect in the Hawkesbury-Nepean Valley

Stylised schematic diagram showing the Hawkesbury –Nepean River from Warragamba Dam to Wisemans Ferry showing the key floodplains (the ‘bathtubs’) at Wallacia, Penrith and Richmond-Windsor.

Figure 4 Relative contribution of different river catchments in previous floods in the Hawkesbury-Nepean Valley

	Contributing catchments				
Catchment area and flood inflows	**Warragamba**	**Nepean River**	**Grose River**	**South Creek**	**Others**
Portion of catchment area upstream of Windsor	70%	15%	5%	1%	9%
November 1961 Flood	62%	17%	6%	3%	12%
June 1975 Flood	65%	21%	6%	2%	6%
August 1986 Flood	42%	21%	12%	10%	15%
August 1990 Flood	73%	16%	5%	1%	5%

Figure 5 Comparison of the differences in flood levels and flood risk between the Hawkesbury-Nepean River at Windsor and other floodplains

	Flood Depth above default 1 in 100 chance per year flood planning level for four areas in New South Wales			
Flood size	**Windsor**	**Penrith**	**Lismore**	**Nyngan**
1 in 100 chance per year	0.0m	0.0m	0.0m	0.0m
1 in 500 chance per year	2.2m	1.2m	1.0m	0.7m
Probable Maximum Flood	8.9m	5.6m	3.6m	2.5m

Figure 6 Current urban development in the Richmond-Windsor has different levels of flood risk within the floodplain, with development located from below the 1 in 100 chance per year flood level to above the level of the probable maximum flood

Schematic of a cross-section of the Hawkesbury-Nepean floodplain at Richmond-Windsor showing that residential development occurs at different flood levels from below the current 1 in 100 chance per year flood to above the probable maximum flood.

Figure 7 Major regional evacuation road routes out of the Valley

Map of Hawkesbury-Nepean floodplain showing the network of the 14 major flood emergency evacuation road routes.

Figure 8 How a flood island can be isolated then fully submerged

Schematic of a cross-section of a floodplain showing how as floodwaters rise, some areas (known as flood islands) can become isolated as lower-level access roads are flooded. As floodwaters continue to rise, these flood islands can become fully submerged.

Figure 9 Current (2015) and future (2041) reduction in flood damages provided by the 14 metre Warragamba Dam wall raising ($billion, 2015)

	Flood event (1 in X chance per year)										
Estimated damages for different flood events in billion dollars in 2015	**5**	**10**	**20**	**50**	**100**	**200**	**500**	**1000**	**2000**	**5000**	**PMF**
Current Warragamba Dam and projected 2041 development	0.024	0.072	0.19	1.1	2.2	3.8	6.8	9.5	17.1	35.8	44.9
Current Warragamba Dam and current 2015 development	0.023	0.071	0.19	0.99	2.1	3	5	6.6	12.2	24.6	29.2
Warragamba Dam raised 14 metres and projected 2041 development	0.007	0.023	0.045	0.16	0.3	0.64	1.9	3.8	7.2	11.1	23.7
Warragamba Dam raised 14 metres and current 2015 development	0.006	0.022	0.043	0.14	0.26	0.59	1.8	3	5.2	7.6	14.7

Figure 10 Projected flood damages by event in 2041 with no change to Warragamba Dam, permanent lowering of the water supply level by 5 metres, and permanent raising of the supply level by 14 metres ($billion, 2015)

	Flood event (1 in X chance per year)										
Estimated damages for different flood events in billion dollars in 2015	**5**	**10**	**20**	**50**	**100**	**200**	**500**	**1000**	**2000**	**5000**	**PMF**
Current Warragamba Dam and projected 2041 development	0.024	0.072	0.19	1.1	2.2	3.8	6.8	9.5	17.1	35.8	44.9
Current Warragamba Dam water level lowered 5 metres and projected 2041 development	0.018	0.044	0.095	0.66	1.6	2.8	5.7	8.3	13.6	29.9	39.6
Warragamba Dam raised 14 metres and projected 2041 development	0.007	0.023	0.045	0.16	0.3	0.64	1.9	3.8	7.2	11.1	23.7

Figure 11 Net benefits, costs and benefits of infrastructure options in order of decreasing net benefits ($millions)

	Million dollars net present value		
Flood mitigation infrastructure option	**Costs**	**Benefits**	**Net benefits**
14 metre Warragamba Dam wall raising	-590	760	170
Permanently lowering dam full supply level by 5 metres	-260	320	60
20 metre Warragamba Dam wall raising	-750	800	50
Dredging the Hawkesbury River	-640	390	-250
Permanently lowering dam full supply level by 12 metres	-1100	610	-490
Currency Creek diversion channel	-640	120	-520
Major regional evacuation road upgrades	-950	40	-910

Figure 12 Monitoring, evaluation, reporting and improvement (MERI) framework for the Strategy and key milestones

Stylised timeline from 2016 to 2020 and beyond for continuous monitoring, evaluation and reporting (MERI framework) for the Flood Strategy, including key milestones: 2017: evacuation route signage installed, 2018: Local road upgrades construction and improved weather predictions and flood forecasting, 2019: regional land use and road planning framework implemented, 2020: full business case prepared and decision made by the NSW Government.