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Environmental Impact Statement – Chapter 16: Health and safety

Warragamba Dam Raising

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16 Health and safety

This chapter provides an assessment of health and safety during construction and operation of the Warragamba Dam Raising. The relevant Secretary's Environmental Assessment Requirements (SEARs) are shown in Table 16-1.

Table 16-1. Secretary's Environmental Assessment Requirements: Health and safety

Desired Performance outcomes	Secretary's Environmental Assessment Requirements[11]	Where addressed
9. Health and Safety Desired performance outcomes: The project avoids or minimises any adverse health impacts arising from the project. The project avoids, to the greatest extent possible, risk to public safety.	1. The Proponent should demonstrate that the proposed works shall comply with Dam Safety Committee[1] Guidance.	Section 16.1
	2. The Proponent must assess the potential health impacts of the project, in accordance with the current guidelines.	Section 16.3 Section 16.4 Section 16.5
	3. The assessment must: (a) describe the current known health status of the affected population;	Section 16.3
	(b) assess health risks associated with exposure to environmental hazards;	Section 16.4 Section 16.5
	(c) assess the effect of the project on other relevant determinants of health such as the level of physical activity and access to social infrastructure;	Section 16.4 Section 16.5
	(d) assess opportunities for health improvement;	Section 16.4 Section 16.5
	(e) assess the distribution of the health risks and benefits; and	Section 16.4 Section 16.5
	(f) discuss how, in the broader social and economic context of the project, the project will minimise negative health impacts while maximising the health benefits.	Section 16.4 Section 16.5
	4. The Proponent must assess the likely risks of the project to public safety, paying particular attention to flood risk, subsidence risks, bushfire risks, and the handling and use of dangerous goods.	Section 16.4 Section 16.5
	5. The Proponent needs to address whether the project incorporates specific measures to manage risk to life from flood, with these matters to be discussed with the SES and relevant Councils.	Section 16.4 Section 16.5

1. This chapter specifically addresses SEAR 9 in addition to those general requirements of the SEARs applicable to all chapters and as identified as such in Chapter 1 (Section 1.5, Table 1-1). Specific assessment requirements in addition to the general requirement in Table 16-1 are detailed in Section 16.4.

[1] Since issue of the SEARs, the NSW Dams Safety Committee has been abolished and replaced by Dams Safety NSW and its Board.

Health and safety assessment is incorporated in the various EIS chapters including:

- Chapter 3 (Project justification), Chapter 15 (Flooding and hydrology) and Chapter 14 (Climate change risk): flooding and safety
- Chapter 7 (Air quality), Chapter 26 (Waste) and Chapter 22 (Soils): exposure to chemical pollutants and contaminants
- Chapter 11 (Aquatic ecology) and Chapter 27 (Water quality): chemical pollutants and pathogenic microbial contaminants in water
- Chapter 19 (Noise and vibration): hearing and amenity
- Chapter 21 (Socio-economic, land use and property): social disruption
- Chapter 24 (Traffic and transport): traffic hazards and safety.

The proposed management and mitigation measures in this chapter are collated in the environmental impact statement synthesis, Project justification and conclusion in Chapter 29.

16.1 Legislation and policies

16.1.1 Overview

Legislation relevant to the Project is discussed in Chapter 2 (Statutory and planning framework). Legislation, guidelines, specifications, and policy documents relevant to health and safety during construction and operation of the Project are outlined in Table 16-2.

Table 16-2. Legislation, guidelines, specifications, and policy documents relevant to health and safety

Legislation, guidelines, specifications and policy documents	Where addressed
Work Health and Safety Act 2011 (WHS Act)	Section 16.1.2
Work Health and Safety Regulation 2017 (WHS Regulations)	Section 16.1.2
Protection of the Environment Operations Act 1997 (POEO Act)	Chapter 22 (Soils)
Protection of the Environment Operations (General) Regulation 2009	Chapter 22 (Soils)
Environmentally Hazardous Chemical Act 1985	Chapter 22 (Soils)
Environmentally Hazardous Chemicals Regulation 2017	Chapter 22 (Soils)
Contaminated Land Management Act 1997	Chapter 22 (Soils)
Australian Standard, AS4801 – Occupational Health and Safety Management Systems	Section 16.5
Waste Classification Guidelines – Part 1: Classifying waste (NSW EPA 2014b)	Chapter 26 (Waste)
Waste Classification Guidelines – Part 2: Immobilisation of waste (NSW EPA 2014c)	Chapter 26 (Waste)
Storing and Handling Liquids, Environmental Protection – Participants Manual (Department of Environment and Climate Change 2007a)	Chapter 22 (Soils)
Bunding and Spill Management (DECC 1997)	Chapter 22 (Soils)

The Project is progressing through detailed concept design concurrently with the preparation of this EIS. The design of the dam would meet all legislative requirements for dam design and safety. Throughout the design process there would be ongoing consultation and assessment with Dams Safety NSW and others as relevant to ensure that the design meets these legislative requirements.

Construction of the dam would meet the requirements of relevant health and safety legislation and guidelines.

The operation of the dam is not anticipated to pose any health impacts.

16.1.2 Dams Safety Act 2015

The *Dams Safety Act 2015* is the overarching legislation governing dam safety in NSW. The objectives of the Act are:

(i) to ensure that any risks that may arise in relation to dams (including any risks to public safety and to environmental and economic assets) are of a level that is acceptable to the community

(ii) to promote transparency in regulating dam safety

(iii) to encourage proper and efficient management in matters relating to dam safety

(iv) to encourage the application of risk management and the principles of cost benefit analysis in relation to dam safety.

Dams Safety NSW regulates dam safety in NSW and is responsible for developing and implementing regulation of effective dam safety management to protect life, property and the environment from dam failures. The requirements of Dams Safety NSW are mandated under the *Dams Safety Act 2015*. Dams Safety NSW is responsible for examining the location, design, construction, operation, and maintenance of prescribed dams, including any proposed changes. Several Dams Safety NSW guidance sheets are relevant to the Project, including:

- DSC2A Dam Safety Management Systems
- DSC2B Documentation and Information Flow over Dam Life Cycle
- DSC2C Surveillance Reports for Dams
- DSC2D Demonstration of Safety for Dams
- DSC2F Operation and Maintenance for Dams
- DSC2G Emergency Management for Dams
- DSC2I Community Consultation and Communication (CC&C)
- DSC3A Consequence Categories for Dams
- DSC3B Acceptable Flood Capacity for Dams
- DSC3C Acceptable Earthquake Capacity for Dams
- DSC3D Reliability of Spillway Flow Control Systems
- DSC3G General Dam Safety Considerations.

Dams Safety NSW requirements relevant to the Warragamba Dam Raising Project (construction and operation) are:

1. proper operation and maintenance of the dam using trained personnel
2. regular dam surveillance using trained personnel
3. development and implementation of appropriate dam safety emergency plans
4. ongoing assessment of the dam behaviour based on surveillance information
5. periodic review of the dam compliance with current Dams Safety NSW requirements
6. review of dam information and assessment by experienced personnel
7. actions, in response to dam assessment, to ensure that the dam is maintained in a safe condition.

The design contractor would consider the above requirements during the development of the concept and detailed designs.

16.1.3 Work Health and Safety Act 2011 and Regulation 2017

The *Work Health and Safety Act 2011* (WHS Act) is the principal legislation providing for a balanced and nationally consistent framework to secure the health and safety of workers and workplaces. Section 26 of the WHS Act states the requirement of a proponent to ensure that they commission structures that are without risk to health and safety for workers throughout their lifecycle and consider the risk to those in and around the workplace.

Under the Work Health and Safety Regulation 2017, proponents have an obligation to consult with designers on how to eliminate or minimise risks to health and safety. Safety in design has been addressed in the detailed concept design and would continue to be assessed as required throughout the development of the detailed design.

16.1.4 Dam design criteria

Important objectives for the development of the design are:

1. maintain the structural integrity of the dam
2. minimise risk to life

3. minimise downstream impact of flooding to properties
4. minimise environmental impact
5. minimise social impacts.

Specific performance and design requirements for the dam raising are detailed in Chapter 5 (Project description). General requirements for the design as they relate to health and safety include:

- use of current internationally recognised guidelines, with first preference given to Australian National Committee on Large Dams (ANCOLD) requirements, supplemented with other guidelines as appropriate. This will contribute to maintaining the structural integrity of the dam and minimising risk to life
- reduce the flood risk to life and property in the Hawkesbury-Nepean Valley downstream of the dam through establishing a flood mitigation zone (FMZ), examination of alternative spillway control configurations (see Chapter 5 (Project description)) and flood modelling to establish best release options
- the facility must remain functional and dam safety risks managed to no greater than existing levels throughout the construction period
- maintain the structural integrity of the dam as a result of the current services and in future design efforts
- design considers use of materials and promoting safety in the construction process
- undertake health and safety risk assessments.

16.1.5 Demonstrating compliance with relevant legislation, specifications and guidelines

The design and construction of the dam would be completed to meet or exceed appropriate engineering standards and safety criteria. The standards of design, construction and operation of the dam would reflect the level of potential adverse consequences from a dam failure. The standards considered include:

- Dams Safety NSW Guidance Sheets (see Section 16.1.1), which reference the current ANCOLD '*Guidelines on Design Criteria for Concrete Gravity Dam*' (2013).
- Elements of best practice from the United States Bureau of Reclamation (USBR) *Guidelines for New Dams* and Chapter III of the US Federal Energy Regulatory Commission (FERC) *Guidelines for Existing Dams*

Following construction, dam safety would be monitored in accordance with recommendations of the corresponding Dams Safety NSW Guidance Sheet, which includes:

- proper operation and maintenance of the dam using trained personnel
- regular dam surveillance using trained personnel
- appropriate dam safety emergency plans to be in place for those dams whose failure could cause loss of non-itinerant life
- ongoing assessment of dam behaviour based on surveillance information
- periodic review of the dam's compliance with current Dams Safety NSW requirements
- review of all dam information and assessments by experienced personnel
- actions, in response to dam assessments, to ensure that their dams are maintained in a safe condition.

At the time of preparation of the EIS a number of guidelines were undergoing review. Operation of the Project would be in accordance with all relevant guidelines issued by Dams Safety NSW.

16.2 Health and safety impact assessment

This chapter considers potential human health risks related to:

- acute (short-term) and chronic (long-term) impacts during both construction and operation
- a worst case operating scenario.

The methodology for the human health risk assessment is in accordance with national and international guidance that is endorsed or accepted by Australian health and environmental authorities, including:

- *Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards* (enHealth 2012b)
- *Health Impact Assessment: Guidelines* (enHealth 2017)
- *Health Impact Assessment: A Practical Guide* (Harris et al. 2007)
- *Australian Exposure Factors Guide* (enHealth 2012a)

- *Schedule B8 Guideline on Community Engagement and Risk Communication* of the National Environment Protection (Assessment of Site Contamination) Measure 1999 (ASC NEPM) (including 2013 amendment)
- *Impact Statement for the National Environment Protection (Air Toxics) Measure* (NEPC 2003)
- State Environmental Planning Policy (SEPP) No. 33 – Hazardous and Offensive Development (NSW)
- *Methodology for Valuing the Health Impacts of Changes in Particle Emissions* (PAEHolmes 2013).

The methodology for the human health risk assessment is based on defining, quantifying where feasible, and assessing the potential risks to human health from the construction and operation of the Project. The assessment focussed on key construction and dam safety impacts.

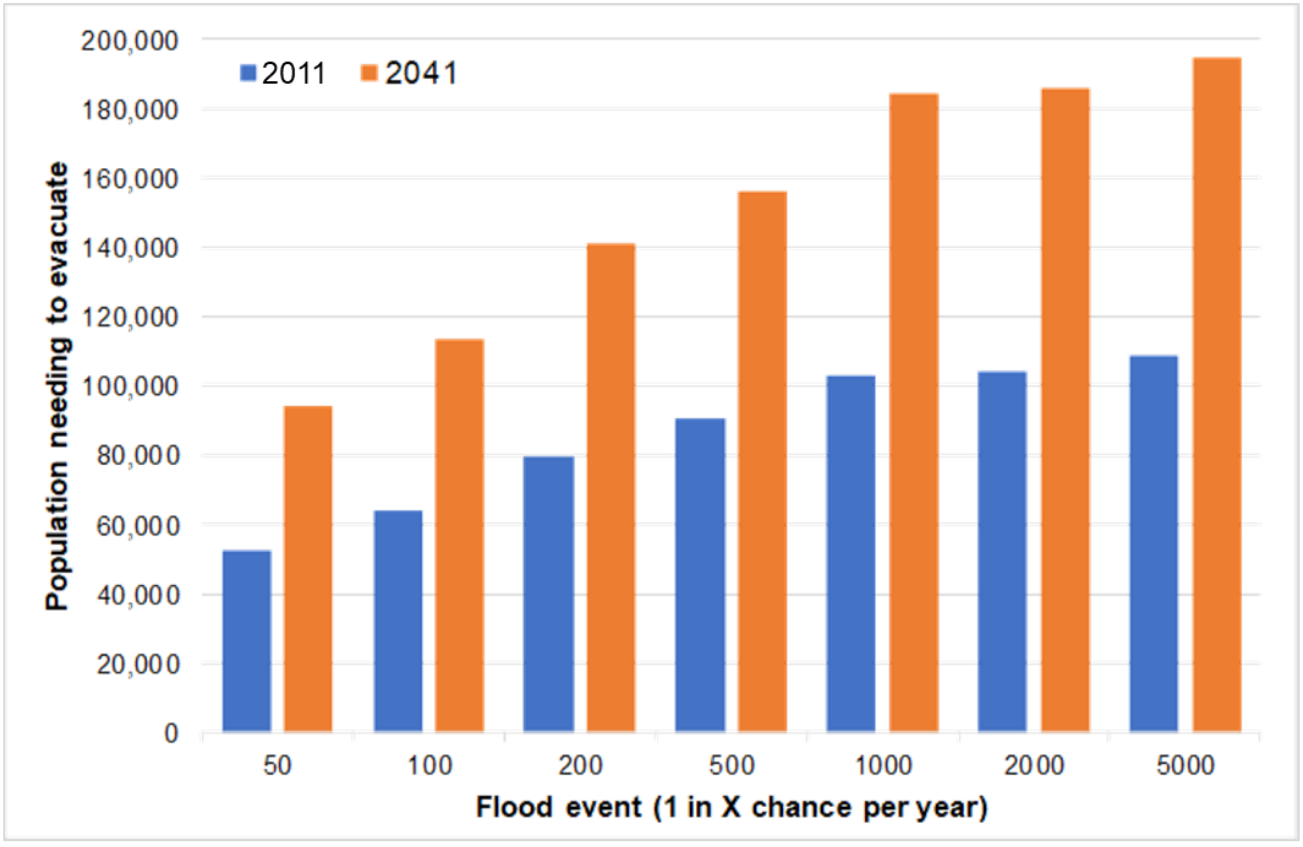
16.3 Existing environment

This assessment considered populations and communities within the construction footprint and the probable maximum flood (PMF) extents of the upstream and downstream study area. The PMF extent for the raised dam for the upstream study area is entirely within the Warragamba Dam Protected and Special Areas (described in Chapter 20 – Protected and sensitive lands), where access is restricted. There is no permanent population within the upstream study area.

16.3.1 Population and flood risk

The socio-economic profile of the study area (upstream, downstream, and construction) is described in detail in Chapter 21 (Socio economic land use and property). The current and projected numbers of people directly affected by flooding and who would need to evacuate are shown on Figure 16-1. Approximately 64,000 people would need to evacuate in a 1 in 100 chance in a year flood event, which would increase to approximately 90,000 people in a 1 in 500 chance in a year flood event. The number of people needing to evacuate would increase significantly by 2041, with approximately 158,000 to 171,000 people needing to evacuate in a 1 in 500 chance in a year flood event, depending on the level of growth (Infrastructure NSW (INSW) 2017).

Figure 16-1. Number of people needing to evacuate for 2011 and 2041 population scenarios, current Warragamba Dam



16.3.2 Critical social infrastructure and sensitive receptors

Potential health and safety impacts were considered for sensitive receptors within the maximum extent of the PMF. These include emergency services, hospitals, child care facilities, schools, and aged care homes/facilities, which are detailed in Table 16-3 and shown in Figure 16-2. All critical social infrastructure is in the downstream study area.

Table 16-3. Critical social infrastructure - downstream catchment (PMF extent)

CSI type	Name	Suburb
Airport	RAAF Base Richmond	Richmond
Emergency services	Richmond Ambulance Station	Richmond
Emergency services	Penrith Ambulance Station	Penrith
Child care centre	Hobartville Day Care Pre-School	Hobartville
Child care centre	My First School Childcare Centre	St Mary's
Education facility	Australian Christian College	Marsden Park
Education facility	Arndell Anglican College	Oakville
Education facility	Wollemi College	Werrington
Aged care	Mountainview Nursing Home	Penrith
Aged care	Chesalon Care Nursing Home	Richmond
Aged care	Richmond Community and RSL Nursing Home	Richmond
Aged care	Summitcare Nursing Home	Penrith
Aged care	Fitzgerald Memorial Aged Care	Windsor
Aged care	Summitcare Nursing Home	St Mary's
Filtration plant	Quakers Hill Water Pollution Plant	Quakers Hill
Emergency services	Regentville Fire Station	Regentville
Emergency services	Richmond Fire Station	Richmond
Emergency services	Riverstone Fire Station	Riverstone
Emergency services	Windsor Fire Station	Windsor
Emergency services	Llandilo Rural Fire Brigade	Llandilo
Emergency services	Wallacia Rural Fire Brigade	Wallacia
Emergency services	Upper Colo Rural Fire Brigade	Upper Colo
Emergency services	Bar Point Rural Fire Brigade	Bar Point
Emergency services	Sackville North Rural Fire Brigade	Sackville North
Emergency services	Lower Macdonald Rural Fire Brigade	Lower Macdonald
Emergency services	Londonderry Rural Fire Brigade	Londonderry
Emergency services	Berowra Waters Rural Fire Brigade	Berowra Waters
Emergency services	Lower Portland-Hawkesbury Rural Fire Brigade	Lower Portland
Emergency services	Hawkesbury Rural Fire Brigade	Blight Park
Emergency services	Schofields Rural Fire Brigade	Schofields
Emergency services	Wisemans Ferry Rural Fire Brigade	Wisemans Ferry
Emergency services	Spencer Rural Fire Brigade	Spencer

CSI type	Name	Suburb
Emergency services	Wendoree Park Rural Fire Brigade	Wendoree Park
Correctional centre	Emu Plains Correctional Centre	Emu Plains
Correctional centre	Emu Plains Juvenile Justice Centre	Emu Plains
Health care facility	RAAF Hospital	Richmond
Health care facility	Hawkesbury District Health Services	Windsor
Education facility	Richmond High School	Richmond
Education facility	Windsor High School	Windsor
Education facility	McCarthy Catholic College	Emu Plains
Education facility	Nepean Creative and Performing Arts High School	Nepean
Education facility	Bede Polding College	Windsor
Health care facility	Penrith Community Health Centre	Penrith
Aged care	Boronia House Aged Care	North St Mary's
Aged care	Uniting Edinglassie Village Nursing Home	Emu Plains
Emergency services	Riverstone Police Station	Riverstone
Emergency services	Windsor Police Station	Windsor
Education facility	St Mary's Public School	St Mary's
Education facility	Maraylya Public School	Maraylya
Education facility	Oakville Public School	Oakville
Education facility	Pitt Town Public School	Pitt Town
Education facility	Cattai Public School	Cattai
Education facility	Our Lady of the Way Public School	Emu Plains
Education facility	Emu Plains Public School	Emu plains
Education facility	Hobartville Public School	Hobartville
Education facility	Richmond North Public School	Richmond North
Education facility	St Monica's Primary School	St Monica's
Education facility	Richmond Public School	Richmond
Education facility	Vineyard Public School	Vineyard
Education facility	Windsor Park Public School	Windsor Park
Education facility	Bligh Park Public School	Blight Park
Education facility	Londonderry Public School	Londonderry
Education facility	St Matthew's Primary School	St Matthew's
Education facility	Windsor Public School	Windsor
Education facility	Windsor South Public School	South Windsor
Education facility	Chisholm Catholic primary School	South Windsor
Education facility	Richard Johnson Anglican School	Marsden Park
Education facility	Wallacia Public School	Wallacia

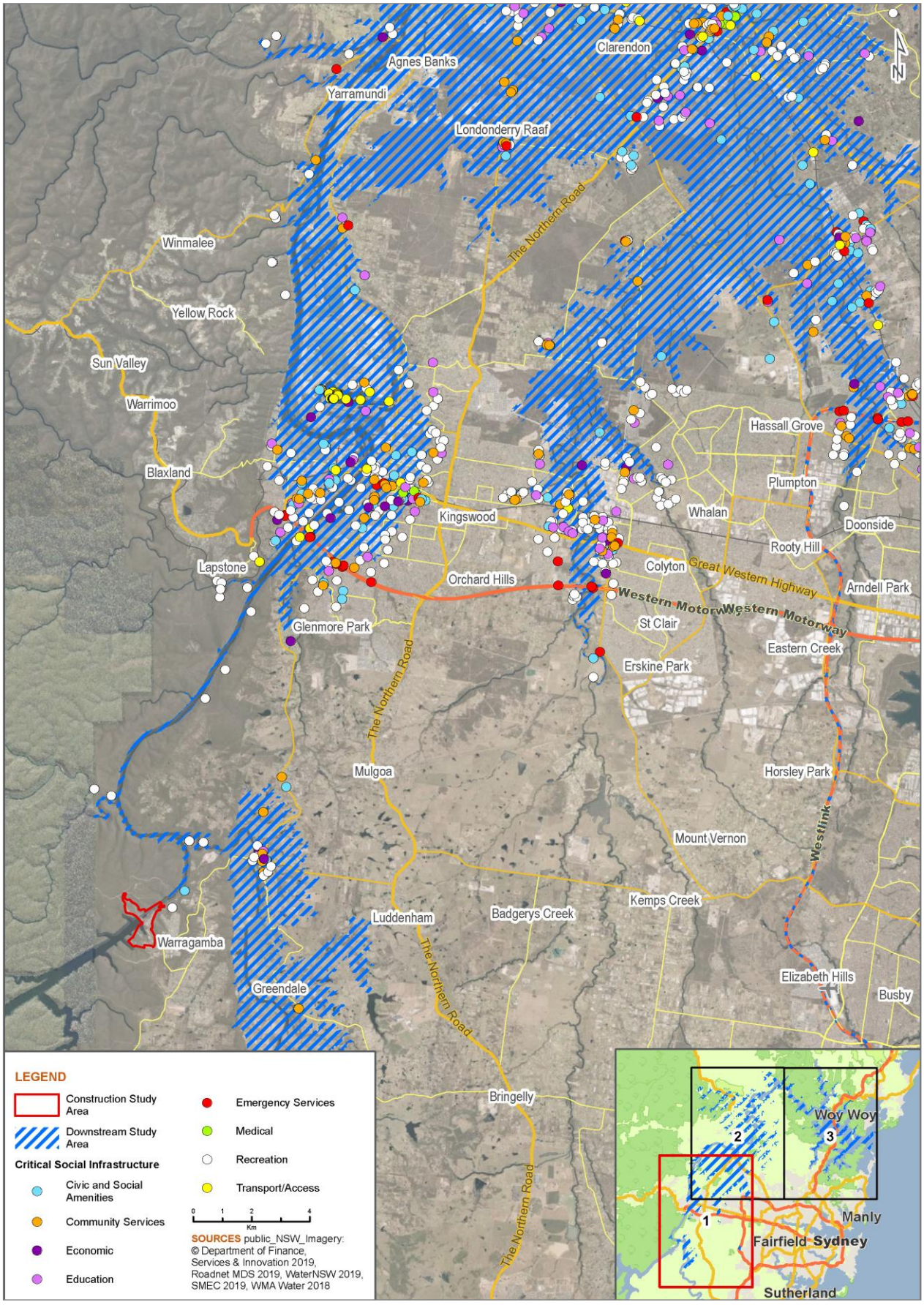
CSI type	Name	Suburb
Railway station	East Richmond Railway Station	East Richmond
Railway station	Richmond Railway Station	Richmond
Railway station	Riverstone Railway Station	Riverstone
Railway station	Werrington Railway Station	Werrington
Railway station	Penrith Railway Station	Penrith
Railway station	Emu Plains Railway Station	Emu Plains
Railway station	Mulgrave Railway Station	Mulgrave
Railway station	Clarendon Railway Station	Clarendon
Railway station	Windsor Railway Station	Windsor
Aged care	Norman Court Retirement Village	Richmond
Aged care	Hawkesbury Village Retirement Village	Richmond
Aged care	Windsor Country Retirement Village	Windsor
Aged care	Regal Oaks Retirement Village	Wallacia
Emergency services	Hawkesbury River SES	Wilberforce
Wastewater treatment	North Richmond Sewage Treatment Plant	North Richmond
Education facility	Aspect Western Sydney School	Richmond
Education facility	Casuarina School	Casuarina
Education facility	Kurrumbee School	Werrington
Education facility	Penrith Valley School	Penrith Valley
Education facility	Eagle Arts and Vocational College	Bligh Park
Education facility	Richmond TAFE College	Richmond
Education facility	Nirimba TAFE College	Schofields
Education facility	Nepean TAFE College	Penrith
Transmission station	International Radio Transmitting Station	Orchard Hills
Transport interchange	Richmond Bus Interchange	Richmond
Transport interchange	Penrith Bus Interchange	Penrith
Transport interchange	Windsor Bus Interchange	Windsor
Education facility	University of Western Sydney	Richmond

A summary of the critical social infrastructure by type within the downstream study area is provided in Table 16-4.

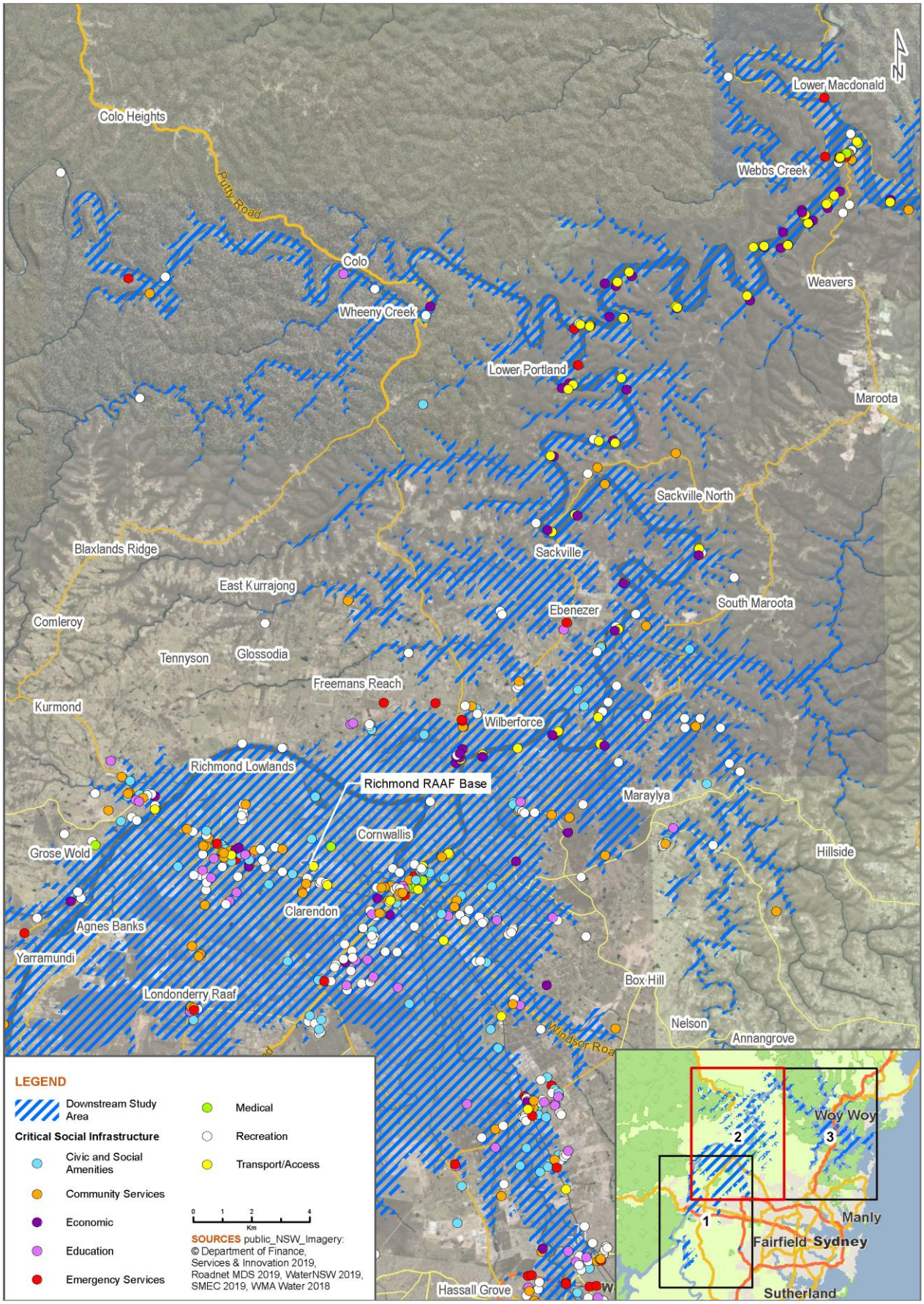
Table 16-4. Summary of critical social infrastructure by type

Receptor Type	Number
Aged Care	12
Airport	1
Child Care Centre	2
Correctional Facility	2
Education Facility – Primary/Public School, High School, TAFE, University	39
Emergency Services – Police, Ambulance, Fire Station, Rural Fire Station, SES	23
Water Filtration Plant	1
Health Care Facility	3
Railway Station	9
Transmission Infrastructure	1
Transport Interchange	3
Wastewater Treatment	1

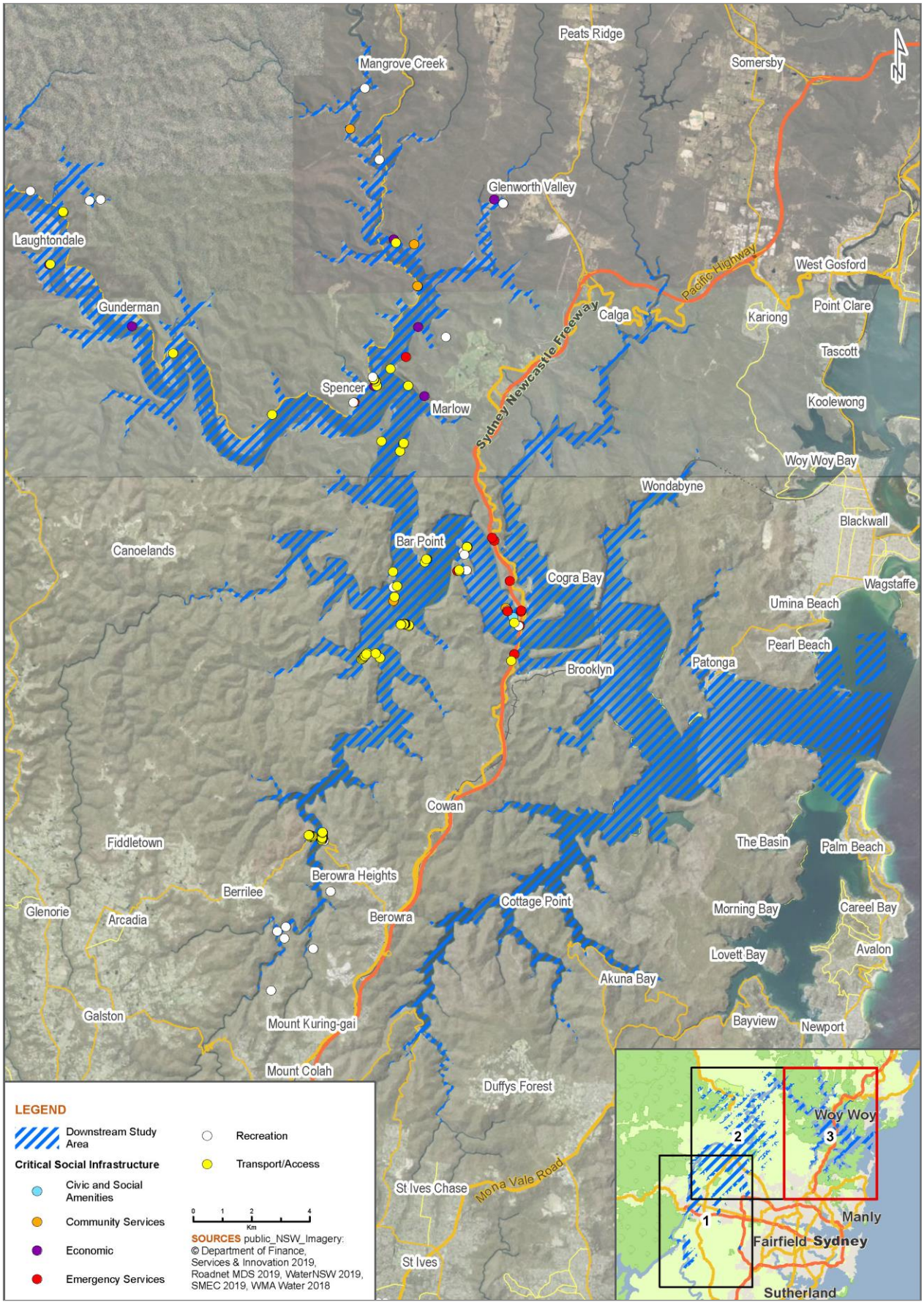
Figure 16-2. Critical social infrastructure within the downstream study area (1 of 3)



Critical social infrastructure within the downstream study area (2 of 3)



Critical social infrastructure within the downstream study area (3 of 3)



16.3.3 Health of existing downstream population

Community health is influenced by several interacting factors, including age, socio-economic status, social networks, genetic predisposition, country of origin, lifestyle, and access to health and social care. The study area overlaps several local health districts and local government area health statistics have been referenced in this assessment. The Penrith LGA has the largest extent overlapping the study area, and therefore this LGA is discussed in more detail.

As the objective of the Project is to reduce flood risk to communities in the downstream catchment, additional (to the current situation) negative impacts on population health are not anticipated, therefore only a high-level summary of population health is provided.

16.3.3.1 Penrith LGA health profile

The Penrith LGA covers approximately 26 percent of the downstream study area, the largest extent of any LGA overlapping the downstream Project study area. The life expectancy at birth for a resident of the Penrith PGA increased from 80.8 to 82.6 years between 2005 and 2015, with females having a higher life expectancy (84.4 years in 2015) than males (80.0 years in 2015). Major indicators of population health in the LGA include:

- overweight and obesity
- mental health and suicide.

Vulnerable population groups include:

- Aboriginal and Torres Strait Islander
- infants and elderly
- culturally and linguistically diverse (CALD) communities
- lesbian, gay, bisexual, transgender, queer and intersex (LGBTQI) people.

In 2014-2015 it was estimated that 32.8 percent of Penrith LGA residents were overweight, and 37.1 percent of those were considered obese. Male residents were more likely to be overweight or obese than females. Critically, about 17.3 percent of children (2 to 17 years old) in the Penrith LGA were overweight and 8.6 percent obese. Both the overall population and child-related overweight and obese figures are higher than the State average (Penrith City Council 2018).

Mental health and physical health are strongly linked, particularly chronic lifestyle diseases such as being overweight and obesity, which can lead to an increased risk of developing mental health problems. In 2014-2015, an estimated 13.6 percent of residents of the Penrith LGA aged 18 years and over had a high or very high psychological distress. A key indicator of poor mental health is intentional self-harm hospitalisations, and in 2014-2016 the rate of these hospitalisations in the Penrith PGA was 141.6 per 100,000. This is higher than the State average of 135.2 per 100,000. Although these figures are high, annual figures have decreased since 2006 (Penrith City Council 2018).

The Aboriginal and Torres Strait Islander view of health encompasses social, emotional, spiritual and cultural wellbeing, and that of the community. Aboriginal and Torres Strait Islander population health statistics are only available for the broader region, which includes Penrith, Hawkesbury, Blue Mountains and Lithgow LGAs. For this region, in 2016-2017 the hospitalisation rate for Aboriginal and Torres Strait Islanders was 46,277 per 100,000, up from 21,910 per 100,000 in 2006-2007. This 2016-2017 rate is higher than that for non-Aboriginal people during this timeframe, which was 32,810 per 100,000. Of these, the rate of hospitalisation of Aboriginal and Torres Strait Islander for dialysis in the region was 3.3 times higher than the non-Aboriginal population, and 1.95 times higher for potentially preventable hospitalisations (for conditions that are vaccine-preventable, chronic or acute) (Penrith City Council 2018).

Life-expectancy for Aboriginal and Torres Strait Islander males (71.0 years) is 9.3 years lower than the non-Aboriginal population, and for females (76.4 years) 8.5 years lower than the non-Aboriginal population. The rate of obesity in Aboriginal and Torres Strait Islanders (32.2 percent) is 8.4 percent higher than for the non-Aboriginal population (23.8 percent). In 2015, 12.6 percent of babies born to Aboriginal mothers in the region had a low birth weight, compared to 7.5 percent for non-Aboriginal mothers. In 2014-2015, rates of psychological distress in Aboriginal and Torres Strait Islanders aged 18 and over were 2.4 times higher compared to the non-Aboriginal population. The prevalence of smoking in Aboriginal adults (37.0 percent) is 11.6 percent higher than in non-Aboriginal adults (25.4 percent) in the region, and the prevalence of high-risk alcohol consumption (46.0 percent) was 18.5 percent higher than the non-Aboriginal population (27.5 percent) of the region (Penrith City Council 2018).

There are some population groups within the community that are considered more vulnerable to poor health outcomes, often due to social determinants. These vulnerable groups can include younger and older age groups, CALD

communities, Aboriginal people (discussed above), and LGBTQI people. Data for these vulnerable groups is not consistently collected; however, some indicators for the region are provided.

Young people can be more vulnerable to poor mental health, generally indicated by rates of self-harm. In 2017, 10.9 percent of adolescents (12 to 17 years old) in the region had self-harmed, and 8.0 percent of these had also self-harmed in the previous 12 months. In 2015-2016 at the Penrith Headspace centre for mental health issues, 60.1 percent of clients were between 15 and 20 years old. Recent regional consultations suggest several issues for young people in the region including a lack of career mentoring and support, and more culturally appropriate services addressing early intervention, mental health and after-hours care (Penrith City Council 2018).

In 2014-2015 the rate of home care assistance for residents in the Penrith LGA was 56.7 per 1,000 people, which is higher than the Greater Sydney average of 54.7. Of these, 36.0 percent lived alone, 3.2 percent identified as indigenous, and 9.6 percent identified as CALD. Recent consultations suggest some health issues for older people including a lack of services and support for independent living, chronic pain management and end-of-life care (Penrith City Council 2018).

Issues for CALD communities include low literacy rates, low health literacy rates, alcohol and drug misuse, increasing levels of chronic disease, mental health issues such as anxiety and depression, under-immunisation, and lack of culturally appropriate mental health services and clinicians (Penrith City Council 2018).

One of the critical issues facing LGBTQI people living in the Penrith LGA region is mental health issues, and these people may not be receiving adequate support for mental illness, sometimes due to barriers to health service access including fear of discrimination or rejection (Penrith City Council 2018).

16.3.3.2 Nepean-Blue Mountains public health network

The Nepean-Blue Mountains public health network comprises Penrith, Blue Mountains, Hawkesbury and Lithgow LGAs. High-level population health information from this region gives an indication of the population health of the Hawkesbury LGA, which overlaps the downstream study area.

The major risk factors contributing to the development of chronic and preventable conditions and their prevalence in the region are smoking, high body mass, physical inactivity, high blood pressure and excessive alcohol consumption.

Life expectancy at birth of residents in the Hawkesbury-Blue Mountains region is 78.7 years for males and 83.3 years for females. In 2011, 15.3 percent of mothers smoked during pregnancy, and (not always related) 6.7 percent of babies were of low birth weight when born. Infant mortality in the region declined from 7.2 per 1,000 in 1992 to 2.3 per 1,000 in 2011; however, in 2016 infant mortality rate was at 3.2 per 1,000, slightly higher than the average for all local health districts, which is 2.7 per 1,000 births. In 2014-2015 child immunisation rates in children under 1 years old were below the national target (92 percent) for both Aboriginal (88.8 percent) and non-Aboriginal (91.2) populations; however, at age four immunisation rates were above the national target for both Aboriginal (94.8) and non-Aboriginal (94 percent) populations (Wentworth Healthcare 2017).

In 2013, about one in every three (33.3 percent) youths (15 to 24 years old) were overweight or obese; one in every three youths consumed alcohol at risky levels; more than three in every 20 youths smoked tobacco; males comprised seven in every ten youth deaths, and; almost one in every four youths (or 24 percent) had a mental health disorder (Wentworth Healthcare 2017).

General trends in adult (aged over 16 years) health for the region include:

- the leading causes of death (2016) were:
  - malignant neoplasms (tumours): 346 per 100,000 population
  - circulatory diseases: 324 per 100,000 population
  - respiratory diseases: 134 per 100,000 population
  - injury and poisoning: 108 per 100,000 population
  - other causes of death: 298 per 100,000
- the major risk factors for health within the region (2011-2012) were identified as:
  - high body mass: 59.8 percent
  - physical inactivity: 46.1 percent
  - high alcohol use: 29.6 percent
  - high blood pressure: 29.0 percent
  - tobacco use: 21.6 percent

- in 2012 life expectancy for Aboriginal males (70.5 years) was almost 10 years less that non-Aboriginal males (80.4 years), and 74.6 years for Aboriginal females compared to 83.1 years for non-Aboriginal females.

16.3.3.3 Western Sydney Local Health District

The Western Sydney Local Health District (WSLHD) encompasses two LGAs that overlap the downstream study area – Blacktown (17.68 percent overlap) and The Hills Shire (11.12 percent overlap). The community health profile of the WSLHD includes:

- a significantly higher proportion (48.0 percent) of babies born to mothers from CALD communities compared to the NSW average (26.0 percent)
- infant mortality in 2016 was reported at 3.2 per 1,000 births, compared to the NSW average of 2.7 per 1,000 births
- the health status of children in the WSLHD is comparable to their NSW counterparts
- in 2016, life expectancy at birth for males was 81.8 years and for females 85.2 years
- in 2018, immunisation rate for Aboriginal children aged 1 year was 94.2 percent, and for non-Aboriginal children aged 1 year was 92.9
- in 2017, 31.0 percent of adults were considered overweight, and 20.8 percent were considered obese.

16.3.4 Existing flood risk

Flooding is discussed in detail in Chapter 15 (Flooding and hydrology). Flood risk is a combination of the likelihood of occurrence of a flood event and the consequences of that event when it occurs. The Hawkesbury-Nepean Valley faces serious ongoing flood risk due largely to the unique natural characteristics of the valley, which can lead to a significant extent and depth of flooding over urban areas. The area downstream of Warragamba Dam supports several major population centres and there is significant pressure for further development.

The Hawkesbury-Nepean catchment is one of the largest coastal basins in NSW covering an area of some 21,400 square kilometres. Floodwaters flowing into the Hawkesbury-Nepean Valley come from several different river catchments. Warragamba Dam controls approximately 40 percent of the total area of the Hawkesbury-Nepean River catchment and about 70 percent of the catchment upstream of the start of the Sackville gorges. There are five other major dams in the catchment upstream of Sackville: four on the headwaters of the Nepean River and one near the head of the Wingecarribee River. The total area controlled by these and other dams are a small proportion of the total catchment and have minimal impact on floods.

The largest contributor to flood flows is the Warragamba catchment, which represents 80 percent of the total Hawkesbury-Nepean catchment at Penrith and 70 percent of the total catchment at Windsor. The Nepean catchment at its junction with the Warragamba is 20 percent of the size of the Warragamba catchment; however, the Nepean River drains a region of high rainfall along the top of the Illawarra Escarpment, and its contribution to downstream flooding is usually greater than a portion of catchment area might suggest. During significant rainfall events, substantial flows from the Warragamba catchment into the Nepean River results in existing upstream flows in the river to back up and cause localised flooding in the floodplain at Wallacia. Further inflows come from the Grose River, South Creek and other smaller tributaries. While floods can occur without contribution from the Warragamba catchment, most significant floods (above the 1 in 100 chance in a year flood event) include significant floodwater inflows from the Warragamba River catchment. However, each flood event is unique due to the timing of rainfall across the Hawkesbury-Nepean Valley catchment.

Downstream of the junction with the Warragamba River, the Nepean River continues to flow through a narrow gorge until it emerges into a more open floodplain upstream from Penrith. The elevation of the floodplain near Penrith, including Emu Plains and the Penrith Lakes Scheme, is high and does not convey floodwaters until floods almost reach the magnitude of 1 in 100 chance in a year event. Once water starts flowing over the floodplain, they are partially restricted from flowing downstream by the Castlereagh Gorge, upstream of the junction of the Grose River.

The Richmond/Windsor lowlands are below the Grose River junction. These floodplains are inundated by minor (1 in 5 chance in a year event) and moderate (1 in 20 chance in a year event) flooding. The main towns in the area, Richmond and Windsor, are mostly elevated above the level of inundation of smaller floods but are significantly affected by moderate sized floods.

The Sackville Gorge at Sackville presents a significant constriction to flood flow, causing backwater flooding of the Windsor and Richmond area and restricting drainage of the floodplains. This is characterised by a substantial

difference between the 1 in 100 chance in a year flood level and the PMF, which is significantly greater than for other coastal rivers in NSW.

Evacuating people from flood affected areas is the primary method of reducing the risk to life during a flood event, which is discussed in Chapter 15 (Flooding and hydrology). In the Hawkesbury-Nepean Valley, the NSW State Emergency Service (SES) 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. However, currently there is insufficient road capacity to safely evacuate the whole population in time, with multiple communities relying on common, constrained and congested road links as their means of evacuation.

The undulating topography of the Hawkesbury-Nepean Valley results in 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 such as a 1 in 100 chance in a year event.

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 floods such as the 1 in 100 chance in a year event. However, the SES requires more than 15 hours to evacuate some flood islands in the Hawkesbury-Nepean Valley during large flood events. This could force the SES to make evacuation orders based on uncertain flood predictions. 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.

Detailed planning for the evacuation of flood affected areas has been undertaken by the NSW Government and SES (NSW SES 2015, INSW 2017). Infrastructure NSW estimates that if a 1 in 100 chance in a year flood occurred today, more than 64,000 people would need to evacuate, and in a 1 in 500 chance in a year flood event occurred, more than 90,000 people would need to evacuate (INSW 2017). By 2041, for a 1 in 500 chance in a year flood event between 158,000 and 171,000 people would need to evacuate.

Further detailed analysis of flood risk is provided in Chapter 15 (Flooding and hydrology) and Chapter 24 (Traffic and transport).

16.4 Assessment of potential construction impacts

Construction to raise Warragamba Dam may involve activities that could increase risk to human health for receptors in the study area. These impacts relate to noise and vibration, air quality, hazardous materials use and storage, blasting and public safety.

16.4.1 Health impact assessment

Table 16-5 presents the health impact assessment for the construction phase of the Project.

Table 16-5. Health impact assessment – construction

Category	Assessment
Noise and Vibration	Chapter 19 (Noise and vibration) discusses the existing noise and vibration environment within the study area, as well as potential impacts that may result from activities undertaken during construction and operation of the Project. These impacts are restricted to the construction study area. The noise and vibration impact assessment found that noise impacts on sensitive receptors during standard working hours, from activities during both the site establishment and main construction stages are not predicted to exceed the highly noise effected noise criterion of 75 dB(A) at any receiver for any of the construction scenarios modelled. Certain construction work activities that may need to be undertaken out of standard work hours would potentially result in exceedances of noise management levels and could potentially lead to sleep disturbance impacts at receptors close to construction works. The addition of construction traffic did not result in a noise level increase greater than 2 dB(A), which is not considered significant. The noise and vibration impact assessment found that the main activities associated with operation of the Project are not expected to change noise and vibration from current levels. Potential health impacts relating to noise and vibration during Project construction relate to noise levels from some out-of-hours construction activities that may result in sleep disturbance. The

Category	Assessment
	potential area of impact is restricted to sensitive receptors within the construction study area, limited to within three kilometres from the construction zone. These impacts are likely to be temporary, short-term and would be minimised through the implementation of safeguards and management measures as discussed in Chapter 19 (Noise and vibration) and Chapter 29 (EIS synthesis, Project justification and conclusion). Blasting would be carried out at times during the construction period to remove rock at the toe of the dam and on the left abutment. Blasts would be planned to meet the required blast limits and would only be undertaken between 9 am and 5 pm to reduce adverse noise and vibration impacts for nearby sensitive receptors. Blasting would need to be controlled to meet ANZEC Guideline overpressure and ground vibration limits, and WaterNSW dam infrastructure ground vibration limits.
Air quality	Chapter 7 (Air quality) discusses the existing air quality within the study area, as well as potential impacts that may result from activities undertaken during construction and operation of the Project. The main potential impact of the Project on air quality relates to emissions (mainly dust) during construction. Emissions would comprise potential increased concentrations of particulate matter (TSP, PM_{10} and $PM_{2.5}$) occurring due to site establishment works and construction stages. Minor increases in vehicle emissions (carbon monoxide(CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2)) may also occur due to increased construction traffic. Dispersion modelling predicted minor increases in both the 24-hour and annual average concentrations of TSP, PM_{10} and $PM_{2.5}$; however, the magnitude of these increases was determined to be low and unlikely to result in measurable differences in air quality or exceedances of the EPA air quality assessment criteria at the nearest receptors. The air quality impact assessment found that main activities associated with operation of the Project are not expected to change the air quality from current levels. Potential health impacts relating to air quality relate to an increase in dust and particulate matter (TSP, $PM_{2.5}$. PM_{10}) emissions during Project construction. Potential impacts to air quality during the construction stage were assessed using a qualitative assessment approach, including dispersion modelling. Although this modelling showed the potential for a minor increase in both the 24-hour and annual average particulate matter concentrations, these were unlikely to result in measurable differences in air quality or exceedances of the EPA air quality assessment criteria at the nearest receptors. This risk would be further reduced with the implementation of industry standard safeguards and management measures, which would be detailed in the Construction environmental management plan (CEMP).
Food	There would be no increase to flood extents from current levels during the construction phase of the Project. Therefore, no additional impacts to the production, quality, or price of foods are anticipated.
Water (excluding wastewater)	There would be no increase to flood extents from current levels during the construction phase of the Project. Therefore, no additional impacts to surface, ground water, recreational or drinking water are anticipated. Potential impacts to water resources and mitigation measures to minimise these are detailed further in: ▪ Chapter 22 (Soils) ▪ Chapter 27 (Water quality).
Wastewater	There would be no increase to flood extents from current levels during the construction phase of the Project. Therefore, no additional impacts to wastewater disposal or treatment are expected.
Storage, handling and disposal of	The volume of dangerous goods stored at the construction site would be low. Goods would be stored in bunded areas to contain any spills should they eventuate. Relevant materials would be stored in accordance with the Australian Dangerous Goods Code that mandates the use of bunding, ventilation of areas where gases or substances that may produce

Category	Assessment
hazardous materials	gases are stored, locating stores of dangerous materials away from sensitive receptors, and maintaining a register of dangerous goods storage and use.
Built environment	There would be no increase to flood extents from current levels during the construction phase of the Project. Therefore, no additional impacts to the built environment are expected.
Infrastructure and services	There would be no increase to flood extents from current levels during the construction phase of the Project. Therefore, no additional impacts to infrastructure and services are expected.
Transport	There would be no increase to flood extents from current levels during the construction phase of the Project. Therefore, no additional impacts to transport are expected.
Socio-economic determinants	Chapter 21 (Socio-economic, land use and property) discusses the existing socio-economic environment within the study area, as well as potential impacts that may result from activities undertaken during construction and operation of the Project. Project construction may impact on the local community due to adverse traffic, noise, air and water impacts, which are summarised above. Other socio-economic impacts relate to temporary community anxiety and pressure on community due to the influx of workers during construction and potential changes to flood extents. However, potential impacts are not expected to be significant, as it is expected that there would be minimal interactions between workers and local communities, and there will be an overall positive benefit to downstream flooding.

16.4.2 Flood risk

Construction areas would be directly exposed to dam spills and flooding resulting in potential impacts to worker safety, construction works and scheduling, plant and equipment, erosion and sedimentation, and water quality. Debris may potentially wash downstream causing environmental and safety impacts.

Preliminary flood management options for construction have been developed and include:

- *Temporarily lowering the full supply level of the storage by up to five metres*: This would provide about 20 percent of the existing dam capacity for flood mitigation which would protect construction works up to the 1 in 20 chance in a year rain event and allow sufficient time to move plant and equipment and secure the construction area. A similar level of flood mitigation would be provided to downstream flood prone areas.
- *Coffer dams*: Protective coffer dams would be constructed upstream of the auxiliary spillway works and downstream of the dam wall works.
- *Temporary spillway gates*: These would be used during the construction of the new central spillway.
- *Construction staging*: Construction of the central and auxiliary spillway works would be staged to ensure that one spillway is always able to pass floodwaters.

A construction management plan will be developed as part of construction planning, which is discussed in Chapter 29 (EIS synthesis, Project justification and conclusion). Development of the plan would include further investigation of the above options, and which also include appropriate risk assessments to address the safety of construction personnel and the general public.

Temporary operating rules would be implemented in consultation with the SES, the Bureau of Meteorology, and relevant Councils, to manage flood risk in accordance with the requirements of Dams Safety NSW.

The design and construction would be undertaken in accordance with a flood management strategy, which would include the sequencing of construction events to ensure that the risk to public is not increased during construction. Construction sequencing would be planned to ensure that flooding cannot cause dam overtopping and failure due to the need to reduce the spillway capacity at times during construction.

Existing downstream flows would be maintained by diverting water around the dam construction site.

16.4.3 Workforce and public safety

Potential workforce or public safety hazards and risks during Project construction are outlined in Table 16-6.

Table 16-6. Construction related public safety hazards and risks

Public safety hazard	Public safety risk profile
Health risks associated with exposure to environmental hazards	Potential noise and vibration, and air quality impacts are discussed in Table 16-5. Other risks to public health include exposure to hazardous materials used during construction, or potentially contaminated materials disturbed during construction activities, construction vehicle movements, and blasting activities. These are discussed below.
Compromise of dam integrity during construction leading to flooding	Some activities could compromise the integrity of the dam during construction. These include blasting and flooding. Measures to reduce downstream flood risk during construction are discussed in Section 16.4.2. Blasting would be planned to ensure that ANZECC Guideline overpressure and ground vibration limits, and Water NSW dam infrastructure ground vibration limits would be achieved, thus reducing the risk of critical infrastructure damage.
Ground contamination	Chapter 22 (Soils) details the present known or assumed Project contamination risks. Several sites within the construction area were identified as potentially contaminated. Only one area within the construction footprint was identified as potentially contaminated. Acid sulfate soil risk mapping indicates that the proposed construction area for the dam and associated laydown areas that surround it are not located within or near areas mapped with acid sulfate soil risks. Due to the relatively high elevation of the area it is considered that acid sulfate soils would not be disturbed as part of the work and therefore not impacted.
Transportation of dangerous goods	Traffic is addressed in Chapter 24 (Traffic and transport). The volume and frequency of transport of dangerous goods would be low. Transport of dangerous goods would be via vehicles that are suitable to transport respective materials, with procedures to manage accidental leaks and spills.
Bushfire risk, or risk of fires that may spread off-site and affect nearby receptors	The construction area is adjacent to bush fire prone land. A total of 22.5 hectares of native vegetation will be cleared prior to construction, which will provide a cleared buffer to adjoining bush areas. However, some construction activities such as welding and metal work are potential bushfire ignition sources, and fire management procedures will be implemented throughout the construction phase.
Increased construction vehicle traffic on local roads	Construction traffic volumes are low compared to existing traffic volumes, and as such impacts to road safety are expected to be minor.
Subsidence	Project construction activities are not being undertaken in a high-risk subsidence zone. Construction activities are not anticipated to increase subsidence risk.
Construction workforce	Safety risks to the construction workforce include: ▪ working at heights ▪ working near construction vehicles ▪ working on or near water ▪ blasting ▪ management of hazardous materials ▪ general construction activities. Safety systems would be implemented in accordance with the WHS Regulation 2017, and other relevant legislation.
Impacts on the level of physical activity and access to social infrastructure	The Project is not anticipated to impact the level of physical activity or access to social infrastructure. This is considered in detail in Chapter 21 (Socio-economic, land use and property).

16.5 Assessment of potential operational impacts

The downstream flood risk was a key driver of the *Hawkesbury-Nepean Flood Management Review* (Department of Primary Industries (DPI) 2014s), culminating in the *Hawkesbury-Nepean Valley Flood Risk Management Strategy* (INSW 2017). The Hawkesbury-Nepean Valley Flood Risk Management Strategy provided 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. One of the key outcomes of the strategy was to reduce flood risk in the valley by raising Warragamba Dam to create an FMZ. This is discussed further in Chapter 3 (Strategic justification and project need).

As part of the assessment, the Hawkesbury-Nepean Valley Flood Management Taskforce commissioned the assessment of current and future flood risk in terms of flood damages and risk to life, including factoring in climate change (WMAwater 2018a). The primary objective of the Project is to reduce flood risk to populations within the floodplains of the Hawkesbury-Nepean Valley, which is outlined in Section 16.3. As such, the operation of the Project would:

- result in positive changes to the community through reduction of flood risk
- would benefit all sectors of the community
- reduce flood liability in the valley
- reduce visual impacts which may impart social impacts through visual design and landscaping.

Once operational, there are no anticipated adverse effects from the Project relating to air quality, noise and vibration, or hazardous materials impacts to the public. Public safety would be increased by the implementation of the FMZ, which would allow dam operators to store inflows temporarily, and release them in a more controlled manner (than the present arrangement).

Implementation of the FMZ would reduce the downstream extent of floodwaters for all modelled flood events. This in turn would provide physical and mental health improvements by minimising the percentage of the population subject to potential flooding. Additionally, this would reduce the number of people needing to be evacuated by emergency services, and where people are unable, or do not evacuate, the number of people needing to be rescued. The temporary capture of inflows in the FMZ prior to major downstream flooding would also increase the time for the onset of major flooding downstream and in turn provide additional time for implementation of responses to flooding and for evacuations.

Releases from the FMZ would increase the duration of flood events for some low-lying areas of the floodplain, which translates to a longer duration of impact. These areas are around the 1 in 2 chance in a year flood level, with the areas subject to prolonged flooding having no dwellings and being mainly environmental or recreational areas, or farm lands.

Table 16-7 presents the health impact assessment relevant to the operation of the FMZ.

Table 16-7. Health impact assessment – operation of the FMZ

Category	Assessment
Noise and vibration	Based on the background noise monitoring, dam noise emissions were not identified as an audible noise source at any of the monitoring locations. Refer to Chapter 19 (Noise and vibration) for further details.
Air quality	Operation of the FMZ would not present any health risks related to air quality.
Food	Operation of the FMZ would decrease flood extents within the downstream study area, in turn providing benefits to food production and related matters such as quality and price.
Water (excluding wastewater)	The Project would reduce the heights of downstream flood peaks and the extent of downstream flooding. Operation of the FMZ would result in an increased period of elevated water levels for up to about the 1 in 2 chance in a year event with flows largely within the river channel except for low lying areas around Richmond and Pitt Town. The Project would not result in any changes in water quality in the dam during normal operations as there would be no change in the full supply level (FSL) or how the dam is operated currently.

Category	Assessment
	The water quality of dam spills when the Project is operational is not envisaged to change from the existing dam spill events and therefore has not been assessed in detail for this EIS. The impact of the Project on the quantity and quality has been shown to be minimal. Refer to Chapter 27 (Water quality) for further details.
Wastewater	Operation of the FMZ would decrease flood extents within the downstream study area and would provide a benefit through a reduced risk of inundation of wastewater treatment facilities such as effluent ponds that are currently affected by flooding.
Storage, handling and disposal of hazardous materials	The Project would provide a benefit through the reduced likelihood of downstream flooding affecting sources of hazardous materials that could be mobilised by flooding thereby presenting risk to human health and safety.
Built environment	Operation of the FMZ would decrease flood extents from current levels within the downstream study area. This would significantly minimise impacts to the built environment within the floodplain.
Infrastructure and services	Operation of the FMZ would decrease flood extents from current levels within the downstream study area. This would significantly minimise impacts to infrastructure and services within the floodplain.
Transport	Operation of the FMZ would decrease flood extents from current levels within the downstream study area. This would significantly minimise impacts to transport infrastructure and services within the floodplain. This is addressed in Chapter 24 (Traffic and transport).
Socio-economic determinants	Socio-economic impacts and benefits are addressed in Chapter 21 (Socio-economic, land use and property).

16.6 Environmental management measures

Safeguards and management measures to minimise adverse human health and risk are detailed in Table 16-8, and in the relevant EIS chapters (see Table 16-10, Section 16.7). These are summarised in Chapter 29 (EIS synthesis, Project justification and conclusion).

The proponent would also assess the likely risks associated with the design, construction and operation of the dam, and where necessary apply mitigation measures to reduce risks as far as practicable. Relevant risks include:

- geology/geotechnical:
  - a comprehensive geotechnical investigation would be undertaken prior to finalising the design
  - during construction, all excavations forming part of the permanent works, would be geologically mapped, foundation levels recorded, features photographed and results of water tests and grouting recorded
  - these works would be undertaken by suitably qualified personnel.
- floods:
  - all data, assumptions, methodologies and outcomes of the hydrology study would be explicitly noted and documented
  - construction flood provisions would be nominated and allowed for in the design, and form the basis on which the risks are assessed to be tolerable
  - during construction, the objective would be that risks from flood during upgrading should be not greater than those existing; if this objective cannot be achieved, WaterNSW should demonstrate that the risks are as low as reasonably practicable
  - a flood frequency curve for the catchment and storage would be prepared and used to inform the design and construction sequencing
  - seasonality of flooding would be considered where appropriate
  - the design would consider all incremental surge impacts downstream, to minimise these impacts where people are at risk.
- foundation/abutments:

  - all exposed foundations and excavations would be logged by a suitably qualified engineering geologist
  - special care would be taken in the design of any interface between foundation rock and concrete to minimise the leakage risks along the interface
  - the design would consider the effectiveness of the uplift relief system and make provision for its accessibility and maintenance.
- concrete - special consideration should be given to the issue of durability. This would be addressed in the design report
- tendons and post-tensioning:
  - if included in the design, only re-stressable and monitorable post-tensioning tendons would be used.
  - tendons would be fully encapsulated in protective grout and there would be an impermeable barrier between the tendon and the rock foundation and one stage grouting of the cable length to maximise corrosion resistance.
- hydraulics - the design of erosion resistance for all discharge channels would make appropriate allowance for envisaged flow depths and velocities particularly where there may be sudden changes in channel cross-section or direction of flow
- mechanical and electrical - all mechanical and electrical systems essential for dam safety would have adequate back up provisions including back-up power sources
- gates and valves:
  - a procedure would be prepared for spillway gate opening practices
  - a risk assessment would be undertaken to inform the design of gated systems to determine the potential for gate control system failures
  - all emergency opening and closing devices would have protected access for all emergency conditions
  - the design of the outlet works would consider the adequacy for emergency dewatering.
- construction work:
  - experienced construction supervisors would be engaged
  - the designers would continue to be involved throughout construction
  - no changes would be made to the design without the approval of the designer and a record of all design changes would be kept
  - appropriate records of construction would be kept, and a *Construction certificate and construction report* would be submitted to Dams Safety NSW on completion of construction
  - *Work-as-executed* (WAE) drawings would be prepared and preserved.
- operations and maintenance:
  - the existing *Operation and maintenance (O&M) manual* for Warragamba Dam would be revised as required to include additional functions required as a result of the Project
  - procedures would be prepared for the training of all operations personnel
  - all systems would have formal incident reporting
  - the dam would have automatic and telemetered monitoring systems for storage level and seepage (where practicable)
  - provisions shall be made for chemical testing of seepage water where the foundations or dam materials are of a soluble or dispersive nature
  - planting of trees, or any vegetation that impairs surveillance of the dam would not be permitted.
- documentation:
  - all relevant design decisions would be recorded in a formal design report
  - specifications for the construction would be documented in a formal construction report, including work-as executed drawings, be prepared on completion of the works.

Table 16-8. Safeguards and management measures – health and safety

Impact	ID#	Environmental management measure	Timing	Responsible
Dam failure due to design	HS1	The Project will be designed to meet relevant State, national and international dam safety guidelines and in consultation with the Dams Safety NSW.	Design	WaterNSW
Safety risks during construction	HS2	A construction safety management plan will be prepared in consultation with relevant stakeholders and will address safety of the construction workforce and public during general construction, in the event of a flood and for other likely hazards or risks	Pre-construction Construction	WaterNSW Construction Contractor,
Risks from dangerous goods management	HS3	All dangerous goods and materials will be stored and handled on site in accordance with relevant Australian Standards	Construction	WaterNSW Construction Contractor,
Transportation of dangerous goods	HS4	Materials will be transported in accordance with the *Dangerous Goods (Road and Rail Transport) Act 2008* (NSW), Dangerous Goods (Road and Rail Transport) Regulation 2014 (NSW) and relevant Australian Standards.	Construction	WaterNSW Construction Contractor,
Compromise of dam integrity during construction	HS5	ANZEC Guideline overpressure and ground vibration limits, and Water NSW dam infrastructure ground vibration limits will be met for all blasting activities.	Construction	WaterNSW Construction Contractor,
Bushfire risk	HS6	Construction activities involving ignition or flammable sources, will be managed to minimise fire risks. High risk construction activities relating to bushfire, such as welding and metal work, would not be undertaken on total fire ban days, and would be managed as appropriate.	Construction	WaterNSW Construction Contractor,
Ground contamination	HS7	Ground contamination management measures are provided in Chapter 22 (Soils). These include requirements for additional surveys and a protocol for managing unexpected finds.	Construction	WaterNSW Construction Contractor,

16.7 Risk assessment

16.7.1 Risk assessment methodology

Assessments of health and safety risks were carried out in accordance with the SEARs. Risk assessments for most of the key issue impacts were undertaken using the methodology provided in Appendix C. A Project risk matrix was developed and risk ranking evaluated by considering:

- the likelihood (L) of an impact occurring
- the severity or consequence (C) of the impact in a biophysical and/or socio-economic context, with consideration of:
  - whether the impact will be in breach of regulatory or policy requirements
  - the sensitivity of receptors
  - duration of impact, that is, whether the impact is permanent or temporary
  - the areal extent of the impact and/or the magnitude of the impact on receptors.

The likelihood and consequence matrix is shown on Figure 16-3.

Once the consequence and likelihood of an impact are assessed, the risk matrix provides an associated ranking of risk significance: **Low**; **Medium**; **High** or **Extreme,** as shown in Table 16-9**.** The residual risk was determined after the application of proposed mitigation measures.

Table 16-9. Risk ranking definitions

Risk definitions	
Extreme 21 – 25	Widespread and diverse primary and secondary impacts with significant long-term effects on the environment, livelihood and quality of life. Those affected will have irreparable impacts on livelihoods and quality of life.
High 15 – 20	Significant resources and/or Project modification would be required to manage potential environmental damage. These risks can be accommodated in a project of this size, however comprehensive and effective monitoring measures would need to be employed such that Project activities are halted and/or appropriately moderated. Those impacted may be able to adapt to change and regain their livelihoods and quality of life with a degree of difficulty.
Medium 9 – 14	Risk is tolerable if mitigation measures are in place, however management procedures will need to ensure necessary actions are quickly taken in response to perceived or actual environmental damage. Those impacted will be able to adapt to changes.
Low 1 – 8	On-going monitoring is required however resources allocation and responses would have low priority compared to higher ranked risks. Those impacted will be able to adapt to change with relative ease.

Separate risk assessment methodologies were used to assess climate change and socio-economic impacts, which are described in the following assessment reports:

- Climate change assessment report (Appendix G)
- Socio-economic, land use and property assessment report (Appendix M)

Health and safety residual risks (Medium or higher) are summarised in Table 16-10. More detailed risk information has been extracted from the relevant EIS Chapters and presented in Table 16-11.

Table 16-10. Summary of residual health and safety risks

EIS Chapters	Health and safety – key issue impacts	Summary of key health and safety residual risks	
		Construction	Operation
Chapter 7	Air quality	**Medium**	
Chapter 14	Climate change risk	**Medium**	**High** (Downstream)
Chapter 15	Flooding and hydrology	**Medium**	**Medium** (Downstream)
Chapter 19	Noise and vibration	**Medium**	
Chapter 22	Soils	**Medium**	**Medium** (upstream); **High** (Downstream)
Chapter 24	Traffic and transport	**High**	**Medium** (downstream)
Chapter 21	Socio economic	Key issue impacts presented in relevant chapters.	

Figure 16-3. Risk matrix

		Consequence				
		Negligible	Minor	Medium	Major	Extreme
	LEGAL	No legal consequences	No legal consequences	Incident potentially causing breach of licence conditions	Breach of licence conditions	Breach of licence conditions resulting in shutdown of Project operations.
	SOCIO-ECONOMIC	Impacts that are practically indistinguishable from the social baseline, or consist of solely localised or temporary/short-term effects with no consequences on livelihoods and quality of life.	Short-term or temporary impacts with limited consequences on livelihoods and quality of life. Those affected will be able to adapt to the changes with relative ease and regain their pre-impact livelihoods and quality of life.	Primary and secondary impacts with moderate effects on livelihoods and quality of life. Will be able to adapt to the changes with some difficulty and regain their pre-impact livelihoods and quality of life.	Widespread and diverse primary and secondary impacts with significant long-term effects on livelihoods and quality of life. Those affected may be able to adapt to changes with a degree of difficulty and regain their pre-impact livelihoods and quality of life.	Widespread and diverse primary and secondary impacts with irreparable impacts on livelihoods and quality of life and no possibility to restore livelihoods.
	HEALTH	No health consequences	Accident or illness with little or no impact on ability to function. Medical treatment required is limited or unnecessary.	Accident or illness leading to mild to moderate functional impairment requiring medical treatment.	Accident or illness leading to permanent disability or requiring a high level of medical treatment or management.	Accident, serious illness or chronic exposure resulting in fatality.
	ENVIRONMENT	Localised (on-site), short-term impact on habitat, species or environmental media	Localised or widespread medium-term impact to habitat, species or environmental media	Localised degradation of sensitive habitat or widespread long-term impacts on habitat, species or environmental media. Possible contribution to cumulative impacts.	Widespread and long-term changes to sensitive habitat, species diversity or abundance or environmental media. Temporary loss of ecosystem function at landscape scale. Moderate contribution to cumulative impacts.	Loss of a nationally or internationally recognised threatened species or vegetation community. Permanent loss of ecosystem function on a landscape scale. Major contribution to cumulative effects
		A - negligible	**B** - minor	**C** - medium	**D** - major	**E** - extreme
Expected to occur during the Project or beyond the Project	**a** - expected	**13**	**14**	**20**	**24**	**25**
May occur during the Project or beyond the Project	**b** - may	**8**	**12**	**19**	**22**	**23**
Possible under exceptional circumstances	**c** - possible	**6**	**7**	**11**	**18**	**21**
Unlikely to occur during the Project	**d** - unlikely	**4**	**5**	**10**	**16**	**17**
Rare or previously unknown to occur	**e** - rare	**1**	**2**	**3**	**9**	**15**

Risk Definition (see Table 16-9)	**Low**	**Medium**	**High**	**Extreme**

Table 16-11. Risk assessment

1 Air quality health and safety risk assessment (Chapter 7)

Air quality								
Key impacts	Risk before mitigation			Mitigation and management	Risk after mitigation			Residual risk
	L	C	R		L	C	R	
Construction								
Air pollution emissions resulting in nuisance, licence breaches and health issues: *Site establishment works* ▪ land clearing ▪ stockpiling ▪ supporting infrastructure *Construction works* ▪ vehicle movements ▪ material movements and storage ▪ concrete batching	b	C	**19**	Chapter 7, AQ1, AQ2	c	C	**11**	High health and safety risk because predicted PM10 dust criterion may be exceeded at some residences, although this was expected to be a rare event. Mitigation including monitoring, dust suppression and construction staging reduces risk to a **Medium residual risk**.

2 Flooding and hydrology health and safety risk assessment (Chapter 15)

Flooding and hydrology								
Key impacts	Risk before mitigation			Mitigation and management	Risk after mitigation			Residual risk
	L	C	R		L	C	R	
Construction								
▪ construction areas would be directly exposed to dam spills and flooding resulting in potential impacts to worker safety, construction works and scheduling, plant and equipment, erosion and sedimentation, and water quality ▪ debris may potentially wash downstream causing environmental and safety impacts	b	D	22	Chapter 15, H1	d	C	11	Extreme risk due to flooding of the construction area and debris, and potential pollutants washing downstream. Mitigation including flood mitigation, construction staging and implementing potential hazard response protocols reduces risk to a **Medium residual risk**.
Operation: Downstream								
▪ discharges from the FMZ may result in environmental, social and economic impacts as water levels and velocities downstream of the dam would be higher for a longer period than the existing situation for lower level flood events.	a	C	20	Chapter 15, H2, H3, H4, H5, H6, H7	b	B	12	There is a High risk of safety impacts related to extended periods of inundation during emptying of the FMZ. Mitigation would see a FMZ operations manual established and emergency procedures updated along with increasing community awareness about dam operations and flooding characteristics Improving community preparedness would also reduce the adverse consequences, resulting in a **Medium residual risk**.

3 Noise and vibration health and safety risk assessment (Chapter 19)

Noise and vibration								
Key impacts	**Risk before mitigation**			**Chapter reference Mitigation and management**	**Risk after mitigation**			**Residual risk**
	L	**C**	**R**		**L**	**C**	**R**	
Construction								
Noise emissions resulting in nuisance, licence breaches and health issues: ▪ *Site establishment works* - land clearing - stockpiling - supporting infrastructure ▪ *Construction works* - vehicle movements - blasting - material movements and storage - concrete batching - general construction - out of hours work and sleep disturbance	b	C	**19**	Chapter 19, NV1, NV2, NV3, NV4, NV5, NV6, NV7, NV8	c	C	**11**	High risk due to construction work activities that may need to be undertaken out of standard work hours, which could potentially result in exceedances of noise management levels and lead to sleep disturbance impacts at receptors close to construction works. Mitigation including monitoring, construction staging and other management controls reduces risk to a **Medium residual risk**.

4 Soils health and safety risk assessment (Chapter 22)

Soils								
Key impacts	Risk before mitigation			Chapter reference Mitigation and management	Risk after mitigation			Residual risk
	L	C	R		L	C	R	
Construction								
Most construction works would occur on the existing wall, with some disturbance of adjacent areas required for ancillary works. Potential health and safety impacts relate to the presence of soil contamination.	b	C	**19**	Chapter 22, S1, S2, S3, S4, S5, S6, S7, S8, S9	b	B	**12**	High risk due to potential exposure to contaminated soil. Mitigation including undertaking additional surveys and implementing a protocol for managing unexpected finds reduces risk to a **Medium residual risk**.

5 Transport and traffic health and safety assessment (Chapter 24)

Transport and traffic								
Key impacts	Risk before mitigation			Chapter reference Mitigation and management	Risk after mitigation			Residual risk
	L	C	R		L	C	R	
Construction								
Traffic generation causing noise, dust, safety and road function impacts along access routes. ▪ Trucks: up to 208 trucks/day. Major transport activities include heavy vehicle transport of concrete production materials (concrete aggregate, fly ash and cement), and other construction materials. ▪ Cars: up to 250 cars/day. Workforce generated traffic.	b	E	23	Chapter 24, TT1, TT2, TT3, TT4, TT5, TT6, TT7, TT8, TT9, T10, TT11, TT12, TT13, TT14, TT16, TT17	d	E	17	Extreme risk due to the potential for accidents and potential fatalities. Mitigation including implementing detailed traffic management plans and contingency management plans for flood, fire and pavement failure, as well as ongoing community engagement reduces risk to a **High residual risk**.
Operation								
Low level bridges would experience longer times of closure during some flood events due to the emptying of the FMZ. This would result in longer travel times for some roads users.	b	C	19	Chapter 24, TT14	b	B	12	Bridge closures would happen infrequently and provided sufficient information and planning of alternative routes is provided to road users, any additional impacts should be minimal and reducing this to a **Medium residual risk.**

6 Climate change risk assessment (Chapter 14)

A risk assessment methodology and assessment is provided in Appendix G (Climate change assessment report) and summarised below. This risk assessment methodology was undertaken in accordance with relevant standards and guidelines including Australian Standard AS 5334-2013 (Climate Change Adaptation for Settlements and Infrastructure – A Risk-based Approach). Risk definitions are similar to those adopted for other key issue impacts presented in other EIS Chapters

Construction risk/impact	Risk before mitigation	Mitigation and management	Risk after mitigation	Residual risk
Risk definitions ▪ **Extreme**: these are priority risks that demand urgent attention and cannot be accepted as part of routine operations ▪ **High**: are the most severe risks that can be accepted as part of routine operations ▪ **Medium**: can be expected to form part of routine operations but should be assigned higher management priority ▪ **Low**: can be maintained under review but existing controls should be enough				
Construction				
Health and safety impacts related to: ▪ Increase in consecutive extended wet periods – flooding impact on works, timing, and construction staging ▪ Increase in consecutive extended wet periods – flooding or saturation of embankments and ground conditions ▪ Increased number of hot days/heatwaves – impact to construction staging/timing due to reduced workforce capacity ▪ Increased number of hot days/heatwaves – impact on times of day that concrete could be poured	**High**	Chapter 14, CC1, CC2, CC3, CC5, CC6	**Medium**	High risk due to extended wet periods and flooding of construction area, and increase in number of hot days and heatwaves. Mitigation including flood mitigation, construction staging and out of work hours reduces risk to a **Medium residual risk**.
Operation				
Downstream Increase in extreme flood producing rain would reduce downstream flood mitigation benefits, thereby increasing health and safety impacts.	**Extreme**	Chapter 14, CC1, CC4, CC6	**High**	Extreme risk due to increase in flood producing rains and downstream flooding. Mitigation including design adaptation to increase FMZ and other implementation of works under the Hawkesbury-Nepean Flood Strategy reduces risk to a **High residual risk**.

7 Socio economic risk assessment (Chapter 21)

A risk assessment methodology and assessment is provided in Appendix M (Socio-economic, land use and property assessment report). This risk assessment methodology was undertaken in accordance with the NSW Social Impact Assessment Guideline (DPE 2017b).

Key issue health and safety impacts relate to air quality, noise and vibration, climate change risk, flooding, contaminated soils and traffic. Risk definitions used in Appendix M vary from the standard definitions used in other Chapters, however there is general consistency with the residual risks assessed in relevant EIS Chapters and summarised above.

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